WATER SERVICES ASSOCIATION
of Australia

Best Practice Environmental Management

Catchments for Recreational Water:

Conducting and Assessing Sanitary Inspections

Occasional Paper No. 8 - May 2003

Prepared by Egis Consulting Australia Pty Limited for
Water Services Association *of Australia*

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Executive Summary

These guidelines have been developed for use by Australian water authorities and other stakeholders to assist them in:

- *undertaking Sanitary Inspections of Drainage Catchments associated with recreational waters, and*
- *classifying the recreational waters in accordance with World Health Organisation (WHO) guidelines on safe recreational water environments.*

In 1998, the WHO issued draft guidelines on safe recreational water environments for public comment. Following this, the WHO (1999) Annapolis Protocol proposed a new risk-based approach to the management of recreational waters. This approach combines the results of a sanitary inspection of pollution sources with the monitoring of faecal streptococci indicator organisms to assign beach classifications.

In a report to WSAA, Sinclair and Fairley (2000) reviewed the draft guidelines and the Annapolis Protocol and found difficulties, particularly in the qualitative approach and lack of definition of criteria.

The purpose of this Guidance Manual is to provide advice on how to estimate the numbers of microorganisms that are likely to be present in recreational waters, and therefore how to classify these waters in the absence of adequate monitoring information. The approach builds on the excellent advice contained in the Annapolis Protocol and the book *"Monitoring Bathing Waters: a practical guide to the design and implementation of assessments and monitoring programs"* by Bartram and Rees (2000).

It is not the intention of these guidelines to replace the requirement for monitoring, or to provide detailed advice on the monitoring of recreational waters or the management of these waters.

Identifying Sources of Contamination

Identifying sources of contamination which can affect the recreational water body of interest and assessing their significance is achieved using a multi step approach. This involves the following steps:

- definition of the relevant area of the water body and its associated catchments,
- planning for the sanitary survey and the development of a checklist of issues that need to be considered,
- field inspection,
- assembly of information (including existing long term monitoring data) and its review, and
- an interview and/or undertake a workshop with key stakeholders.

Microbiological Quality Assessment

The extent of microbiological contamination present in recreational waters is dependent on:

- the number of organisms likely to be associated with the sources of contamination,
- the nature of these organisms and the likelihood that they will be infective to humans,
- the extent of dilution and dispersion of the contamination in the receiving water, and
- the reduction of the contamination with time in the receiving water.

Table 1 illustrates the approach which is taken in these guidelines for estimating the numbers of organisms which are likely to be present at the point where recreation takes place. It should be completed for both wet and dry weather.

Information is provided in the body of the Guidelines on how to complete the various entries in the table, ie on how to estimate the:

- concentrations of enterococci / faecal streptococci associated with various pollution sources,
- extent of dilution of the contamination,
- attenuation with time, and
- infectivity of the pathogens to humans.

Once Table 1 has been completed, the significance of the contamination can be determined, using Table 2.

The estimated concentration of faecal streptococci determined using this process is then checked against the results of water quality monitoring and testing as may be available, and the recreational water classified in accordance with Table 3.

A recreational water body may have more than one classification reflecting, for example, the different numbers of organisms that may be present under differing weather conditions (eg wet weather or dry weather).

Once the likelihood of microorganisms being present has been determined, the consequence (or significance) of the contamination can be determined, and the risk and requirements for management responses to reduce the risk to an acceptable level can be determined.

Executive Summary
Continued

Table 1: Illustration of the Approach to Estimating the Significance of Faecal Contamination in Recreational Waters

Number of organisms is estimated by multiplication across the table, ie $10^5 * 0.04 * 1 = 4,000$

Weather: wet

Source	Concentration (faecal streptococci)	Effect of Dilution & Dispersion		Effect of time	Resulting Concentration (for comparison with monitoring results)	Effect of Origin of Micro-organisms	Resulting Concentration (for determining significance)	Significance
		Nature of discharge and receiving water situation	Dilution factor					
Wastewater discharge A (secondary treatment, no disinfection)	10^5	Short outfall close to shoreline and beach	0.04	1	~4,000	1	~4,000	Very High
Wastewater discharge B (primary treatment with disinfection)	10^5	High flowrate discharge via long outfall	0.01	1	~1,000	1	~1,000	High
Stormwater A (urban, no sewage overflows)	10^4	Drain direct to beach	0.2	1	~2000	0.5	~1000	High
Stormwater B (rural, no sewage contribution)	10^4	Drain 500 m upstream (prevailing current), direct discharge at beach	0.05	1	~500	0.1	~50	Moderate
Bathers (less than 20 per 150 ^{m3})	10^1	No dilution – volume of swimming area ~150 m3	1	1	~10	1	~10	Low
Rural stream	10^3	Discharges downstream (prevailing current)	0.02	1	~2	0.1	~0.2	Very Low
Total					>7,500		>6,000	Very High

Executive Summary
Continued

Table 2: Ranking of Significance of Numbers of Faecal Streptococci

Number of Faecal Streptococci (organisms per 100 mL)	Significance Ranking
<8	Very low
8 – 40	Low
41 – 200	Moderate
201 - 1,000	High
> 1000	Very High

Table 3: Classifications based on results of Monitoring and Sanitary Inspection

Ranking of Significance of Contamination[3]	Number of Faecal Streptococci determined from Monitoring[4]			
	<40	40 – 200	201 – 500	> 500
	Risk Level Inferred from Numbers of Organisms[2]			
	GI < 1 in 100 exposures AFRI < 1 in 300 exposures	GI < 1 in 20 exposures AFRI < 1 in 40 exposures	GI < 1 in 10 exposures AFRI < 1 in 25 exposures	GI > 1 in 10 exposures AFRI > 1 in 25 exposures
Very Low	Very good	Very good	Follow up[1]	Follow up[1]
Low	Very good	Good	Fair	Follow up[1]
Moderate	Follow up[1]	Good	Fair	Poor
High	Follow up[1]	Follow up[1]	Poor	Very poor
Very High	Follow up[1]	Follow up[1]	Poor	Very poor

Notes to Table 3:

1. *Unexpected result requiring reconciliation as far as is practicable. Generally, monitoring data for the bathing water should take precedence over estimates from the sanitary inspection unless the monitoring data is uncertain or limited (e.g. does not include the range of conditions such as wet weather).*
2. *AFRI: acute febrile respiratory illness; GI: gastrointestinal illness*
3. *Ranking based on numbers of Faecal Streptococci present estimated from Sanitary Inspection with particular emphasis on human faecal contamination. Order of magnitude estimates only, based on available data.*
4. *95th percentile values, as nominated by WHO. Monitoring results with a high degree of variability will need to be reviewed to determine the cause of the variability and the appropriate method for estimating the upper confidence limit. It may be appropriate to distinguish and separately classify different conditions such as wet weather.*

1 Introduction

1.1 Purpose of this Guidance Manual

These guidelines have been developed for use by Australian water authorities and other stakeholders to assist them in:

- *undertaking sanitary inspections of drainage catchments associated with recreational waters, and*
- *classifying the recreational waters in accordance with World Health Organisation (WHO) guidelines on safe recreational water environments.*

These guidelines provide a framework for undertaking sanitary inspections of drainage catchments in accordance with the WHO guidelines and, where monitoring information is not available or is uncertain, developing preliminary estimates of the level of microbiological contamination that may be present in the recreational waters.

It is not the intention of these guidelines to replace the requirement for monitoring, or to provide detailed advice on the monitoring of recreational waters for microorganisms or the management of these waters.

In particular, the key aspects of this document are guidelines to:

- conduct sanitary inspections to identify risks to recreational waters associated with microbiological organisms, such as may occur from sewage outfalls, stormwater outfalls, riverine discharges, and bathers;
- evaluate and rank those variables that directly relate to risks associated with human faecal matter which contaminate recreational waters;
- follow a risk-based approach that parallels the beach "classification matrix" outlined in the WHO bathing water guidelines (WHO 2001; p30).

Undertaking a sanitary inspection can assist in:

- understanding the significant causes of contamination within a catchment and the circumstances in which contamination may occur, and developing preliminary estimates of the level of contamination;
- developing an appropriate recreational water monitoring program and reviewing the results of the monitoring program; and
- targeting pollution reduction measures.

Quantifying the risks associated with contamination of recreational waters involves consideration of a range of factors, including:

- the sources of contamination (including the likelihood that contamination will occur and its magnitude),
- the dilution and dispersion of the contamination in the receiving water,
- the nature of pathogens and the likelihood that they will be infective to humans,
- reduction in infectivity with time in the receiving water, and
- the likelihood of ingestion or other exposure (including consideration of the nature of the recreation occurring).

The approach taken in these guidelines includes:

- identification of all scenarios and factors affecting numbers of organisms likely to be present,
- an initial screening of these to determine those sources and factors that are most important,
- advice on how the most important sources and factors can be better quantified,
- separation of sources and subsequent modifying effects, and
- comparison of results from the sanitary survey and results from monitoring.

The framework of these guidelines is consistent with taking a risk management approach to managing recreational waters and, while it is not the intention of these guidelines to provide guidance on the management of recreational waters, extension of the approach to consider the consequences and significance of the contamination necessary in the management of recreational waters is discussed in Appendix G.

1.2 Background

In October 1998, the WHO issued draft guidelines on safe recreational water environments for public comment. The guidelines briefly review epidemiological studies on the association of adverse health outcomes with recreational water exposure.

Shortly after its release, a meeting of experts took place in Annapolis, Maryland, USA. This group developed an alternative approach for the regulation of recreational waters, which incorporated an assessment of the sources of faecal pollution as well as measurement of faecal indicator micro-organisms. Their work became known as the Annapolis Protocol (WHO 1999).

This protocol proposed a new risk-based approach that combines results of a sanitary inspection of pollution sources with microbiological water quality as measured by faecal streptococci indicator organisms. The sanitary inspection primarily assesses sources of human faecal pollution, while the microbiological quality measurement includes both human and animal sources.

Introduction
Continued

There are various sources of faecal contamination; for example:

- sewage outfalls, combined sewer overflows, stormwater outfalls,
- riverine discharges, and
- bather shedding.

Under this protocol, in cases where multiple sources of contamination exist, the single most significant source is used to determine the susceptibility to faecal influence.

In a report to WSAA, Sinclair and Fairley (2000) reviewed the draft guidelines and the Annapolis Protocol and found difficulties, especially the lack of definition of criteria relating to the Annapolis Protocol. Components of the sanitary inspection use a number of qualitative terms to classify parameters with little or no guidance on how these should be interpreted. For example:

- riverine discharges are to be classified as coming from "large", "medium" or "small" populations,
- river flow is to be classified as being "high", "medium" or "low" flow,
- bather density is to be classified as "high" or "low", and
- dilution is to be classified as "high" or "low".

Although these terms can be useful for grading sources, they need to be further defined if they are to be applied uniformly. Without some quantification, the terms are subject to individual interpretation, and may therefore be applied inconsistently by different observers. This is likely to lead to divergence in the resultant risk assessments, which will in turn affect the eventual classification of swimming beaches. (Sinclair and Fairley, 2000).

Following release of the Annapolis Protocol, the WHO, USEPA and EC also published a book entitled *"Monitoring Bathing Waters: a practical guide to the design and implementation of assessments and monitoring programs"* (Bartram and Rees 2000). This document provides excellent information on understanding the risks associated with recreational waters, but provides limited advice on how to undertake sanitary inspections and quantify beach classifications.

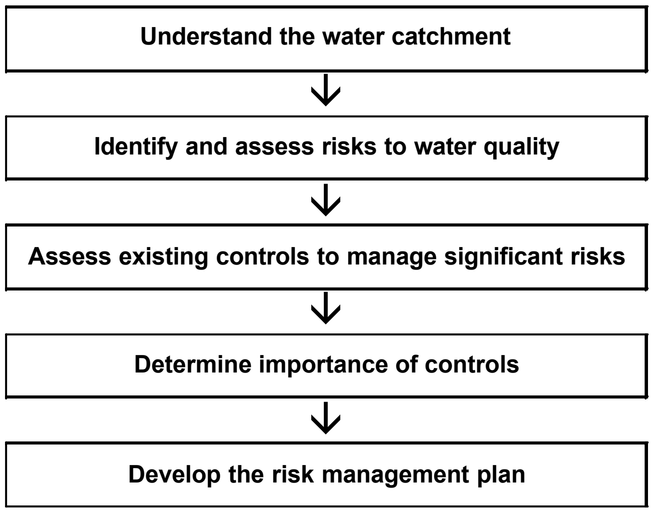
It is the purpose of this Guidance Manual to provide advice on how to better quantify the risk associated with contamination in recreational waters and therefore classify the recreational waters, building on the excellent advice that is already contained in the Annapolis Protocol and the book published by the WHO, USEPA and EC.

1.3 Risk-Based Approach

Over the last few years many of the major urban water authorities in Australian have been undertaking programs to improve their management of drinking water supplies. In this work, water authorities are applying the principles of all or some of, the following: ISO 9000:2000 (Quality Management Systems - Requirements), AS/NZS 4360 (Risk Management) and HACCP (Hazard Analysis and Critical Control Points - developed for the food industry). Some authorities have achieved certification for HACCP.

The Key Elements of AS/NZS 4360 and HACCP are outlined below in Figure 1.

Figure 1: Key Elements of AS/NZS 4360 and HACCP



1.4 Limitations of this Manual

This Guidance Manual is intended to provide a methodology for assessment of surface water catchments. It is intended that the methodology be sufficiently robust to take into account geographical and climatic differences, however it is possible that potential risks to water quality which are specific (and possibly unique) to a site have not been referred to in these guidelines. In such instances, it is recommended that direct measurement of faecal streptococci be undertaken to confirm the actual situation.

In the development of these guidelines a conservative approach has been taken. Guidance on the estimation of faecal streptococci numbers for each source is based on available literature and represents "a best estimate" approach. Clearly the literature does not cover every situation and potential risk to water quality, thus assumptions have been made with respect to estimated levels of faecal streptococci.

The highest number of faecal streptococci in a particular source has been considered in assigning a concentration for that source thereby providing a "safety margin" and guarding against underestimation of the estimated faecal streptococci level for a particular catchment. Where possible, direct measurement of faecal streptococci levels should be undertaken to verify the assumptions.

It is desirable that this Guidance Document be periodically reviewed and updated to reflect information that become available related to the numbers of organisms associated with particular sources and the effect of Australian climatic conditions.

2 Terminology of Risk Assessment

Risk assessment involves a number of terms which are in general use, but have particular meanings when applied in the assessment of risk related to recreational waters. These are:

- ***"catchment"*** refers to the area upstream of the recreational water which gives rise to discharges of contamination to the recreational water, and can include the area of land from which stormwater discharges, as well as specific point discharges such as wastewater,
- ***"hazards"*** are those water quality parameters which, if particular concentrations in water are exceeded will give rise to "unacceptable" quality where it is used for normal recreational purposes such as swimming, boating, water skiing etc. Examples of hazards are particular pathogens, such as Adenovirus or Enterovirus, which may present a concern for public health,
- ***"risk"*** is a function of the ***"likelihood"*** that a hazard will occur and the severity of the effect it will have (or the ***"consequences"***). Using Adenovirus or Enterovirus again as the example, the *"significance"* (*eg. Low, high*) of this *"risk"* is a function of the *"likelihood"* of a concentration above the "unacceptable level" and the *"consequences"* if it occurs. The *"consequences"* may be established by considering the following aspects; number of people who may get ill, and the degree of public outrage (which may depend on the significance of the affected waters and the significance of their closure),
- ***"risk assessment"*** is the systematic evaluation of the inputs to the recreational water, from the catchment to the water itself, and involves:
  - identifying the hazards and their sources,
  - establishing the risks,
  - ranking the significance of the risks,
- ***"sources"*** of hazard are the natural and man made origins which can result in the hazard being present in the water. There can be a number of sources for a single hazard. The sources may be continuous, or may occur only infrequently such as during rain.

