

**A PILOT STUDY TO DEMONSTRATE
IMPLEMENTATION OF THE NATIONAL
MICROBIAL MONITORING PROGRAMME**

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Report to the Water Research Commission

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EXECUTIVE SUMMARY

South Africa does not currently have a central source of information for assessing the potential health risks associated with natural waters contaminated with faecal pollution. With numerous dense settlements (both formal and informal), increasing urbanisation and other factors, South Africa's water resources are coming under increasing threat from faecal contamination.

The Department of Water Affairs and Forestry (DWAF) is responsible (in terms of the National Water Act) for the operation and maintenance of national water quality monitoring and assessment programmes.

Because microbes behave in a non-conservative manner in water, a national grid of monitoring sites (like that used for monitoring chemical water quality variables) is both undesirable and impractical. This document is the culmination of five years of work towards creating a National Microbial Monitoring Programme (NMMP) that aims to overcome this problem. The programme has the following objectives:

NMMP Objectives

- ★ To provide information on the status and trends regarding the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas;
- ★ To provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water resources.

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"A pilot study to demonstrate implementation of the National Microbial Monitoring Programme"

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1 BACKGROUND

Monitoring, recording, assessing and disseminating information on water resources is critically important to achieving the objectives of the National Water Act (Act No. 36 of 1998). The Department of Water Affairs and Forestry (DWAF), the custodian of South Africa's water resources, must ensure that waters remain fit for use on a sustainable basis. To this end, a number of monitoring programmes are already in place (e.g. the national chemical and biomonitoring programmes). However, given the human health impact associated with faecally contaminated surface waters, a need to assess the potential health risks associated with faecal water pollution in South Africa has become vital for water quality management and strategic decision making.

To assess the status and trends of faecal pollution of South Africa's surface water a national microbial monitoring programme was proposed as early as 1994. In 1996 a conceptual design for microbial quality monitoring of surface water, on a national basis, was compiled by the Institute for Water Quality Studies of the Department of Water and Forestry, IWQS (DWAF) and Environmentek, CSIR. During 1997 and 1998 the proposed monitoring design was evaluated during two pilot scale studies. Recommendations and changes to the design which emanated from the pilot studies are summarised in "Selection of procedures for faecal pollution monitoring to describe health risks" (WRC Report no: K5/824/0/1). The refined monitoring design was used as a basis for a National Microbial Monitoring Implementation Manual which was produced in 1999 (In the Water Research Commission project K5/1118/0/1). The manual deals with all aspects necessary to initiate a microbial monitoring programme for surface waters on a national scale.

The current project tested and indeed demonstrated the viability of the concepts and procedures described in the implementation manual for the National Microbial Water Quality Programme. Actual implementation of the National Microbial Monitoring Programme (NMMP) was initiated in several regions in South Africa. This included registration of local monitoring programmes, commencement of sampling and water sample analysis, data handling, data dissemination, data quality assessment and ongoing marketing to create and sustain awareness of the monitoring programme. The lessons learned and the experiences gained during the pilot scale implementation of the monitoring programme have been incorporated in the revised NMMP Implementation Manual, the main deliverable for this project [Murray *et al.*, 2002].

2. OBJECTIVES

The current two year project funded by the Water Research Commission specifically had the following objective.

"Demonstration of National Microbial Monitoring Programme implementation in selected high risk areas."

3 DEMONSTRATION OF NMMP IMPLEMENTATION VIABILITY

3.1 Implementation successes

3.1.1 *Implementation in eight water management areas*

Water resource management structures within DWAF are in the process of change. The creation of catchment management agencies (CMAs) to replace regional DWAF offices and the associated rezoning of South Africa into Water Management Areas (WMAs) have changed the way areas are chosen for monitoring. Monitoring programmes are now initiated by the National Coordinator in a WMA. It is envisaged that, ultimately, monitoring programmes will exist in all nineteen WMAs. A regional monitoring coordinator will be appointed who will have the responsibility of sustaining monitoring in the WMAs identified. The first areas chosen should satisfy the criteria described in the implementation manual, namely that the following exist.

- Existing capacity
- Local willingness
- Real issues (the area should experience significant microbial contamination of surface waters)
- Suitability for demonstration (successful implementation should be feasible)

To test the procedures described in the Implementation Manual, monitoring programmes were initiated following the series of actions required to set up and sustain a microbial monitoring programme. Awareness of the NMMP was created by personal contact with local role players. The National Coordinator visited each WMA. During meetings with representatives of the DWAF Regional Offices, the Department of Health, members of Local Transitional Councils and other local stakeholders, awareness of the NMMP was created and aims of the programme explained. During these visits, areas posing a high health risk due to faecal pollution were identified. Discussions with local concerned parties and other stakeholders led to the selection of appropriate sampling sites in these areas.

This process proved successful and monitoring is currently being conducted in the following eight Water Management Areas:

1. **Upper Orange:** Three sampling sites have been chosen in a large formal settlement east of Bloemfontein. The regional monitoring coordinator resides at DWAF Free State Regional Office. The sampling is done by Environmental Health staff and the analyses by the Free State Technikon at the Unit for Water and Health, Health and Environmental Sciences.
2. **Crocodile (West) Marico:** Ga-Rankuwa/Makapanstad area (Winterveld area), overlapping North West and Gauteng provinces. Three sampling

sites, on the Tolwane, Moretele and the Sand rivers are currently being sampled. The samples are analysed by IWQS staff. The regional monitoring coordinator is from the DWAF Regional Office, Gauteng Region.

3. **Berg:** This area is managed by a regional monitoring coordinator from the DWAF Regional Office, Western Cape Region. The sampling is done by DWAF and analysis by the Cape Metropolitan Council, Microbiology Department, Scientific Services
4. **Levuvhu and Letaba:** This area is managed by a regional monitoring coordinator from the DWAF Regional Office in Giyani. Sampling is shared between DWAF personnel and environmental officers from the Department of Health. The analyses are performed at the local DWAF laboratory.
5. **Usutu to Mhlathuze:** Sampling at four points is shared by the Richards Bay Transitional Council, the Department of Health and Mhlathuze Water. The analyses are performed at Mhlathuze Water.
6. **Inkomati:** This area is sampled by Department of Health environmental health officers and DWAF personnel. Samples are analysed at the National Health laboratories in Nelspruit.
7. **Lower Orange:** This area is managed by a regional monitoring coordinator from the DWAF offices. Samples are analysed at the National Health laboratories in Upington.
8. **Mzimvubu to Keiskamma:** The regional monitoring coordinator resides at regional DWAF office. Sampling is shared by the Department of Health, DWAF and Amatola Water .

3.1.2 Inter-sectoral cooperation

The main challenges of implementation of a national monitoring programme are the extent of resources required and logistical difficulties associated with sampling and analyses. Inter-sectoral cooperation has had the effect that the Department of Health, water boards, the Medical Research Council, the Free State Technicon and many other local stakeholder organisations are playing a significant role in implementation of the NMMP. Regional environmental health officers know the areas well and contribute to identifying sampling areas and sites where faecal pollution poses a real risk to human health. They also perform sampling at selected sites.

3.1.3 Sustained awareness

Apart from visits by the National Coordinator to each WMA and his sustained contact with the involved parties, awareness of the programme was sustained

by a series of newsletters (NMMP NEWS). The following article headings illustrate some of the issues addressed during the period of this current project.

- Areas currently monitored
- How to become involved
- Water forums - mutual benefits
- Cholera scourge continues
- Department of Health committed to the NMMP
- IWQS(DWAF) to finance NMMP analyses
- How the NMMP data are used
- NMMP roles and information flow
- Understanding what the NMMP measures
- *E. coli* included as an indicator
- Future plans

Furthermore, regional monitoring coordinators received assessments of results on a bimonthly basis. Regional coordinators make the information available to persons involved with the NMMP, local role players and other interested parties. Feed-back on the bimonthly reports has been positive indicating that they are adding value to the project.

An annual report designed to give clear and unambiguous information will be compiled when sufficient data have been accumulated. A prototype format is currently being developed by IWQS (DWAF).

3.2 Improved design

3.2.1 Data verification and quality assurance

A spreadsheet interface has been developed that directly addresses the issue of quality assurance at the time of data capture in the remote laboratory. This occurs before transmission of the data to the National Coordinator. The facility is, in effect, a data verification tool that strives to detect and hence avoid obvious mistakes being made by the person entering the data.

This is a 'quality assurance' facility because its purpose is to prevent quality problems. A multitude of mistakes can easily be made by the person capturing the data for transmission. Possible problems are automatically detected by the spreadsheet. Simple messages appear that alert the person entering the data to each possible problem. That person can then determine whether the problem is indeed a real problem and can fix it if necessary.

The following possible problems are detected:

1. Dates out of order.
2. Dates incorrectly specified.
3. Different samples having exactly equal coliform counts, pH, temperature and turbidity.
4. Data missing for some dates.

5. Datasets having no dates specified.
6. Dates in the future.
7. Missing sampling site ID.
8. Excessive time intervals between sampling dates.
9. Dates more than 6 months ago (e.g. caused by incorrect year being specified).
10. Duplicate columns of data for all specified sampling dates (e.g. coliform counts equal pHs, pHs equal temperatures, pHs equal turbidities, etc.)
11. Coliform counts, pHs, temperatures or turbidities not specified as numbers.
12. No data specified for one or more of the four variables (coliform counts, pHs, temperatures and turbidities)
13. All coliform counts equal.
14. All pHs equal.
15. All temperatures equal.
16. All turbidities equal.
17. Negative coliform counts.
18. Negative turbidities.
19. Excessively low or high coliform counts, pHs, temperatures or turbidities.
20. Extreme fluctuations in coliform counts (that may indicate that conversions of measurements back to counts/100mL did not take dilutions into account).

If the person entering the data determines that the possible problem is, in fact, not a problem, the message can be ignored. However, all messages remain on the interface. After transmission (as an Email attachment), the National Coordinator immediately sees any remaining messages and hence is automatically alerted to possible problems that the data enterer has chosen (possibly correctly) to ignore. The facility therefore not only makes data capture more accurate *at the time of data entry* but also minimises the time the National Coordinator needs to spend verifying the data before formal entry into the national database.

The interface is very simple. Furthermore, straightforward 'copy and paste' operations allow transfer of the data into other spreadsheets for more elaborate assessments and reporting.

The interface handles data for up to 12 sampling dates at a default number of three sites. (Eight sampling dates are usually required since sampling is done weekly and reporting occurs every two months.) If the number of sites needs to be increased then this is done very simply by copying any of the existing site worksheets. This can either be done using the standard 'Move and Copy' facility in Excel or by following trivial instructions which require executing a macro (by pressing Ctrl m) and renaming the copy.

The size of the file (handling three sites) is about 250 KB which is a manageable size for Email attachments.

3.2.2 Bimonthly assessment reports

The previous (and first) version of an Excel spreadsheet template was produced before this project began that facilitated the production of simple bimonthly assessment reporting. This spreadsheet required the data assessor to enter the measurements of faecal coliforms, pH, temperature and turbidity for each sampling date at each sampling site over the most recent two month reporting period.

It then automatically provided two outputs:

1. An assessment of each faecal coliform value against guidelines (documented in the implementation manual) for low, medium and high health risk for the following four water uses:
 - a. Drinking untreated water
 - b. Drinking water after limited treatment
 - c. Full or partial contact
 - d. Irrigation of crops eaten raw
2. A time series plot for each site of each of the four variables over the two months.

These assessments and plots could be printed and faxed to the area managers or the whole spreadsheet could simply be E-mailed. This comprised the bimonthly assessment report.

This project provided a good opportunity to test this facility. On the whole it worked well and good feedback was obtained from a number of local stakeholders who received the report. However, changes to the interface were necessitated for two main reasons.

1. Changes in the general local versus regional versus national implementation philosophy. The increasing focus on the autonomy of regions (specifically Water Management Areas and ultimately their associated Catchment Management Agencies) changed the focus somewhat away from 'local' programmes to 'regional' programmes. One of a number of consequences of this was the need for the interface to handle a greater number of individual sampling sites per area (previously restricted to six).
2. A number of relatively minor problems were encountered with the spreadsheet interface itself. These included, for example, the inability to adequately handle faecal coliform counts being entered as 'greater than' specific counts.

Accordingly, this spreadsheet interface was improved to handle these and a number of other issues. Specifically, the following improvements were implemented:

1. 'Area' is now explicitly 'Water Management Area' and the formal WMA names are used in the interface.
2. A total of 18 sampling sites can be handled per WMA.
3. Up to 12 sampling dates can be handled per sampling site.
4. A simple and user-friendly interface now allows the selection and plotting of time series graphs for any sampling site (over that reporting period).
5. The clarity of the individual plots (one for faecal coliforms, which allows direct comparison with the high risk guidelines, and another with pH, temperature and turbidity) was considerably improved.
6. Compatibility with the above-mentioned data verification facility allows simple "cut and paste" operations to transfer the data from this to the bimonthly assessment template which also handles "greater than" faecal counts.

The size of the spreadsheet file is around 275 KB which is quite manageable in respect of attaching it to E-mails for transmission to concerned parties.

3.2.3 Remote data capture

Recently, a 'Winterm' interface has been made available by IWQS (DWAF) which serves a similar purpose to the above-mentioned spreadsheet that verifies data input. Its primary aim is to allow remote entry of data from throughout South Africa directly into the WMS database. It performs the same kind of checks as mentioned above and only when all data are confirmed correct are they included in WMS itself. Some technical problems have been experienced by DWAF in its implementation but these are being overcome. This interface is likely to replace the spreadsheet facility mentioned above.

3.3 *E. coli* as an additional indicator

3.3.1 *E. coli* versus faecal coliforms

The original monitoring design for the NMMP stated faecal coliform membrane filtration method using M-FC agar as the preferred analysis method. If the laboratory is not equipped to perform the membrane filtration procedure or if the turbidity of the sample is high, then the Most Probable Number (MPN) procedure can be used.

This method was chosen as the preferred method because it is a standard procedure used in many laboratories, is relatively easy to perform, not very expensive and provides information of possible faecal pollution. Available water quality guidelines are mostly based on faecal coliform counts.

It was decided that an evolutionary approach should be followed to introduce *E. coli* as an indicator instead of faecal coliforms. This is the trend internationally and reasons for this are discussed below. The Colilert method, which simultaneously detects coliform bacteria and *E. coli*, has therefore been

introduced as an additional method for the analysis of water samples for this monitoring programme.

The total coliform group of bacteria has served as the main indicator of faecal contamination of water for many years. Many of the organisms in this group are not of faecal origin. A subgroup within the coliform group known as faecal coliforms has thermotolerant characteristics (they grow at 44.5°C) and has the ability to ferment lactose. The fact that they are thermotolerant distinguishes them from the coliforms. They are considered to be a better indicator for faecal contamination because a greater number within this group originates from the intestines of warm blooded mammals. However a number of faecal coliforms originate from non-faecal sources of which the most important is *Klebsiella* organisms. Testing water for faecal coliforms therefore can yield a significant percentage of false positive results (Oliver *et al.*, 1987)

Since *E. coli* is one of the principal species making up the thermotolerant coliform group. This group is useful for indicating the potential presence of enteric pathogens in water, but where the means are available, *E. coli* is the preferred indicator because it excludes most of the *Klebsiella* organisms which may or may not originate from faecal sources (Bagley *et al.*, 1978; Dufour, 1986; Duncan, 1988). Furthermore *E. coli* is the only member of the coliform group that unquestionably is an inhabitant of the intestinal tract. It has become the definitive organism indicating faecal contamination (Oliver *et al.* 1987).

E. coli meets the criteria of a valid faecal indicator because

- it is present in the intestine in larger numbers than the enteric pathogens,
- it behaves similarly to enteric pathogens in the water environment, and
- it is less susceptible than most enteric pathogens to disinfectant and treatment procedures.

The presence of *E. coli* in a water supply indicates contamination with faecal matter from warm-blooded mammals including humans.

3.3.2 Colilert as a detection method for *E. coli*

Colilert has been developed for direct and simultaneous detection of coliforms and *E. coli* without confirmation. The media utilizes two substrates, o-nitro-phenyl-β-D galactopiranoside (ONPG) and 4-methylumbelliferyl-β-D-glucuronide (MUG) which are combined to simultaneously detect total coliforms and *E. coli*. Total coliforms produce the enzyme β-galactosidase which hydrolyses ONPG and thereby releases o-nitrophenol which produces a yellow colour. *E. coli* produces the enzyme β-glucuronidase which hydrolyses MUG to form a fluorescent compound.

The Colilert Quanti-Tray system from IDEXX is based on a MPN (most probable number) method as opposed to the membrane filtration method. The Colilert MPN method is also referred to as the Defined Substrate Technology or DST.

Colilert has been approved by the US EPA, is included in Standard Methods for the Examination of Water and Wastewater, Edition 20, 1998, and has been accepted as a method by the South African Bureau of Standards, South Africa (SABS 241 Ed. 5, 2000).

The Colilert method has been extensively investigated locally and internationally, and has been found superior to the standard membrane filtration method (Edberg *et al.*, 1989; Covert *et al.*, 1989; Genthe and du Preez 1995). The advantages of using Colilert are numerous:

- The Colilert method is rapid;
- It is easy to use and minimal training results in competent use;
- It is less labour intensive;
- No preparation of media is required;
- No confirmation is required;
- Results are more reliable and accurate because false-positive results are minimized;
- It is more sensitive as injured bacteria are less inhibited in the liquid medium than when using membrane filters;
- There is no ambiguity in reading the results as there is in counting colonies on M-FC agar;
- Results are comparable between laboratories and laboratory analysts.

3.3.3 Implications of including *E. coli* as an indicator

A cost comparison between colilert and the MFC membrane filtration methods is shown in the table below. These figures were supplied by local colilert agents DEHTEQ. Capital depreciation is based on a five year period and 20 working days per month. One technician and one laboratory assistant is assumed and costs include basic equipment, preparation time, cleaning time and counting time. Quality control, storage and bench space are excluded. The figures show that the colilert method compares favourably with the MFC membrane filtration method.

Table 1. Summary of comparative analytical costs.

	Water type	Colilert	Membrane filtration	
Capital costs		R 58 421.00	R 147 700.00	
Depreciation		R 48.68	R 122.25	per day
Consumables	Potable	R 57.27	R 59.58	per test
	Non-potable	R 66.25	R 83.78	per test

A further important implication of including *E. coli* as an indicator is that one needs an equivalent set of guidelines to those originally developed by the NMMP project team for faecal coliforms (given **Table 2**).

It is important to note that, in the current context, there is only one certain criterion that these *E. coli* guidelines must satisfy. If the above faecal coliform guidelines are accepted as given (*i.e.* adequate and non-debatable), then this criterion is as follows.

For a sufficiently high percentage (say, >90%) of a large number of analysed samples, the E. coli counts and E. coli guidelines must give the same potential health risks (i.e. low, medium or high) for each of the four water uses as those obtained from the faecal coliform counts and faecal coliform guidelines.

If this is not the case, then the overall health risk index based on *E. coli* will be incompatible (*i.e.* not comparable) with the index based on faecal coliforms. This has serious implications for reporting.

Table 2. Guidelines for assessing the potential health risk for the four water uses.

(Note that these guidelines were developed specifically for use in the NMMP and were not tested in other contexts.)

	Potential Health Risk		
	Low	Medium	High
Water use attribute	Faecal coliform counts/100 ml		
1. Drinking untreated water	0	1-10	> 10
2. Drinking water after limited treatment (see explanatory note* below)	< 2 000	2 000-20 000	> 20 000
3. Full or partial contact	< 600	600-2 000	> 2 000
4. Irrigation of crops to be eaten raw	< 1 000	1 000-4 000	> 4 000

* Note: In this case, the water is used (*i.e.* for drinking) after limited treatment though the guidelines necessarily refer to the raw water before such treatment. For example, raw water with < 2 000 counts/100 ml subjected to limited treatment and then used for drinking, will be associated with a low potential health risk. "Limited treatment" means not conventional treatment. Conventional treatment means all of flocculation, sedimentation, filtration and disinfection.

The project team undertook to perform a preliminary assessment of *E. coli* guidelines (and include these in the implementation manual) as well as make recommendations for future research. *It was decided, primarily in the interests*

of simplicity and consistency, to propose that, for an initial trial period of NMMP implementation (say one or two years) the *E. coli* guidelines should be the same as the originally proposed faecal coliform values. The following reasons are presented for this decision.

- The South African Water Quality Guidelines (1996) for irrigation give a target water quality range as 1-1000 *E. coli* counts/100 ml. For this range, they note that "likelihood of contamination from vegetables ... will result in transmission of human pathogens". The value of 1000 corresponds exactly to the cutoff between low and medium health risk faecal coliform guidelines in the implementation manual. This suggests, to a rough first approximation, that all other *E. coli* guidelines (for the other water uses) should also be equivalent to those in the implementation manual.
- An examination of local and international water quality guidelines for drinking, irrigation and recreation revealed that the majority of the guidelines are based on faecal coliform counts (Australian Drinking Water Guidelines, 1996; Canadian Water Quality Guidelines, 1987-1992; South African Water Quality Guidelines, 1993; SABS 2000). The few exceptions base their *E. coli* guidelines on criteria that make it difficult or impossible to deduce equivalent *E. coli* guidelines relevant to the NMMP (namely as low, medium or high health risk). Therefore, the choice of *E. coli* guidelines for the NMMP is a non-trivial exercise. Given that such an in-depth study was not within the scope of this project, this suggests simplicity in the initial choice of such guidelines is appropriate.
- All published faecal coliform and *E. coli* guidelines (including those in the implementation manual) inherently contain considerable uncertainty. This is unavoidable, given the nature of these variables and concept of guidelines in general. At the very least this suggests that debate over relatively small differences in guideline values for faecal coliforms and *E. coli* is inappropriate.
- NMMP reporting is based on a health risk index which is split into only three risk categories (low, medium and high). This, by its very nature, absorbs and dampens the effects of small errors in guidelines (and, indeed, *E. coli* and faecal coliform measurements). This is typical of such indices (and is often used as a criticism of them!). Again, this means that debate over relatively small differences in guideline values is inappropriate.