3 Undertaking a Sanitary Inspection

3.1 Overall Approach

Identifying sources of contamination, which can affect the water body of interest and assessing their significance is achieved using a staged approach which involves the following steps:

- plan for the sanitary survey and develop a checklist of issues that need to be considered,
- assemble information (including existing long term monitoring data) and review it,
- carry out field inspection,
- conduct interviews and/or undertake a workshop with key stakeholders, and
- assess the contamination sources to determine the level of risk.

3.2 Planning for a Sanitary Inspection

3.2.1 Introduction

The purpose of a sanitary inspection is to provide an "assessment of the area's susceptibility of influence from human faecal contamination" (WHO, 1999, "Annapolis Approach").

The primary focus of these guidelines is on human faecal contamination (WHO, 2001 p30); however, potential contamination from animals, herbicides, pesticides and so on should be included where it may be significant. In most cases the most important risk will arise from microbiological contamination. It is possible that risks associated with toxic algae may arise in some inland waters, and may well be associated with the discharges that would give rise to microbiological contamination (ie from the associated nutrients). It would be very unusual that other sources of contamination such as from chemicals would be limiting. This document addresses microbiological contamination only; however, the approach can be extended to consider other risks if desired.

The results of the sanitary inspection will be combined with the microbiological faecal streptococci indicator measure of faecal contamination to provide a primary classification of the location (ie beach, lake, river, etc). This is discussed in later sections.

The success of a sanitary inspection relies heavily on preparation and planning. It is important that as much accurate, relevant information as possible (including past monitoring results for faecal streptococci, where available) be collected prior to the survey. This enables important issues to be identified for further investigation, improves quantification of each risk, and minimises the need for repeat interviews and visits.

In most cases the sanitary inspection of the catchment should be undertaken under both dry and wet weather conditions and a beach classification determined for each circumstance. The rationale for this is that under certain conditions (eg during rainfall and for up to 2 days after heavy rainfall) bathing water quality may deteriorate and a beach classification may be 'Good' under dry weather conditions but 'Poor' during rainfall driven events. Under the wet weather conditions the sanitary survey would show additional sources of pollution (eg sewage overflows into stormwater) and this would be expected to be supported by an increase in microbiological (faecal streptococci) monitoring results.

3.2.2 Define the Recreational Area

It is important to define the recreational water body of interest so as to focus data collection. For example, is it just the official swim zone between flags, is it the entire beach, or is it also areas which are officially excluded from access but where nevertheless people do swim?

Information relevant to the assessment of the recreational water body is listed in Table 3.1.

Table 3.1: Useful Information on the Recreational Water Body

- A map which shows the depth of water and currents.
- The quality of the waters of interest, and the time and immediate history relevant to these measurements (particularly before and after rain).
- Usage, particularly numbers of bathers (including proportion of vulnerable people, eg children, the elderly, persons with weakened immune systems, international or other tourists where relevant) and existence of toilet facilities.
- Information pertinent to the dilution, dispersion and attenuation of discharges in the waters of interest, including information on currents and stratification, temperature, light intensity.
- Previous events relating to the water body of interest, which led to closure or illness (eg occurrence of microorganisms, or other factors such as algal blooms).
- The significance of the recreational water body, importance to the community, and community reaction to the water being unsuitable for recreational purposes and closure.

Undertaking a Sanitary Inspection
Continued

3.2.3 Identify Contaminant Sources and Assemble Relevant Information

The quality of information about the unique features of each catchment and each discharge largely determines the accuracy and usefulness of the sanitary inspection.

Information should be gathered as early in the process as possible. Contact with multiple stakeholders is likely to be necessary, eg State natural resource agencies, environmental regulators, catchment management authorities, and other water and land management agencies.

As first steps in the information gathering, it will be important to:

- define the catchment of relevance to the water body and where pollution discharges may arise from and contaminants may travel to the water body of interest. Thus the catchment will not extend downstream unless there is potential for back flow,
- identify all possible sources of potentially significant contamination, so that information gathering can focus on these sources. A checklist of possible sources is included in Table 3.2.

Table 3.3 provides a checklist of information that should be sought on relevant sources of contamination. Appendix A provides a useful listing of possible sources of this information. Reasonable effort should be applied to gaining this information; however, it should not be seen as an exclusive or mandatory list, and other information sources can be used as appropriate.

Table 3.2: Checklist of Possible Contamination Sources

Likely to be Most Significant	Likely to be Less Significant
• Bathers	• Sediments
• Wastewater discharges, major centres	• Vegetation (rotting, mobilisation)
• Local sewage discharges (eg toilet facilities, campers, fishermen, boats, septic tanks)	• Pesticide/herbicide spraying/ wastes
• Urban development, stormwater runoff	• Forestry
• Farming, cattle, agriculture, intensive animal farming especially where animals have direct access to the water body	• Transport and roads (eg runoff, erosion)
• Birds	• Landfills
• Storm event causing high pollutant load	• Spills of hazardous materials (eg fuel, fertilisers, septage)
• Native animals	• Industry (wastes, aerial deposition)
• Algal blooms (including nutrients)	• Mining
	• Contaminated groundwater sources

Undertaking a Sanitary Inspection
Continued

Table 3.3: Useful Information on Contamination Sources

Maps
- A map of the catchment on which to identify potential contamination sources.

Discharges of Stormwater
- The location of urban areas and their main stormwater drainage systems which lead to the water body of interest, including the provision of stormwater retention basins and their storm capacity.
- The location and type of stormwater treatment, where relevant.
- The frequency and duration of storm events, and the flow rate and quality that results including any information on the first flush.

Discharges of Municipal Wastewater
- Information on the sewerage system, particularly where common effluent drainage systems may exist, and information on the frequency and location of overflows from the sewerage system and failure of pumping systems (both under storm conditions, or through system failure), or significant septic tank systems (and the potential for run off from these);
- The location of dry weather discharges which have a significant potential for contamination, such as discharges from wastewater treatment plants and from broken pipes, and the level of treatment prior to discharge.
- Other wet weather and dry weather discharges to streams or drainage systems which can affect the waters of interest.
- Areas where reuse of wastewater occurs, and situations in which run off from these areas may occur.
- The presence and location of any illegal connections from sewerage to stormwater systems.

Other Potentially Significant Discharges
- Other sources of potentially significant microbiological contamination, such as feedlots, abattoirs, farms with cattle/sheep/pigs/horses/chickens, refuse depots/ dumps.
- Sources of potentially significant industrial contaminants such as may occur from industrial manufacturing operations. Other sources that may be considered but are generally less likely to give rise to significant contamination that would affect recreational users include leakage from fuel depots, pesticide/herbicides (orchards (chemical spray drift), intensive horticulture sites (eg. berries), pine forest activities (eg. atrazine/fertiliser use)), or spills such as may occur from traffic accidents (possibly relevant if there is limited dilution and accidents are likely).
- The presence of large populations of birds (water fowl etc).

3.3 Assemble Information and Review

The assembled information should be thoroughly reviewed prior to undertaking the field inspection, to maximise the effectiveness and efficiency of the field work and interviews.

Summary tables and diagrams are particularly useful for ensuring the system and the issues are well understood prior to proceeding to the next stage. An example catchment schematic is shown in Appendix C.

3.4 Field Inspection, Interviews and Workshop

3.4.1 Field Inspection

In undertaking the sanitary inspection it is important to take a systematic approach, so that issues are not overlooked. It is recommended that a checklist of issues that need to be considered be developed at the outset.

Only personnel who are familiar with the catchment and with good operational knowledge of water, wastewater and stormwater systems should undertake the sanitary inspection.

The field inspection involves visiting locations identified in the data review stage as potential sources of faecal contamination.

Specific issues to review at different sites are outlined in Appendix B.

Undertaking a Sanitary Inspection
Continued

3.4.2 Interviews

Persons with knowledge of the catchment and water body should be interviewed to identify issues, which could pose a risk with respect to receiving water quality. By way of example, the range of people to be interviewed should include those from authorities responsible for:

- the recreational water body,
- river discharges to the water body,
- urban drainage and other discharges such as septic tanks,
- discharges from the sewerage system,
- environmental regulation (such as EPA).

Specific to be addressed are outlined in Appendix B.

3.4.3 Workshop

A workshop may be held, with stakeholders, to identify and assess the risks arising from the hazards identified during the initial data review, site visits and interviews.

A workshop is particularly useful if there are several areas and catchments to be assessed, and if there are other authorities with relevant responsibilities (such as EPA or a catchment management board) who need to understand the issues and their management responsibilities. If there is only one simple area and catchment to be assessed, then a workshop may not be warranted.

The workshop should be facilitated by a person with significant experience in HACCP and Risk Assessment, to keep the responses focused within the framework. The workshop can involve addressing large amounts of information, with significant consequences, and a focused approach is necessary to make best use of the knowledge and ideas generated. To assist in this, the findings from the initial stages should be summarised for presentation and review at the stakeholder workshop; the tabular approach outlined later in these guidelines (Table 4.1) can form a useful format for the progressive assembly of information.

3.5 Assessment of Contamination Sources

The findings of the workshop should then be summarised and assessed. The most effective way of doing this will be to continue adding to and refining the assessment tables (eg Table 4.1), as this will quickly identify the most significant sources so that these can be focussed on in further work.

Then there can be follow up of the most important contamination sources to obtain the information necessary to complete the microbiological quality assessment (ie to determine the likely loads of pathogens, dilution and attenuation, and infectivity).

4 Microbiological Quality Assessment

4.1 Introduction

The sanitary inspection can provide information which is important in designing a sampling and analysis program, and also in interpreting the program. It can also be used to develop an understanding of the contamination situation that is likely to apply, in the absence of direct information from a sampling and analysis program.

The extent of microbiological contamination present in recreational water is dependent on:

- the number (ie load) of organisms likely to be infective to humans and likely to be present in the sources of contamination,
- the nature of these organisms and the likelihood that they will be infective to humans,
- the dilution and dispersion of the contamination in the receiving water,
- the reduction with time in the receiving water.

The intent of the sanitary inspection is to assemble the information in a systematic way. These guidelines propose a tabular approach.

Table 4.1 illustrates the process which underlies these guidelines for a beach involving two wastewater treatment plant discharges, two stormwater discharges, a stream from a rural area, and bathers. It indicates how, for this example case, the expected level of contamination from each significant source can be systematically accounted for by considering the factors which will affect the level of contamination that is likely to occur at the point where recreation takes place. After the table has been completed, the estimates of contamination can be compared with results of monitoring and testing, as may be available.

The following sections provide guidance on how such a table is to be completed for a particular water body of interest.

Wet and dry weather can result in very different microbiological conditions in a receiving water, and it is recommended that the table be completed separately for both wet and dry weather conditions. Further discussion of the impact of rain is provided in Section 4.2.3.

Microbiological Quality Assessment
Continued

Table 4.1: Illustration of the Approach to Estimating Significance of Faecal Contamination in Recreational Waters

The resulting concentration is found by multiplication across the table, ie 10^5 * 0.04 * 1 = 4,000

Source	Concentration (faecal streptococci) (refer Table 4.2)	Effect of Dilution & Dispersion		Effect of time [(2)] (for factor refer Table 4.5)	Resulting Concentration (for comparison with monitoring results)	Effect of Origin of Micro-organisms (for factor refer Table 4.3)	Resulting Concentration (for determining significance)	Significance (refer Table 4.6)
		Nature of discharge and receiving water situation	Dilution factor [(1)] (refer Table 4.4)					
Wastewater discharge A (secondary treatment, no disinfection)	10^5	Short outfall close to shoreline and beach	0.04	1	~4,000	1	~4,000	Very High
Wastewater discharge B (primary treatment with disinfection)	10^5	High flowrate discharge via long outfall	0.01	1	~1,000	1	~1,000	High
Stormwater A (urban, no sewage overflows)	10^4	Drain direct to beach	0.2	1	~2000	0.5	~1000	High
Stormwater B (rural, no sewage contribution)	10^4	Drain 500 m upstream (prevailing current), direct discharge at beach	0.05	1	~500	0.1	~50	Moderate
Bathers (less than 20 per 150 m^3)	10^1	No dilution – volume of swimming area ~150 m^3	1	1	~10	1	~10	Low
Rural stream	10^3	Discharges downstream (prevailing current)	0.02	1	~2	0.1	~0.2	Very Low
Total					>7,500		>6,000	Very High

Weather: wet

Notes to Table 4.1:

(1) Dilution factor obtained from Table 4.4 given "nature of discharge and receiving water situation" for each source. Refer Appendix H for detailed calculations of sample situations.

(2) "Effect of time factor" (refer Table 4.5) for each of the items assumes that the time between discharge and 'transmission' of faecal streptococci to the recreational area is less than 1 day. As such, the "Effect of time factor" is 1 in all cases.

4.2 Estimation of Microbiological Quality from a Sanitary Inspection

4.2.1 Concentrations of Pathogens Associated with Various Sources

The concentrations (or numbers) of faecal streptococci organisms that can be present in discharges of contaminated water, such as from wastewater treatment plants and stormwater can vary widely. For the purposes of initial estimation of the numbers that are likely to be present, the information summarised in Table 4.2 is useful in assigning concentrations to particular sources. If direct information is available (eg measured by the WWTP operator), then this may be substituted.

Information is also provided in semi-quantitative terms as information regarding the numbers of faecal streptococci organisms likely to be present in various sources in particular, is limited and because there is often significant overlap in numbers of faecal streptococci in various sources. While these are clearly uncertain and will depend on the particular situation that applies, they do provide an initial indication of the relative importance of particular sources.

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Table 4.2: Concentrations of Enterococci / Faecal Streptococci associated with Various Sources

Source	Assigned Concentration (No. per 100 mL)	Reference Information[3,4,7]	
		No of Faecal Streptococci/ Enterococci per 100mL (waters) or per gram (faecal matter)	Reference
Raw Sewage	10^7	$6.4x10^4$ - $2.9x10^6$	Geldreich, 1990
		$2.1x10^6$	Grabow & Nupen, 1972
		$1x10^4$ - $1x10^7$	Kueh & Grohmann, 1989
		$3.9x10^5$	Ashbolt, Grohmann & Kueh, 1993
		$1x10^6$	Lord, Grabow & Roberts, 1988
		$5.9x10^6$	Rajala &Heinonen-Tanski, 1988
		$1.5x10^6$ – $8.5x10^6$	Turner & Lewis, 1995
		$4.9x10^5$	Cheung, Chang &Hung, 1991
Primary treatment	10^7	1.7 – $8.9x10^6$ (sludge)	Pedersen, 1981
Primary treatment with disinfection	10^5	Plant 1: $3.8x10^3$ (median); 60 –$1x10^6$ (range) Plant 2: $3.6x10^3$ (median), 1 –$3.3x10^5$ (range)	Appendix D, Table D-4
Secondary treatment, no disinfection	10^5	$3x10^5$ (activated sludge process, 97% removal, assuming $1x10^6$= raw) $1.7x10^5$ (trickling filter, 98.3% removal, assuming $1x10^6$ raw)	Omuma, Omuma, Aizawa & Yagi, 1989
Lagoon treatment	10^3	$1.1x10^1$ – $2.4x10^2$ (pop 150,000, lagoons) 0 - $1.6x10^3$ (pop 10,000, lagoons)	Donnison & Ross, 1995
Secondary treatment with disinfection (chlorine)	10^3	Combined effluent 4 plants: 137 (mean); 0 – 2.3 $x10^3$ (range) Plant 3: 1.8 $x10^3$(median); 0 –$1.2x10^5$ (range) Plant 4: $1.1x10^3$ (median), 0 – $2.8x10^5$ (range)	Melb Water, 2001 Appendix D, Table D-4
Secondary treatment with disinfection (UV)	10^4	Plant 5: $1.1x10^4$ (median); $8.0x10^2$ – $2.6x10^6$ (range)	Appendix D, Table D-4
Tertiary treatment with disinfection	10^2	1 <10 – $1.4x10^2$ (dry) 8 – $3.1x10^2$ (wet)	Grabow et al, 1978 Gannon & Busse, 1989
Stormwater, urban area, no sewage overflows	10^4	$2.0x10^4$ – $3.9x10^5$ $2.1x10^4$ 4 – $1.5x10^3$ mean dry (max $2.7x10^4$) $2.3x10^1$ – $1.1x10^4$ mean wet (max $3.4x10^5$) $5.4x10^2$ – $1.5x10^4$(sewered catchments)	Burm & Vaughan, 1966 Geldreich et al, 1968 Gannon & Busse, 1989 Rowlands et al,1992
Stormwater, urban area including sewage overflows	10^7	$3.3x10^5$ – $7.4x10^5$ $6.5x10^2$ – $3.0x10^6$ (unsewered catchment)	Burm & Vaughan, 1966 Rowlands et al,1992
Stormwater, rural	10^4- $10^{7(6)}$	$2.1x10^3$ – $7.9x10^5$ 10 – $2.3x10^3$ (catchment with predominant park reserves)	Geldreich et al, 1968 Rowlands et al,1992
Animal sources (faecal matter)	10^6	$1.4x10^6$ (ducks) $1.65x10^1$ – $1.58x10^6$ (domestic animals) $1.2x10^2$ – $1.38x10^7$(feral animals) $5.13x10^2$ – $3.48x10^4$ (seagulls) $1.45x10^4$ - $7.9x10^6$ (birds)	Roll & Fujioka, 1997 Anderson et al, 1997
Livestock waste (faecal matter)	10^6	$1.0x10^5$	Cheung, Chang & Hung, 1991
Meat processing waste	10^3	5 –$1.3x10^2$ (60days) 1.7 – $1.3x10^3$(30days)	Donnison & Ross, 1995
Bathers low (<20)	$10^{1(5)}$	5.5 (20 bathers/150 m^3)[1,2]	WHO, 2001; Gerba, 2000 Rose 1991
Bathers high (>20)	$10^{3\ (5)}$	2.6 $x10^2$ (200 bathers/ 150 m^3)[1,2] 3-$8.8x10^2$ (marine tidal, shallow, mean 39 bathers) 44-129 (marine, tidal, bather levels 50- 1680)	WHO, 2001; Gerba, 2000, Rose 1991 Genthe et al, 1995 Cheung et al, 1991

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Notes to Table 4.2:

1. *Volume of water in which recreation takes place is assigned to be 150 m^3 (ie 1m x 10m x 15m).*
2. *Estimate based on average concentration of faecal coliforms shed per swim per bather for all age groups of 2.27 x10^6 (Rose et al,1991).*
3. *Equation: Log faecal coliform count = 1.028+0.601*log faecal streptococci count used to compute faecal streptococci levels (WHO, 2001, p 38) – refer to Section 4.2.1.*
4. *In some cases the data sources did not identify whether wet or dry weather applied. This introduces uncertainty; however, because there the faecal streptococci data is limited the data has been included. In general, the assigned concentrations can be expected to be conservative as discussed in Section 1.4.*
5. *Number may vary depending on the availability of toilet facilities.*
6. *Depends on whether sewage is present.*
7. *It is recommended that this Table be periodically updated to reflect published information.*

In assembling Table 4.2 it should be noted that faecal streptococci levels in some sources were unavailable, such as those relating to bather's contributions. Where only faecal coliform or E.coli data and not faecal streptococci data are available, and noting that there is no exact relationship between faecal streptococci and E.coli counts, the following equation provided by WHO (2001) can be useful in interpreting historical faecal coliform/ E.coli data:

Log faecal coliform count = 1.028+0.601*log faecal streptococci count

Thus counts of 100 faecal coliforms per 100mL can equate to ~40 faecal streptococci per 100mL. This equation has been used to derive relevant levels of faecal streptococci levels in some sources where indicated in Table 4.2. WHO (2001) comments that "this equivalence is not exact" and may vary in different local environments.

With respect to bather shedding in particular, the estimation method of Gerba (2000) has also been employed. This is based on each bather shedding some 10^5-10^6 thermotolerant coliforms per swimmer. In particular, the average concentration of faecal coliforms shed for all age groups during bathing of 2.27 x 10^6 (Rose et al, 1991) has been employed. The volume of water in which recreation takes place has been adopted as 150 m^3, however, where larger or smaller volumes are relevant, the appropriate dilution/ concentration factor should be employed in deriving the assigned concentration.

4.2.2 Infectivity of the Pathogens to Humans

The concept of a beach classification based on results of microbiological monitoring and sanitary inspection is based on the premise that the measure of a microbiological indicator of faecal contamination can be "interpreted" with additional information, relating to the presence or absence of evidence of human faecal contamination. This premise is underpinned by the assumption that in general, sources other than human faecal contamination present a significantly lesser risk to human health. As stated in the WHO document (WHO, 1999), "...due to the "species barrier", the density of pathogens of public health importance is generally assumed to be less in aggregate in animal excreta than in human excreta and may therefore represent a significantly lower risk to human health."

The issue then is how to "discount" the estimated numbers of faecal streptococci in sources such as agricultural and animal inputs to reflect this lower risk when computing the number of faecal streptococci estimated from sanitary inspection. Using the information in the table below, a possible solution is to "discount" the numbers of faecal streptococci as found in the literature by a designated factor. This approach assumes that the numbers of human derived faecal streptococci in an agricultural or animal source represents only a proportion of the total population. Other considerations also apply as the human health risk associated with pollution of recreational waters from animal excreta is not zero and some pathogens such as *Cryptosporidium* can be transmitted through this route (WHO, 1999). Information on the numbers of *Cryptosporidium* and *Giardia* associated with various pollution sources are summarised in Appendix F. Farm animals and wildlife (including birds) can be important reservoirs for pathogenic *E coli*, *Salmonella* and *Campylobacter*. Thus in some instances the discounting may *not* be applied – for details refer to comment section below.

A substantial research program relevant to determining the origin of microbiological contamination and its significance to human health is being carried out by the Cooperative Research Centre for Water Quality and Treatment involving the University of New South Wales, CSIRO, Melbourne Water Corporation and others. This program involves the use of faecal sterols to characterise the contamination sources, and promises to provide a useful method of determining whether contaminants are likely to be of human origin. It can be expected that the findings of this program will be published in due course.

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Table 4.3: Infectivity Factor to Take into account the Origin of Pathogens

Source	Infectivity Factor	Reference
Human	1	WHO, 2001
Cattle	0.2[1]	Solo-Gabriele & Neumeister, 1996, Lisle & Rose, 1995
Sheep	0.2[1]	Solo-Gabriele & Neumeister, 1996, Lisle & Rose, 1995
Birds	0.1	Anderson et al, 1997
Native animals	0.1	Fayer et al,1997
Rural runoff, no human contribution	0.1	-
Urban runoff, human contribution uncertain	0.5 - 1	-
Runoff associated with animal farming practices	0.2[1]	Koenraad *et al*, 1994 Jacob *et al*, 1991

1. The references indicate that pathogens infective to humans can be present, but a factor less than 1 has been assigned because the overall risk is expected to be less than that associated with sewage (Sinclair, 2002).

Comment to Table 4.3

In both marine and freshwater studies of the impact of faecal pollution on the health of recreational-water users, several faecal indicator bacteria have been used for describing water quality (WHO, 2001). These bacteria are not postulated as the causative agents of illnesses in swimmers, but appear to behave in a similar way to the actual faecally-derived pathogens (Pruss, 1998).

Faecal streptococci (Intestinal enterococci / enterococci), on the basis of available data, are considered to provide the best available match with health outcomes resulting from exposure to recreational waters in seawaters and alongside E.coli for fresh waters (Pruss, 1998). As a consequence of this they have been selected as the guideline indicator of recreational water quality in the most recent WHO guidelines (WHO, 2001).

The term faecal streptococci, refers to those streptococci generally present in the faeces of humans and animals. The genus Enterococcus within the faecal streptococci group can generally be regarded as specific indicators of human faecal pollution under many practical circumstances. They may however be isolated from the faeces of animals and certain species and subspecies occur primarily on plant material (WHO, 1993). Because of the seemingly ubiquitous presence of S.faecalis subsp.liquefaciens in animal faeces, plants, soils, insects and aquatic environments, identification of faecal streptococci strains has been suggested by investigators as being necessary to validate the use of this group in determining the origin of faecal contamination (Mc Neill 1985).

The organisms S. bovis and S.equinis, which are members of the faecal streptococci group but not the Enterococcus genus mainly, have animal faeces as their source. As a consequence, the proposed use of S.bovis and S.equinis is in pollution investigation for recent animal contamination from cattle feedlot runoff, farm land drainage, dairy plant, abattoir and poultry processing wastes (Geldreich, 1978).

The occurrence of Enterococci in faecal samples from humans and other warm blooded animals is readily available in numerous texts including the recent WHO, 2001 publication.

While other animals may either directly or indirectly ingest Cryptosporidium infective to humans and thus be the source of Cryptosporidium contamination of recreational waters, the recreational human health risk associated with such occurring is considered lower for bird and native animal origins. This assumption is made on the basis of the fact that native animals are not penned or found in larger groups as for farmed or grazing animals. In addition, the possible reduced host specificity of Cryptosporidium from these origins (eg from bird sources) is also a factor. For birds and native animal origins the reduction of one order of magnitude of faecal streptococci counts is thus allowed.

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4.2.3 Wet Weather

It is often observed that, in wet weather, the concentration of micro-organisms increases markedly in discharges. This can occur because of, for example:

- overflows of sewage from the sewerage system into the stormwater drainage system,
- runoff of contamination such as dog faeces from urban streets,
- ineffective disinfection at sewage treatment plants during high flows.

In some situations the contamination levels may decrease through dilution. This might occur, for example, in the case of a sewage treatment plant discharge to a receiving water, in which the flow of treated sewage is not greatly increased, compared with a major increase in the receiving water flow under storm conditions. However, in most situations it can be expected that there will be a net increase in the numbers of faecal organisms in wet weather conditions.

It is recommended that these considerations be accounted for by separately estimating the resulting faecal streptococci concentration that will apply under both wet weather, and dry weather conditions. This can be done most simply by completing an assessment table (ie Table 4.1) for each condition. Where there is a decrease in contamination levels through dilution, the dilution factor (refer Table 4.4) should be altered accordingly for wet weather versus dry weather conditions.

In instances where there are overflows of sewage from the sewerage system into the stormwater drainage system under high rainfall wet weather conditions but not under low rainfall conditions, this can affect the contamination level (eg it could result in a concentration designation of 10^7 for high rainfall wet weather vs 10^4 for low rainfall conditions (refer Table 4.2)). In such situations "wet weather" may be qualified by "high rainfall" and the higher level assigned.

Where agricultural catchments are involved, the magnitude of the rainfall event may affect the level of contamination; in flood for example effluent ponds may be flooded and wastewater sludge treatment areas eroded. These factors need to be taken into account when assigning source concentrations.

4.2.4 Dilution of the Source Contamination

The magnitude of the source will affect the concentrations of organisms actually observed in the water where recreation takes place. Clearly a very small discharge into a large water body is much less significant than a large discharge into a small water body. The WHO, by way of example, indicate that the contributing population associated with the source needs to be taken into account.

In this section information is provided which will allow dilution factors to be applied.

The term "Dilution Ratio" is commonly used in dilution and dispersion studies, however, for consistency throughout this document, a "Dilution Factor" has been adopted. The Dilution Factor is simply the reciprocal of Dilution Ratio.

The key objective of these estimates is to determine how much dilution there will be in the receiving water, and hence the concentration of organisms in the water where recreation takes place.

The concentration of organisms present in receiving waters will depend on the mass discharge rate, and the subsequent rate of mixing between the discharge point and that part of the receiving waters likely to be used for contact recreation. Information on typical dilution factors that can be applied in various discharge and receiving water situations is summarised in Table 4.4.

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The mixing process operating on the discharge can be viewed as a staged process as follows:

(a) Initial Mixing

Here the geometry of release, exit velocity and temperature and/or salinity difference between the discharge and receiving waters are the parameters that define the dilution achieved in this stage.

The process at work is entrainment of surrounding receiving waters into the discharge jet/plume. This acts to thicken and dilute the plume as well as to decrease the plume velocity relative to the surrounding ambient receiving waters.

When there is a density difference between the discharge and receiving waters then buoyancy forces will act on the plume, extending the time/distance over which entrainment into a distinct plume occurs.

Typically the initial mixing can result in a dilution factor of 0.002 to 0.2, depending on the mixing efficiency of the discharge, and the magnitude of the zone in which the mixing takes place. This is indicated in Table 4.4.

(b) Subsequent Dilution

Once the diluted jet/plume release has completed the entrainment process, the contaminant field moves with the local velocity of the receiving waters, and is progressively dispersed by the ambient turbulence present.

The degree and rate of additional dilution obtained during this stage is principally determined by the intensity of ambient turbulence and the velocity gradient across the field. In turn the ambient turbulence can vary substantially - from a maximum in the surf zone on an open coastline, to an intermediate level in lakes where wind action occurs or in rivers in turbulent flow, to near zero in stably stratified waters.

In time the turbulent diffusion/dispersion of the field will spread it to the limits of the receiving waters. In the case of discharge to a stream or river, the vertical mixing throughout the depth will normally occur prior to the uniform mixing across the channel width. Once mixed through the cross section, the maximum dilution that can occur will be limited by the relative flow rates of the discharge and the throughflow or replenishment of the receiving water (eg river flow, in the case of a river).

The time scales during which lateral and vertical mixing occur can be approximately determined, and used to establish the likely degree of mixing that has occurred between the discharge source and the portion of receiving waters of interest.

In the case of an open coastline, two modes of discharge are commonly used; (i) a near-shoreline discharge from a single port, and (ii) an off-shore discharge in deeper water from a multiport diffuser on the seabed.

The near-shore outfall is commonly routed to a rock outcrop - it takes advantage of high turbulence when a sea or swell is running, but is limited in the ultimate Dilution Ratio achieved by the water depth. The mean longshore current operating also limits the Dilution Ratio achieved.