Notwithstanding the above reasons for keeping them the same, it is acknowledged that there are the following reasons for making *E. coli* guidelines more stringent than those for faecal coliforms.

- *E. coli* is generally acknowledged as being a better indicator (than faecal coliforms) of the presence of faecal contamination from warm blooded animals and hence the presence of pathogens. Specifically, some

bacteria detected by the faecal coliform analysis are not necessarily of faecal origin.

- *E. coli* form a subgroup of faecal coliforms.

Nevertheless, consideration of these issues merely raises the questions of how much more stringent they should be and whether this factor should be uniformly applied to all water uses and thresholds between low, medium and high risk.

Rather than try to deal with these questions from first principles at this time, it is proposed that, for the time being, the guidelines for *E. coli* and faecal coliforms remain equal and that a project is initiated to test and refine these proposed *E. coli* guidelines so that the above criterion is met.

The proposed project should be designed specifically for the NMMP. It should entail the choice of a series of different sampling sites sampled over an extended period (say one year). For each sample taken, both *E. coli* and faecal coliforms should be measured by the NMMP recommended methods. The degree to which the above criterion is satisfied should then be determined. If it is satisfied, then identical guidelines for *E. coli* and faecal coliforms can remain. If not, then the *E. coli* guidelines can be modified (for example, by examining the issue from first principles using professional judgement and experience) until agreement is sufficiently good.

It can be noted that this proposed project need not impact negatively on the current and future normal implementation of the NMMP. This is for the following reasons.

- Samples from any particular site, whether analysed for either *E. coli* or faecal coliforms, will contribute to bimonthly assessments that can be used, as they have been in the past, for examining quantitative recent trends at that site. That is, nothing changes in this respect. (Potential problems only arise when comparing health risks based on *E. coli* and faecal coliforms.)
- The issue being addressed (namely the comparability of the *E. coli* and faecal coliforms guidelines) is most relevant when the annual report needs to be produced and both *E. coli* and faecal coliforms data are available. Some time is available for collecting the necessary data before this occurs.

The advantage of this approach is that the difficulties of choosing faecal coliform and *E. coli* guidelines from first principles are greatly simplified. The *E. coli* guidelines will be based on an appropriately large and representative dataset (taken under South African conditions) and adjusted (by whatever method) to the extent that they are compatible with the defined NMMP calculation of health risk.

It can be noted that this problem can be defined as a mathematical optimisation problem, as follows. Assuming the faecal coliform guidelines fixed, there are two potentially adjustable parameters per water use. The first corresponds to

the threshold between low and medium risk, the second to the threshold between medium and high risk. The objective function would be the agreement between the calculated health risks (low, medium and high) for each water use for each sample (calculated using *E. coli* and faecal coliforms). Maximisation of this agreement (or, equivalently, minimisation of the disagreement) using the eight adjustable parameters will yield a set of *E. coli* guidelines that are exactly internally consistent with the chosen faecal coliform guidelines. The result will be a mathematically correct set of guidelines for both faecal coliforms and *E. coli* perfectly appropriate to the NMMP under local South African conditions.

Finally, it can be mentioned that an advantage of the purely mathematical approach is that if the faecal coliforms guidelines are changed in future, then the mathematical exercise may be more easily repeated to produce the new set of consistent *E. coli* guidelines. Of course, it will be possible to optimise the *E. coli* guidelines subjectively. It may simply be more time consuming.

3.4 NMMP reporting issues

3.4.1 Health risk index

After one year of local monitoring, annual assessments of each area must be performed and combined in a single report. An overall annual potential health risk index based on the percentage of incidents associated with high risk of all four water uses at each site in the area has been proposed. However, it was decided that the index also be calculated and reported per water use (drinking untreated water, after limited treatment, full or partial contact and irrigation of crops eaten raw). The motivation for this was to illustrate results to a higher resolution. The implementation manual has been modified accordingly.

However, caution with the interpretation of indices is necessary. The overall annual potential health risk index was originally designed to enable comparison of areas with each other. One would also be able to determine whether an improvement or deterioration took place during the monitoring period in an area (by comparing the current year's assessment with that of the previous year). Providing more resolution by dividing the overall index into four indices creates a danger that they become over sensitive and hence at risk of being incorrectly interpreted.

Calculating the index per water use deviates from the original monitoring design and therefore has not been tested properly. A careful assessment of ramifications of this change should be made once this way of reporting is applied.

3.4.2 Missing data

An issue arose during the project concerning how missing data would be handled in trend analysis.

Trend analysis, *per se*, is not a reporting option considered in the NMMP. Annual reporting of the health risk indices is done using simple colour coding (showing low, medium and high risk categories) as well as a simple bar indicating the value of the index on a continuous scale. It is recommended that comparison with previous years is simply done visually. The very nature of the indices precludes detailed "trend analysis".

Providing simple assessment feedback reports every two months currently entails producing time series plots (including a comparison with the various guidelines) and an assessment of the risk as low, medium or high at each sampling site. Providing a "trend analysis" is inappropriate at this local level. This is mainly because the NMMP is a national programme with national objectives.

It is not the objective of the programme to provide local stakeholders with any degree of detailed statistical analyses (of which trend analysis is but one).

The occasional missing datum is not problematic in terms of calculation of the indices. The indices are based on geometric means which remain well defined even when some data are missing.

3.4.3 Assessment guide

The original proposal for this current project had defined a task to develop an assessment guide for use by the data assessor. Specifically it was stated that "assessment of the data during monitoring of water samples requires a skilled person with an appropriate background in microbiology".

Recent advances within DWAF in defining the scope of national 'status and trends' monitoring programmes (of which the NMMP is one) has focussed specifically on what such programmes should, and should not, be doing. Of particular relevance to the issue of an assessment guide, is that national programmes should be focussed primarily on providing national information, not local information. Furthermore, establishing the causes of local faecal pollution problems is not the concern of a national programme.

Clearly, the calculation of the health risk index (well-defined in the implementation manual) provides the necessary national information. The above-mentioned assessment guide was focussed on assessments of data for local stakeholders, for example, as provided for in the bimonthly assessment reports (in spreadsheet format). The development of an assessment guide in this context is now deemed an inappropriate use of resources.

Notwithstanding the above, and, in effect, moving towards improved local assessments, two improvements have indeed been introduced. First, as noted above, the bimonthly spreadsheet assessment report has been improved in various ways. Secondly, some explanatory text has been added to the implementation manual that aims at improving the understanding of the inter-relationships between the various variables measured by this national

programme (depicted in figure 4.2 of the implementation manual).

3.4.4 *Interface between WMS and bimonthly report spreadsheet*

IWQS staff are developing a facility to interface a WMS report format (*i.e.* lists of data extracted from the database) with the current bimonthly reporting spreadsheet interface. This would enable data to be extracted efficiently and for the bimonthly reporting to be as efficient as possible. This is currently being tested.

3.5 Some problems encountered and solved

3.5.1 *Data transmission delays*

It has been found that some laboratories have difficulty finding the time to extract the NMMP data from their own Laboratory Information Management Systems and then to submit this data to the National Coordinator. This causes delays in the bimonthly reporting. However, it is hoped that the above-mentioned facilities for data capture (either the spreadsheet or the remote entry interface) will simplify this task for them.

3.5.2 *Changing local priorities*

The lack of capacity in some areas and, in particular, changing priorities of local stakeholders, have impeded sustained implementation of the monitoring programme. This issue is a difficult one because the National Coordinator has no direct control over such decisions made by the local stakeholders. It disrupts the collection of monitoring data.

Possible solutions involve DWAF taking full responsibility for co-ordination, sampling and analysis or to identify other local stakeholders who perceive greater benefits from the NMMP (and hence inherently have greater buy-in and commitment). Contractual binding has been identified as a more promising long term solution. This issue is still under discussion with DWAF and has not yet been implemented.

In the meantime DWAF has agreed to carry the costs of the analysis until definite decisions have been made on the issue.

3.5.3 *Sampling frequency*

Lack of human resources in some cases had the effect that the recommended sampling frequency (weekly) could not be sustained. However, to prevent losing the momentum of the NMMP it was agreed that fortnightly sampling would be acceptable providing the regions involved understand that this decreases the available information and hence, possibly, increases certain management risks.

3.5.4 Inappropriate sample dilution

By its very nature, the NMMP often assesses the quality of highly polluted surface waters. Samples from such waters have to be serially diluted to obtain acceptable results. Difficulties applying acceptable and accurate procedures when making serial dilutions and calculating the final results have been experienced at some laboratories. Unreliable, or even the absence of, results for a project of this scale have far reaching consequences. This has to be avoided as far as possible. A third analytical method namely, the Colilert method, has therefore been assessed in one laboratory. This study has showed that the problems previously experienced could be minimized and reliable data generated.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

This project has resulted in the implementation of the National Microbial Monitoring Programme in eight Water Management Areas. It has therefore achieved the aims of the project of demonstrating implementation.

Inevitably, as might be expected of any such complex undertaking, the actual implementation highlighted certain shortcomings in the original implementation plan (as described in the implementation manual). However, none were of a particularly fundamental nature. All resulted in a refined and improved approach to NMMP implementation. These new concepts and insights have now been incorporated in an updated implementation manual.

The opportunity provided by this project to test and update the implementation manual has ensured that future implementation will be more efficient, focussed and cost-effective.

4.2 Recommendations

It is recommended that the updated manual [Murray *et al.*, 2002] becomes the new basis of NMMP implementation in DWAF. DWAF and other interested stakeholders can have more confidence in the appropriateness of the approach contained therein.

A further recommendation relates to the introduction of an *E. coli*-based indicator of health risk. This will necessitate a careful examination of its compatibility with the indicator based on faecal coliforms. A research project should be undertaken to examine the proposed interim guidelines for *E. coli* and modify them as necessary. The danger of not doing this may mean that the ultimate reporting of health risks will be inaccurate and hence potentially misleading.

Future implementation should also carefully examine the interpretation of the health risk indices reported for individual water uses. It must be ensured that interpretation is unambiguous and accurate.

4.3 Technology transfer

During the period of this project the data collected in the Upper Orange water management area contributed to a number of degree projects at the Free State Technikon.

The manual itself will be the primary vehicle of technology transfer from this project to all current and future role players in the NMMP. The manual is structured in a way that different target readerships are addressed in a modular series of chapters and sections. These vary from overall coordination and management roles (e.g. performed by the National Coordinator) to technical roles such as sampling and analysis.

DWAF will be responsible for future revision of the implementation manual.

4.4 Presentations

A presentation was given at the international River Basin Management Conference in Cardiff, Wales (van Niekerk *et al.*, 2001) on the implementation of the programme.

4.5 The way forward

The appointment of Regional Monitoring Coordinators in the water management areas should take immediate priority. DWAF can then confidently sustain monitoring at existing sites, extend the NMMP to more water management areas and to more local sites within water management areas in which NMMP monitoring already exists. Bimonthly assessment feedback to regional stakeholders should continue unabated at existing sites.

6. REFERENCES

- Bagley ST, Ramon J, Seidler HW, Talbot Jr. and Morrow JE, 1978. *Isolation of Klebsiellaea from within living wood*. Applied and Environmental Microbiology. Vol 36, No 1, 178-185.
- Canadian Water Quality Guidelines & updates, 1987-92. Canadian Council of Resource and Environment Ministers.
- Covert TC, Shadix LC, Rice EW, Haines JR and Freyberg RW, 1989. *Evaluation of Autoanalysis Colilert Test for the Detection and Enumeration of Total Coliforms*. Applied and Environmental Microbiology. Vol 55, No 10, 2443-2447.
- Dufour AP, 1986. *Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters*. U.S Environmental Protection Agency, NTIS PB 86-158045. Washington D.C. and Cincinatti, OH.
- Duncan IBR, 1988. *Waterborne Klebsiella and Human Disease*. Toxicity Assessment: Vol 3, 581-598.
- Edberg SC, Martin JA, Smith DB, 1989. *National Field Evaluation of a Defined Substrate Method for the Simultaneous Enumeration of Total Coliforms and Escherichia coli from drinking Water: Comparison of presence absence techniques*. Applied and Environmental Microbiology. Vol 55, No 4, 1003-1008.
- Genthe B and du Preez M, 1995. *Evaluation of Rapid Methods for the Detection of Indicator Organisms in Drinking Water*. WRC Report No 610/1/95
- Murray K, du Preez M, Kühn A and van Niekerk H, 2002. *National Microbial Monitoring Programme Implementation Manual for Surface Waters*. Department of Water Affairs and Forestry
- Oliver DO, Newman RA and Cortruvo JA, 1987. *Drinking Water Microbiology*. Journal of Environmental Pathology, Toxicology and Oncology. Vol 7, No:5/6.
- Pipes WO, 1990. *Microbiological Methods and Monitoring of Drinking Water*, pp. 428-451. In: *Drinking Water Microbiology*, (ed.), Mcfeters GA.
- South African Water Quality Guidelines. 1996. Volumes 1, 2, and 4. Department of Water Affairs and Forestry. Second Edition.
- South African Water Quality Guidelines. 1993. Volume 4. Department of Water Affairs and Forestry. First Edition.
- South African Bureau of Standards Specification, Drinking Water. 2000. SABS 241, Ed. 5.
- van Niekerk H, Kühn A and Kempster P, 2001. *Implementation of a catchment based national microbial water quality monitoring programme in prioritised high health risk areas*. River Basin Management Conference, Cardiff, Wales, Sep 11-13.

ANNEXURE

National Microbial Monitoring Programme Implementation Manual *for Surface Waters*

EXECUTIVE SUMMARY

South Africa does not currently have a central source of information for assessing the potential health risks associated with natural waters contaminated with faecal pollution. With numerous dense settlements (both formal and informal), increasing urbanisation and other factors, South Africa's water resources are coming under increasing threat from faecal contamination.

The Department of Water Affairs and Forestry (DWAF) is responsible (in terms of the National Water Act) for the operation and maintenance of national water quality monitoring and assessment programmes.

Because microbes behave in a non-conservative manner in water, a national grid of monitoring sites (like that used for monitoring chemical water quality variables) is both undesirable and impractical. This document is the culmination of five years of work towards creating a National Microbial Monitoring Programme (NMMP) that overcomes this problem. This programme has the following objectives:

NMMP Objectives

- ★ To provide information on the status and trends of the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas.
- ★ To provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water resources.

It is emphasised that these objectives are primarily national, not regional. That is, it is not the intention that the individual causes and impacts of faecal pollution are identified by the programme.

This document aims to facilitate the successful implementation of the programme nationally. Although the primary responsibility for implementation rests with DWAF, many organisations and people will necessarily be involved. They range from the sampler to the Minister of Water Affairs.

A glossary of terms, a list of references and a reproduction of Chapter 14 of the National Water Act also enable ready access to some of the more technical aspects.

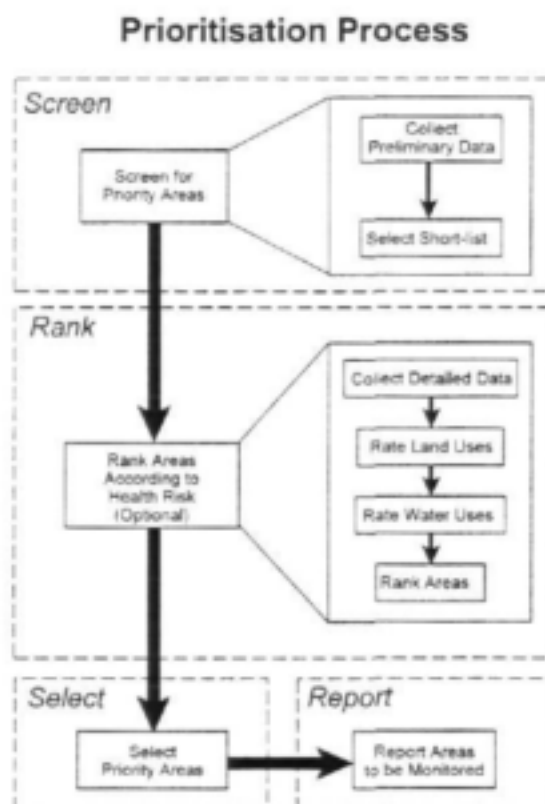
Prioritisation Process

Given (a) the distinct non-conservative behaviour of microbes in water and (b) the essential need to use resources as cost-effectively as possible, a process has been developed that ranks priority areas. This is based on the identification of problematic land uses and water uses sensitive to microbial quality. The process is a desk study only, not involving actual monitoring.

Land uses that can result in significant faecal pollution include settlements that have no sanitation infrastructure or one that is inadequate. Intensive livestock farming without sound waste handling practices is also problematic. Settlements that result in high runoff after rainfall events (and hence contamination of surface waters) are also considered.

There is only a health risk when people are actually exposed to faecally contaminated water. Particularly sensitive water uses include drinking of untreated or partially treated surface waters. Full or partial external contact with water (such as from swimming or washing) also exposes people to significant health risk. The irrigation of crops that are ultimately eaten raw (like lettuce and tomatoes) is likewise a serious problem.

The prioritisation process involves an initial screening phase based on relatively simple criteria. The resulting short-list will often be sufficient for managers to choose from when initialising microbial monitoring. If a more objective (and quantitative) process is necessary then the next ranking and selection phases can be carried out. The overall process will facilitate a phased implementation of the programme. The areas with highest risk are earmarked for individual monitoring programmes.



National Implementation Process

Creating national coordination is important in a nationwide implementation process. A single person, ideally within DWAF, should be assigned this role. This person should facilitate in whatever way possible both national and regional implementation.

The general implementation model is based on the "Demonstration-for-Resource Allocation Spiral" approach used successfully by the River Health Programme (a national biomonitoring programme). This involves choosing a few priority areas and implementing the NMMP full scale in those areas. The results of this exercise can then be presented to other potential concerned parties in order to demonstrate success, create buy-in and hence willing allocation of resources for further implementation.



The "Demonstration-for-Resource Allocation Spiral" model of the River Health Programme [Roux, 1997].

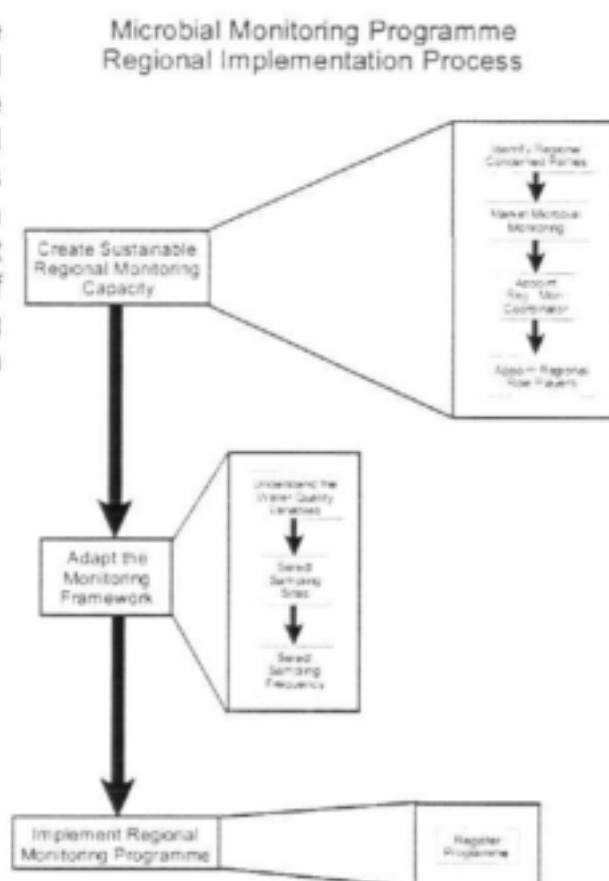
An annual national assessment report will also be produced that summarises the situation in all areas being monitored. This report presents the information in a way that communicates well with the water resource managers, for example by using colour maps. It will indicate the potential health risk of the four most sensitive water uses at all sampling sites. It will also present an overall potential health risk index for the year (which can be compared with equivalent values for previous years).

Regional Implementation Process

Once an area is identified as a priority area by the prioritisation process, a regional monitoring programme must be established that meets the national objectives of the NMMP. Although the primary responsibility rests with DWAF, the regional concerned parties that can benefit from a local monitoring programme must be identified and approached. These include, among others, the Department of Health, catchment management agencies, water user associations, major industry and so on. Ideally, their involvement should be a 'win-win' situation.

To achieve this, it will be necessary to 'market' microbial monitoring. A wide range of tools is presented in this document for doing this. These include various diagrammatic representations of issues, processes and how information flows from sampler to Minister. Tables are presented that summarise information, including resources required.

A regional monitoring coordinator must be appointed. That person must identify and appoint the various other regional role players and decide where sampling should take place. Sampling frequency is proposed to be weekly (based on a statistical analysis of the results of the pilot studies) though this can be changed if justified. Once the regional monitoring programme is formally registered with DWAF, sampling can begin.



Monitoring Roles

Monitoring programmes involve the collection of data and converting this to useful information. The overall structure of data and information flow has been carefully considered in this document (and is presented diagrammatically). Individual roles have also been identified and described in detail. This structure will facilitate a clear definition of these roles and buy-in to the process by ensuring each individual role player understands where he or she fits into the overall picture.

The following diagram illustrates the roles and information flow. The following table identifies typical role players for each role.

Notes and Information Flow



Table 1. Summary of roles and typical role players.

Role	Typical Role Players
National Policy Maker	Minister of Water Affairs and Forestry, Minister of Health.
Concerned Parties	Any person or organisation with an interest in microbial water quality or that might be affected by deteriorating microbial water quality.
National Coordinator	A single person from the Department of Water Affairs and Forestry (DWAF).
Prioritiser	The Department of Water Affairs and Forestry (DWAF) and/or appointee. (Possibly the National Coordinator.)
National Custodian	Department of Water Affairs and Forestry (DWAF) Directors or Chief Directors.
Regional Manager	Water Quality Managers of Department of Water Affairs and Forestry (DWAF) Regional Offices or appointed representative of the relevant catchment management agency. (Possibly the Regional Monitoring Coordinator.)
Regional Monitoring Coordinator	Typically a representative of the relevant catchment management agency or a DWAF Regional Office.
Data Assessor	Microbiologist with experience in the behaviour of faecal coliforms in environmental waters. Typically in the Department of Water Affairs and Forestry (DWAF).
National Database Manager	The Department of Water Affairs and Forestry (DWAF).
Data Transmitter	Laboratory.
Data Verifier	Laboratory microbiologist with experience in the behaviour of faecal coliforms in environmental waters.
Analyst	Laboratory.
Sampler	Laboratory, DOH environmental health officers, water board or local authority.

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LIST OF ABBREVIATIONS



DEAT	Department of Environmental Affairs and Tourism
DOH	Department of Health
DWAF	Department of Water Affairs and Forestry
I&AP	Interested and Affected Party
IWQS	Institute for Water Quality Studies
SoE	State of the Environment
WHO	World Health Organisation
WRC	Water Research Commission

GLOSSARY



Aquaculture. The production of protein for human consumption in an aquatic environment under controlled or semi-controlled conditions. It includes the production of fish, shell-fish, crustaceans and plants.

Assessment Endpoint. An explicit expression of the environmental value that bears directly on the management of resources (for example, "human health risk"). The assessment endpoint is based directly on values of the measurement endpoint (by adding value to it).

Autoclave. An apparatus for sterilising objects by the use of steam under pressure.

Catchment. The area that receives the rain that flows into a particular watercourse.

Catchment Management Agency. A statutory body established by the Minister of Water Affairs to delegate water resource management to a local level and to involve local communities. They may be established for specific geographical areas, after public consultation, on the initiative of the community and stakeholders concerned.

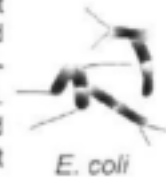
Coliforms: Bacteria that are members of the *Enterobacteriaceae* family with the ability to ferment lactose. These bacteria make up about 10% of the intestinal microorganisms of human and other animals.

Diffuse-source Pollution. Pollution that comes from a wide area, such as fertilisers draining off farmlands or pollutants in the runoff from urban areas.

Disinfection. The killing, inhibition, or removal of microorganisms that may cause disease.

Ecosystem. The total community of living organisms and their associated physical and chemical environment.

Faecal Coliforms. Thermotolerant (max 44.5°C) coliforms derived from the intestines of warm-blooded animals, including man. For a water to be considered potable, faecal coliforms must not be present.



Filtration. The process whereby suspended solid particles are removed by passing a liquid through a porous material (the filter) so that the liquid portion passes through the filter and the solid particles are retained by the filter.

Floc. Small masses formed in water through coagulation, agglomeration of fine suspended particles.

Flocculation. The bringing together of fine particles to form flocs.

Groundwater. Water found underground, typically supplying wells, boreholes, and springs.

Infrastructure. The basic structure of an organisation, system, etc.

Measurement Endpoint. The attribute of the water resource actually measured (for example, faecal coliforms).

Microbes. Microscopic organisms, especially disease-causing organisms.

Microbiology. The study of organisms that are usually too small to be seen with the naked eye. Special techniques are required to isolate and grow them.

Microorganisms. Microscopic biological organisms such as bacteria, viruses, protozoa, etc. some of which cause diseases.

Morbidity Rate. The number of individuals who become ill as a result of a particular disease within a susceptible population during a specific time period.

Nutrient. Substance that supports growth and reproduction.

Pathogen. An organism that causes disease. Derived from the Greek *Patho* (meaning disease) and *gen* (meaning giving rise to).

Potable. Drinkable.

Point-source Pollution. Pollution that comes from a single source, such as a pipe, that is usually easily quantifiable.

Prioritisation. The process of establishing an order of things based on the degree to which they require special attention.

Runoff. Water that does not filter into soil but flows over the surface and into natural surface waters.

Sanitation. Practical measures for preserving public health. Typically associated with the reduction of the microbial population to levels judged safe by public health standards.

Sanitation Services. The collection, removal, disposal or purification of human excreta, domestic waste-water, sewage and effluent resulting from the use of water for commercial purposes.

Sedimentation. The process by which suspended solids settle downwards.

Settlement. A permanently populated area of high population density.

Site-specific. Conditions that are unique or specific to a certain locality.

Sterilisation. The process by which all living cells, viable spores, viruses, viroids are either destroyed or removed from an object or habitat.

Surface Water. Water above the ground surface in lakes, dams and rivers.

Suspended Solids. Inorganic or organic matter, such as clay, minerals, decay products and living organisms, that remains in suspension in water. In surface waters it is usually associated with erosion or runoff after rainfall events.

Thermotolerant. Tolerant of high temperatures.

Turbidity. A measure of the light-scattering ability of water. It indicates the concentration of suspended solids in the water.

Urbanisation. The migration of an increasing proportion of rural people to cities.

UV Radiation. Ultraviolet radiation of shorter wavelength than visible light (about 10 to 400 nm) and higher energy.

Virus. An infectious agent having a simple acellular organisation with a protein coat and a single type of nucleic acid, lacking independent metabolism, and reproducing only within living host cells.

Water Board. An organ of state established or regarded as having been established in terms of the Water Services Act (No. 108 of 1997) to perform, as its primary activity, a public function.

Waterborne Disease. A disease resulting from infection from water that contains pathogens. Many important human pathogens are maintained in association with living organisms other than humans, including many wild animals and birds. Some of these bacterial and protozoan pathogens can survive in water.

Watercourse. A river or spring; a natural channel in which water flows regularly or intermittently; a wetland, lake or dam into which, or from which, water flows.

Water Management Area. An area established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources.

Water Management Institution. A catchment management agency, a water user association, a body responsible for international water management or any person who fulfils the functions of a water management institution in terms of the National Water Act (Act No. 36 of 1998).

Water Resource. Includes a watercourse, surface water, estuary or aquifer.

Water Services Institution. A water services authority, a water services provider, a water board or a water services committee.

Water User Association. Cooperative associations of individual water users who wish to undertake water-related activities for their mutual benefit. Their primary purpose is *not* water management.

Wetland. Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

1. BACKGROUND

This chapter should be read by anyone wanting a brief background to the events leading up to the monitoring design in this manual or an overview of the manual.

CHAPTER CONTENTS

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1.2	OBJECTIVES THAT SATISFY THE NEEDS	1-5
1.3	FACTORS DICTATING PROGRAMME DESIGN	1-5
1.4	THE PROGRAMME THUS FAR	1-6
1.5	THE STRUCTURE OF THIS DOCUMENT	1-10

1.1 THE NEED FOR MICROBIAL MONITORING

There have been rapid and extensive demographic changes in South Africa in recent decades. Many areas lack appropriate sanitation facilities. This has resulted in South Africa's water resources coming under increasing threat from faecal pollution. Using such contaminated water for drinking, recreation or irrigation poses serious health risks. In particular, contracting such waterborne diseases as gastroenteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis, becomes increasingly likely.

Increasing faecal pollution ...

Most waterborne diseases are caused by pathogens associated with faecal contamination of water. However, pathogens excreted into water from healthy skin or hair, wounds, urine, mucus, saliva, etc. can also be transmitted, particularly by recreational exposure. Some waterborne pathogens are excreted by healthy carriers (*i.e.* infected persons, in many cases children, who show no clinical symptoms of disease) [DWAf, 1996a].

...increases health risks.

The risk of infection is greatest when the contaminated water is used for drinking purposes. The guidelines for faecal coliforms (which are used as indicator organisms) note that less than 10 counts per 100 ml may cause infections in some sensitive groups. Up to 100 counts per 100 ml will commonly cause infections, even after a single consumption [DWAf, DOH and WRC, 1998]. It is clear that even very low concentrations can be significantly problematic.



Cholera is a waterborne disease that was confined to Asia (mainly India) until the early 1800s. Then epidemics occurred at intervals throughout Europe and America during the 19th and early 20th centuries. Outbreaks continue to occur every year in different parts of the world. In particular, they have occurred in countries to the north of South Africa, particularly in Mozambique, and a number of imported cases are identified each summer in South Africa [Klugman, 1999].

Cholera is caused by a bacterium, *Vibrio cholerae*, that invades the intestines causing acute diarrhoea. If present in a surface water, it will be due to faecal pollution.

By using the presence of faecal coliforms as an indicator of recent faecal pollution, the National Microbial Monitoring Programme not only helps prevent disease associated with faecal coliforms but will also help prevent outbreaks of cholera.

DWAF must ensure water is fit for use ...

The Department of Water Affairs and Forestry (DWAF) is the primary custodian of South Africa's water resources. As such it must ensure that waters remain fit for use on a sustainable basis. A number of national monitoring programmes are already in place. The chemical water quality monitoring programme has been operational for many years. A national biomonitoring programme is currently being implemented. However, given the serious human health risks associated with surface waters exposed to faecal pollution, there is a pressing need to implement a national programme that focuses on microbial water quality.

Water resource managers and various other role players involved in maintaining the quality of South Africa's water resources will be the main users of information from a national microbial monitoring programme.

... and is bound by the National Water Act to establish monitoring systems.

There are basic statutory requirements for establishing monitoring systems in South Africa. Monitoring, recording, assessing and disseminating information on water resources are critically important for achieving the objectives of the National Water Act (Act No 36 of 1998). The Act provides for establishing national monitoring systems and national information systems on water resources. It also deals with accessibility of this information.

**See National Water Act
Chapter 14 Section 137.**

This document describes a national monitoring programme.

This document describes an implementation strategy for a national programme. The objective of the programme is to provide general information on the status and trends in the microbial water quality in priority areas, as well as to give an indication of the potential health risk associated with the use of surface water in those areas. The data could be used to give some general indication of the effectiveness of measures taken to protect water resources against faecal pollution. Ground water resources are not included in the present design, nor are marine waters because they are specialist fields best dealt with separately.

1.2 OBJECTIVES THAT SATISFY THE NEEDS

In order to satisfy the various national needs, the following are adopted as the specific objectives of the national microbial monitoring programme.

NMMP Objectives

- ★ To provide information on the status and trends of the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas.
- ★ To provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water resources.

The objective is not to quantify the effect of individual activities on the microbiological water quality, nor to determine the potential health risk to specific water users at specific points of abstraction or contact. The latter would require a local monitoring programme which would need to reconsider such design aspects as sampling frequency, sampling variables, and selection of sampling sites.

1.3 FACTORS DICTATING PROGRAMME DESIGN

Microbial water quality and the potential health risk associated with faecal pollution are not geographically evenly distributed. Combined with the non-conservative nature of microbial pollution, this makes an evenly distributed grid of monitoring sites undesirable and impractical.

Therefore, the programme focuses on priority areas only. These areas are identified by the following general criteria:

- Land-uses that are typically associated with faecal pollution of water resources;
- The number of people likely to be impacted by exposure to water of poor microbial quality as a consequence of the way they use the water.

There are a number of problematic land uses and various ways in which people can be exposed to faecally contaminated water. These are summarised diagrammatically in a formal systems model (a set of interacting issues) in **Figures 1.1 and 1.2**.

1.4 THE PROGRAMME THUS FAR

Many organisations in South Africa have been involved in the monitoring of faecal pollution for many years. However, there had been no previous attempt to collate information in a coordinated and focused way to provide a nationwide picture of faecal pollution. The design of a National Microbial Monitoring Programme was initiated in 1994. This was driven by DWAF since such projects form part of its official function. The underlying research upon which the programme is based is described by du Preez *et al.* (1999). Further research reports that describe the basis of various aspects of the design are also available [du Preez *et al.* (2001), du Preez *et al.* (2002)].

The following table summarises some of the events henceforth.

Table 1.1. Summary of events in the design of the National Microbial Monitoring Programme.

Date	Event	Comments
1994	IWQS (DWAF) starts project to design a NMMP	
1995	Monitoring system product specification expectations established	Input from various water resource managers
Apr 1996	Report: <i>Design Framework for a National Microbiological Monitoring Programme to Assess the Faecal Pollution of SA Surface Water Resources</i>	By: Environmentek, CSIR Purpose: Draft specification of conceptual design framework for NMMP
Jul 1996	Report: <i>A National Microbiological Monitoring Programme to Assess Faecal Pollution of South African Water Resources: Conceptual Monitoring Programme Design</i>	By: IWQS (DWAF) and Environmentek, CSIR. Detailed design approach
Jan 1997	WRC project starts. Objectives: Select high risk areas, initiate pilot scale monitoring, recommend procedures	Joint IWQS (DWAF) and CSIR venture (with Rand Water and Umgeni Water doing the pilot scale monitoring)
Oct 1997	NMMP News No. 1	First newsletter, IWQS (DWAF)
Mar 1998	Article in CSIR's "Envisage" newsletter	M du Preez, 1998a
Apr 1998	Article in <i>Engineering News</i> : Plan to Monitor Water Quality	M du Preez, 1998b
May 1998	WISA Conference presentation: <i>National Microbiological Water Quality Monitoring Programme for South Africa</i>	Kühn <i>et al.</i> , 1998
Jun 1998	IAWQ Conference presentation: <i>A Method for the Prioritisation of Areas Experiencing Microbial Pollution of Surface Water.</i>	Venter <i>et al.</i> , 1998
Jun 1999	NMMP Implementation Manual produced including recommended procedures.	K Murray 2000
May 2000	WISA Conference presentation: <i>Identification of Areas with Faecally Polluted Surface Water Sources in South Africa.</i>	Kühn <i>et al.</i> , 2000
Aug 2001	Progress report: A pilot study to demonstrate implementation of the national microbial monitoring programme	du Preez <i>et al.</i> , 2001
Sep 2001	River Basin Management Conference presentation, Wales: <i>Implementation of a catchment based national microbial water quality monitoring programme in prioritised high health risk areas.</i>	van Niekerk <i>et al.</i> , 2001
Jan 2002	Research report: A pilot study to demonstrate implementation of the national microbial monitoring programme	du Preez <i>et al.</i> , 2002
Feb 2002	Updated NMMP Implementation Manual	K Murray <i>et al.</i> , 2002

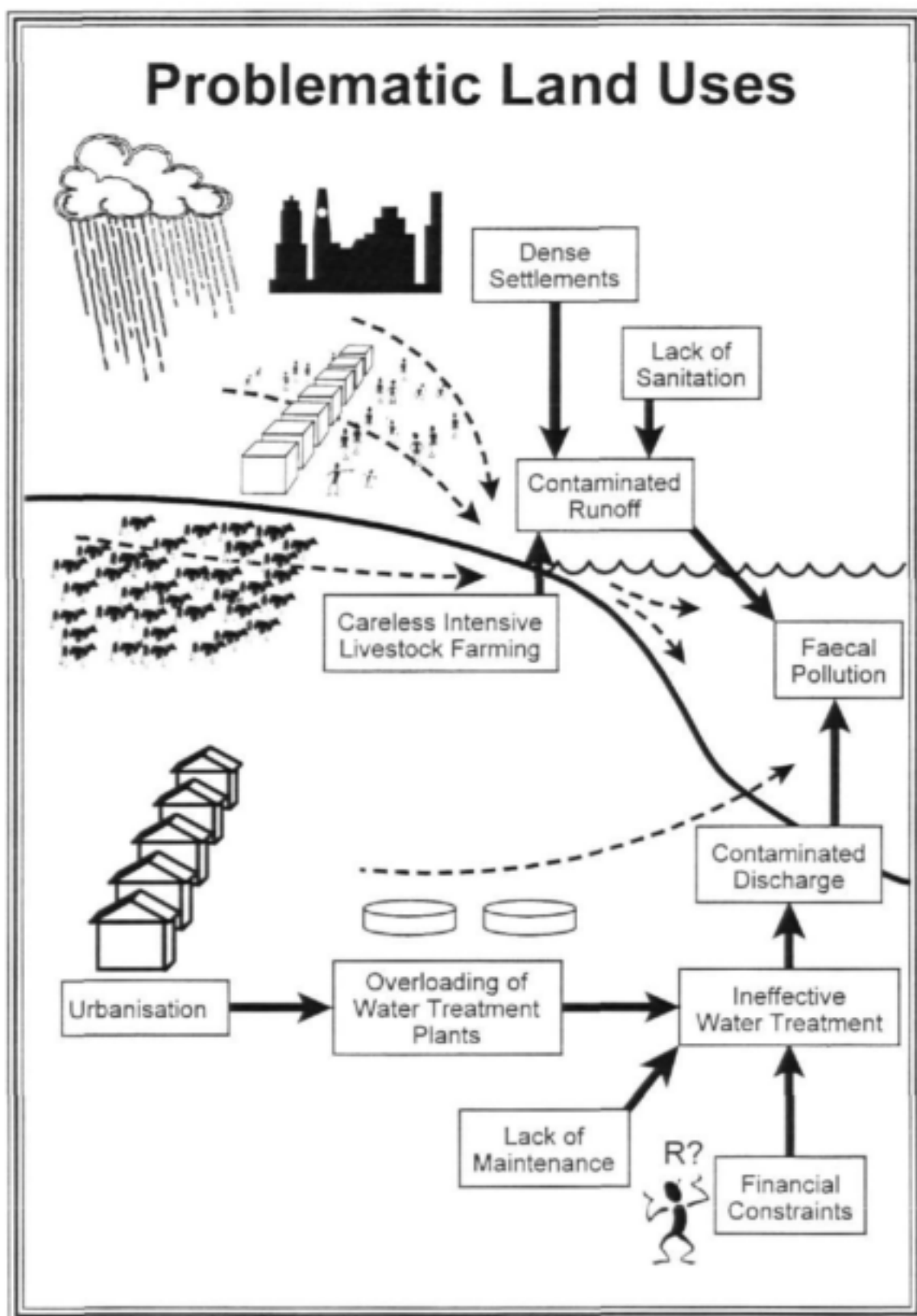


Figure 1.1. Schematic illustration of problematic land uses.

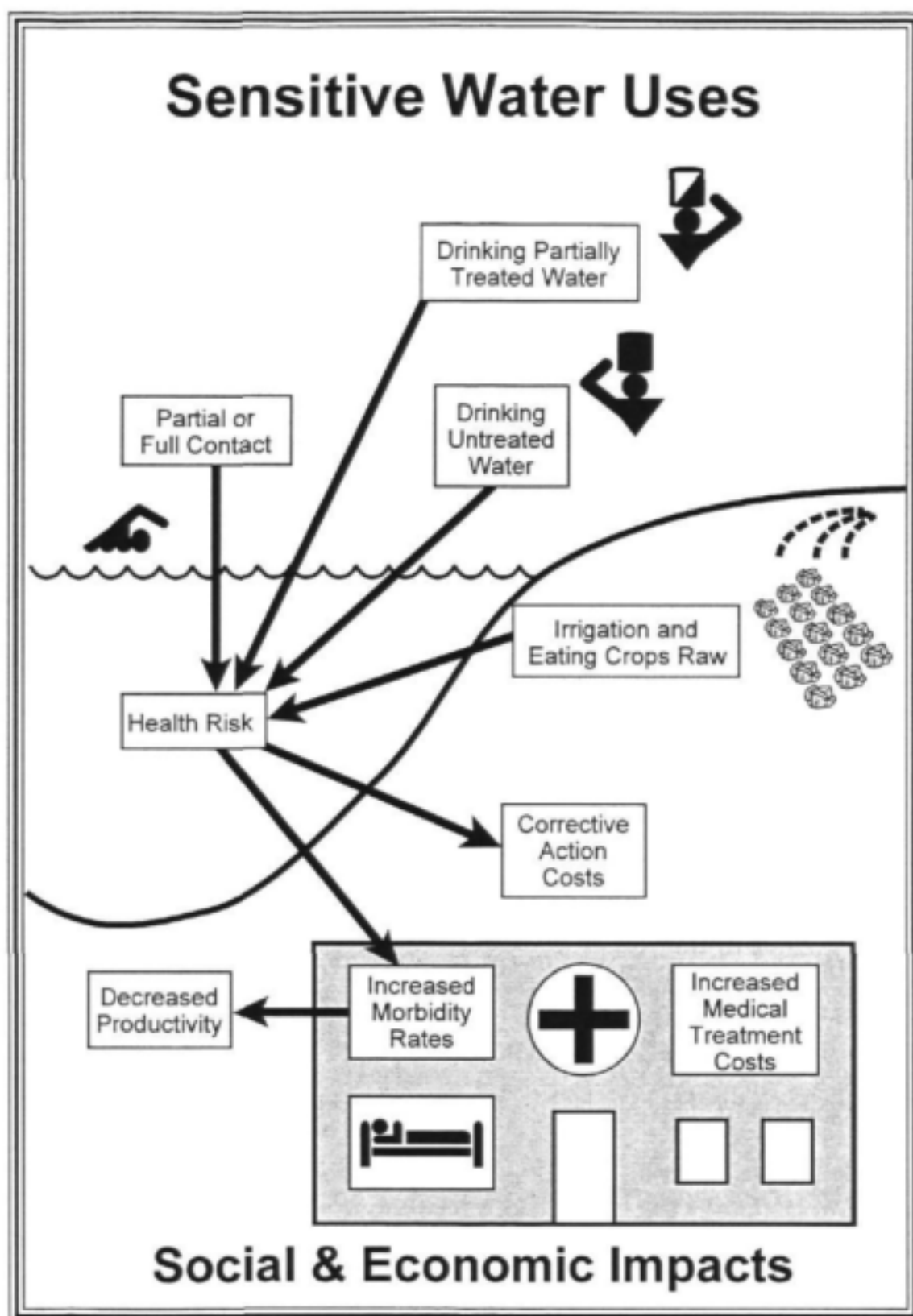


Figure 1.2. Schematic illustration of sensitive water uses and impacts of health risk.