A multiport deep water outfall will typically achieve initial dilution of 1/100 (0.01) as the buoyant plumes rise and merge to form a surface field if the receiving waters are only lightly stratified, or a sub-surface field where the stratification of receiving waters is significant. The latter case can occur in coastal waters in summer when solar insolation can generate significant thermal stratification in the upper layers.

An off-shore discharge has an additional advantage in that the contaminant field would normally only reach bathing (i.e. shallow) waters on the shoreline when on-shore winds are sufficient to drive the surface field towards shore. In contrast, a near-shore release will sweep all bathing waters down-current of the outfall.

Wind and tide can also affect the movement of contamination within coastal waters, and the range of conditions that can occur should be considered. Monitoring information may provide useful information on such effects.

Table 4.4 gives indicative dilution factors which are likely to be achieved, based on experience, for three typical discharge releases. Where further precision is desired, the governing equations for dilution factor are given in footnotes.

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Table 4.4: Typical Dilution Factors

Mixing Stage	Release Type		
	Side Bank Release to River/Estuary	Near Shore Coastline	Off-Shore Diffuser Outfall
Initial Dilution (3) Can apply when the recreation takes place in the zone of the discharge	0.05 – 0.5	0.02 – 0.2	0.002 – 0.02(1)
Subsequent Dilution (3) Can apply when the recreation takes place outside of the zone of the discharge. Initial dilution x subsequent dilution cannot exceed the ultimate dilution.	~ 0.2	~ 0.2	~ 0.2
Ultimate dilution (4) (takes into account the ultimate dilution that may occur due to the discharge volume flowrate relative to the flowrate or scale of the receiving water.	q / Q	$q / (V_L ½ Wh)$	$q / (^2/_3 L_D V_L h)$

Notes to Table 4.4:

1. *Dilution factor for initial dilution from offshore outfall =* $(6 / h) * [q / L_D]^{2/3}$
2. *Symbols:*
   q = effluent discharge rate
   Q = river discharge rate
   L_D = diffuser length
   V_L = longshore current
   W = field width
   h = water depth at seaward edge of field
3. *Example: dilution of 0.01 (high turbulence) - 0.1 (low turbulence) was measured in receiving waters at 200 – 1000 m from the point of discharge (Bergstein -Ben Dan & Stone, 1991)*
4. *Example: dilution of 10^{-5} at distances of more than 10 km from the point of discharge (Lord et al, 1988)*

Discharges to a small lake, lagoon, coastal embayment

In the case of discharges to a small lake, lagoon, coastal embayment with restricted flow and little water replacement, the amount of dilution is limited and it is recommended that a dilution factor of 1 (ie no dilution) apply in these circumstances (WHO, 2001).

Direct Measurement of Dilution

If direct information on the degree of dilution and dispersion is available, then this may be substituted. This may involve, for example:

- measurements of numbers of organisms,
- tracer studies. Commonly, the fluorescent dye Rhodamine WT is used as a tracer for these type of studies. If the extent of the receiving water is not large, then a continuous release of tracer can be made for a duration of several hours up to a half tide cycle. Direct measurements of the dye concentration using a fluorometer can be made at points down-current from the discharge, and the concentration ratios between these points give the dilution factors operating.

  Alternatively, if the extent of the receiving water makes continuous dosing prohibitive, a one-off or 'slug' release of dye can be made. A series of traverses (longitudinal, lateral and vertical) is then required, so as to determine the rate of spread and consequent dilution factors,
- measurement of conservative components of the discharge, such as coprostanol (a measure of human faeces),
- visual observation, eg of changed colour or refractive index of the water.

Upstream Dilution

There may also be upstream dilution in the catchment, for example, a WWTP may discharge treated effluent into a river which then discharges to the beach under consideration. In this case the upstream dilution in the river should be determined.

For example, consider the following case:

A small town of 2000 people with a lagoon WWTP (primary treatment) discharges to creek. There is sufficient balancing storage in WWTP lagoons to ensure the final lagoon discharges at average day flow. The creek discharges to a lake which is under investigation as a recreational water body.

If the creek flows at 5 ML/d in summer and 15 ML/d in winter, and the WWTP average day flow = 2000 pop x 200 L/h/d = 0.4 ML/d, then:

Upstream dilution (summer) = 0.4 / 5 = 0.08

Upstream dilution (winter) = 0.4 / 15 = 0.027

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How far does a beach classification apply?

The extent of a bathing site to which a classification will apply will depend on the proximity of significant sources, and the local variation in contaminant numbers that will therefore result. If there is a major source close by, then variations with relatively small changes in distance may be marked. If the sources are distant, then the local variations will be small and the beach classification can apply over a substantial area.

4.2.5 Attenuation with Time

The survival of faecal streptococci, as for other bacteria in the aquatic environment is influenced by physical, chemical and biological factors. Of all possible causes of bacterial die-off with time, solar radiation, sedimentation effects and nutrient related effects are considered to be the most likely causes as compared with other causes such as predation, bacteriophage activity, algal and bacterial toxins and physico-chemical factors (Mc Neill, 1985).

Table 4.5 shows possible reductions in organism concentration due to attenuation with time for different water body types. In this table no difference has been assigned to effects of solar radiation. Note that for sources high in the catchment, there may be considerable time taken for the contamination to reach the site under consideration and the reduction may be significant.

Table 4.5: Reduction due to Attenuation with Time in a Receiving Water Body

Medium	Reduction with Time			Reference
	1 day	3 days	10 days	
Sewage Impacted Marine water (ie turbidity elevated, and content supporting bacterial life)	1	1	0.3	Alkan et al, 1995
Fresh water	1	0.3[1]	0.1	Rajala, RL & Tanski, H, 1998 WHO, 1999
Marine water	1	0.1	0.03	Alkan et al, 1995 WHO, 1999

Comment to Table 4.5:

For the purposes of estimating the reduction of organisms with time, in the absence of direct data pertaining to the water body of interest, it is suggested that the reductions listed in Table 4.5 are assumed.

No differentiation has been made for high and low levels of solar radiation on the attenuation with time. This is a conservative approach as clearly where solar radiation intensity is high, attenuation with time can be expected to be more rapid (Alkan, et al, 1995),

In assembling Table 4.5, consideration has been given to the Effect of Solar Radiation and Temperature and Survival of Different Organisms.

Effect of Solar Radiation and Temperature

Recent investigations suggest that solar radiation plays a more important role than temperature. Investigators have found the variability of bacterial die off rates in sea water to be primarily attributed to the variability in the intensity of radiation and the micro environmental factors (turbidity, sewage and vertical mixing) influencing the depth profile of the intensity of radiation and the bacterial concentration (Alkan et al, 1995). The fact that bacterial die off rates were not altered significantly by the variation in temperature from 10 to 30 degrees Celsius was attributed to the fact that the effect of light on the die off rate overrides the effect of temperature (Alkan et al, 1995).

The enterococci (predominant in human faeces) survive for longer periods (in temperate waters) than faecal coliforms, which persist longer than *S.bovis* and *S.equinis* (Mc Neill 1985). Caution should be exercised with respect to tropical waters as the die off of faecal streptococci at temperatures exceeding 20°C is more rapid (Evison and James, 1975). Faecal streptococci survival times are generally greater than those for faecal coliforms at a variety of temperatures, although the survival of *Streptococcus bovis* and *Streptococcus equinis* is much less (Mc Neill, 1985).

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Survival of Different Organisms

Alkan et al (1995) found that enterococci species survive only marginally better in marine waters than *E.coli*. Other investigators however, have found a greater differential in die off rates between Enterococci and faecal coliforms. Their findings suggest that enterococci persist much longer in seawater compared with faecal coliforms because of both the broader shoulder on inactivation curves and the lower inactivation coefficient (Davies- Colley et al, 1994). These researchers further hypothesise that the persistence of enterococci as compared with faecal coliforms may explain why enterococci predicts gastrointestinal symptoms better than traditional coliform indicators (Davies-Colley et al, 1994). They also state that it is more difficult to model enterococci inactivation in seawater receiving effluent discharges as compared with faecal coliforms. The differential die-off for enterococci in freshwater and seawater is also acknowledged in the recent WHO document as not being as great as that for *E. coli (WHO, 2001).*

Faecal streptococci rarely multiply in polluted water (WHO, 1993). However, some investigators believe that enterococci can grow in soil in tropical climates (WHO, 2001). Recent studies have also found elevated enterococci levels in seaweed, indicating possible expansion of enterococci in this growth permissive medium (Anderson et al, 1989).

Enterococci, whilst sensitive to chlorine is more resistant to the disinfectant than *E.coli*. For example, to achieve 2 log removal, reported CT values for enterococci are 24 times that of E.coli (WHO, 2001).

4.3 Assessment of Contamination

4.3.1 Summation of Sources of Contamination

From the information gathered in the sanitary inspection, a table similar to Table 4.1 can be completed for each recreational water body.

4.3.2 Ranking of Significance of Numbers of Faecal Streptococci

Table 4.6 provides guidance on the ranking which can be associated with different level of faecal streptococci organisms within the recreational water. These are based on the WHO classifications (Appendix G), although the range of the numbers of organisms has been broadened to maintain a range of 5 fold in each category, and a lower range has been added.

Table 4.6: Ranking of Significance of Numbers of Faecal Streptococci

Number of Faecal Streptococci (organisms per 100 mL)	Significance Ranking
<8	Very low
8 – 40	Low
41 – 200	Moderate
201 - 1,000	High
> 1000	Very High

5 Water Quality Monitoring and Testing

5.1 Designing a Water Quality Monitoring Program

The most direct information on the microbiological quality of recreational waters can be obtained by taking samples of the water in the zone of usage and analysing them for indicators of microbiological contamination relevant to human health.

Information on designing a sampling and analysis program is provided in the WHO publication, Bathing Water Quality and Human Health: Faecal pollution (WHO, 2001p37). This document describes the various stages involved in assessment of the microbiological quality of a recreational-water environment. Key elements are that:

- initial sampling determines whether spatial variation exists by collecting samples at spatially separated sampling sites,
- timing of sampling takes into consideration the likely period of maximum contamination,
- the sampling program is representative of the range of conditions in the recreational-water environment while it is being used,
- sufficient numbers of samples are collected so as to make an appropriate estimation of the likely densities to which recreational-water users are exposed.

It is important to recognise when designing and interpreting a sampling and analysis program that the numbers of organisms will vary with time, and will depend on many factors. These include: whether there has been rain (which can flush large numbers of organisms into the receiving water), the performance of wastewater treatment plants, whether there have been upset conditions which give rise to short lived discharges of organisms to the receiving water, the time that has elapsed after discharges have occurred, and the conditions in the receiving water and whether discharges are routed into the zone of usage.

Because of the variation in numbers of organisms that is likely to occur, taking only a few samples under conditions which are not representative of the range of conditions is likely to provide only a limited understanding of the level of contamination.

The sanitary survey will provide useful information in understanding the situation that applies, and therefore when samples should be taken to best characterise the numbers of organisms likely to be present.

Because of the variability in numbers of organisms that can be present, the objective should be to obtain sufficient information to characterise the worst case conditions, and more normal conditions. Towards this end, the sampling program should include:

- sampling immediately following storm events, over a sufficient time to characterise the peak contamination level and reduction in numbers that occurs over time,
- sampling during more usual (eg dry weather) conditions, taking samples over a sufficient period or periods to encompass the worst case conditions that occur on a regular basis (eg under conditions of an incoming tide) or a stratified water body,
- sampling to include locations and times of heaviest bather or other recreational use (eg surfers, windsurfers etc).

Further considerations both in relation to the selection of sampling locations within recreational-water environments and in the frequency of monitoring are also required. For example, selection of sampling locations in marine and estuarine waters in particular, includes consideration of tidal cycles, current patterns, stratification, seasonal fluctuations, dispersion of discharges and multi-depth samplings.

Selection of sampling sites and depths is critical in marine waters where there are daily fluctuations in temperature, and where there are variations in water movement at different depths as a consequence of wave action.

Likewise, for estuarine sampling, the point at which tributary waters enter the main stream needs to be considered as does any marked stratification (between the salt water from the sea and the fresh water supplied by a river) at different locations and depths of the estuary.

Sampling in some instances should also take into consideration onshore winds. Such circumstances may result in the pollution of (even distant) recreational-water environments severely (WHO, 2001).

With respect to the frequency of sampling, there must be consideration of the nature of the pollution. For example, where there is cyclic pollution, more frequent monitoring is required to characterise the impact of this on recreational-water locations as compared with uniform pollution loads. For marine and estuarine sampling, the frequency of sampling is also determined by climatic and tidal conditions.

Once samples have been collected the adherence to sample preservation and holding time limits is also critical to the production of valid microbiological data. Samples exceeding prescribed guidelines should not be analysed. Sample analysis is recommended to be initiated within 8-12 hours of sample collection (WH0, 1999).

Analysis of samples should be performed using standards methods, which incorporate relevant quality assurance procedures to ensure the comparability of microbiological data between locations and temporally.

5.2 Practical Application for a Variety of Available Microbiological Monitoring Data

The following are guidelines for the practical application of the Best Practice Environmental Management Guidelines for a variety of available microbiological monitoring data

5.2.1 Selection of Microbiological Dataset(s)

A variety of microbiological data may be available relating to the source(s) to recreational water and for the recreational water itself. In some instances, monitoring data may comprise faecal coliform/ *E.coli* data only. In other instances enterococci and / or faecal streptococci data may be available.

The practical guidelines below indicate which data should be selected and how it should be used. Some explanation and rationale for data selection is given. Note is made however, that future monitoring should comprise testing for enterococci in both source and recreational water.

i) No available microbiological data

The protocol requires, in the absence of any Microbiological monitoring data for sources that an "Estimated resulting faecal streptococci/ enterococci concentration" be computed taking into account findings of a sanitary inspection.

Thus, if the sanitary inspection reveals that there is a wastewater discharge with secondary treatment and no disinfection, Table 4.2 would be referred to and a faecal streptococci/ enterococci concentration of 10^5 would be assigned. The "Estimated resulting faecal streptococci/ enterococci concentration" is then computed taking into account other factors also determined in the sanitary survey (ie origin of microorganisms, effect of dilution and dispersion, effect of time, infectivity and so on).

Note should be made that a conservative approach has been taken with respect to the assigned values allocated for particular sources in Table 4.2 and also in relation to dilution, dispersion and time etc hence, enterococci monitoring when undertaken, may show a different concentration than that assigned in Table 4.2 and greater (or lesser) die-off with time, depending upon site specifics, treatment regime etc.

Where no monitoring data are available for recreational water, enterococci monitoring should be initiated.

ii) E.coli / faecal coliform data only available

Where *E.coli* / faecal coliform data only is available for the source the same approach as for (i) above should be taken.

Where only historical *E.coli* / faecal coliform data are available for recreational water, this data may be used to determine a corresponding faecal streptococci count using the equation provided by WHO (2001):

Log faecal coliform count = 1.028+0.601*log faecal streptococci count.

It should be noted that there is no exact relationship between faecal streptococci and faecal coliform/ *E.coli* counts and the relationship varies with location. WHO (2001, p39) state, "the equivalence is not exact and, if possible, local recreational water environment managers should define the relationship that exists in their own waters." Hence, use of the conversion equation is only an interim measure and enterococci monitoring of recreational waters should be initiated for the purposes of recreational water classification.

Water Quality Monitoring and Testing
Continued

iii) Faecal streptococci data only

Where faecal streptococci data only are available, this data should be employed.