1.5 THE STRUCTURE OF THIS DOCUMENT

Chapter Two describes how priority areas should be identified

The chapter following this one describes the prioritisation process used for identifying priority areas. This is a desk study not involving sampling. The purpose is to create a short-list of areas in which a microbial monitoring programme should be established. The chapter describes the screening and, if necessary, ranking, selecting and reporting of the final results.

Chapter Three describes a national implementation strategy

Chapter three describes the overall national implementation strategy. In particular it deals with national coordination and creating public awareness. It also describes the national assessment that should be performed annually.

Chapter Four describes how to implement regionally

Chapter four deals with the process of implementing the national programme in a region (Water Management Area). It addresses creating capacity and adapting the existing framework to the point of registering the monitoring programme formally with DWAF.

Chapter Five defines the individual roles

The final chapter defines each of the roles from the sampler to the minister. It notes typical role players (*i.e.* organisations capable of executing the role), their individual tasks and resources required.

**Chapter 14 of the National Water Act
(Monitoring: Assessment & Information)
is reproduced as an appendix**

Table 1.1. Summary of events in the design of the National Microbial Monitoring Programme.	1-7
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Figure 1.1. Schematic illustration of problematic land uses.	1-8
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Figure 1.2. Schematic illustration of sensitive water uses and impacts of health risk.	1-9
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2. PRIORITISATION PROCESS

This chapter should be used by the person appointed to perform the prioritisation process to obtain a detailed description of how to prioritise surface water resources.

CHAPTER CONTENTS

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2.1 WHY A PRIORITISATION PROCESS?

Microbial water quality indicators such as faecal coliforms are non-conservative. This means that levels can change independently of how much was originally added to the surface water. It is not feasible (logistically and financially) to set up a nationwide uniform grid of sampling sites (as is possible for normal chemical variables). With 278 tertiary catchments in South Africa, DWAF (who is responsible for the prioritisation

Prioritisation Improves Cost-Effectiveness

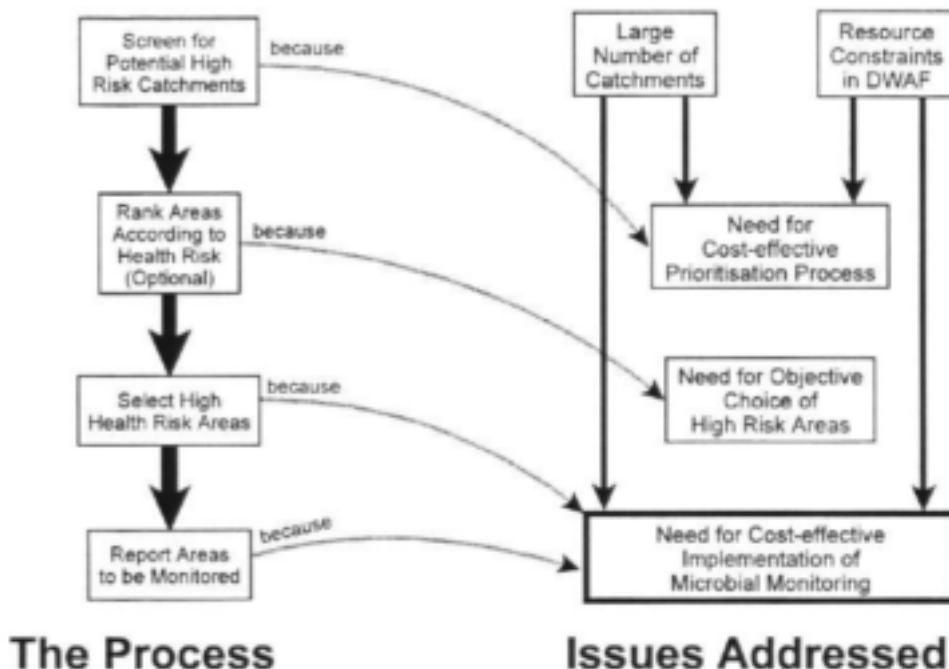


Figure 2.1. An illustration of some of the issues addressed directly by the major steps in the prioritisation process for microbial monitoring.

process) has a daunting task. The need for cost-minimisation is critical. Therefore, resources should focus on those areas most in need of monitoring. This prioritisation process helps identify those areas. The adjacent figure illustrates some of the issues that individual steps in this prioritisation process address.

2.2 OVERVIEW OF PROCESS

The prioritisation process is a quantitative desk study that identifies catchments (throughout South Africa) in which problematic land uses and sensitive water uses are most likely to result in a significant health risk due to faecal pollution. (It does not involve any actual sampling of waters.) Areas within these catchments become candidates for a microbial monitoring programme. The process is summarised in

Figure 2.2. The figure is referred to in the following sections which give details of the individual steps.

The first complete prioritisation process has been performed and was very comprehensive. Many tens of areas were identified as requiring a monitoring programme. The primary purpose of any follow-up prioritisation process will be to identify whether *new* areas have arisen which rank very highly (in terms of potential health risk).

Prioritisation Process

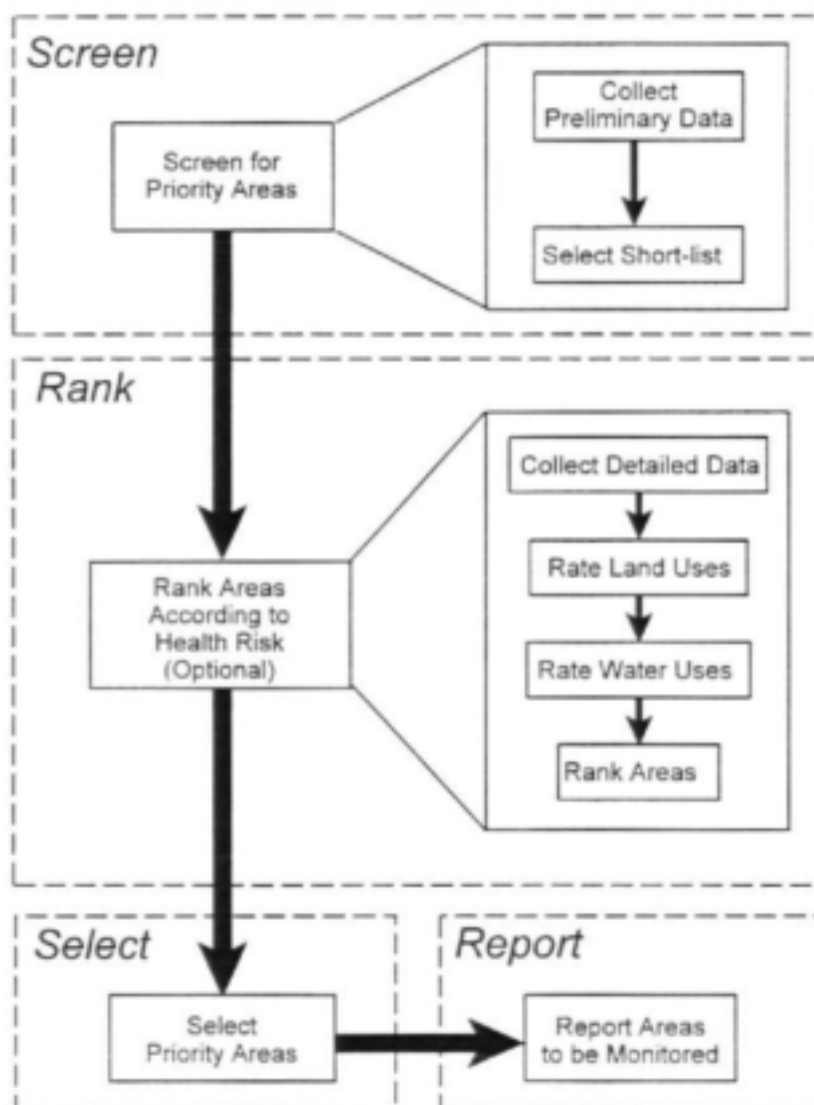
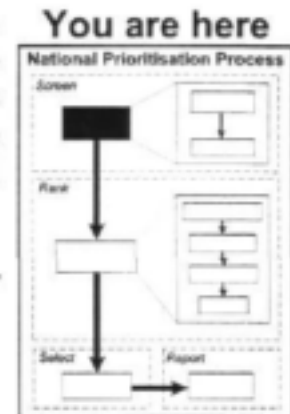


Figure 2.2. Overall Prioritisation Process.

2.3 SCREEN FOR PRIORITY AREAS

Monitoring is costly. Therefore only those catchments posing a significant potential risk to water users should be monitored. The first screening step involves creating a short-list of catchments most likely to exhibit a major health risk based on non-quantitative preliminary data. Those with no potential or actual microbial problems are excluded.

It is recommended that this screening be done on tertiary catchments.



2.3.1 Collect Preliminary Data

One is likely to be able to obtain the necessary information from the water resource managers in the regions. For each region, contact the DWAF Regional Director or local agent (e.g. Catchment Management Agency) first, typically by phone. Explain the purpose of the prioritisation process. Then contact other people in that region and obtain as much information as possible. It is advisable that the people contacted have copies of a map of each tertiary catchment in their region during discussions.



A catchment is included in the short-list if *any* of the following is true:

1. Microbial water quality problems have been experienced in the catchment.
2. A high incidence of waterborne diseases is evident in communities in the catchment.
3. Some people in the catchment use untreated or partially treated surface water from the catchment for domestic use.
4. Settlements (or parts thereof) in the catchment (or upstream of the catchment) do not have the necessary sanitation infrastructure to ensure effective disposal of human waste.

It should be borne in mind that if *any* of the above criteria is met, the catchment is included in the short-list. Only these questions should be addressed. It is a waste of your time and that of any respondent to request data that is unnecessary at this stage.

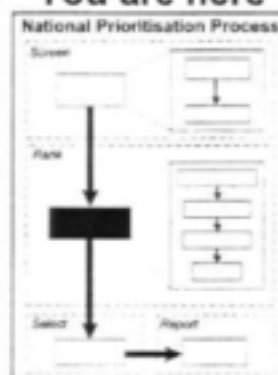
2.3.2 Select Short-list

In most cases, the list of catchments obtained above will be sufficient to create a short-list which regional managers can choose from when initialising microbial monitoring in their areas. However, if a more objective (and quantitative) prioritisation is necessary, then proceed to the next step.

2.4 RANK AREAS ACCORDING TO HEALTH RISK (OPTIONAL)

The purpose of this second main step is to quantitatively rank areas in the catchments (on the above short-list) according to their likely health risk. Because it is time-consuming, this should only be done if it is deemed necessary to be totally objective in the selection of those areas which should be subjected to actual monitoring. Frequently, such objectivity is not necessary because final decisions on what catchments are monitored initially also depend on factors other than simply which has the highest potential health risk. The most common factors are available finances and capacity.

You are here



In summary, to perform the quantitative prioritisation process, for each settlement in each catchment, you need to do the following:

1. Quantify whether the land uses are likely to contribute to a health risk (if people are exposed to downstream surface water).
2. Quantify whether the way the water is used exposes an unacceptable number of people to major health risk.
3. Finally, combine these two factors to establish the overall ranking. The higher the ranking, the higher the health risk.

The details on how to perform these tasks follow.

2.4.1 Collect Detailed Data

The way the data is obtained and ultimately processed creates a number of basic requirements. First, some of the data can be obtained directly from the DWAF Water Supply and Sanitation Database. You need to be able to import this data directly (*i.e.* electronically). You also need to obtain data by personal communication. It is useful to be able to show others what you are looking for. Of course, you also need to be able to process the data in various ways to calculate the final ratings. You can achieve all of these if you use a spreadsheet.



Set up this spreadsheet in such a way that you can print out the pages conveniently. If you wish to obtain data from anyone else, it is always

best to provide that person with some background. The more they are informed about the reasons for the process, the more likely you are to get the right information from them. In particular, provide the following:

1. A copy of the diagram showing the issues addressed by the prioritisation process (**Figure 2.1**). (This will show them the reasons for the exercise.)
2. A copy of the overall process diagram (**Figure 2.2**). (This will show them where they fit into the overall prioritisation process.)
3. Pages printed from the spreadsheet showing the various column headings of data required. (This will show them what data is needed.)
4. A copy of the two tables of the land and water use attributes, with explanations on each attribute, **Tables 2.1** and **2.2**. (This will define each attribute exactly and explain why it is important.)
5. A map of each tertiary catchment. (This will help orient the choice of settlements and spatially link the data and information being obtained.)

Information sources ...

DWAF Water Supply and Sanitation Database
 Agricultural Research Council
 Regional Deputy Directors, Water Quality Management
 Regional Water Quality Managers
 Water User Associations (including large Water Boards)

Obtain as much data as possible directly from the DWAF Water Supply and Sanitation Database. Identify each settlement that occurs either totally or partially within the catchment in the above short-list. (This information can be obtained from regional DWAF offices.) A settlement is necessarily an area with a relatively high concentration of people. Note that you will also need to be able to identify intensive livestock farming units in rural areas.

It is best not to simply send the above information to respondents and ask them to fill in the data and return them. Rather do the following:

1. Phone each person likely to have data (the "respondent") and say that you will be sending some information (and why).
2. Post or fax the above diagrams, tables and maps to each respondent. This will enable them to get an overview of the data required and why it is necessary.
3. Make an appointment to either meet or phone each respondent at a particular time. This enables both you and the respondent to choose the best time with the minimum of likely interruptions.
4. Begin the interview by making it clear what the objectives are. (Refer to the diagrams.)
5. Go through the spreadsheet with the respondent. Fill in the responses yourself. Ensure that the respondent understands each issue and the possible implications



2-8 Prioritisation Process

- of responses he/she makes.
6. If the respondent needs to obtain data from elsewhere, immediately make another appointment to visit or phone to get the data at a later time.
 7. Finally, when you have completed the spreadsheet, send a copy to the respondent for confirmation. This is an important validation step, the purpose of which is to ensure that all numbers "look reasonable".

New appointees to posts may not know the catchments well enough to be able to provide all the necessary information. In such a case, you may need to speak to more than one person to get what is required.

Table 2.1. Summary of information required to determine land use ratings.

No.	Land Use Attribute	Background																		
1	The number of individuals, N , with no sanitation infrastructure (weight=53)*	These are individuals who do not have easy access to sanitation facilities. This can give rise to significant faecal pollution.																		
2	The number of individuals, N , with sanitation infrastructure that is either inefficient, poorly maintained (or operated) or inappropriate (weight=43)*	These are individuals affected by sanitation facilities which are (i) poorly maintained, or (ii) not able to cope with the present population or (iii) not appropriate for the local situation. This includes wastewater treatment works that do not meet the relaxed microbiological effluent standard of 1 000 <i>E. coli</i> / 100 ml.																		
3	Average population density, N (weight=1)*	The population density is used here as an indicator of the surface area covered by solid surfaces that are impermeable to rain. These include roads, pavements, buildings, and so on. This data gives an indication of the extent of storm water runoff that might occur as a result of rainfall events. This runoff usually enters surface waters, taking with it faecal and other contaminants.																		
4	Intensive livestock farming with no waste handling practices in place (small, medium or large) (weight=3)*	This attribute includes such farming as aquaculture, dairy farming, pig farming, cattle feedlots, poultry farming and ostrich farming. Enterprises are classified as intensive when substantial capital and labour inputs are required per unit area. Use the following ranges to estimate the relative size of intensive farming units:																		
		<table> <tr> <th>Unit</th><th>Numbers</th><th>Size</th></tr> <tr> <td>Cattle feedlot</td><td>< 5 000 cattle</td><td rowspan="2">Small</td></tr> <tr> <td>Piggery</td><td>< 500 pigs</td></tr> <tr> <td>Cattle feedlot</td><td>5 000-10 000 cattle</td><td rowspan="2">Medium</td></tr> <tr> <td>Piggery</td><td>500-2 000 pigs</td></tr> <tr> <td>Cattle feedlot</td><td>> 10 000 cattle</td><td rowspan="2">Large</td></tr> <tr> <td>Piggery</td><td>> 2 000 pigs</td></tr> </table>	Unit	Numbers	Size	Cattle feedlot	< 5 000 cattle	Small	Piggery	< 500 pigs	Cattle feedlot	5 000-10 000 cattle	Medium	Piggery	500-2 000 pigs	Cattle feedlot	> 10 000 cattle	Large	Piggery	> 2 000 pigs
Unit	Numbers	Size																		
Cattle feedlot	< 5 000 cattle	Small																		
Piggery	< 500 pigs																			
Cattle feedlot	5 000-10 000 cattle	Medium																		
Piggery	500-2 000 pigs																			
Cattle feedlot	> 10 000 cattle	Large																		
Piggery	> 2 000 pigs																			

* see Section 2.7 "Rationale Behind the Relative Priorities".

Table 2.2. Summary of information required to determine water use ratings.

No.	Water Use Attribute	Background
1 	The number of individuals, N , without appropriate or reliable water supply infrastructure, that have to rely on <u>untreated</u> surface water for drinking (weight=50)*	This typically includes people who need to physically collect water or who have to rely on surface water as an additional supply.
2 	The number of individuals, N , supplied with surface water from the catchment for drinking after <u>limited</u> treatment (weight=10)*	Limited treatment means "not conventional treatment". Conventional treatment means all of flocculation, sedimentation, filtration and disinfection.
3 	The maximum number of people <u>per month</u> , N , that have full or partial contact with surface water in the catchment (weight=25)*	This includes such activities as swimming, washing of laundry, wading across streams and so on. Typically, the maximum number of people using surface waters for recreation will be reached in summer.
4 	The area in hectares, ha , with vegetables that are irrigated with surface water from the catchment (weight=15)*	Of primary interest are those crops that are spray irrigated and that may be consumed raw (carrots, lettuce, tomato, sweet potatoes and so on). However, these data are difficult to obtain, therefore the total area of vegetables being irrigated is used as an indicator.

* see Section 2.7 "Rationale Behind the Relative Priorities".

2.4.2 Rate Land Use

Particular care must be taken that data for parts of settlements that occur outside the catchment are not included in the analysis. For each settlement all data should be obtained for the following attributes. The values for these attributes can be summed over all settlements in an area and the final priority rating calculated using the formulae in the following table.

Table 2.3. Determination of the total land use rating for an area.

No.	Land Use Attribute (whole area)	Priority Rating (PR)
1	The number of individuals, N , with no sanitation infrastructure	$(N/100\ 000) \times 100 \times 53$
2	The number of individuals, N , with sanitation infrastructure that is either inefficient, poorly maintained (or operated) or inappropriate	$(N/100\ 000) \times 100 \times 43$
3	Average population density, N	$(N/20\ 000) \times 100$
4	Intensive livestock farming with ...	
	... no waste handling practices in place	
	Small-scale Unit	90
	Medium-scale Unit	180
	Large-scale Unit	300
	... all units with appropriate waste handling practices in place	0
	Total Land Use Rating for Area =	Sum

For example ...

No:	1	2	3	3
Settl A	1 000	10 000	3 000	90
Settl B	8 000	5 000	2 000	180
Settl C	5 000	1 000	3 000	0
Settl D	7 000	3 000	8 000	0
Total	21 000	19 000	16 000	270

Therefore, the total land use rating for the area is $(21\ 000/100\ 000) \times 100 \times 53 + (19\ 000/100\ 000) \times 100 \times 43 + (16\ 000/20\ 000) \times 100 + 270 = 1113 + 817 + 80 + 270 = 2\ 280$.

2.4.3 Rate Water Use

Values for the following attributes should be obtained for all settlements in an area. The final priority rating is then calculated using the formulae in the following table.

Table 2.4. Determination of the total water use rating for an area.

No.	Water Use Attribute (whole area)	Priority Rating
1 	The number of individuals, N , without appropriate or reliable water supply infrastructure, that have to rely on untreated surface water for drinking	$(N/100\ 000) \times 100 \times 50$
	The number of individuals, N , supplied with surface water from the catchment for drinking after ...	
2 	... limited treatment	$(N/100\ 000) \times 100 \times 10$
	... conventional treatment	0
3 	The maximum number of people <u>per month</u> , N , that have full or partial contact with surface water in the catchment	$(N/10\ 000) \times 100 \times 25$
4 	The area in hectares, ha , with vegetables that are irrigated with surface water from the catchment	ha x 15
	Total Water Use Rating for Area =	Sum

For example ...

No:	1	2	3	4
Settl A	12 000	5 000	1 000	20
Settl B	10 000	3 000	500	50
Settl C	3 000	2 000	5 000	0
Settl D	5 000	1 000	400	300
Total	30 000	11 000	6 900	370

Therefore, the total water use rating for the area is
 $(30\ 000/100\ 000) \times 100 \times 50 + (11\ 000/100\ 000) \times 100 \times 10 + (6\ 900/10\ 000) \times 100 \times 25 + 370 \times 15 = 1\ 500 + 110 + 1\ 725 + 5\ 550 = 8\ 885.$

2.4.4 Rank Areas

The task now is to use the land and water use ratings to identify the high risk areas in the catchment. It is very useful to display the data on a map of the catchment. One can then spatially link and understand the data more easily.

Bear the following basic principles in mind when interpreting a map:

- // *A particular set of land and water uses can only be considered to be part of the same area if those land uses are the ones that have impacts on those water uses. Equivalently, water uses upstream of the most upstream land use in the catchment should be ignored.*
- // *As a general rule of thumb, the distance between a land use and the water use which it might have an impact on should not be more than 100 km. However, site-specific conditions may overrule this. These include topography, vegetation (e.g. vegetated flood-plains) and flow patterns (such as narrow fast-flowing streams or impoundments and wetlands which limit water movement).*
- // *Large water impoundments (such as dams) often decrease the effect of upstream land uses on water uses downstream of the impoundment and hence could be appropriate boundaries for the areas chosen.*

An area containing a number of problematic settlements is a likely high risk area. Identify an area that contains a set of impacted water uses (*i.e.* with high priority ratings) that seem likely to be associated with high risk land uses (*i.e.* again with high ratings). Such an area should have an overall priority rating calculated for it as follows.

Overall Area Rating =

$$0.4 \times (\text{Total Land Use Rating for Area}) + \\ 0.6 \times (\text{Total Water Use Rating for Area})$$

This overall area rating (or priority assessment) is the value that quantitatively represents the degree of health risk associated with the area.

For example ...

$$\text{Overall Area Rating} = 0.4 \times 2\,280 + 0.6 \times 8\,885 = 6\,243$$

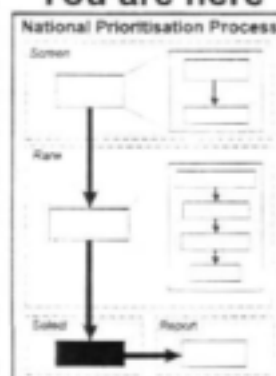
When the overall area rating for each area has been calculated, the areas should be ranked by sorting into decreasing order of overall rating.

2.5 SELECT PRIORITY AREAS

The areas with the highest overall ratings will be those that have the most urgent need for attention. As a rough guide, areas with a rating of above 200 000 should automatically be flagged as requiring a monitoring programme. However, this does not mean that areas with lower ratings do not have serious problems. For the purposes of this prioritisation exercise, this cutoff value is deemed appropriate, based on experience gained during pilot studies.

As noted above, a number of factors other than this rating will determine whether a monitoring programme is actually initiated. These include the existence (or creation) of the necessary capacity and finance. This is dealt with in more detail elsewhere (see Chapter 4).

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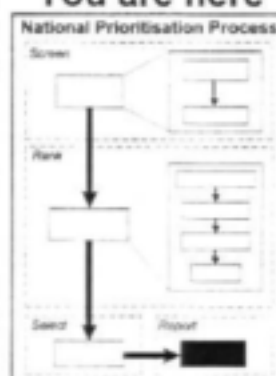
2.6 REPORT AREAS TO BE MONITORED

See National Water Act
Chapter 14 Sections 140 & 142.

A brief report of the results of the prioritisation process should contain the following:

1. A brief description of the background of the prioritisation process.
2. A clear reference to this manual for further details.
3. A map of the whole of South Africa highlighting those areas that are high risk. The areas should be colour coded according to the overall area rating.

You are here



The format used in the 1999 report should be used as a template for future reports.

This report should be sent to the following:

1. Water Advisory Council.
2. DWAF, Directorate Project Planning.
3. All DWAF Regional Directors.
4. DOH.
5. DEAT.
6. National Coordinator.
7. Any Concerned Party that has expressed an interest in obtaining the report.

2.7 RATIONALE BEHIND THE RELATIVE PRIORITIES

2.7.1 The Objective

The formulae used to calculate total land and water use ratings for a settlement involve numbers that take account of the relative importance (priorities) of the various attributes. For example, individuals that have to use untreated water are exposed to a greater health risk than those using water after limited treatment. Values are necessary that describe their relative contribution *quantitatively*.

Use was made of the Simple Multi-Attribute Rating Technique (SMART) as described by Goodmin and Wright (1991). The objective is to "identify high risk areas where severe faecal pollution due to land use activities could pose a health risk to water users". Two main attributes, namely land use and water use, were identified that could be used to measure the performance of areas in this regard. Each attribute was then further sub-divided into sub-attributes.

This section describes how the relative values for the attributes and sub-attributes were chosen.

2.7.2 Relative Land Use Priorities

The sub-attributes chosen for land use are shown in the following table. The weights were chosen by a technical team and normalised so that their sum equalled 100.

Table 2.5. Land use attributes and assigned weights.

Land use attribute	Normalised weight
No sanitation infrastructure	53
Sanitation infrastructure that is either inefficient, poorly maintained (or operated) or inappropriate	43
Average population density	1
Intensive animal farming enterprises	3
	100

Each of the above sub-attributes requires a means of measurement.

Sub-attributes 1 and 2 (relating to no or ineffective sanitation infrastructure) were chosen to be quantified by the number of individuals, N, that fell into the category. A value of $(N/100\ 000) \times 100$ was assigned.

The population density (people/km²), N, is used as indicator of the surface area covered by solid surfaces (like roads, etc.). The latter data are difficult and time consuming to

obtain, therefore population density was chosen instead. A value of $(N/20\ 000) \times 100$ was assigned.

An intensive animal farming enterprise was rated as a function of its size. The following table shows the values assigned.

Table 2.6. Measurement values chosen for intensive farming enterprises.

Intensive Farming Enterprise	Measurement Value
All units with appropriate waste handling practices in place	0
No waste handling practices in place ...	
Small-scale unit	30
Medium-scale unit	60
Large-scale unit	100

The relative sizes of feedlots and piggeries were based on the opinion of DWAF pollution control officers. These are summarised in **Table 2.1**.

2.7.3 Relative Water Use Priorities

The sub-attributes chosen for water use are shown in the following table. The relative weights were again chosen by a technical team.

Table 2.7. Water use attributes and assigned weights.

Water use attribute	Normalised weight
Drinking untreated water	50
Full or partial contact	25
Irrigation of crops	15
Drinking after limited treatment	10
Drinking after conventional treatment	0
	100

Each of the above sub-attributes requires a means of measurement.

The attributes associated with drinking water that has been subject to either no or limited treatment were chosen to be measured in terms of the number of individuals in each category. In each case a value of $(N/100\ 000) \times 100$ was assigned. If the water was subject to conventional treatment, a value of 0 was assigned.

The attribute associated with full or partial contact was assigned a value of 0 when

nobody came into either full or partial contact with water. A value of $(N/10\ 000) \times 100$ was assigned otherwise.

Various assumptions had to be made regarding the sub-attribute of irrigation of crops. Originally the primary concern was those crops that would be eaten raw. Furthermore, those crops spray irrigated were of most concern. However, partly because of practices such as crop rotation, this is difficult to estimate. The calculation of the potential number of people that could be exposed was based on figures for the production of lettuce. This was regarded as a worst case scenario as the exposure risk during ingestion of other produce (such as cabbage or tomato) was regarded as less.

The average lettuce production figure used was 15 000 kg/ha or 30 000 lettuces when a weight of 500 g was assumed. (Information was supplied by the Vegetable and Ornamental Plant Institute, Agricultural Research Council.) If it is assumed that on average an individual or 4 people would be exposed per lettuce, 1 ha corresponds to the exposure of 120 000 people. In addition, it was assumed that 25% of the total area (all vegetable types) under irrigation could be associated with crops that could be eaten raw.

Therefore, a value of 0 was assigned to the situation when nobody would be exposed to vegetables irrigated with surface water. The actual water use priority was assumed proportional to the hectares under irrigation: $ha \times 100$.

2.7.4 Water Use Relative to Land Use

The technical team decided that water uses rate higher than land uses. The following table summarises the normalised weights.

Table 2.8. Relative water and land use weights.

Main attribute	Normalised weight
Water uses	60
Land uses	40
	100

These normalised weights are used in the calculation of the overall area ratings (each reduced by a factor of 100, i.e. 0.6 and 0.4).

2.8 RESOURCES REQUIRED

The following table provides rough estimates of the time required for execution of the main steps in the overall process.

Costing Time: The time actively involved in the task.

Elapsed Time: The time from start to end of the task (taking account of inevitable delays such as waiting for others to provide information, lack of immediate availability of people and so on).

Table 2.9. Estimates of times required to perform individual steps in the prioritisation process.

Step	Costing Time	Elapsed Time
Screen for Potential High Risk Catchments	2 weeks	1 month
Rank Areas According to Health Risk	2.5 months	5 months
Select High Risk Areas	1 day	2 days
Report Areas to be Monitored	1 week	2 week
Approximate Total:	3.25 months	6.5 months

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3. NATIONAL IMPLEMENTATION PROCESS

This chapter should be used primarily by the National Coordinator for overall guidance on the implementation process of the NMMP at a national level.

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3.1 CREATING NATIONAL COORDINATION

There are general statutory requirements in respect of coordinating the monitoring of water resources in South Africa. For the programme to be well coordinated nationally, everyone must be clear on the objectives. It is reiterated here that the primary purpose of the programme is to monitor the extent of faecal pollution in priority areas on a national basis. Note that there is particular focus on high risk areas (primarily to ensure cost-effective use of resources). This means that, at least initially, those areas exposed to moderate (but nevertheless significant) faecal pollution may not be included. Furthermore, it is not the primary purpose to identify the precise causes of the faecal pollution.

See National Water Act
Chapter 14 Section 138.

Department of Water Affairs and Forestry (DWAF) has a mandate under the National Water Act (Act No 36 of 1998) to monitor water resources. However, although the DWAF is primarily responsible for the implementation of national microbial monitoring, the Department of Health also has an important role to play. Both will benefit from the programme and both have resources that can contribute to it.

A single person from DWAF should be formally assigned the role of **National Coordinator**. (See Roles and Responsibilities chapter for more detail.)

3.2 CREATING PUBLIC AWARENESS

The Department of Health would typically develop national public awareness campaigns for conveying generic health-related messages to water users. The National Microbial Monitoring Programme has an important role to play in this by providing information on where the worst problems exist. The results of the 1997 prioritisation process can also be used to focus resources cost-effectively in any such campaign.

A public awareness campaign will have a number of benefits.

1. It will contribute to avoiding health problems when water is faecally contaminated.
2. It will contribute to minimising future faecal pollution because users will be aware of the consequences.
3. It may create an awareness sufficient to mobilise pressure on polluters and relevant local authorities to deal with the problem.

3.3 AN IMPLEMENTATION MODEL

The National Aquatic Ecosystem Biomonitoring Programme (NAEBP) (or River Health Programme) is implementing a so-called "Demonstration-for-Resource Allocation Spiral" model. A similar approach should be adopted for the National Microbial Monitoring Programme.

In the case of the NAEBP, small-scale demonstration of the role of biomonitoring in water resource assessment and management led to a recognition of its usefulness. This recognition, and the acceptance of a need for the technology, resulted in the further allocation of resources (financial and human). Basically, this approach assumes that demonstrating good results leads to increased support.

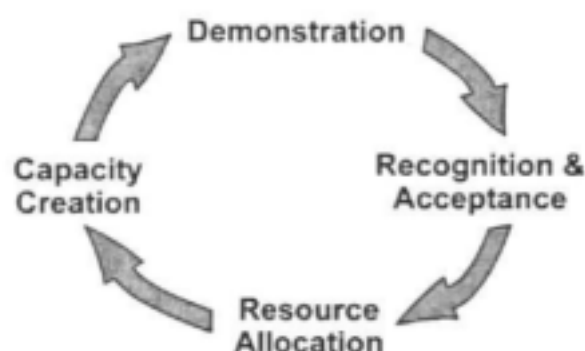


Figure 3.1. The "Demonstration-for-Resource Allocation Spiral" model of the River Health Programme [Roux, 1997].

The National Microbial Monitoring Programme must choose at least two local areas which it can use to demonstrate the usefulness of microbial monitoring. However, a failed attempt could have disastrous consequences and delay ultimate implementation significantly. Therefore, the Programme must "get it right first time". Accordingly, the areas chosen should satisfy at least the following criteria:

1. **Existing capacity.** There must be existing capacity in the area. This means there must already exist players who have the capacity to adopt the roles from **Sampler to Data Assessor** and preferably **Regional Monitoring Coordinator**.
2. **Local willingness.** The local players should reap well-defined benefits from an involvement in the local programme. That is, there should be an inherent willingness to get involved.
3. **Real issues.** The area should be experiencing significant microbial contamination of surface waters. (Preferably the area should have been rated as high risk in the prioritisation process.)
4. **Suitability for demonstration.** It should be remembered that one purpose of this exercise is to demonstrate success. Factors other than those identified here which may enhance or impede the chances of success will need to be identified and carefully considered.

The above criteria essentially make initial implementation as easy as possible by removing many of the most obvious difficulties. A successful implementation of microbial monitoring in, say, two areas will help in a number of ways. First, success can be demonstrated and hence more resources motivated. Secondly, technical and managerial problems (which will inevitably exist, notwithstanding the above criteria) will

be identified and overcome. This will increase the chances of future successes in areas in which implementation is inherently more difficult.

3.4 ANNUAL NATIONAL ASSESSMENT

See National Water Act
Chapter 14 Sections 140 & 142.

Frequency: Annual
Elapsed Time: 1 week
Costing Time: 8 hours

After one year of local monitoring, annual assessments of each area must be performed and combined into a single report. This section illustrates the process.



The complete Annual National Assessment calculation (with instructions) is available from DWAF as a Microsoft Excel spreadsheet. It requires only that the raw data be entered.

To maintain consistency and minimise the chances of human error, this spreadsheet should always be used to produce the necessary information for the maps.

Step 1: Each datum from each sampling site over the past year should be assigned a low, medium or high potential health risk (based on the guidelines in Table 3.1).

Table 3.1. Guidelines for assessing the potential health risk for the four water uses. (Note that these guidelines were developed specifically for use in the NMMP and were not tested in other contexts.)

Water use attribute	Potential Health Risk		
	Low	Medium	High
	Faecal coliform or <i>E. Coli</i> counts/100 ml		
1. Drinking untreated water	0	1-10	> 10
2. Drinking water after limited treatment (see explanatory note* below)	< 2 000	2 000-20 000	> 20 000
3. Full or partial contact	< 600	600-2 000	> 2 000
4. Irrigation of crops to be eaten raw	< 1 000	1 000-4 000	> 4 000

* Note: In this case, the water is used (*i.e.* for drinking) after limited treatment though the guidelines necessarily refer to the raw water before such treatment. For example, raw water with < 2 000 counts/100 ml subjected to limited treatment and then used for drinking, will be associated with a low potential health risk. "Limited treatment" means not conventional treatment. Conventional treatment means all of flocculation, sedimentation, filtration and disinfection.

For example ...

Assume the following (fictitious) annual data (Faecal coliforms/100 ml) had been collected at three sites A, B and C. (Although weekly data is usually used, for the purposes of this example the table only shows monthly data.) The second table shows the potential health risk (Site A only) associated with full or partial contact.

Faecal coliforms/100 ml			Site A: Full/partial contact		
			Potential Health Risk		
Site A	Site B	Site C	Low	Medium	High
9667	14667	2600	L	M	H
1111	1889	433			
23333	73333	3000			H
14667	4000	600			H
11333	1778	211			H
17788	667	60			H
3000	883	880			H
421	3700	2100		M	
733	2889	6200			
30000	1593	933		M	H
2700	13667	1600			H
890	667	1000			
Geometric Mean			Total		
4377	3237	934	1	3	8

Step 2: Tabulate the total counts (lows, mediums and highs) for each site and each water use.

For example ...

The following total counts are obtained at each site for each water use.

Water Use	Site A				Site B				Site C			
	L	M	H	Sum	L	M	H	Sum	L	M	H	Sum
1	0	0	12	12	0	0	12	12	0	0	12	12
2	4	6	2	12	6	5	1	12	8	4	0	12
3	1	3	8	12	0	6	6	12	3	5	4	12
4	3	3	6	12	3	6	3	12	6	5	1	12
Total:	8	12	28	48	9	17	22	48	17	14	17	48



Number of high risk incidents

Step 3: Tabulate (1) the overall yearly assessment (using the geometric means) and (2) the number of high risk incidents for each water use at each site.

For example ...

The following yearly assessments (from geometric means) and numbers of high risk incidents are obtained at each site for each water use.

Water Use	Site A		Site B		Site C	
	Yearly assessment	High Risk Incidents	Yearly assessment	High Risk Incidents	Yearly assessment	High Risk Incidents
1	High	12	High	12	High	12
2	Medium	2	Medium	1	Low	0
3	High	8	High	6	Medium	4
4	High	6	Medium	3	Low	1

Step 4: Calculate the potential health risk indices.

This is based on the percentage of incidents associated with high risk over all water uses at each site in the area.

$$\text{Potential Health Risk Index} = 100 \times (\sum(\text{all high risk incidents})) / (\text{total number of incidents})$$

Use the following guidelines to interpret the calculated index.

Table 3.2. Guidelines for interpretation of the potential health risk index.

Index Range	Interpretation
Index $\leq$ 30	Limited faecal pollution of surface water
30 < Index $\leq$ 60	Moderate faecal pollution of surface water
Index > 60	Heavy faecal pollution of surface water

For example ...

The following numbers of high risk incidents are obtained at each site for each water use.

Site A		Site B		Site C	
High Risk Incidents	Total Incidents	High Risk Incidents	Total Incidents	High Risk Incidents	Total Incidents
28	48	22	48	17	48

$$\text{Potential Health Risk Index} = 100 \times (28 + 22 + 17) / (48 + 48 + 48) = 46.5$$

This indicates Moderate Faecal Pollution of Surface Water

The equivalent index should be calculated for each water use. Use exactly the same formula as above except restrict to each of the water uses in turn. The necessary data appear in the table under step 2. For example, for drinking after limited treatment (water use 2), the index would be $100 \times (2 + 1 + 0) / (12 + 12 + 12) = 8.333$ which should be rounded to the nearest integer, namely 8.

Step 5: Report results.

This brief annual report should contain the following.

1. A brief background on the Programme.
2. A clear reference to this manual for further details.
3. A colour map for each Water Management Area. Each map must show
 - a. the sampling sites,
 - b. the yearly assessment for each water use at each site (with icon colours reflecting the yearly assessment - low, medium or high, based on the geometric means)*,
 - c. a sliding scale (bar) showing the annual assessment of the potential health risk per water use for the area as a whole for the current and previous year,
 - d. a sliding scale (bar) showing the annual assessment of the potential health risk for the area as a whole for the current and previous year.

* Care should be taken with the interpretation of the individual health risks represented by these four indices. When the first such report is produced, careful consideration should be given to the way these indices are interpreted by the various concerned parties. If deemed necessary, special steps should be taken to ensure any incorrect interpretations are avoided.

The report should be sent to the following:

4. Each DWAF Regional Director in whose region a monitoring programme exists.
5. DWAF, Directorate Project Planning.
6. National Policy Maker.
7. National Coordinator.
8. DOH.
9. Each Regional Manager.
10. Any Concerned Party that has expressed an interest in obtaining the report.

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4. REGIONAL IMPLEMENTATION PROCESS

This chapter should be used primarily by the Regional Monitoring Coordinator for guidance on the overall implementation process of the NMMP in a Water Management Area.

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4.1 OVERVIEW

A "regional implementation process" is that series of actions required to set up and sustain a successful microbial monitoring programme in a region (defined as a Water Management Area) so that the national objectives of the programme are realised.

The primary responsibility for regional implementation is likely to be delegated to a Catchment Management Agency. Coordination can be expected to be guided by the national coordinator (see Chapter 5 on "Monitoring Roles"). Regional resources will need to be mobilised.

It needs to be mentioned that if the detailed causes of faecal pollution in a local area need to be identified, the responsibility for this monitoring becomes that of the region. It is not within the scope of this document to deal with regional responsibilities under these conditions. However, it can be mentioned that this is likely to have a number of ramifications. The number of sampling sites is likely to increase (with associated costs and logistical problems). It may be necessary to include other water quality variables in the analysis. The selection of sampling sites requires considerably more care. The frequency of sampling may also differ from that of the national programme (*i.e.* most likely be more frequent).

The following figure shows the steps in the regional implementation process. The sections that follow refer to this figure and give details of the individual steps.

Microbial Monitoring Programme Regional Implementation Process

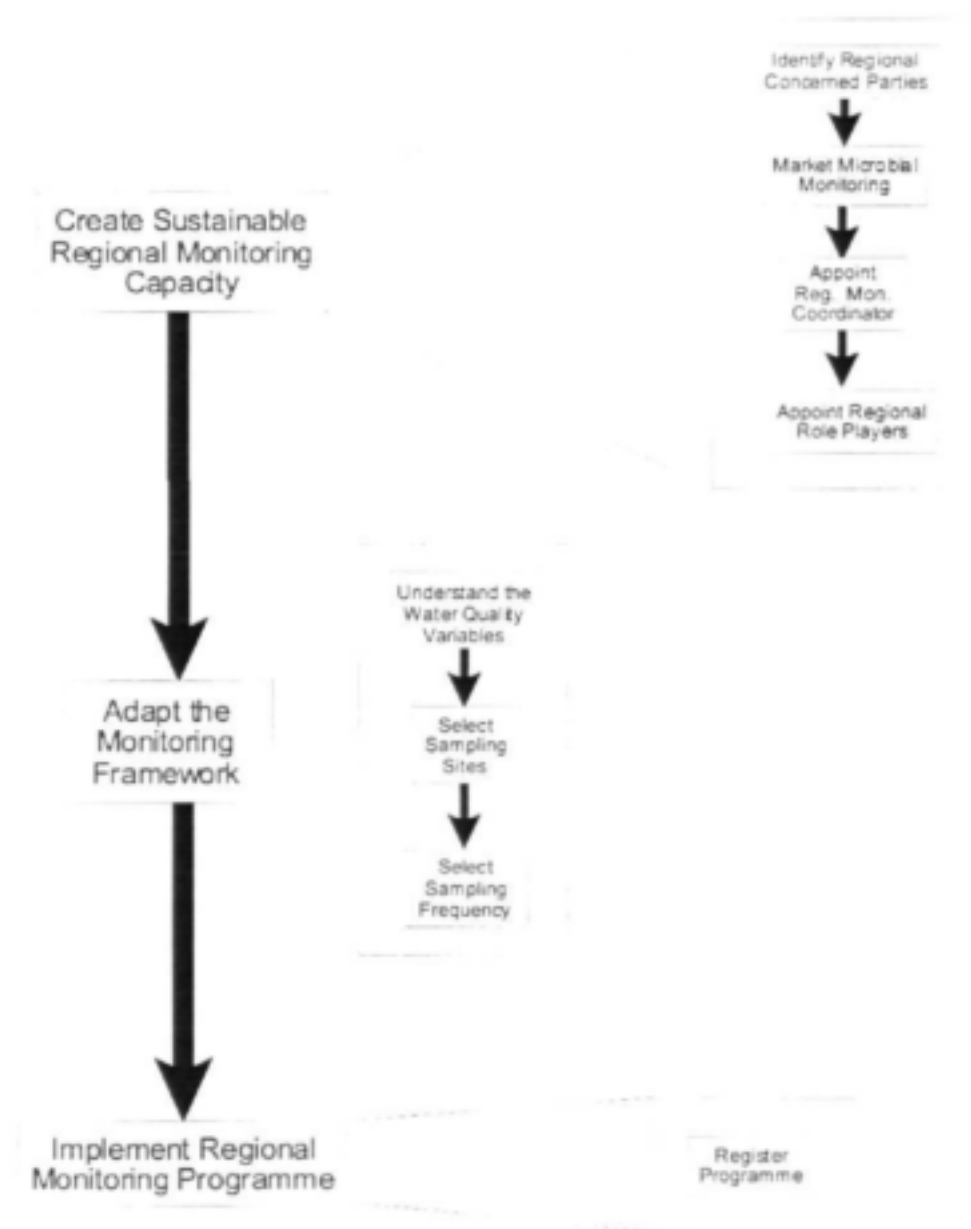


Figure 4.1. Overall Regional Implementation Process

4.2 CREATE REGIONAL MONITORING CAPACITY

4.2.1 Identify Regional Concerned Parties



It is the primary responsibility of DWAF to implement a national microbial monitoring programme for surface waters. However, the involvement of regional concerned parties is likely to be to the advantage of all involved.