Thus, results for faecal streptococci monitoring of a water source would be used to "assign" a concentration for the source, rather than using Table 4.2. Due to the predominance in the literature of faecal streptococci compared with enterococci data, much of Table 4.2 relates to faecal streptococci rather than enterococci levels.

For the purposes of the document, as for WHO (2001), the terms of faecal streptococci, intestinal enterococci and enterococci have been considered to be synonymous, despite the fact that the faecal streptococci group contains *S bovis* and *S equinis* (which have animal faeces as their source) in addition to enterococci. Some allowance has been made for this, as the computation of the "Estimated resulting concentration" in Table 4.1 also takes into account the infectivity factor relating to the source of pathogens. For example, in the event that monitoring data for a livestock waste source gave a concentration of 10^5 faecal streptococci per 100 mL it would be discounted by 0.5 on the basis of infectivity (this assumes that the source of pathogens are animal and indirectly assumes that not all of the faecal streptococci detected are likely to be enterococci).

In contrast, source water subjected to human effluent would not be discounted due to the human source of pathogens and the presumption that the majority of faecal streptococci are likely to be enterococci (ie human faecal streptococci).

For recreational waters, faecal streptococci data likewise would be employed if available, but as enterococci levels most accurately reflect the ranking of significance of contamination, faecal streptococci monitoring should be replaced with monitoring for enterococci.

iv) Faecal streptococci data and Enterococci data

Where both sets of data are available the question arises as to which dataset should be employed.

In instances where the faecal streptococci and enterococci concentrations are the same or similar, this indicates that all (or the majority) of faecal streptococci are enterococci. Such a scenario is expected for sources with predominantly human inputs. In such an instance, either dataset could be employed. While it makes little difference which dataset is used in this circumstance, sanitary survey observations should be "overlaid" onto the data for "sense". If sanitary survey observations indicate the source to have high animal faecal input, it is unexpected that enterococci and faecal streptococci counts would be the same or similar, requiring investigation of analytical testing, sample locations etc.

In the instance where the faecal streptococci data and enterococci data are significantly different, the question arises as to which dataset should be employed. Prior to the use of either dataset, sanitary survey observations should be "overlaid" on data for "sense".

For sources where enterococci counts are significantly lower than faecal streptococci counts (the opposite cannot occur) it indicates a significant animal faecal input (ie a predominance of faecal streptococci of non human origin). If the sanitary inspection has not revealed such an input, a site inspection should be carried out to ascertain whether this is in fact the case. If validated by site inspection (ie a known animal faecal input associated with the source), either dataset may be used but with different treatment, giving consideration to the infectivity factor. For example, if the sanitary inspection has confirmed a significant domestic animal input then the faecal streptococci count may be employed in combination with an infectivity factor of 0.5 (domestic animal). If the enterococci dataset is used, it may be necessary to make relevant adjustment for infectivity (infectivity factor = 0.5-1.0 ie human contribution uncertain).

In theory, either dataset in combination with the relevant infectivity factor should yield the same numerical result. Clearly this highlights the need to "overlay" faecal streptococci/ enterococci data with relevant site-specific sanitary survey information to give the data relevance.

For recreational waters, as enterococci levels most accurately reflect the ranking of significance of contamination, enterococci data is preferred over faecal streptococci data (despite the stated interchangeability of terms faecal streptococci, intestinal enterococci and enterococci).

v) Enterococci data only

As for (iv) above, use of enterococci data is preferred to rank the significance of contamination both in source and recreational waters. For sources, enterococci data should be "overlaid" with sanitary site inspection information to ensure that the "Estimated resulting faecal streptococci/ enterococci concentration" reflects site information.

Water Quality Monitoring and Testing
Continued

5.2.2 Numerical Value / Statistic Used to Ascertain Significance Ranking Prior to Determination of Proposed Recreational Water Classification

Another issue relating to data selection is which numerical value or statistic should be used when computing the "Estimated resulting faecal streptococci/ enterococci concentration" for sources, prior to the determination of significance ranking which is an input for the determination of proposed classification as per Table 6.2.

Recreational monitoring data against which the ranking of significance of contamination is undertaken is a 95^{th} percentile value of faecal streptococci / enterococci. This however, is not the case for assigned concentration values for sources presented in Table 4.2, as 95^{th} percentile values were generally not available in the literature. A variety of statistics including median, arithmetic mean, geometric mean and ranges were cited from the literature to describe faecal streptococci/ enterococci concentrations in various sources in Table 4.2.

In addition, with few exceptions, data cited in Table 4.2 does not distinguish wet from dry weather conditions (due to the scarcity of such information) hence larger ranges than might be encountered in either dry or wet weather are a consequence. The concentration of faecal streptococci / enterococci attributed to each source was conservatively assigned, in most cases representing the maximum order of magnitude from the literature for that source type.

The overlapping ranges of various sources complicated the assignation of values. Where there are existing monitoring data for sources, it is recommended that a 95^{th} percentile value be employed where available. Where this is not practicable, upper confidence limit or other measures appropriate to the data should be used.

If data shows a high value of an outlier, investigation should ascertain whether some operational factor (eg sewage plant treatment failure) is the cause etc. It may also be relevant to segment data into periods of good operational control and poor control (breakdown or under-dosing for example), as may be the case with sewage treatment plants, deriving a 95^{th} percentile or other upper confidence limit value for each circumstance.

Likewise, it is recommended that wet and dry weather data is segmented if possible so that a faecal streptococci / enterococci concentration can be assigned for both conditions. Assignation/ computation of microbial concentration and any assumptions regarding effect of dilution, dispersion, effect of origin of microorganism etc should be supported by sanitary survey information.

When data collection programs are designed, provision should be made to collect key attributes, such as weather conditions, plant operating conditions, timing of school holidays (eg for beach areas), and so on so as to better understand and analyse the microbiological data collected.

Water Quality Monitoring and Testing
Continued

5.2.3 Summary

The tables below provide a summary of actions discussed in detail above.

Source Data

Available microbiological monitoring data	Action
None	Refer Table 4.2 to assign faecal streptococci / enterococci concentration In long term verify assumptions with enterococci monitoring, where economically justifiable
E.coli / faecal coliform data only	Refer Table 4.2 to assign faecal streptococci / enterococci concentration. In long term verify assumptions with enterococci monitoring
faecal streptococci only	Use this data but overlay sanitary survey observations In the long term initiate enterococci monitoring
enterococci & faecal streptococci data	Use enterococci data and use additional information provided by faecal streptococci data and sanitary survey to inform assumptions (May also use faecal streptococci data providing relevant assumptions are made)
enterococci data	Use this data

Use 95^{th} percentile data where available, else upper confidence limit or other measure appropriate to the data.

Recreational Water

Available microbiological monitoring data	Action
None	Initiate enterococci monitoring
E.coli / faecal coliform data only	Apply WHO conversion equation, but in the long term initiate enterococci monitoring
faecal streptococci only	Use this data (95^{th} percentile) but in the long term initiate enterococci monitoring
enterococci & faecal streptococci data	Use enterococci data (95^{th} percentile). Use faecal streptococci data to inform sanitary survey observations
enterococci data	Use this data (95^{th} percentile)

6 Classification of the Water Body

6.1 WHO Basis for Classification

The WHO has provided particular classifications of recreational waters based on numbers of faecal streptococci present or likely to be present. The selection of these numbers is based on a consideration of the likelihood that the contamination will give rise to infection and illness in those persons using the water body for recreational purposes. The basis for the WHO Beach Classifications is summarised in Table 6.1, and the full classification is listed in Appendix E.

Table 6.1: Basis for WHO Beach Classifications

Number of Faecal Streptococci	Risk of Illness(1)	Beach Classification(2)
< 40	GI < 1 in 100 exposures AFRI < 1 in 300 exposures	Very good
40 – 200	GI < 1 in 20 exposures AFRI < 1 in 40 exposures	Very Good – Good
201 – 500	GI < 1 in 10 exposures AFRI < 1 in 25 exposures	Fair – Poor
> 500	GI > 1 in 10 exposures AFRI > 1 in 25 exposures	Poor – Very Poor

Notes to Table 6.1:

1. *AFRI: acute febrile respiratory illness; GI: gastrointestinal illness*
2. *The assignment depends on whether the sanitary inspection infers higher or lower numbers of organisms.*

It can be seen from Table 6.1 that the WHO classifications are based on categorising recreational waters as:

- "very good" or "good" if the infection levels are such that they would not normally be detectable (ie less than 5% of those exposed are likely to become ill with a gastrointestinal illness), and
- "poor" or "very poor" if the infection levels are at levels at which they may become detectable (ie more than 5% of those exposed are likely to become ill with a gastrointestinal illness).

The WHO beach classifications have been accepted as the basis for this guidance paper although, in general, the risk levels may be higher than some would accept for a "very good" and "good" classification.

It can also be seen that there are only small differences in the numbers of organisms and risk levels for the various gradings; in practice these differences may not be able to be distinguished because of the variability in numbers of organisms in waters.

The WHO qualify the assignment of a ranking to a particular water body depending on the results of the sanitary inspection. If the results of the sanitary inspection are generally consistent with the monitoring results, then the classification is based on the numbers determined in monitoring. If the sanitary inspection indicates that the contamination levels appear to be substantially higher or lower than indicated in monitoring, then the classification is adjusted or further follow up is indicated to resolve the inconsistency.

The results of the WHO sanitary inspection are not directly related to particular numbers of organisms that might be present, and therefore the results of the WHO sanitary inspection are simply ranked as having a "Very low", "Low", "Moderate", "High" or "Very High" contamination potential.

Classification of the Water Body
Continued

6.2 Recommended Basis for Classification

In the preceding sections of these guidelines it has been indicated how the sanitary inspection can provide a qualitative grading indicating the potential number of organisms which may be present.

Adopting a similar approach to that of the WHO (Appendix E), it is proposed that the classification of the recreational waters be based on the results of monitoring and sanitary inspection as listed in Table 6.2.

The management requirements for recreational waters will depend on a variety of factors, including for example the potential for contamination to be present, the extent to which the water body is likely to be used for recreational purposes, and the expectations of the community as to the suitability of the water for recreational purposes. Suggestions for consideration when establishing management requirements are discussed in Appendix G.

A water body may have more than one classification. For example, a recreational area may have a lower classification for wet weather conditions than for dry weather conditions. The management actions required therefore may vary depending on external conditions (weather, time of year, etc).

Table 6.2: Proposed Classifications based on the results of Monitoring and Sanitary Inspection carried out in accordance with these Guidelines

Ranking of Significance of Contamination[3]	Number of Faecal Streptococci determined from Monitoring[4]			
	<40	40 – 200	201 – 500	> 500
	Risk Level Inferred from Numbers of Organisms[2]			
	GI < 1 in 100 exposures AFRI < 1 in 300 exposures	GI < 1 in 20 exposures AFRI < 1 in 40 exposures	GI < 1 in 10 exposures AFRI < 1 in 25 exposures	GI > 1 in 10 exposures AFRI > 1 in 25 exposures
Very Low	Very good	Very good	Follow up[1]	Follow up[1]
Low	Very good	Good	Fair	Follow up[1]
Moderate	Follow up[1]	Good	Fair	Poor
High	Follow up[1]	Follow up[1]	Poor	Very poor
Very High	Follow up[1]	Follow up[1]	Poor	Very poor

Notes to Table 6.2:

1. *Unexpected result requiring reconciliation as far as is practicable. Because monitoring data for the bathing water provides direct information on microbiological levels, this data should take precedence over estimates from sanitary inspection unless the monitoring data is uncertain or limited (e.g. does not include the range of applicable conditions such as wet weather).*
2. *AFRI: acute febrile respiratory illness; GI: gastrointestinal illness*
3. *Ranking based on numbers of Faecal Streptococci present estimated from Sanitary Inspection with particular emphasis on human faecal contamination. Order of magnitude estimates only – source data is not available to produce 95th percentile values.*
4. *95th percentile values, as nominated by WHO, and in accordance with common practice for assessing health outcomes. Monitoring results may show considerable variability reflecting the nature of bathing water sites. In such cases the data and causes of the variability will need to be reviewed to determine an appropriate method for treating outliers and estimating the upper confidence limit. It may be appropriate to distinguish and separately classify different conditions such as wet weather if these are associated with significantly different levels of contamination.*

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Appendix A

Sanitary Survey Information Sources

Maps:

- Detailed 1:25,000 maps showing water courses, land contours, roads, towns, WWTPs, landfills, major industrial centres,
- Maps showing water depth and currents in receiving water body,
- Colour aerial photos (1:50,000),
- Maps of land use, from regional strategy plans.

Information on the Water Body of Interest:

- Interview with water body management (usually government authority, but may be privately run facilities, eg water skiing, kiosk, etc),
- Natural resource agencies, environmental regulators, catchment management authorities, and other water and land management agencies (local, state and/or federal),
- Water Source Protection Plans,
- Previous survey reports and other investigations,
- Customer complaint history,
- Water quality information (for recreational water and discharges) including nutrients and occurrence of algal blooms (particularly cyanobacteria).

Information on Discharges of Stormwater

- Drainage pipe network plans, especially locations where pipes discharge to water courses from local towns,
- Local council.

Information on Discharges of Municipal Wastewater

- Local tourism authority, facility management for size of towns, major tourist centres, camp grounds (magnitude and timing of population loads),
- Sewered and unsewered areas. Plans showing water authority Sewerage District boundaries; Septic tank authorisations from council,
- Sewerage plans – including location of major pumpstations & emergency overflows. Sewerage system incident and maintenance records – ie frequency of discharge to the environment,
- WWTPs plans, incident records and maintenance records– locations, sizes, discharge of treated effluent to land or water, frequency of untreated discharges.

Information on Other Potentially Significant Discharges

- Commercial/farming activities – locations, types, sizes,
- Landfill sites – location, types, size,
- Hazardous industrial facilities – location, type, size. Frequency and impact of spill or uncontrolled discharge. Response to fire.

Appendix B

Interview / Site Visit Sample Questions

A. Catchment Activities

1. Has the checklist of information been used to identify all potential sources of risk (both point sources, such as waste holding dam discharge points, and diffuse sources such as animals) within the catchment?
2. Have all WWTP and stormwater discharge points and sewer overflow points been identified?
3. Have septic tank areas been identified?
4. Have any waste containment dams and their discharge points (eg piggery or dairy waste holding dams) been identified?
5. What wastes / discharges are produced by industrial and commercial premises within the catchment? How and where are they disposed of (including transport routes for these wastes)? Have there been any spills, fires or incidents which involved discharge of wastes to nearby water courses?
6. Where is domestic rubbish disposed of?
7. Is there significant recreation (legal or illegal) in or near waterbodies in the catchment (eg fishing, marroning, camping, swimming, sailing etc)? What is it, how many people and of what ages are involved (young children, elderly people, persons with weakened immune systems), what toilet facilities are provided?
8. List specific questions to be followed up as a result of information review (in preparation for survey).

B. Catchment Management

1. Identify what other agencies have control or jurisdiction in the catchment. How do the various agencies interact? Are there political agendas or other complications?
2. Is there a Catchment Management Plan? What are the conclusions and recommendations?
3. Does the Catchment Management Authority (if there is one) have the resources (personnel and financial / material) and the authority to identify and resolve catchment and water quality problems?
4. Are water quality records kept to assess trends and to assess the impact of different activities and contaminant control techniques in the catchment?
5. Have past sanitary surveys been undertaken? What were the findings, recommendations and actual actions undertaken?
6. Have other authorities identified problems in the course of their work? What are these problems and have these problems been adequately addressed?