Specific water management institutions may already exist in an area. If so, they may well have interests that overlap with those of the national microbial monitoring programme. Alternatively, such organisations could be established so that one of their functions is the implementation of the microbial monitoring programme in the area.

In general, a guiding principle is to identify those concerned parties that would have an inherent vested interest in a monitoring programme. That is, their involvement in the regional programme would be a “win-win” situation.

The following are typical organisations that could be regarded as concerned parties and even as role players.

4.2.1.1 Catchment Management Agencies

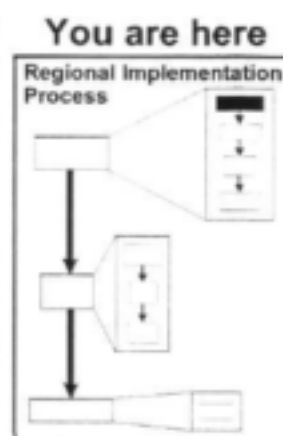
A catchment management agency (CMA) is a statutory body established at the discretion of the Minister to delegate water resource management to a local level and to involve local communities. It may be established for specific geographical areas, after public consultation, on the initiative of the community or stakeholders concerned. The proposal and procedure for its establishment and its powers and duties are detailed in the National Water Act. Its main functions are

**See National Water Act
Chapter 7 & Schedule 3.**

- to investigate and advise on the protection, use, development, conservation, management and control of the water resources in its water management area,
- to develop a catchment management strategy, and
- to coordinate the related activities of the water management institutions within its water management area.

Schedule 3 of the National Water Act deals with the powers and duties of a CMA which are aimed at controlling the permitted water use by users.

Before these agencies come into being in any particular area, DWAF will act as agent in the meantime for the necessary water resource management. The process of



4-6 Regional Implementation Process

establishing them is time-consuming. This is partly because a cautious bottom-up approach is being adopted involving public participation and consultation. The aim is to do more than just consult but rather engage interested parties [Karodia, 1999, DWAF].

A number of "forerunner" regions have been identified as water management areas. These have been proposed in the Government Gazette and comment was invited before 31 March 1999.

See Government Gazette
No 19641, 31 December 1998

It is likely that CMAs will be the primary agent for regional implementation of the NMMP.

4.2.1.2 *Department of Health*

The Department of Health has a significant role to play in the successful implementation of the National Microbial Monitoring Programme. They should also be contributing to establishing overall direction. The possibility of regional environmental health officers playing a role in sampling should be investigated.

4.2.1.3 *Water User Associations*

A water user association (WUA) is a cooperative association of individual water users who wish to undertake water-related activities for their mutual benefit. The purpose of WUAs is to represent specific water users relating to specific water use activities. It is not to undertake overall water resources management aimed at sustainability.

See National Water Act
Chapter 8 & Schedule 5.

A water user association for a particular purpose would usually be established following a proposal to the Minister by an interested person, but such an association may also be established on the Minister's initiative. The functions of a water user association depend on its approved constitution. The following are a few examples that might typically be associated with a water user association:

1. To protect water resources.
2. To prevent any unlawful act likely to reduce the quality of water in any water resource.
3. To exercise general supervision over water resources.
4. To regulate flow.
5. To provide management services, training and support to rural communities and water services institutions, and to provide catchment management services on behalf of responsible authorities.

4.2.1.4 Water Boards

The primary activity of a water board is to provide water services to other water services institutions within its service area.

See Water Services Act (Act No 108 of 1997) Chapter VI & X.
--

A water board must achieve a balance between (among other aspects) (i) striving to provide efficient, reliable and sustainable water services, (ii) striving to be financially viable, (iii) taking into account national and provincial policies, objects and developments, (iv) complying with health and environmental policies, and (v) taking reasonable measures to promote water conservation and water demand management, including promoting public awareness of these matters.

The Water Services Act further requires that a national information system of water services be established. One purpose is to record and provide data for the development, implementation and monitoring of national policy on water services. Another is to provide information to water services institutions, consumers and the public.

Therefore, water boards (among others) may well wish to involve themselves in a monitoring programme. It is usually in their interests to ensure that the quality of raw water that they use for purification and distribution is of consistent quality. Any major deterioration in quality may require changes to their process which could be costly for them. The larger water boards usually also have the necessary sampling and laboratory facilities.

The National Water Act provides for the restructuring of water boards as water user associations.

4.2.1.5 Major Industries

A number of major industries in South Africa take a pro-active role in ensuring (and demonstrating) minimal impacts on their local environments. This is also appropriate in the context of microbial pollution. In the first place, they can convincingly demonstrate a social responsibility to downstream users of the water. Secondly, they can ensure that their own staff are not exposed to faecally polluted surface water. This not only prevents disease but minimises production losses due to sickness. They can also contribute by (i) creating an awareness among staff of potential health risks and (ii) how to minimise risks by treating (e.g. boiling) water suspected to be contaminated.

4.2.2 Market Microbial Monitoring

It may be necessary to "sell" (or at least explain) the concept of microbial monitoring to prospective concerned parties. This may initially be the responsibility of DWAF. However, it may also become the responsibility of the regional monitoring coordinator in order to sustain interest and the necessary support.

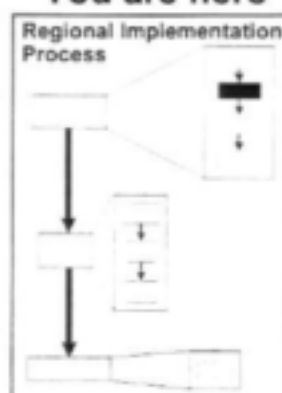
Various tools can be used, depending on the specific audience. The following are contained in this document.

1. The systems model/illustration of problematic land uses and sensitive water uses. (This provides an overall picture of typical causes of the problem and a summary of those most likely to experience problems if contaminated water is used. This diagram contains a formal connection between many important issues as well as a pictorial representation of them, each of which communicates with a different level of audience.)
2. References to the National Water Act (Act No. 36 of 1998) and the Water Services Act (Act No. 108 of 1997). Many such references are made in this document. (These will explicitly convey the statutory requirements of people and organisations associated with water, i.e. what they have to do by law.)
3. The diagram entitled "Prioritisation Improves Cost-Effectiveness". (This enforces the general impression that the national programme is focussed on using resources as wisely as possible.)
4. The diagram showing the "Prioritisation Process". (This will demonstrate the broad steps that were followed that resulted in an area being identified as priority area.)
5. The diagram showing the "Regional Implementation Process". (This will demonstrate the steps required to get a new regional programme off the ground.)
6. The diagram illustrating "Microbial Water Quality Variables". (This shows some detail on what will be measured and why. This information is required to make an appropriate assessment of the raw data.)
7. The diagram showing the overall "Information Flow" from sampler to national policy maker. (This will illustrate all the necessary roles and allow each role player to see exactly where they "fit into the picture". This creates a sense of belonging and hence buy-in to the overall implementation.)
8. Brief descriptions of any specific role for which more information is required. (These summarise each role and details the tasks. They can be sent to prospective role players as broad "terms of reference".)
9. A summary of the funding requirements. (This will enable prospective role players to assess accurately the likely financial impacts.)

Besides specific tools within this document, the following reports can be used in future.

1. Results of a prioritisation process. (This will demonstrate the high risk areas

You are here



- identified and enable comparison with the rest of the country.)
2. An annual report of the national implementation process. (This will show annual results for existing programmes. It will demonstrate how the results are presented and hence facilitate a better understanding of how they can be used.)

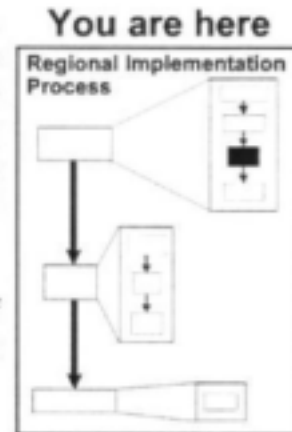
4.2.3 Appoint Regional Monitoring Coordinator



Having identified the concerned parties in the region, it is necessary to appoint one or more people (typically from one of the concerned parties) to take responsibility of being the regional monitoring coordinator. The associated tasks are described elsewhere in this document. One person is considered sufficient to implement and manage a monitoring programme in one area.

The appointment should be contractually based and the choice of regional monitoring coordinator should be based on the following criteria:

1. The candidate should have sufficient time and capacity to carry out the tasks. The percentage of time and other resources required should be estimated.
2. The candidate's superiors should be completely satisfied with the allocation of the regional monitoring coordinator's time and other resources to the monitoring programme.
3. The candidate should have sufficient expertise and experience to enable successful implementation and ongoing management of the regional programme.



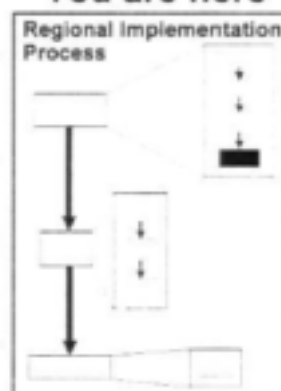
4.2.4 Appoint Regional Role Players

The regional monitoring coordinator, once appointed, needs to formally assign the appropriate organisations and people to each of the required roles. The details of each role are given in chapter 5 "Monitoring Roles".



A critical aspect will be the choice of laboratories. They should preferably be accredited and their locations will need to be such that it is logistically possible to transport samples from the field to the nearest laboratory so that the analysis can be done within 24 hours. This is a demanding requirement. There are many laboratories with existing or potential facilities for microbial analysis, including those within DWAF and at water boards. Laboratories at tertiary education institutions could also be upgraded to provide the necessary analytical services.

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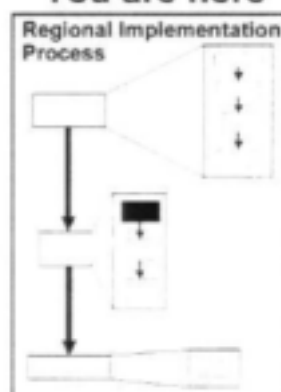
4.3 ADAPT THE MONITORING FRAMEWORK

4.3.1 Understand the Water Quality Variables

It is impractical to measure pathogens directly ...

The overall purpose of the microbial monitoring programme is to assess and manage the health risk to water users due to faecal pollution of water resources. The true health risk to water users is best defined in terms of concentrations of pathogens. However, the measurement of all possible water-associated pathogens in a sample is complex and time-consuming. Furthermore, the low numbers of pathogens relative to the natural microbiological population make detection difficult. This makes direct detection of pathogens in a monitoring programme impractical.

You are here



... so the faecal coliform group is used as an indicator.

Therefore, the level of faecal pollution is assessed on the basis of the presence of "indicator" organisms. Two commonly used indicators are the faecal coliform group and *Escherichia coli* (one of the organisms that comprises the group). The use of the concentration of faecal coliforms in the assessment of water quality is considered to be acceptable (WHO, 1993) though recent trends are towards using *E. coli*.

Both faecal coliforms and *E. coli* can be measured directly and are the microbiological variables used for the NMMP.

For more details ...

CCREM, 1987
DWAF, 1996a
DWAF, 1996b
Gardiner and Zabel, 1989

The other water quality variables that must be measured are pH, temperature and turbidity. **Figure 4.2** illustrates how these variables play a role in determining the level of faecal coliforms. As an example, heavy rainfall creates runoff. Such runoff often carries with it suspended particles that make the water turbid. If, for example, there is a settlement upstream with inadequate sanitation facilities, the runoff may also be contaminated with faecal coliforms. A sudden increase in the faecal coliform levels as well as turbidity indicates that a recent rainfall event may have been the cause of the increased contamination. The presence of both nutrients and suspended solids can be problematic because nutrients adsorb onto particle surfaces. This can increase faecal coliform growth rates. Higher temperatures also increase growth rates while, on the other hand, extreme pH conditions increase the rate at which they decay.

For more details ...

Bowie et al., 1985
Crane and Moore, 1986
WHO, 1993
WHO, 1984

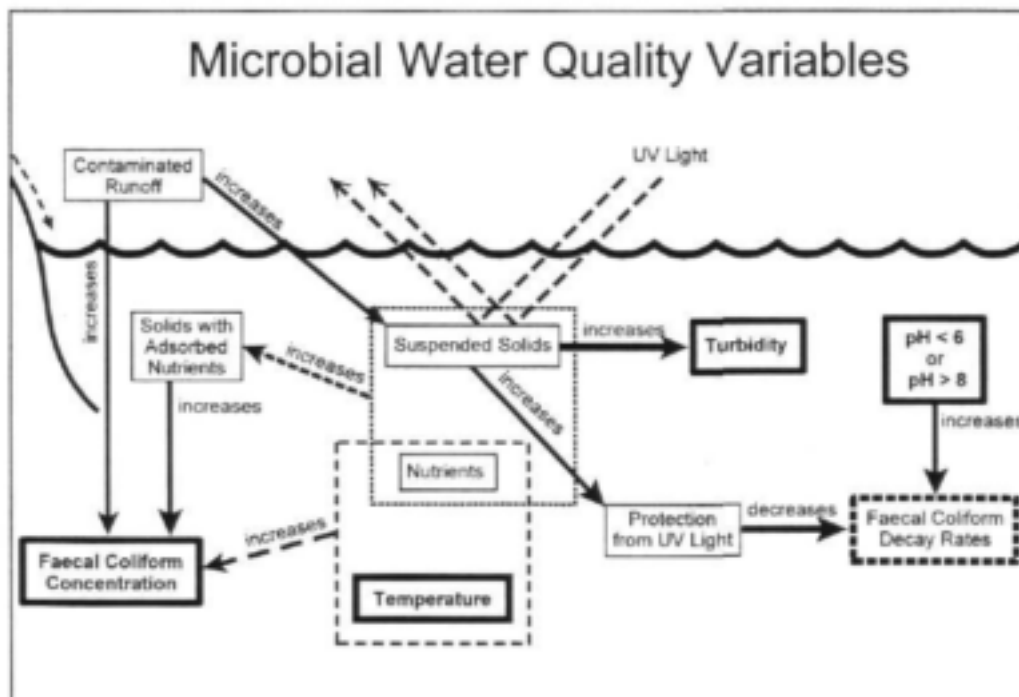


Figure 4.2. The microbial water quality variables and some of their interactions.

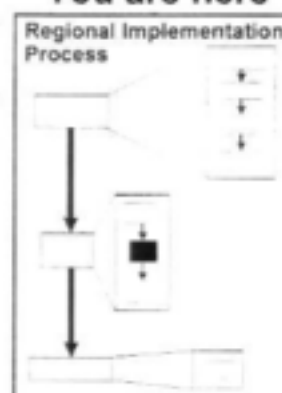
4.3.2 Select Sampling Sites

Elapsed Time: 2 weeks
Costing Time: 2 days

The location of sampling sites is always a critical aspect in the design of a monitoring network. Many factors influence the choice of sites, some specific to microbial monitoring.

The location of sampling sites depends primarily on the national objectives, ...

You are here



It is appropriate to be reminded at this point of the specific objectives of the microbial monitoring programme. These are, nationally,

- ★ to provide information on the status and trends of the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas;
- ★ to provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water.

The results of the prioritisation process are important in the initial choice of sampling sites. That is, areas regarded as having a potentially high risk should receive preferential treatment.

The fact that this programme is a national one and not primarily regional or local has significant implications for choice of sampling sites. For example, fewer sites are necessary for the purposes of the national programme than would be if the purpose was to identify the causes (*i.e.* the polluters) unequivocally.

... the fact that a non-conservative variable
is being measured, ...

Another fundamental factor determining the choice of sampling sites is the fact that a microbial water quality variable (like faecal coliforms) is a non-conservative variable. This means that the concentration varies as a result of a number of processes (see section 4.3.1 "Understanding the Water Quality Variables") causing it to change independently of how much was originally added to the water. (This is in stark contrast to conservative variables. Salts such as chloride, sodium and so on accumulate along the length of a watercourse in the direction of flow. Amounts added at the most upstream point are usually still present when the water passes the most downstream point. Their concentrations are only reduced by such mechanisms as dilution, adsorption or settling.)

A consequence of faecal coliforms being a non-conservative variable is that it is practically impossible (without large investment) to choose sampling sites to be on a uniform grid of representative positions countrywide.

... the proximity to sensitive water uses, ...

With the above in mind, choose sites in areas where the following water uses occur.

1. Where there are households without appropriate or reliable water supply infrastructure, that have to rely on untreated surface water.
2. Where there are households supplied with surface water from the catchment after limited treatment.
3. Where people have full or partial contact with surface water in the catchment.
4. Where crops to be consumed raw are irrigated with surface water from the catchment.

In particular, choose sites near settlements where one or more of the above water uses contributed significantly to the total water use rating for the settlement.

**... the fact that samples must be analysed
within 24 hours, ...**

Another important factor in choosing sampling sites is that samples need to be analysed within 24 hours. The logistics of sampling in remote locations may preclude such sites simply because samples cannot reach the sample analyser in time.

Notwithstanding the above criteria which are specific to microbial pollution, there are a number of generic criteria associated with the choice of sites in any monitoring network. These are as follows.

For more details ...

Sanders et al., 1987
Ward et al., 1990

**... the sample being characteristic
of local conditions, ...**

The site should provide information that is characteristic of the general local conditions. Remember that a "sample" should be representative, because it is being presented as evidence of the quality of the water body from which it is obtained.

... the water being completely mixed, ...

It is critically important that sampling occurs at a point in the watercourse where the water is completely mixed. That is, the microbial water quality should not vary with the

4-14 Regional Implementation Process

depth or width of the watercourse. Remember that complete mixing only occurs some distance downstream of a point discharge. The actual distance depends on local conditions. It may be necessary to take preliminary samples to test whether complete mixing has occurred.

... the site being accessible, ...

The site should be easily accessible to the person taking the sample. Valuable time and resources are wasted if this is not the case.

... sites not being spatially correlated, ...

Ideally, samples taken at different sites should not be "spatially correlated". This means that a sample at one site should not change in composition in a way that can be predicted from the composition of a sample taken at some nearby sampling site. This will occur if there is no significant change in conditions in the watercourse and if no additional pollution sources occur between the two points. If correlation occurs, resources are being wasted because the second sampling site is not providing information that cannot be obtained from the first site.

... account being taken of seasonal variations, ...

Sites should be chosen so that they take account of seasonal variations and other variations over time. Faecal pollution levels can vary seasonally. The flow of water in a watercourse is less in dry seasons so, for a constant pollution source, pollutant concentrations will be higher. On the other hand, wet seasons result in greater surface runoff. Therefore pollution arising from runoff will be greater. High rainfall events also cause sudden increases in pollution levels.

... and available funding.

Funding requirements will vary from area to area depending on the degree of existing infrastructure. A spreadsheet facility is available that enables detailed costing to be done for a single local area. This allows specification of operating and capital costs as well as human resource costs (as hours and hourly rates). It produces a five year cost projection based on various simple assumptions in respect of cost escalation, capital depreciation and so on. This should be used to agree on costs and the relative contributions of the various resource providers.

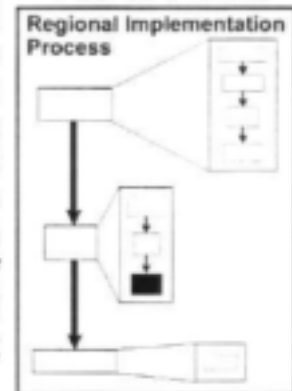
4.3.3 Select Sampling Frequency

Ideally, sampling should be done weekly.

Elapsed Time: 1 hour
Costing Time: 1 hour
(excluding travelling)

An analysis of the data collected during the pilot studies performed during the design phase of this monitoring programme suggested that an appropriate sampling frequency is weekly. This was determined statistically and should be adopted unless there are good reasons to change it. If it is changed, it should ideally be in favour of more frequent sampling rather than less frequent. (If regional monitoring is required that aims at identifying individual causes of faecal pollution, more frequent sampling is almost certainly required.)

You are here



Although less frequent monitoring may be all that is possible in certain circumstances, it must be realised that the usefulness of the data from such monitoring is significantly decreased. This is so for both national purposes and any regional management purposes. In such cases, both the national coordinator and the regional parties involved must explicitly acknowledge the potential information loss and, possibly, the greater risks that may be associated with this.

4.4 IMPLEMENT A REGIONAL MONITORING PROGRAMME

4.4.1 Register Programme

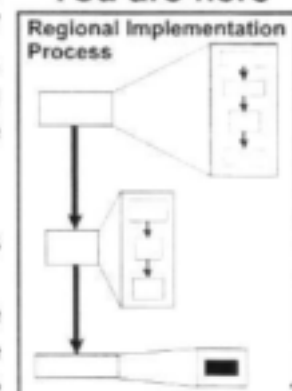
Elapsed Time: 3 weeks
Costing Time: 1 day

Each regional monitoring programme needs to be formally registered with DWAF. To do this, the regional monitoring coordinator should send the

following to DWAF.

1. Completed **Monitoring Programme Registration** forms obtained from DWAF.
2. An A4 or A3 copy of a 1:50 000 scale map of the area. The photocopy must contain (i) the scale on the edge of the original map, (ii) the map number (e.g. 2734AB), (iii) the map name (written clearly if not on the photocopy), and (iv) each sampling site circled and numbered.

You are here



4-16 Regional Implementation Process

3. Information on all the sampling sites including sampling site number, description (so that someone else can find the site easily), name of water body, longitude, latitude, station number (if site is in an existing monitoring programme). An Excel spreadsheet is available from DWAF for this purpose if necessary.

Upon successful registration, DWAF will send a schedule to each sampler confirming exact sampling details (location, frequency, delivery, etc.). Sample bottles suitably tagged (again with sampling details) will also be provided by DWAF. Once the programme is registered, actual monitoring can begin.

4.5 RESOURCES REQUIRED

The following table provides rough estimates of the time required for execution of the main steps in the overall process.

Costing Time: The time actively involved in the task.

Elapsed Time: The time from start to end of the task (taking account of inevitable delays such as lack of immediate availability of people, waiting for others to provide information and so on).

Table 4.1. Estimates of times required to perform main steps in the regional implementation process.

Step	Costing Time	Elapsed Time
Creating Regional Monitoring Capacity	2 weeks	2 months
Adapting the Monitoring Framework	4 days	2 weeks
Implementing a Regional Monitoring Programme	1 day	3 weeks
Approximate Total:	3 weeks	3.25 months

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5. ROLES AND RESPONSIBILITIES

This chapter should be used by any role player to establish the tasks required to be implemented by any of the role players in the NMMP.

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5.1 OVERALL INFORMATION FLOW

A monitoring programme involves analysing samples to obtain data which is assessed to create useful information. A multitude of parties are involved and many individual roles need to be smoothly executed for the overall programme to be successful. This chapter describes each individual role. The actual flow of data and information within the overall scheme is shown in the figures.

The roles cover the whole range from sampler to national policy maker. This approach has been adopted to ensure that each role player understands exactly where they fit into the overall picture. This should create buy-in to the process and hence facilitate initial implementation.

It should be noted that the identification of different roles does not imply that different people or organisations are required to execute those roles. On the contrary, a single person or organisation can be responsible for multiple roles.

Icons have been created for each role to improve visual communication and hence understanding.

National Microbial Monitoring Programme Roles and Information Flow

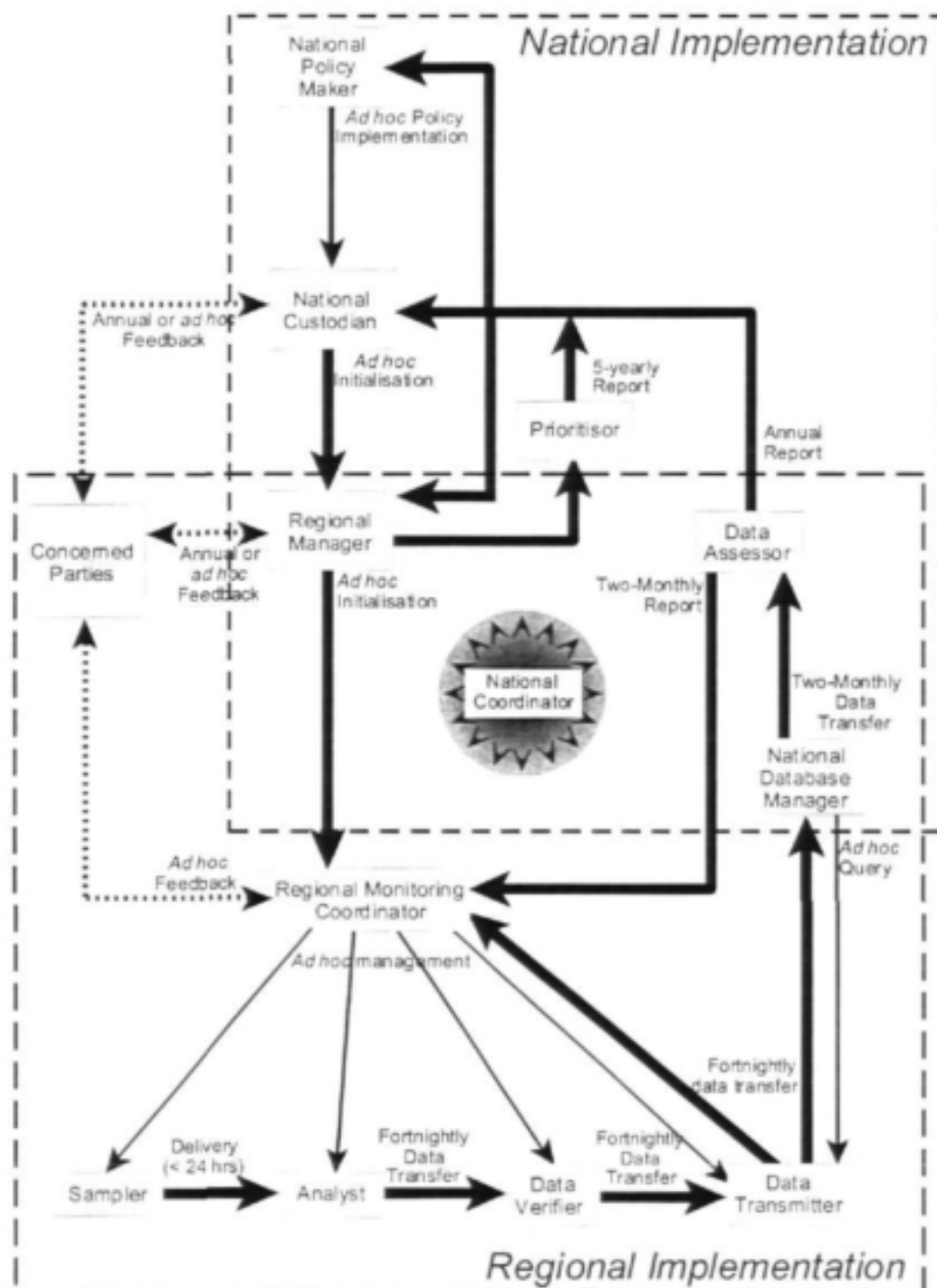


Figure 5.1. Formal roles and information flow.

National Microbial Monitoring Programme Role Icons and Information Flow

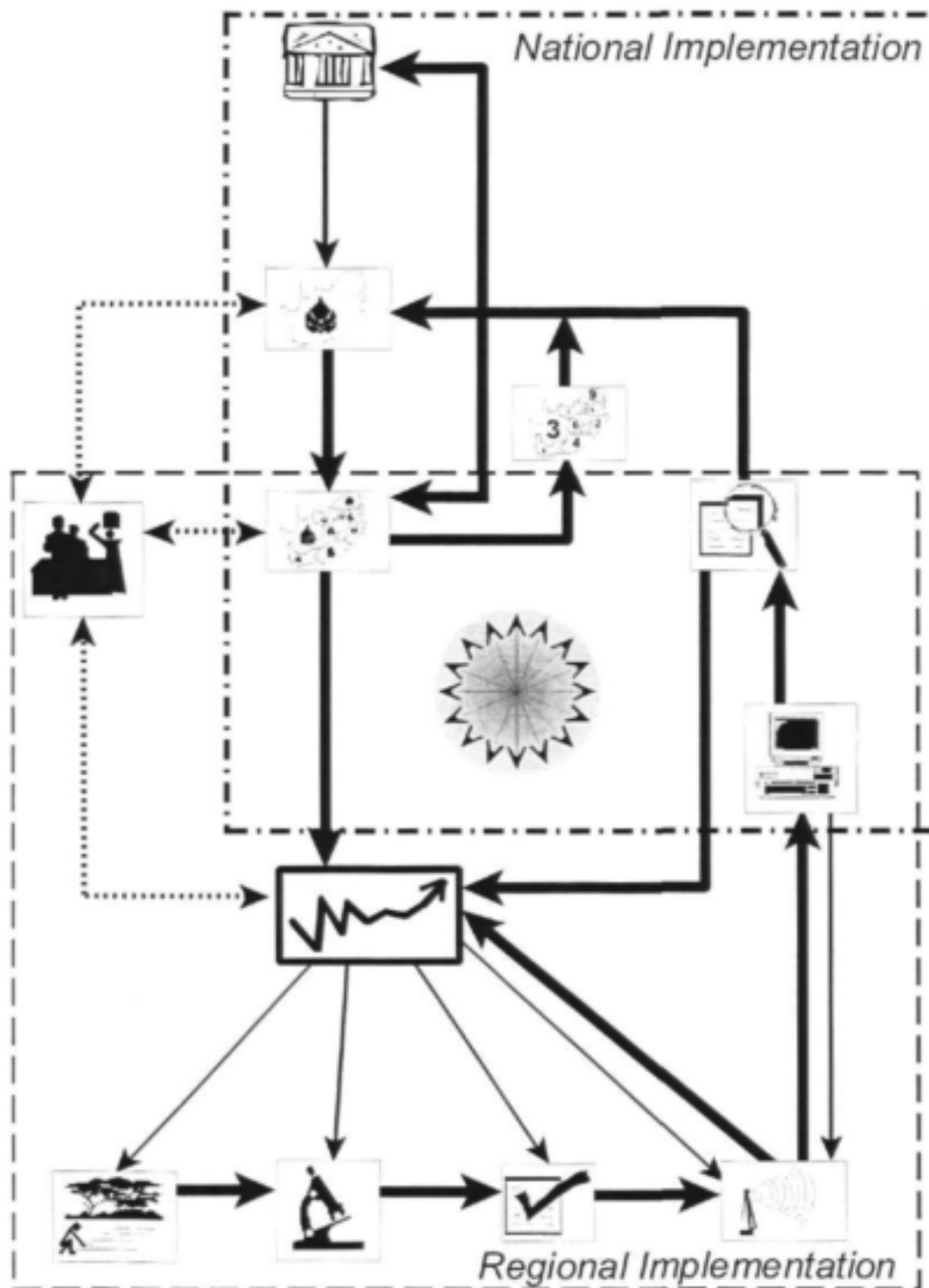


Figure 5.2. Role icons and information flow.

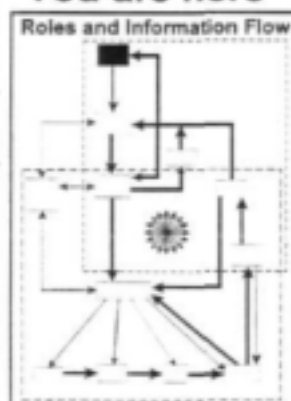
5.2 NATIONAL POLICY MAKER



5.2.1 Summary of Role

The **National Policy Maker** receives reports from the **Prioritiser** (every five years) and the **Data Assessor** (annually). These report on the national *status quo* in respect of faecal pollution in priority areas. It is the responsibility of the **National Policy Maker** to use this information to implement current policy and develop new policy for the national management of surface water resources.

You are here



5.2.2 Typical Role Player

Minister of Water Affairs and Forestry, Minister of Health.

5.2.3 Tasks

A Minister is generally responsible for the powers and functions assigned to him/her by the President. As a Member of Cabinet, he or she is accountable to Parliament for the exercise of these powers and the performance of their functions. A Member of Cabinet must (a) act in accordance with the constitution and (b) provide Parliament with full and regular reports concerning matters under his/her control.

The following extract from the National Water Act (Act No. 36 of 1998) summarises in general terms the ultimate responsibility of the Minister of Water Affairs and Forestry.

Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act. National Government, acting through the Minister, is responsible for the achievement of these fundamental principles in accordance with the Constitutional mandate for water reform. Being empowered to act on behalf of the nation, the Minister has the ultimate responsibility to fulfil certain obligations relating to the use, allocation and protection of and access to water resources.

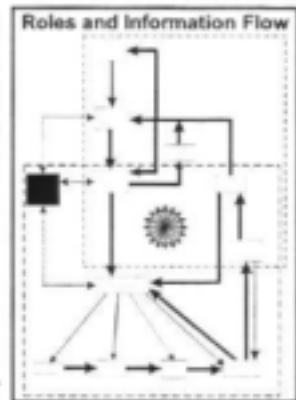
5.3 CONCERNED PARTIES



5.3.1 Summary of Role

The **Concerned Parties** can receive information from a number of sources. These include the **Regional Monitoring Coordinator**, **Regional Manager**, **National Custodian**, **National Coordinator** or the **National Policy Maker**. This could be on an *ad hoc* or routine annual basis. The **Concerned Parties** can communicate directly with the **National Policy Maker**, **National Custodian**, or ideally with the **National Coordinator**.

You are here



5.3.2 Typical Role Player

Any person or organisation with an interest in microbial water quality or that might be affected by deteriorating microbial water quality. These may include the general public, business, lobby groups, water forums, community leaders, etc.

5.3.3 Tasks

5.3.3.1 *Reporting Pollution Incidents*

Pollution incidents (such as spills of hazardous substances or other pollution of surface waters) can be reported directly to the **Regional Manager** by any means.

5.3.3.2 *Other Matters*

The **Regional Manager** can be contacted on any matter concerning the microbial pollution of surface waters. The interests of **Concerned Parties** may be extremely diverse. They can become involved in water related issues using a number of formal structures. These include catchment management agencies, water user associations, water forums and so on. The functions and roles of these are summarised in section 4.2.

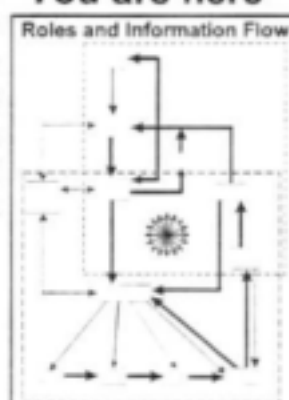
5.4 NATIONAL COORDINATOR



5.4.1 Summary of Role

The primary role is to facilitate the nationwide implementation of the national microbial monitoring programme so that the objectives are achieved. The **National Coordinator** will need to be familiar with all aspects of microbial monitoring and should be able to provide technical and managerial advice to the role players. The **National Coordinator** must ensure effective and efficient transfer of knowledge and experience gained by those involved in the programme.

You are here



5.4.2 Typical Role Player

A single person from the Department of Water Affairs and Forestry (DWAF).

5.4.3 Tasks

5.4.3.1 *Facilitate National Implementation*

The **National Coordinator** should be the driving force behind initial and ongoing implementation on a national basis. This will involve choosing appropriate areas for initial implementation. Details are provided in chapter 3 "National Implementation Process".

5.4.3.2 *Facilitate Regional Implementation*

With the experience gained from implementation in other areas, the **National Coordinator** should facilitate the implementation of monitoring programmes in new priority areas. Details are given in chapter 4 "Regional Implementation Process".

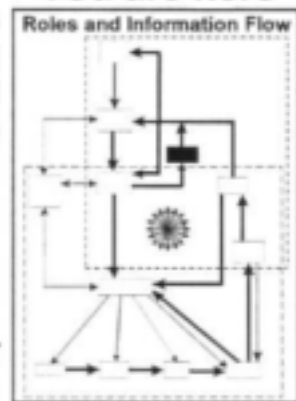
5.5 PRIORITISOR



5.5.1 Summary of Role

The **Prioritisor** screens, ranks, selects and reports the priority areas on a national basis when necessary. This report is submitted to the **Regional Manager**, the **National Custodian** and the **National Policy Maker**. This report summarises the national *status quo* and identifies new priority areas where new monitoring programmes should be initialised.

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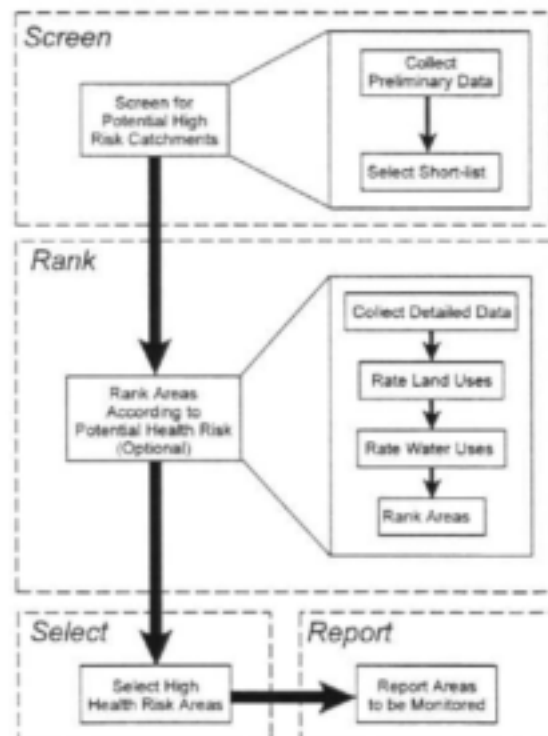
5.5.2 Typical Role Player

The Department of Water Affairs and Forestry (DWAF) and/or appointee. The **National Coordinator** may well take on this role.

5.5.3 Tasks

See chapter 2 "Prioritisation Process".

Prioritisation Process



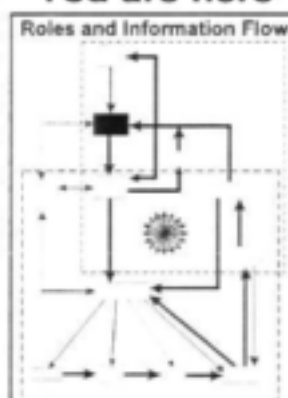
5.6 NATIONAL CUSTODIAN



5.6.1 Summary of Role

The **National Custodian** receives annual reports providing an assessment of each area in which a monitoring programme is in place. It will also receive instructions from the **National Policy Maker** in respect of policy implementation. The **National Custodian** initialises monitoring programmes in new priority areas by communication with the appropriate **Regional Manager** of the **National Coordinator**. It can also communicate directly with **Concerned Parties** routinely on an *ad hoc* or routine annual basis.

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5.6.2 Typical Role Player

Department of Water Affairs and Forestry (DWAF) Director General.

5.6.3 Tasks

5.6.3.1 Initialisation of New Monitoring Programmes

Should a new high risk area be identified by the **Prioritisor**, the appropriate **Regional Manager** is notified as soon as possible. A regional monitoring programme is then established. See chapter 4 "Regional Implementation Process" for more details.

5.6.3.2 Communication with Concerned Parties

The **National Custodian** is bound by the Water Act to report to water management institutions, water users and the public. This can be done routinely every year by making annual assessment reports (see chapter "National Implementation Process") available. This can also be done on an *ad hoc* basis using press releases, radio or DOH environmental health officers when the need for urgency arises.

See National Water Act
Chapter 14 Sections 140 & 145.

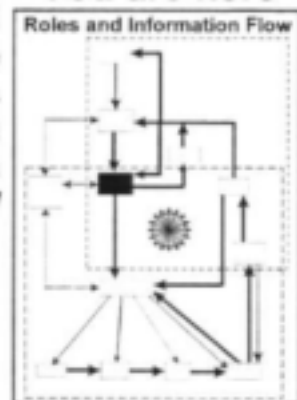
5.7 REGIONAL MANAGER



5.7.1 Summary of Role

The **Regional Manager** receives a 5-yearly report from the **Prioritisor**. This report summarises the national *status quo* and identifies new priority areas where monitoring should be initialised. The **Regional Manager** also receives annual reports providing an assessment of each area in which a monitoring programme is in place. The **Regional Manager** can communicate directly with **Concerned Parties** routinely on an *ad hoc* or routine annual basis.

You are here



5.7.2 Typical Role Player

Water Quality Managers of Department of Water Affairs and Forestry (DWAF) Regional Offices or appointed representative of the relevant catchment management agency. The **Regional Monitoring Coordinator** may also take on this management role.

5.7.3 Tasks

5.7.3.1 Initialisation of a Monitoring Programme

When a new high risk area is identified by the **Prioritisor**, a **Regional Monitoring Coordinator** must be appointed (if one is not already in place) to initialise a microbial monitoring programme in the new high risk region. See chapter 4 "Regional Implementation Process".

5.7.3.2 Communication with Concerned Parties

The **Regional Manager** should receive comments and information from **Concerned Parties** as well as provide them with regular reports or feedback, as deemed appropriate by both parties.

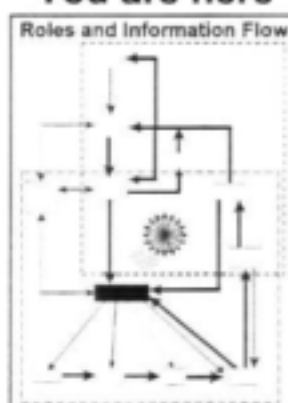
5.8 REGIONAL MONITORING COORDINATOR



5.8.1 Summary of Role

The **Regional Monitoring Coordinator** has many sub-roles. After the position is established when a new priority area is identified, the person is responsible for selecting sampling sites, ensuring that the appropriate training is carried out, implementing monitoring and managing day-to-day problems. The **Regional Monitoring Coordinator** receives a two-monthly report from the **Data Assessor** on the *status quo* of the faecal pollution in the area.