C. Water Body

1. Are shorelines inspected for pollutants?
2. How many people use it? What ages? International / local tourists?
3. What for?
4. What toilet facilites are provided, and what technology (sewered, septic, pit, etc)? Are the toilets close to popular usage sites? How far are the toilets from the water itself?
5. Are there any other pollution hazards near the water body?

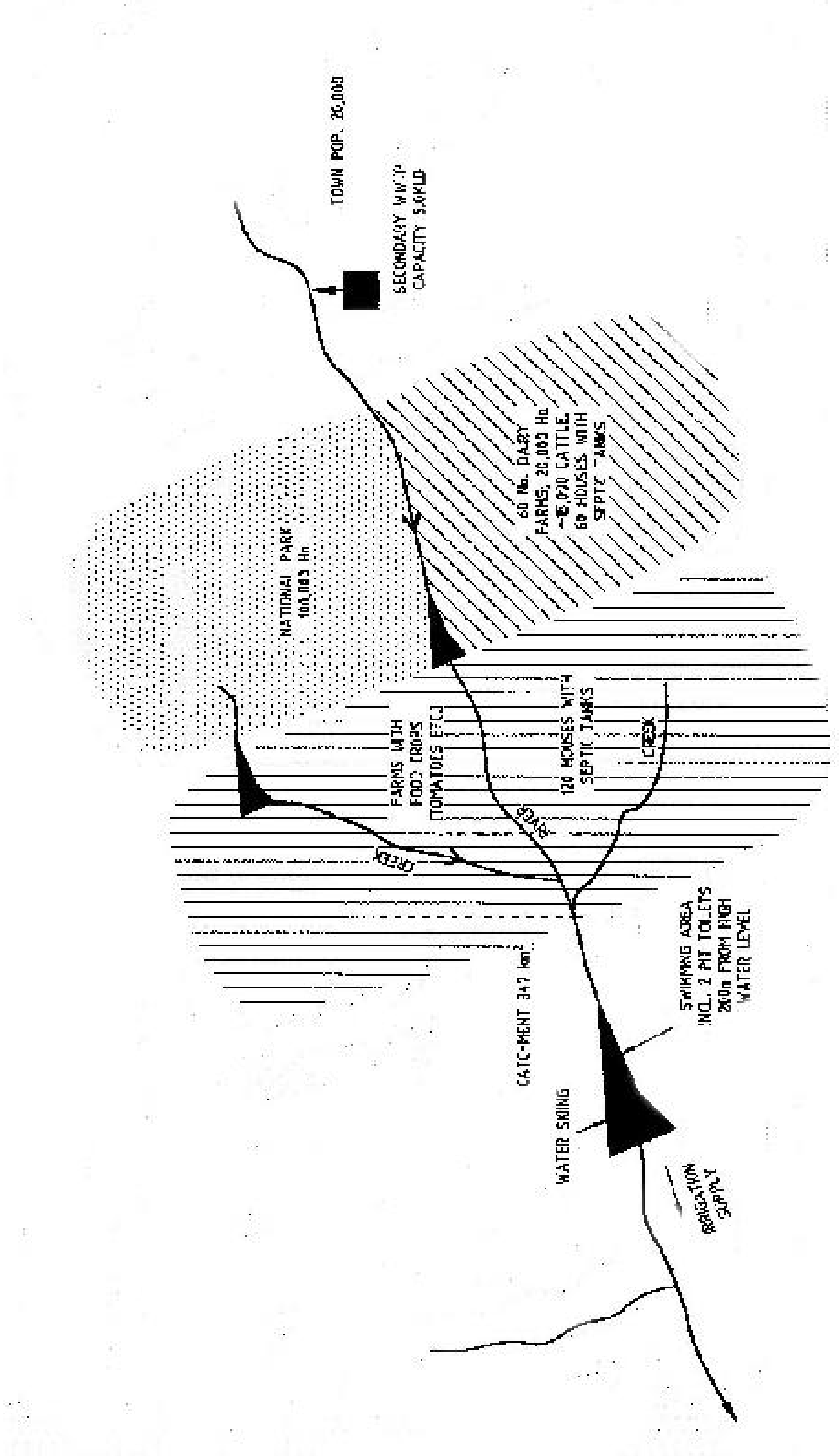
D. Sewage System Inspection

All sewage systems (piped and on-site) should be inspected to identify issues which could pose a risk with respect to water quality.

1. Have leaks from the system been located?
2. Where are overflows? How often do overflows occur? What volume is involved?
3. Are septic tank eduction contractors licensed? Where do they dispose of wastes? Is this monitored / reviewed?
4. Have key stakeholders been interviewed – particularly operators or others with a long history of the system.

Appendix C

Illustration of Catchment System Schematic



Appendix D: Supporting Data

Table D-1 Supporting Data To Aid The Determination Of Likely Faecal Streptococci (Enterococci) Levels In Various Recreational Waters Based Upon Sanitary Survey Observations.

Reference	Content	Category

Achuthan, NR, Brown, JD, Court, JD & Low, DD (1985) 'Development of a Beach Pollution Index for Sydney Coastal Beaches' *Water*, Sept, pp 14-18	• The following aesthetic requirements should apply:
	  • No faecal solids
	  • No noticeable turbidity or discolouration
	  • No perceptible smell
	  • Any sewage slick should be inoffensive
	• Sample Beach Pollution Survey sheet given
		Survey form

Alkan, U, Elliott, DJ & Evison, LM (1995) 'Survival of enteric bacteria in relation to simulated solar radiation and other environmental factors in marine waters' *Water Research*, **29**, pp2071-2080	• Solar radiation as a bactericidal agent cannot be dismissed even for low levels of intensity of radiation and turbid waters. • The variability of bacterial dieoff rates in sea water can be primarily attributed to the variability of the intensity of radiation and the micro environmental factors (turbidity, sewage and vertical mixing) influencing the depth profile of the intensity of radiation and the bacterial concentration (ie the transport of bacteria to the upper layers of the water where light penetration is more pronounced). • Enterococci species were found to survive only marginally better than *E.coli* species • Temperature proved not to exert any significant effect on bacterial survival in seawater in the presence of light. The dieoff rates were not altered significantly by the variation in temperature from 10 to 30 degrees Celsius. This finding was attributed to the fact that the effect of the light on the dieoff rate overrides the effect of temperature.	Solar inactivation
Anderson, SA, Turner, SJ & Lewis, GD (1997) 'Enterococci in the New Zealand environment – implications for water quality monitoring' *Water Science Tech* **35**(11-12), pp325-331	• Heavily contaminated wastewater =>10^7 Enterococci • Unimpacted marine waters=<10^1 Enterococci • However: relatively high enterococci levels were recorded from supposedly pristine freshwaters where direct human impact was minimal or absent • Analysis of levels in animal faecal specimens revealed that birds exhibit a consistently high load. While loads in cattle and sheep are lower the large volume of faecal material from these animals means that they have a significant impact on quality of pastoral runoff (table provided) • Conclude that it is difficult to predict faecal enterococci load from any animals due to variability associated with age, sample location, feed source and animal health • Detection of sunlight exposed *Enterococcus faecalis* by probing was greater than recovery on selective media when probing used and an enterococci quiescent response • Elevated enterococci levels in seaweed indicating possible expansion in this growth permissive medium • Possible implication for this project: large amounts of seaweed at beach location should be recorded	Enterococci levels including sources, persistence and possible growth
Ashbolt, NJ, Grohmann, GS & Kueh, CSW (1993) 'Significance of Specific Bacterial Pathogens in the Assessment of Polluted Receiving Waters of Sydney, Australia' *Water Science Tech* **27** (3-4) pp449-452	• FS in Malabar effluent = 5.6log/100mL	Enterococci levels
Baron, J & Bourbigot, M (1996) 'Repair of Escherichia coli and Enterococci in Sea Water after Ultra Violet Disinfection Quanitification using Diffusion Chambers' *Water Research* **30**(11), pp2817-2821	• With respect to UV disinfection, no repair was shown for enterococci cf E.coli	Solar inactivation
Bergstein-Ben Dan, T & Stone, L (1991) 'The Distribution of Fecal Pollution Indicator Bacteria in Lake Kinneret.' *Water Research*, **25** (3), pp 263-270	• Demonstrated that enterococci accumulation occurs in sediment and bottom waters • Concludes that each bacterial species has its own specific survival rate and unique response characteristics that determine its distribution over depth and time	General /sediment
Bernard, AG (1989) "The Bacteriological Quality of Tidal Bathing Waters in Sydney (Australia)' *Water Science Tech*, **21** (2), pp65-69	• Rainfall increased the incidence of higher faecal streptococci levels even at those bathing areas where the organism is only infrequently detected during dry weather	Rainfall impact
Burm, RJ &Vaughan, RD (1966) "Bacteriological comparison between combined and separate sewer dicharges in southeastern Michigan' *JWPCF* **38**, pp400-409	• A comparison of combined urban sewageplus stormwater collection system (pop 420,000) with a separate stormwater system {pop 67,3000) found that FS density in the separate system ranged from $2.0x10^4$ – $3.9x10^5$/100mL) compared with the combined system with FS ranging from $3.2x10^5$ – $7.4x10^5$)	Enterococci levels
Cheung, WHS, Chang, KCK & Hung, RPS (1991) 'Variations in microbial indicator densities in beach waters and health related assessment of bathing water quality' *Epid Infect* **106**, pp329-344	FS levels: • Channel sewage outfall: $4.9x10^5$ • Tuen Mun Nallah: $3.5x10^4$ • Fai min kok stream: $4.1x10^5$ • Livestock waste: $1.0x10^5$	Enterococci levels

Appendix D: Supporting Data

Continued

Reference	Content	Category
Davies- Colley, RJ, Bell,RG & Donnison, AM (1994) 'Sunlight inactivation of Enterococci and fecal coliforms in sewage effluent diluted in seawater' *Appl Environ Microbiol* **60**(6) pp2049-2058	• Enterococci persists much longer in seawater than faecal coliforms because of both the broader shoulder on inactivation curves and the lower inactivation coefficient • The greater persistence of enterococci than faceal coliform may explain why enterococci predicts GI symptoms of swimmers better than traditional coliform indicator. • It is more difficult to model enterococci inactivation in seawater receiving effluent discharges cf FC	Enterococci persistence
Davies- Colley, RJ, Donnison, AM, Speed, DJ, Ross, CM & Nagels, JW (1999) 'Inactivation of faecal indicator microorganisms in waste stabilisation ponds: interactions of environmental factors with sunlight' *Water Research* **33**(5), pp1220-1230	• Sunlight is the factor of overriding importance in inactivation • Sunlight inactivation of enterococci is strongly dependent on DO and on light absorbing waste stabilisation pond constituents, but independent of pH in the range 7-10. These findings are consistent with inactivation primarily by photo-oxidative damage to the cell membrane • Same inactivation results for enterococci as found for waste stabilisation ponds were obtained for sewage polluted seawater • Can deduce that the longer residence times in waste stabilisation ponds will lead to increased sunlight exposure and thus greater likelihood of inactivation • Note also refers to other papers and relationship of temp to inactivation. Some researcher have found that sunlight more important than temp • Possible implication for this project; record residence times in waste stabilisation ponds where relevant	Solar inactivation
DeGuida, RN (1988) 'Urban runoff and combined sewer overflow' *J WPCF* **6**, pp 864-867	• Refers to a mathematical model	Hydrology
Donnison, AM & Ross, CM (1995) 'Somatic and F-specific coliphages in New Zealand waste treatment lagoons' *Water Research*, **29**, pp1105-1110	Enteroc occi levels: • Final discharge from meat processing wastes (2500 sheep and 150 cattle per day) plus some domestic sewage (1000 people) – 60 day retention: 31/100mL (range=5-130) • Final discharge, meat processing only (150 cattle per day): - 30 days retention: 87/100mL (1.7-1300) • Treated domestic sewage from a city (pop 150,000): 36/100mL (11-240) • Treated domestic sewage from a small town (pop 10,000): 10/100mL (0.2-1900)	Enterococci levels
Gannon, JJ & Busse, MK (1989) '*E.coli* and Enterococci levels in Urban Stormwater, River Water and Chlorinated Treatment Plant Effluent' *Water Research* **23** (9) pp1167-1176	Enterococci levels: • Barton-Argo upstream: mean dry 21, wet 65 (max dry250-wet1000/100mL) • Allen Drain: mean dry 120, wet 6400 (max dry 27,000 wet340,000) • Traver Drain: mean dry 1550 wet10,800 (max dry 13,000 wet 80,000) • Fuller Drain: mean dry 4 wet 23 (max dry10 wet1600) • North Campus mean dry 790 wet 9100 (max dry7000 wet 34,000) • Gallup park d/s mean dry 42, wet 300 (max dry260 wet45,000) • Ann Arbor ww eff mean dry39 wet 57 (max dry140 wet 310) Levels following rain: • Day 0 following rain: mean 1730 Max 52,000 • Day 1 following rain: mean 210 Max 24,000 • Day 2 following rain: mean 94 Max 1100	Enterococci levels
Geldreich, EE (1972) 'Buffalo Lake Recreational Water Quality: A Study in Bacteriological Data Interpretation.' *Water Research*, **6** pp913-924	• FC/ FS ratios only valid during the initial 24hr travel downstream from point of pollution discharge into receiving stream	General
Geldreich, EE (1974/75) 'Microbiological Criteria Concepts for Coastal Bathing Waters.' *Ocean Management*, **3**, pp225-248	• The FS group includes several biotypes that are of limited sanitary significance. The ubiquitious S faecalis var liquefaciens may detract from the significance of this indicator system for defining faecal contamination when interpreting counts less than 100FS/mL because at these low densities this biotype is generally the predominant strain	Indicator concept
Geldreich, EE (1976) 'Applying Bacteriological Parameters to Recreational Water Quality.' *JAWWA* **62**, pp 113-120	Enterococci levels: • Prairie watersheds: 83-180/100mL • lakes: 170-444/100mL • Rivers 88-256/100mL • Private wells:18-8800*/100mL *found to be associated with *E. faecalis var liquefaciens* high percentage of the low faecal streptococci densities common in good quality water	Enterococci levels
Geldreich, EE (1978) 'Bacterial populations and indicator concepts in faeces, sewage, stormwater and solid wastes' in *Indicators of Viruses in Water and Food.* G Berg (ed) Ann Arbor Science Ann Arbor MI pp51-97	• Levels of faecal streptococci in raw sewage given for various communities. Raw sewage ranges from $6.4x10^4$ – $4.5x10^6$	Enterococci levels

Appendix D: Supporting Data
Continued

Reference	Content	Category
Geldreich, EE, Best, LC, Kenner, BA &Van Donsel, DJ (1968) 'The Bacteriological Aspects of Stormwater Pollution' *JWPCF*, Part1, Nov, pp1861-1872	• Levels of FS for stormwater from wooded hillside, street gutters, business district, rural and rainwater given.	Enterococci levels
Genthe, B, Kfir, R &Franck, M (1995) 'Microbial Quality of a Marine Tidal Pool' *Water Science Tech* **31** (5-6) pp299-302	• Findings indicate that pollution in bathing areas with restricted water exchange is associated with bathers themselves	Bather load
Grabow, WOK & Nupen, EM (1972) 'The load of infectious micro-organisms in the waste water of South African hospitals' *Water Research* **6** pp1557-1563	• Average of 2.1×10^{6} per 100mL in raw sewage	Enterococci levels
Grabow, WOK, Bateman, BW &Burger, JS (1978) 'Microbiological quality indicators for routine monitoring of wastewater reclamation systems' *Progress in Water Technology* **10**, pp317-327	• Activated sludge effluent = 1.4×10^{5} • Maturation pond effluent = 1.4×10^{3} • Sand filtration = 1 • Breakpoint chlorination = 0	Enterococci levels
Kueh, CSW & Grohmann, GS (1989) 'Recovery of viruses and bacteria in waters off Bondi beach: a pilot study.' *The Medical Journal of Australia* Dec 4/18 Vol **151** pp 632-638	• FS counts decreased from 10^{4}-10^{7} in the sewage effluent to 10^{2}-10^{4} in the plume to fewer than 10 at the stations • Bacterial counts of the stormwater were comparable with those of the sewage plume and counts in beach water were significantly higher than those in the open water • Counts at the site furthest away from the two sources of pollution (sewage and stormwater) had the lowest FS counts with the exception of control sites	Enterococci levels and dieoff

Kuen, CSW, Grohmann,GS &Sheehan, D (1991) "The impact of Stormwater and Other Urban Runoffs on the Microbiological Quality of Sydney Beaches" AWWA 14th Federal Conference, Perth 1991, Vol 2	• Factors which influence the impact of urban runoff on beach water quality include:
	  • Flow from lagoon / creek etc
	  • Runoff volume relative to the beach (eg impact if vol large and beach semi enclosed)
	  • Topography of the beach
	  • Rate of water exchange and dilution
	  • Coastal structure
	• Rainwater contains street washings, litters, animal faeces and in some instances septic and sewer overflows which have high counts
		Rainfall and other impact

Lord, DA, Grabow, WOK & Roberts, MJ (1988) 'Dispersion of Sewage Wastes in Near shore Coastal Waters' IAWPRC / AWWA Conference Water Quality & Management for Recreation & Tourism July 1988	Enterococci levels: • Untreated marine wastewater discharge: 1×10^{6} • Seawater in the surf zone: at wastewater influent: 1×10^{3} • 12km from surf zone site but adjacent to a smaller discharge: 0	Enterococci levels
Mc Coy, JH (1965) 'Sewage Pollution of Rivers, Estuaries and Beaches' *Sanitarian* **74** pp79-92	• Levels of E.coli and Salmonella occurrence only	FC/ Salmonella
Omuma, T, Onuma, M, Aizawa,J & Yagi, T (1989) 'Removal Efficiencies of Indicator Microorganisms in Sewage Treatment Plants' *Water Science Tech* **21** (3) pp119-124	• Removal efficiencies of enterococcus bacteria up to and including secondary sedimentation tank activated sludge process was 97%; the trickling filter process was 98.3% • Coliform and enterococcus were removed with equal efficiency by the 2 processes • Enterococcus bacteria were often detected when chlorine residuals were below 0.5mg/L	Removal efficiency
Papadakis, JA, Mavridou, A & Richardson,SC (1997) 'Bather related microbial and yeast populations in sand and seawater' *Water Research* **31**, pp799-804	• Discusses the merit of a supplementary indicator with respect to skin related infections and ear, nose and throat etc (ie *S. aureus*)	S.aureus
Paul, JH, Rose, JB, Jiang, S, Kellogg, C & Shinn, EA (1995) 'Occurrence of Fecal Indicator Bacteria in Surface Waters and the Subsurface Aquifer in Key Largo, Florida' *App Environ Microb* **61**(6) pp2235-2241	• Looks at the faecal contamination of the shallow onshore aquifer and current sewage disposal practices	Aquifer

Appendix D: Supporting Data
Continued

Reference	Content	Category
Pederson, DC (1981) 'Density Levels of Pathogenic Organisms in Municipal Wastewater Sludge – A Literature Review' USEPA Cincinnati OH	Enterococci levels in raw sludge: • Primary; $8.9x10^6$ • Secondary: $1.7x10^6$ • Mixed: $3.7x10^6$ • Post high rate anaerobic digestion: $9x10^5$	Enterococci levels
Qureshi, AA & Dutka, BJ (1979) 'Storm Runoff Microbiology Adds to Concerns' *Water & Sewage Works*, March	• The bacterial loading from urban storm runoff can be more significant than for residual sewage • There are no typical rainfalls • Maximum bacterial populations tended to occur occur 60-105 minutes after the water flow in the weir began to change with the change occurring 5-15 minutes of a rain's commencing. • Traditional indicators such as FS approached dilute sewage concentrations during each event	Rainfall impact
Rajala, RI & Heinonen-Tanski, H (1998) 'Survival and transfer of faecal indicator organisms of wastewater effluents in receiving lake waters' *Water Science Tech* **38**(12), pp191-194	Enterococci levels: • In summer in wastewater TP effluent: $5.9x10^6$ • In winter in wastewater TP effluent: $1.46x10^4$ (subartic) • Indicators were found several km downstream from the wastewater discharge point • Greater persistence in winter	Enterococci levels
Roll, BM & Fujioka, RS (1997) 'Sources of faecal indicator bacteria in a brackish, tropical stream and their impact on recreational water quality' *Water Science Tech* **35**(11-12), pp179-186	Enterococci levels: • Upper Lake, inland site near inflow of tributary: 1453/100mL • Major tributary and storm drain: 2311/100mL; Major tributary and storm drain: 1232/100mL • Upper stream near mouth of lake: 701/100mL • mid point of stream: 541/100mL • dead end branch of stream poor water circulation: 1346/100mL • lower stream: 286/100mL • mouth of stream usually stagnant, shallow water blocked by sandbar: 74/100mL • Ocean water site opposite mouth of stream7/100mL • Results show that streams and storm drains are major external sources of faecal bacteria and nutrients. During heavy rain conditions, the concentration of faecal indicator bacteria at all sites was shown to increase by over 100 fold as compared to dry days. Faecal droppings of pets, birds, and animals occur on land and are washed into streams and storm drains by rain. Some animals discharge faeces directly to streams on a daily basis. Four samples of duck faeces were analysed and contained $1.4x10^6$ enterococci per gram of faeces. Soil samples were found to contain $3.9x10^5$ enterococci corresponding to the concentration in streams indicating that soil rather than sewage or animal faeces is the major environmental source of faecal indicator bacteria recovered from streams.	Enterococci levels
Salter, HE, Boyle, L, Ouki, SK, Quarmby, J & Williams, SC (1999) "The performance of tertiary lagoons in the United Kingdom' *Water Research* **33**(18), pp3775-3781	Enterococci levels: • Average in inlet to lagoon: $1.6x10^3$ • Average in outlet to lagoon: $8.9x10^2$ • Mean removal = 0.6log Maximum removal= 2.3 log	Enterococci persistence
Sinton, LW, Finlay, RK & Lynch, PA (1999) 'Sunlight inactivation of fecal bacteriophages and bacteria in sewage polluted seawater' *Appl Environ Microbiol* **65**(8), pp3605-3613	• Concludes that somatic coliphages persist in sunlight exposed seawater longer than faecal coliforms, enterococci and f-RNA phage	Solar inactivation
Turner, SJ & Lewis, GD (1995) 'Comparison of F specific bacteriophage, enterococci and faecal coliform densities through a wastewater treatment process employing oxidation ponds' *Water Science Tech* **31**(5-6), pp85-89	Enterococci levels: • Raw sewage: 3.6×10^6 ($1.5x10^6$-$8.5x10^6$) • Fixed Growth reactors: $1.0x10^6$ ($1.0x10^5$-$2.3x10^6$) • Pond 1 effluent: $8.7x10^3$ ($2.5x10^2$-$2.5x10^4$) • Pond 2 effluent: $9.8x10^2$ ($9.0x10^1$-$9.5x10^3$) • Overall reduction of enterococci = 99.97% • All three indicators were removed with similar efficiency by whole process but F phage and faecal coliforms were reduced at a higher rate than enterococci in second pond. Hence enterococci may be better indicators than F phage as indicators of oxidation pond treatment efficiency	Enterococci levels in sewage and removal efficiency
Weibel, SR, Anderson, RJ &Woodward, RL (1964) 'Urban land runoff as a factor in stream pollution' *JWPCF* **36**, pp914-924	• Characterisation of stormwater from small urban and rural sites revealed fluctuations in quality that reflect human activities over the watershed as well as the magnitude and frequency of storm events • Urban mean FS=3.5x104 (Range1.3-$5.6x10^4$) • Rural mean FS= 4.0x105 (Range$2.1x10^3$–$7.9x10^5$)	Enterococci levels

Appendix D: Supporting Data

Continued

Table D-2 Faecal Streptococci levels (orgs/100mL) in stormwater discharges

(Reference: Rowlands, WG et al., (1992) Coastal Stormwater Study Final Report. Environmental Projects Group Environment Management Unit Sydney Water Board)

Catchment Characteristics	Faecal Streptococci levels orgs/100mL	
	Dry Weather	Wet Weather
Whale Beach Unsewered catchment Low population density: 1143 persons/km^2 Stormwater catchment is 5.4 hectares Total impervious surface area is low (33%)	Median $1.7x10^4$ (650 – $3.0x10^6$)	$1.3x10^3$ – $5.8x10^5$ wet weather maximum one order of magnitude lower wet weather minimum one order of magnitude higher
Greendale Creek Large sewered mixed residential and industrial catchment Stormwater catchment is 227 hectares Total impervious surface area is 49% Population density is 5104 persons/km^2	Median $1.5x10^3$ (40 – $7.0x10^5$)	$4.3x10^3$– $2.0x10^5$ wet weather maximum same order of magnitude wet weather minimum two orders of magnitude higher
Bondi Combined stormwater drain from two sewered areas Stormwater catchment is 91.4hectares Total impervious surface is 75% Very high population density: 9556 persons/km^2	Median $1.5x10^4$ (320 – $5.5x10^5$)	$1.0x10^4$ – $3.2x10^4$ wet weather maximum one order of magnitude lower wet weather minimum two orders of magnitude higher
Malabar Sewered catchment Stormwater catchment is 92 hectares 40% of area is parks and reserves Total impervious area is 28% Population density is 1,350 persons/km^2	Median 110 (10 – $2.3x10^3$)	500 – $4.2x10^3$ wet weather maximum same order of magnitude wet weather minimum one order of magnitude higher
Shelley Beach Sewered catchment Stormwater catchment is 35hectares Total impervious area is 46% Population density is 4549 persons/km^2	Median 540 (10 – $8.5x10^4$)	530 –$4.6x10^4$ wet weather maximum same order of magnitude wet weather minimum one order of magnitude higher

Appendix D: Supporting Data

Continued

Table D-3 Faecal Streptococci levels (orgs/100mL) in receiving waters from the discharge of stormwater

(Reference: Rowlands, WG et al, (1992) Coastal Stormwater Study Final Report. Environmental Projects Group Environment Management Unit Sydney Water Board)

Swimming Beach	Faecal Streptococci orgs/100mL
Whale Beach Stormwater drain outlet discharges directly onto beach and not into receiving waters except during storm events Outlet is just above sea level The closest ocean outfall is 10km (Warriewood STP)	Median 3 (2 – 180) Log decrease median discharge = 3
Greendale Creek Discharge via Curl Curl Lagoon and North Curl Curl Beach The closest outfall is 7km (North Head STP ocean outfall)	Median 9 (2 – 540) Log decrease median discharge = 3
Bondi Discharge to the southern end of Bondi Beach which is close to the Bondi STP ocean outfall	Median 18 (2 – 300) Log decrease median discharge = 3
Malabar Discharge to the northern end of Malabar beach and into Long Bay	Median 38 (2 – 400) Log decrease median discharge = 1
Shelly Beach Discharge is 6km from Cronulla STP ocean outfall Drain runs beneath Shelly Park, approx 1m below ground level before discharging into a gap in the rock platform	Median 4 (2 –170) Log decrease median discharge = 2

Appendix D: Supporting Data
Continued

Table D-4 Summary of Faecal coliform and Enterococci results for sewage treatment plant ocean discharges,

NSW Australia for period July 2000- September 2001 inclusive
(Source: Sydney Water individual routine monitoring reports)

Effluent site	Faecal coliforms (orgs/100mL)	Enterococci (orgs/100mL)	Relationship of Faecal coliform and enterococci levels
Plant 1 (primary sedimentation, sodium hypochlorite disinfection)	Mean – $7.3x10^5$ Median - $4.4x10^3$ Max – $6.2x10^6$ Min – 14 N = 75	Mean – $6.9x10^4$ Median – $3.8x10^3$ Max – $1x10^6$ Min – 60 N = 75	Log faecal coliform = 1.2135 x log enterococci – 0.5437
Plant 2 (primary sedimentation, sodium hypochlorite disinfection)	Mean – $7.5x10^5$ Median - $6.0x10^4$ Max – $6.4x10^6$ Min – 2 N = 75	Mean – $3.1x10^4$ Median – $3.6x10^3$ Max – $3.3x10^5$ Min – 1 N = 75	Log faecal coliform = 1.1087 x log enterococci + 0.775
Plant 3 (screenings, grit and solids removal, biological treatment and disinfection)	Mean – $9.1x10^4$ Median – $7.0x10^3$ Max – $9.3x10^5$ Min – 0 N = 77	Mean – $9.4x10^3$ Median – $1.8x10^3$ Max – $1.2x10^5$ Min – 0 N = 77	Log faecal coliform = 1.173x log enterococci – 0.0777
Plant 4 (secondary treatment including intermittent extended aeration, chlorine disinfection)	Mean –$1.0x10^5$ Median – $2.1x10^4$ Max – $7.6x10^5$ Min – 1 N = 77	Mean – $8.7x10^3$ Median –$1.1x10^3$ Max – $2.8x10^5$ Min – 0 N = 77	Log faecal coliform = 1.0904x log enterococci + 0.7026
Plant 5 (secondary treatment including aeration and UV disinfection)	Mean - $5.8x10^5$ Median - $2.3x10^5$ Max - $9.3x10^6$ Min - $1.4x10^4$ N = 77	Mean - $7.5x10^4$ Median - $1.1x10^4$ Max - $2.6x10^6$ Min - $8.0x10^2$ N = 77	Log faecal coliform = 0.6933 x log enterococci + 2.4893

Table D-5: Statistical analysis of Enterococci results for period 16/3/00 – 11/10/01 for Boag's Rock discharge

Reference: Melbourne Water database, 2001

Site	Enterococci count (orgs/100mL)	
	Average	Range
Effluent sample from outfall pipeline approx 57km away from Eastern Treatment Plant at Carrum (GUNN 7)	137 (N=68)	0 -2300
Onshore seawater sample taken approx 3m southeast of discharge point (GUNN 1)	6 (N=72)	0 - 74
Onshore sample taken approx 1km northwest from the discharge point (GUNN 6)	1 (N=72)	0 - 10
Offshore seawater sample taken 2km from shoreline northwest from the discharge point (control for offshore sampling points located 800km from shoreline) (GUNN 14)	23 (N=71)	0 - 750

Appendix E

WHO Classifications and Indicated Risk Level

	Category	A	B	C	D
	Number of Faecal Streptococci[4]	<40	40 - 200	201 – 500	> 500
	Risk Level[2]	GI < 1 in 100 exposures AFRI < 1 in 300 exposures	GI < 1 in 20 exposures AFRI < 1 in 40 exposures	GI < 1 in 10 exposures AFRI < 1 in 25 exposures	GI > 1 in 10 exposures AFRI > 1 in 25 exposures
Sanitary Inspection Category[3]	Very low	Very good	Very good	Follow up[1]	Follow up[1]
	Low	Very good	Good	Fair	Follow up[1]
	Moderate	Follow up[1]	Good	Fair	Poor
	High	Follow up[1]	Follow up[1]	Poor	Very poor
	Very high	Follow up[1]	Follow up[1]	Poor	Very poor

Notes:

1. Unexpected result requiring investigation
2. AFRI: acute febrile respiratory illness; GI: gastrointestinal illness
3. Ranking based on numbers of Faecal Streptococci present estimated from Sanitary Order of magnitude estimates only – source data is not available to produce 95th percentile values.
4. 95th percentile values, as per WHO.

Appendix F

Comparative *Giardia* and *Cryptosporidium* Levels

Giardia

Water body / source	Typical No. Cysts per L in water body	Reference
River in protected watershed	0.009	Rose et al 1988
Rural areas, no stock	0.005 – 0.34	Ongerth et al 1995
Lake with domestic effluent discharges	0.35	Rose et al 1988
River with domestic effluent & cattle pasture	1.2	Rose et al 1988
Rural areas, farming	17 – 22	Ong et al 1996
Chlorinated secondary sewage effluent	0 – 2.6 <5 – 3080	Rose et al 1988 Thomas et al, in press
Raw sewage	26 – 3022 0.7 – 198	Roach et al 1993 Rose et al 1988

Cryptosporidium

Water body / source	Typical No. Oocysts per L in water body	Reference
Agricultural runoff (dairy/ranch)	2904 1.53 1.09	Madore et al 1987 Ongerth & Stibbs 1987 Rose et al 1988
Raw sewage	Up to 14,000	Madore et al 1987
Treated domestic wastewater	1864 1.0 0.58 <5 - 390	Madore et al 1987 Ongerth & Stibbs 1987 Rose et al 1988 Thomas et al, in press
Pristine waterways (no agriculture, no WWTPs, and very limited or no human access)	0.003 – 0.2	Rose et al 1997
Urbanised waterways	Up to 5,800 0.5 – 4.7	Madore et al 1987 Rose et al 1997

Appendix F
Continued

Cryptosporidium from animals

Total oocyst excretion (oocysts/g):

Calves = 7.3 $x10^9$

Lambs = 4.3 $x10^9$

Mice = 0.98 $x10^9$

Reference: *Cryptosporidium* in Water Seminar, 20 May 1999, Melbourne

Other animals found to excrete *Cryptosporidium* when infected include goats, deer, water buffalo, camels, pigs, horses, native marsupials (eg kangaroos, bandicoots, koalas).

Reference: Fayer, R. et al (1997) *Cryptosporidium and Cryptosporidiosis*. CRC Press. 1-41.

Total oocyst excretion (oocysts/g):

Calves = 40 – 4,000,000

Lambs = 220 – 470,000

Cow = 0.15 – 390

Calf bedding = 6 – 120,000

Lamb bedding = 28 - 5000

Reference: AWA Catchment Management Seminar 13th June 2000

References

Cryptosporidium in Water Seminar, 20 May 1999, Melbourne

Fayer, R. et al (1997) *Cryptosporidium and Cryptosporidiosis*. CRC Press. 1-41.

Madore, M.S., Rose, J.B., Gerba, C.P., Arrowood, M.J. and Sterling, C.R. (1987) Occurrence of *Cryptosporidium* oocysts in sewage effluent and selected surface waters. *J. Parasitol*. **73**: 702-705.

Ong, C., Moorehead, W., Ross, A. and Isaac-Renton, J. (1996) Studies of Giardia spp. and Cryptosporidium spp. in two adjacent watersheds. *Appl. Environ. Microbiol*. **62**: 2798-2805.

Ongerth, J.E. and Stibbs, H.H. (1987) Identification of *Cryptosporidium* oocysts in river water. *Appl. Environ. Microbiol*. **53**: 672-676.

Roach, P.D., Olson, M.E., Whitley, G. and Wallis, P.M. (1993) Waterborne *Giardia* and *Cryptosporidium* oocysts in the Yukon, Canada. *Appl. Environ. Microbiol*. **59**: 67-73.

Rose, J.B., Kayed, D., Madore, M.S., Gerba, C.P., Arrowood, M.J., Stirling, C.R. and Riggs, J.L. (1988) Methods for the recovery of *Giardia* and *Cryptosporidium* from environmental waters and their comparative occurrence. University of Arizona, Tuscon.

Rose, J. B., Lisle, J. T., and LeChevallier, M. (1997) Waterborne *Cryptosporidium*: Incidence, Outbreaks, and Treatment Strategies. In: *Cryptosporidium* and Cryptosporidiosis. Fayer, R. (ed). CRC Press, New York.

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Appendix G

Risk Management Framework

The management requirements for recreational waters will depend on a variety of factors, including for example the potential for contamination to be present, the extent to which the water body is likely to be used for recreational purposes, and the expectations of the community as to the suitability of the water for recreational purposes.

The following sections suggest a framework which can be considered when establishing management requirements.

Risk Associated with Contamination and Management Requirements

The risk or significance of contamination depends on:

- the likelihood that contamination will be present at concentrations that are a cause for concern. This is dependent on the contamination levels, and the recreational water classification levels (Very Good – Very Poor) provide a direct measure of this, and
- the consequence of the contamination or severity of the effects that could be associated with the contamination. The severity of the effects depend, for example, on the potential for illness in those involved in recreation on the water body (which in turn is dependant on the usage of the water body and the nature of the recreation), or level of concern by stakeholders (such as the bathers or the general public) if the contamination were to be present. Typical descriptions of levels of concern are listed in Table G.1.

Based on the likelihood of contamination (ie the Water Classifications (Table 6.1)) and the Consequence rankings in Table G.1, the risk can be determined from Table G.2.

In practice:

- the Consequence descriptors used in Table G.1 should be adjusted to reflect the specific risk management requirements of the responsible authority, and
- the assignment of the level of Consequence for each particular recreational water body needs to reflect the range of issues that are relevant to the water body and are important to the responsible authority and stakeholders. A workshop approach can be useful in doing this.

Table G.1: Level of Concern Associated with Contamination

Severity Ranking	Consequence of the Contamination
1 Negligible	The contamination will not give rise to detectable illness or effects; or The contamination can be regarded as insignificant given the potential for usage of the area or expectations of users
2 Minor	The contamination is unlikely to give rise to detectable levels of illness; or The contamination is unlikely to give rise to a noticeable increase in complaints or concern taking into account the potential for usage or expectations of users.
3 Medium	The contamination has potential for some occasional illness in users and there is potential for the water to be used for recreational purposes; or the contamination is likely to give rise to an increase in complaints or concern taking into account the potential for usage or expectations of users.
4 High	The contamination is likely to give rise to illness in users and there is potential for the water to be used for recreational purposes; or the contamination is likely to give rise to a large number of complaints or a significant level of stakeholder concern; or the contamination or its effects introduces a potential for litigation
5 Very High	The contamination poses a high level of risk to users of contracting illness and there is potential for the water to be used for recreational purposes; or The contamination is likely to be viewed as very unacceptable by the community at large; or The contamination or its effects is likely to result in litigation.

Appendix G: Risk Management Framework

Continued

Control Measures for the Various Classifications of Waters

The responsibility for determining the appropriate response to the level of risk determined for the particular recreational water body will lie with the responsible authority.

It can be expected that the management response will be in accordance with the risk, and an illustration of how this might be defined is indicated in Table G.3. In general, the management response should reduce the risk to an acceptable level.

Table G.2: Ranking of Risk Associated with Contamination

	Likelihood / **Consequence**	*Likelihood of Contamination Being Present [= Beach Classification]*				
		Very Low [Very Good]	Low [Good]	Medium [Fair]	High [Poor]	Very High [Very Poor]
Consequence of the Contamination	1 [Negligible]	Negligible	Negligible	Negligible	Negligible	Low
	2 [Minor]	Negligible	Negligible	Low	Medium	Medium
	3 [Medium]	Low	Low	Medium	High	High
	4 [High]	Medium	High	High	Very high	Very high
	5 [Very High]	High	Very high	Very high	Very high	Very high

Table G.3: Risk and Management Response (for illustration)

Risk	Possible Management Requirement (appropriate management responses to be established by the managing body)
Negligible	No requirement
Low	Monitor
Medium	Monitor
High	Signage
Very High	Signage

Appendix H

Worked Example

*** Disclaimer: the following example is fictitious.*

The authority which manages a sheltered swimming beach has received complaints of illness from people who swam at the beach on a day immediately following a summer storm. The authority wants to determine whether they should close the beach following high rainfall in summer.

1. Sanitary Inspection

The following information was obtained from the Sanitary Inspection:

Recreational Water:

- Sheltered swimming beach area in small town (permanent pop 3,000; summer pop up to 15,000).
- Users
  - Very few April to November
  - Peak usage late December & January (up to 8,000 visitors per day; mostly young families, as there is a surf beach 4 km away). Most visitors are tourists from capital city 80 km away; few international visitors. Traditional holiday town.
  - Approximately 500-1000 visitors per day on weekends in February and March.
- Industry:
  - Fish processing
  - Tourism (summer)
  - One small garment manufacturer for surf wear industry.

Catchment:

- WWTP for town
  - Average Winter Dry Weather Flow = 0.6 ML/d; Average Summer Dry Weather Flow 2.2 ML/d
  - Peak Wet Weather Flow = 3.2 (winter) to 4.6 (summer) ML/d (significant infiltration in old town sewerage system)
  - Plant uses trickling filters to treat to a secondary standard
  - No disinfection
  - Plant achieves secondary standard effluent 95% of time
  - Disposal is to ocean approximately 5 km from beach
  - Short outfall across rocky outcrop
  - Plant overflows and discharges untreated wastewater to creek approximately once every 3 years (long term average).
- The only surface freshwater flow to the beach is from a small creek
  - Flows through a narrow valley containing farmland & state forest, and one small settlement
  - Town stormwater system discharges to creek 0.5 km upstream of beach
    - Dry weather discharge is 0.1 ML/d (due to small old stream now piped)
    - Wet weather discharge is 25 ML/d.
  - Average dry weather flow in creek upstream of town is 6 ML/d
  - Peak wet weather flow upstream of town is ~15 ML/d to 20 ML/d.
- Farmland
  - Dairy cattle area due to high rainfall
  - ~100 farms ranging from 50 to 300 head on each.
  - Total cattle population 13,500; total farm area 35,000 ha
  - One piggery with 500 pigs kept in sheds. New facility with waste management & secondary standard treatment including bunding to prevent untreated discharge to environment in up to 1:10 year ARI storm.
  - Farm houses have septic tanks. Ground is generally rocky, so tanks are often small and may contain toilet (black) waste only; grey water discharged to surface drains or stored & reused for small scale irrigation (eg gardens).
- State forest
  - Area 40,000 ha
  - Currently logged – access by logging trucks.
  - Animal population unknown – anecdotal information from rangers indicates wallaby numbers have increased in recent years but unable to quantify.

Appendix H: Worked Example

Continued

2. Estimated Level of Contamination

The Level of Contamination is estimated for each source under **wet** summer conditions as shown below.

Source	Concentration (refer Table 4.2)	Effect of Dilution & Dispersion		Effect of time (2) (for factor refer Table 4.5)	Resulting Concentration (for comparison with monitoring results)	Effect of Origin of Micro-organisms (for factor refer Table 4.3)	Resulting Concentration (for determining significance)	Significance (refer Table 4.6)
		Nature of discharge and receiving water situation	Dilution factor (1) (refer Table 4.4)					
Town WWTP (Secondary treatment, no disinfection)	10^5	Short outfall close to shoreline	0.0027 (1)	1	~300	1	~300	High
Town stormwater system (wet weather only, no sewage overflows))	10^4	Creek outfall to beach	0.006 (2)	1	~60	1	~60	Moderate
Dairy Farm Runoff (stormwater, rural, wet weather only)	10^4	Creek outfall to beach	0.014 (3)	1	~150	0.5	~75	Moderate
Total					~510		~440	High

Notes:

(1) Dilution Ratio = q / V_L ½ W h; q = 4.6 ML/d = 0.053 m^3/s; Dilution Ratio = 0.053 m^3/s / (0.5 m/s * 20 m * 2 m) = 0.0027

(2) Upstream Dilution: 25 ML/d diluted by stream flow of 20 ML/d => Dilution Ratio is 25/45 = 0.55
Dilution Ratio at beach = 0.23 m3/s / (0.5 m/s * 20 m * 2 m) = 0.01
Overall Dilution Ratio = 0.55*0.01 = 0.006

(3) Upstream Dilution: 20 mm/d * 35,000 ha = 7 ML/d = 0.081 m^3/s
7 ML/d diluted by stream flow of 13 ML/d (20 –7) => Dilution Ratio is 7 / 20 = 0.35
Dilution Ratio at beach = 0.08 m3/s / (0.5 m/s * 20 m * 2 m) = 0.004
Overall Dilution Ratio = 0.35*0.004 = 0.0014

These calculations assume that full dilution is achieved. Inspection is required to confirm this; it may be necessary to assume a lesser level of dilution if full dilution is not likely.

3. Monitoring Results

A monitoring program initiated by the authority found levels of faecal streptococci of 50 to 500 organisms per 100 mL

Appendix H: Worked Example
Continued

4. Classify Recreational Water

The results from the monitoring are consistent with the results predicted from the sanitary survey, and place the beach in the "poor" (shaded box) in the classification table below.

As the water classification is "poor", the responsible authority should consider what management response is required for this recreational water body.

It appears that the greatest contributor to the pathogen load is the WWTP. If the WWTP discharge was disinfected, the numbers of faecal streptococci may reduce to 150 organisms/100 mL, the significance would reduce to "moderate", and classification would improve to "good" or "fair", depending on the actual numbers of organisms determined through monitoring. Other options to further improve the water body would be to extend the outfall, or to reduce the potential for run off from the dairy farm to enter the water body.

Number of Faecal Streptococci estimated from Sanitary Inspection[3]	Number of Faecal Streptococci determined from Monitoring[4]			
	<40	40 - 200	201 – 500	> 500
	Risk Level Inferred from Numbers of Organisms[2]			
	GI < 1 in 100 exposures AFRI < 1 in 300 exposures	GI < 1 in 20 exposures AFRI < 1 in 40 exposures	GI < 1 in 10 exposures AFRI < 1 in 25 exposures	GI > 1 in 10 exposures AFRI > 1 in 25 exposures
Very Low	Very good	Very good	Follow up[1]	Follow up[1]
Low	Very good	Good	Fair	Follow up[1]
Moderate	Follow up[1]	Good	Fair	Poor
High	Follow up[1]	Follow up[1]	Poor	Very poor
Very High	Follow up[1]	Follow up[1]	Poor	Very poor

Notes:

1. *Unexpected result requiring investigation*
2. *AFRI: acute febrile respiratory illness; GI: gastrointestinal illness*
3. *Ranking based on numbers of Faecal Streptococci present estimated from Sanitary Order of magnitude estimates only – source data is not available to produce 95^th^ percentile values.*
4. *95th percentile values, as per WHO.*

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