You are here



5.8.2 Typical Role Player

Typically a representative of the relevant catchment management agency or a DWAF Regional Office.

5.8.3 Tasks

Once appointed, the tasks of the **Regional Monitoring Coordinator** are to initialise, implement and coordinate the microbial monitoring programme in the identified high risk area. The individual tasks are given in detail in chapter 4 "Regional Implementation Process".



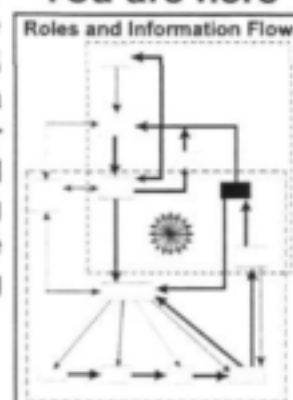
5.9 DATA ASSESSOR



5.9.1 Summary of Role

The **Data Assessor** receives data (for each area in which a monitoring programme is in place) from the **National Database Manager** every two months. The data should be assessed and the current status and trends of faecal contamination in the area should be reported to the **Regional Monitoring Coordinator** every two months. The **Data Assessor** also produces annual reports on all water management areas with monitoring programmes in place. The fundamental role is to add value to the numerical results for the benefit of the **Regional Monitoring Coordinator**.

You are here



5.9.2 Typical Role Player

Microbiologist with experience in the behaviour of faecal coliforms in environmental waters. Typically in the Department of Water Affairs and Forestry (DWAF).

5.9.3 Tasks

It is the primary task of the data assessor to provide information on the "assessment endpoint" (the human health risk) based on the "measurement endpoint" (the measured values of faecal coliforms etc.).

5.9.3.1 Annual National Assessment

For details see chapter 3 "National Implementation Process".

Elapsed Time: 1 week
Costing Time: 8 hours
(per 10 areas assuming established methods)

5.9.3.2 Two-monthly Assessment to Regional Monitoring Coordinator

Elapsed Time: 1 hour
Costing Time: 1 hour
(per area)

The data (i.e. faecal coliform or *E. coli* counts, pH, turbidity and temperature) should be obtained from the database for each sampling site in the area being assessed. Trends need to be displayed, therefore the data should ideally be imported into a spreadsheet.



The complete Bi-monthly Assessment calculation (with instructions) is available from DWAF as a Microsoft Excel spreadsheet. It requires only that the raw data be entered.

To maintain consistency and minimise the chances of human error, this spreadsheet should always be used for the assessment.

Each **Regional Monitoring Coordinator** simply wants to know what the current status is and what the trend is in the area under their jurisdiction. A spreadsheet format is sufficient for this purpose and is cost-effective. The bi-monthly assessment spreadsheet assigns low, medium and high potential health risks to each datum for each water use. It also automatically provides graphs showing how the data has changed over the period being assessed. The final assessment can either be transmitted to the **Regional Monitoring Coordinator** directly (by E-mail) or copies of A4 printouts of the spreadsheet pages can be faxed.

The following specific individual assessments can be done on the data (directly in the spreadsheet or on the fax cover page).

1. Individual high or low faecal coliform values can be commented on. For example, give possible reasons (if known) such as "high rainfall event on 1998-Feb-12", "sewage spill at point X on 1999-Jan-5", and so on. Often such local information is not immediately available to the **Data Assessor** since he/she is centrally based. If this is the case, unusually high values could be questioned simply to bring them to the attention of the **Regional Monitoring Coordinator**.
2. Include any other comments that will assist the **Regional Monitoring Coordinator** to understand the full implications of the data that have been measured in the area.

This report should be seen primarily as providing regular feedback to the **Regional Monitoring Coordinators** while also providing whatever assessment is possible.

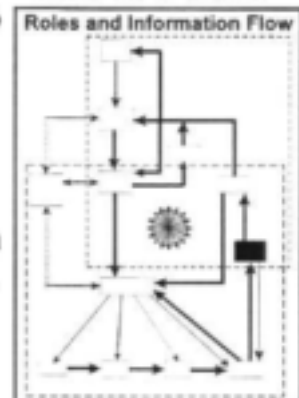
5.10 NATIONAL DATABASE MANAGER



5.10.1 Summary of Role

The **National Database Manager** receives verified analytical data from the **Data Transmitter**. A database must be maintained so that data can be supplied to the **Data Assessor** monthly.

You are here



5.10.2 Typical Role Player

The Department of Water Affairs and Forestry (DWAF). Ideally a person associated with the Water Management System (WMS).

5.10.3 Tasks

5.10.3.1 Database Management

This includes all tasks typically associated with the data input and maintenance of computer databases.

5.10.3.2 Data Extraction on Demand

Upon demand from the **Data Assessor**, data should be provided in a format appropriate for the use intended. Automated data extraction procedures will need to be developed that provide the data in the most appropriate form.

Elapsed Time: <30 mins
Costing Time: < 30 mins
(per area)

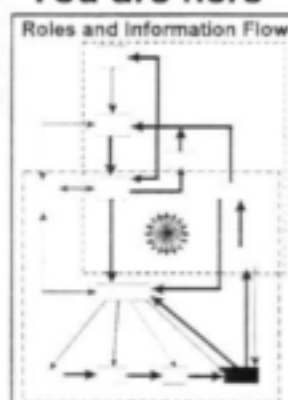
5.11 DATA TRANSMITTER



5.11.1 Summary of Role

The **Data Transmitter** receives verified analytical data from the **Data Verifier**. The data must be electronically transmitted on a weekly basis, preferably as a comma delimited ASCII file attached to an E-mail, to the **National Database Manager** and the **Regional Monitoring Coordinator**.

You are here



5.11.2 Typical Role Player

Laboratory.

5.11.3 Tasks

Frequency: Supply the data to the **National Database Manager** and the **Regional Monitoring Coordinator** every two weeks if the transfer process is easy, otherwise on a monthly basis. It is important that data be transmitted regularly. If the **Regional Monitoring Coordinator** has the necessary expertise to play the role of the **Data Assessor**, data can be received directly from the **Data Transmitter** (and not via the **National Database Manager**).

Elapsed Time: <30 mins
Costing Time: < 30 mins
(per area)

Means of data transmission. The most important basic principle to bear in mind in respect of data transmission is that the amount of manual work (particularly repeated manual data entry) should be minimised. This will minimise the potential for mistakes (that can easily occur). Ideally, data should be entered manually only once.

If direct entry of the data into the IQWS Water Management System (WMS) is possible (e.g. using the interface Winterm), then this is preferable. If this is not possible, then data should be transmitted electronically as an E-mail attachment. A simple Excel spreadsheet interface is available from IWQS for this purpose. The interface performs a series of simple checks for obvious mistakes as the data are being entered.

If one does not have access to E-mail, it can be posted on a 3½" floppy disk to the **National Database Manager**. However, this is not ideal. There will be postal delays, it is more expensive and the risk of loss in the postal system is significant. It may also be possible to submit data on paper. Upon registration of the monitoring programme, the **National Database Manager** will provide the **Regional Monitoring Coordinator** with a schedule which will describe the format in which data should be transmitted.

Provision may be made in future for certain data transmitters (at perhaps the larger laboratories) to insert the data directly into the database via a direct line.

Data file type: If direct remote data entry is not possible, data should ideally be transmitted as the above Excel spreadsheet. Alternatively, the data can be transmitted as a Comma Delimited ASCII file. This can be produced by exporting a file of this type ("Saving As") from most spreadsheet software packages.

From Excel: Save As File Type: CSV (Comma delimited) (filename.csv)

From Quattro Pro: Save As File type: ASCII Text ("Comma delimited") (filename.txt)

Note, however, that commas in text strings can cause problems in comma delimited files. If they cannot be avoided, then rather produce a 'tab delimited' file.

If an electronic file is to be transmitted, *physically test the file* by sending it to the **National Database Manager** (and confirming receipt) to ensure that it can be read correctly.

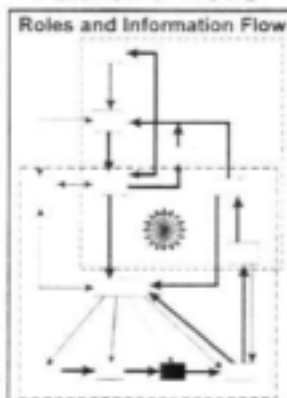
5.12 DATA VERIFIER



5.12.1 Summary of Role

The **Data Verifier** receives analytical data from the **Analyst** every two weeks. This data includes sample site identification, faecal coliform counts, temperature, pH and turbidity. The data must be verified as "reasonable" and explanations must be found for unexpected results. Verification is then recorded as having been carried out. Verified data is then made available to the **Data Transmitter**.

You are here



5.12.2 Typical Role Player

Laboratory microbiologist with experience in the behaviour of faecal coliforms in environmental waters.

5.12.3 Tasks

The primary purpose of data verification is to ensure that the experimental measurements are not obviously wrong (e.g. are in the incorrect units). If the result is unexpected, an explanation must be found. Consider the following.

Elapsed Time: <10 mins
Costing Time: < 10 mins
(per area, possibly longer if unexpected results found)

1. Previous trends;
2. High rainfall events (that may have resulted in a sudden increase in faecal coliforms);
3. Actions that may have been taken to minimise or contain the pollution source (that may have lowered the faecal coliform level);
4. The possible effects of any changes in temperature, pH and turbidity (see **Figure 4.2**).

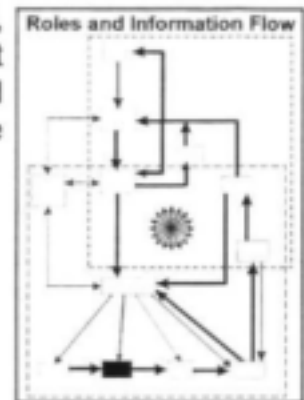
5.13 ANALYST



5.13.1 Summary of Role

The **Analyst** receives samples from the **Sampler** at two-weekly intervals. The sample should be analysed for faecal coliforms, pH and turbidity. This data must be stored directly in the format that will ultimately be used by the **Data Transmitter** (prescribed by the **National Database Manager**). This is then made available to the **Data Verifier**.

You are here



5.13.2 Typical Role Player

Laboratory.

5.13.3 Tasks

Elapsed Time: 24 hours
Costing Time: 1 hour
(10 samples, all analyses)

5.13.3.1 Sample Preservation

Store samples at a temperature of less than 10°C (though not frozen). Analyse the sample within 24 hours of collection.

For more details ...

WRC, DWAF & DOH, 1999b

5.13.3.2 Faecal Coliform Analysis

The preferred method is the Faecal coliform membrane filter procedure. This uses commercial M-FC agar. Results are available within 24 hours. This is a well-described standard method.

For more details ...

Standard Methods, 1998
SABS method 221-1990
SABS method 221-1/1 NP (draft)

If the laboratory is not equipped to perform the membrane filter procedure or if the turbidity of the sample is high, the Faecal coliform MPN procedure can be used.

Report the result as Faecal coliforms/100 ml. Every effort should be made to report results as absolute counts, not using a 'greater than' symbol, >.

5.13.3.3 *E. coli* Analysis

E. coli should preferably be measured by the colilert method although other standard methods may also be used. However, if the laboratory does not measure *E. coli*, or does not have the resources to set this up, then faecal coliforms should be analysed, as described above

For more details ...

Standard Methods, 1998
SABS 241 Ed.5 2001

Report the result as *E. coli*/100 ml. Every effort should be made to report results as absolute counts, not using a 'greater than' symbol, >.

5.13.3.4 *Turbidity Analysis*

Measure turbidity using the standard nephelometric method. Any apparatus based on this principle can be used. Report the result in nephelometric turbidity units (NTU).

For more details ...

Standard Methods, 1998

5.13.3.5 *pH Measurement*

Use a calibrated pH meter equipped with a temperature conversion device. Report in pH units.

For more details ...

Standard Methods, 1998

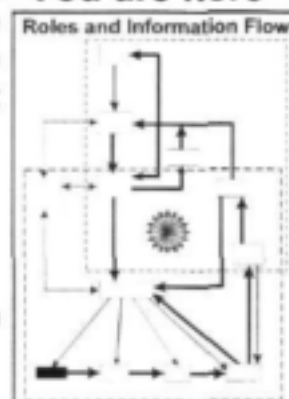
5.14 SAMPLER



5.14.1 Summary of Role

The **Sampler** physically travels to the designated sample sites at the required frequency (typically weekly), takes the samples in the specified way, marks the containers with the date and sample site identification and delivers the sample containers to the **Analyst** for analysis within 24 hours.

You are here



5.14.2 Typical Role Player

DWAF regional offices, laboratory, DOH environmental health officers, water board or local authority.

5.14.3 Tasks

5.14.3.1 Choice of Sample Containers

Wide-mouth glass or heat-resistant plastic bottles of a volume of at least 250 ml are ideal. The bottles and caps should not produce toxic or nutritional compounds when sterilised. Commercially available plastic bags intended for sterile sampling can also be used.

Clean all sample containers thoroughly and ensure that all traces of detergent are removed. Sterilise the containers in an autoclave at 121°C for 15 minutes. Dry glassware can also be sterilised in a hot air oven at 170°C for at least two hours.

For more details ...

Bordner and Winter, 1978
Standard Methods, 1998
WRC, DWAF & DOH, 1999a

5.14.3.2 Temperature Measurement

Measure the ambient water temperature in-stream at the sampling site.

5.14.3.3 Sampling Procedure

Samples could be collected either by hand or with a sampling device. A variety of sampling devices are available on the market and when used they should be operated according to the instructions of the manufacturer. Contact with the bank or stream bed should be avoided otherwise fouling of the sample may occur.

Elapsed Time: 1-8 hours
Costing Time: 1-8 hour

Sampling Procedure	
To take a grab sample by hand, hold the container close to the base with one hand (carefully avoiding touching the neck at all times) and plunge into the water with the mouth downwards. This avoids the introduction of surface scum into the sample. Take the usual precautions to avoid contact with skin.	
Point the submerged container towards the current or push to create a current if the water is static. Tilt the container slightly upwards to allow the air in the container to escape, and fill the container.	
If the water sample contains residual chlorine, add 1 ml of a 10% sodium thiosulphate solution for every litre of sample taken (Standard Methods, 1995).	
Ensure that an air space exists at the top of the sample before sealing the container with the stopper. This will allow the sample to be properly mixed before analysis.	
Fill in the necessary information on the tag on the container. Also, note the measured temperature.	
If the sample cannot be delivered to the Analyst and analysed within one hour after collection, store and transport the samples in iced coolers.	

Figure 5.1. Formal roles and information flow.

Figure 5.2. Role icons and information flow.

6. REFERENCES



Bordner R and Winter J, 1978. *Microbiological methods for monitoring the environment: Water and wastes*. EPA document EPA-600/8-78-017, U.S. Environmental Protection Agency, Cincinnati, USA.

Bowie GL, Mills WB, Porcella DB, Campbell CL, Pagenkopf JR, Rupp GL, Johnson KM, Chan PWH, Gherini SA and Chamberlin CE, 1985. *Rates, constants and kinetic formulations in surface water quality modelling*. 2nd Edition. EPA document EPA-600/3-85-040, U.S. Environmental Protection Agency, Cincinnati, USA.

Canadian Council of Resource and Environment Ministers, 1987. *Canadian water quality guidelines*. Environment Canada, Ottawa, Canada.

Crane SR and Moore JA, 1986. Modelling enteric bacterial die-off: A review. *Water, Air and Soil Pollut.*, **27**, 411 - 439.

Du Preez M, 1998a. National Microbiological Water Quality Monitoring Programme. *Envisage*, Autumn 1998. Environmentek, CSIR.

Du Preez M, 1998b. Plan to Monitor Water Quality. *Engineering News*. April, 1998.

Du Preez M, Venter SN, van Ginkel C, Harris J, Kühn A, Zingitwa L and Silberbauer M, 1999. *Research on the Selection of Procedures for Faecal Pollution Monitoring to Describe Health Risks*. WRC Report No. K5/824/0/1.

Du Preez M, Murray K and van Niekerk H, 2001. *A Pilot Study to Demonstrate Implementation of the National Microbial Monitoring Programme*. Progress report to the Water Research Commission.

Du Preez M, Murray K and van Niekerk H, 2002. *A Pilot Study to Demonstrate Implementation of the National Microbial Monitoring Programme*. Research report to the Water Research Commission.

Department of Water Affairs and Forestry, 1994. *A conceptual design of a monitoring programme and implementation protocol assessing the microbiological quality of surface water in South Africa - Literature study*. Pretoria, South Africa.

Department of Water Affairs and Forestry, 1995. *Design framework for a monitoring programme to assess the faecal pollution of SA water resources*. Pretoria, South Africa.

6-2 References

Department of Water Affairs and Forestry, 1996a. *South African water quality guidelines, Volume 1, Domestic use*. 2nd Edition. Pretoria, South Africa.

Department of Water Affairs and Forestry, 1996b. *South African water quality guidelines, Volume 1, Recreational use*. 2nd Edition. Pretoria, South Africa.

Department of Water Affairs and Forestry, Department of Health and Water Research Commission, 1998. *Quality of Domestic Water Supplies. Volume 1: Assessment Guide*. Water Research Commission Report No. TT 101/98.

Gardiner J and Zabel T, 1989. *United Kingdom water quality standards arising from European Community directives - an update*. Water Research Centre, Buckinghamshire, U.K.

Goodmin P and Wright G, 1991. *Decision analysis for management judgement*. John Wiley and Sons Ltd, Chichester, UK. pp 7 - 36.

Harris J, van Veelen M and Gilfillan TC, 1992. *Conceptual Design Report for a National River Water Quality Assessment Programme*. Water Research Commission Report No. 204/1/92.

Hohls D, du Plessis G, Venter SN, Steynberg MC, de Wet CME, Rodda N and Kfir R, 1995. Estimation of the fate of microbial water quality contaminants in a South African river. *Wat.Sci.Tech.*, **31**, 5-6, 271 - 274.

Klugman KP, 1999. *Emerging Infectious Diseases—South Africa*. URL: <http://www.cdc.gov/ncidod/EID/vol4no4/klugman.htm>.

Kühn AL, Venter SN, Harris J and Zingitwa L, 1998. *National Microbiological Water Quality Monitoring Programme for South Africa*. Water Institute of Southern Africa Biennial Conference. Cape Town, May 1998.

Kühn AL, Venter SN, van Ginkel C, Vermaak E and Zingitwa L, 2000. *Identification of Areas with Faecally Polluted Surface Water Sources in South Africa*. Water Institute of Southern Africa Biennial Conference. Sun City, May 2000.

Roux D, 1997. *National Aquatic Ecosystem Biomonitoring Programme: Overview of the Design Process and Guidelines for Implementation*. NAEBP Report Series No. 6. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Sanders TG, Ward RC, Loftis RC, Steele TD, Adrian DD and Yevjevich V, 1987. *Design of Networks for Monitoring Water Quality*. Water Resources Publications, Littleton, Colorado.

Standard Methods, 1998. *Standard methods for the examination of water and*

wastewater. 20th Ed., Eds. Eaton AD, Clesceri LS and Greenberg AE. American Public Health Association, Washington D.C., USA.

Venter SN, Harris J and Kühn AL, 1998. *A Method for the Prioritisation of Areas Experiencing Microbial Pollution of Surface Water*. Conference of the IAWQ, Specialist Group on Health Related Water Microbiology, June. Vancouver, USA.

Ward RC, Loftis JC and McBride GB, 1990. *Design of Water Quality Monitoring Systems*. Van Nostrand Reinhold, New York.

World Health Organization, 1984. *Guidelines for drinking-water quality, Volume 2, Health Criteria and Other Supporting Information*. Geneva.

World Health Organization, 1993. *Guidelines for drinking-water quality, Volume 1, Recommendations*. 2nd Edition. Geneva.

Water Research Commission, Department of Water Affairs and Forestry & Department of Health, 1999a. *Quality of Domestic Water Supplies - Vol: II Sampling Guide*.

Water Research Commission, Department of Water Affairs and Forestry & Department of Health, 1999b. *Quality of Domestic Water Supplies - Vol: III Analysis Guide*.

6. REFERENCES	6-1
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**Appendix A:
National Water Act (Act No. 36 of 1998)
Chapter 14**

(For the complete Act, see http://www.acts.co.za/ntl_water/index.htm)

CHAPTER 14

MONITORING, ASSESSMENT AND INFORMATION

Monitoring, recording, assessing and disseminating information on water resources is critically important for achieving the objects of the Act. Part 1 of this Chapter places a duty on the Minister, as soon as it is practicable to do so, to establish national monitoring systems. The purpose of the systems will be to facilitate the continued and co-ordinated monitoring of various aspects of water resources by collecting relevant information and data, through established procedures and mechanisms, from a variety of sources including organs of state, water management institutions and water users.

*Part 1: National monitoring systems***Establishment of national monitoring systems**

137. (1) The Minister must establish national monitoring systems on water resources as soon as reasonably practicable.
 (2) The systems must provide for the collection of appropriate data and information necessary to assess, among other matters -
 (a) the quantity of water in the various water resources;
 (b) the quality of water resources;
 (c) the use of water resources;
 (d) the rehabilitation of water resources;
 (e) compliance with resource quality objectives;
 (f) the health of aquatic ecosystems; and
 (g) atmospheric conditions which may influence water resources.

Establishment of mechanisms to co-ordinate monitoring of water resources

137. The Minister must, after consultation with relevant -
 (a) organs of state;
 (b) water management institutions; and
 (c) existing and potential users of water, establish mechanisms and procedures to co-ordinate the monitoring of water resources.

Part 2: National information systems on water resources

Part 2 requires the Minister, as soon as it is practicable to do so, to establish national information systems, each covering a different aspect of water resources, such as a national register of water use authorisations, or an information system on the quantity and quality of all water resources. The Minister may require any person to provide the Department with information prescribed by the Minister in regulations. In addition to its use by the Department and water management institutions, and subject to any limitations imposed by law, information in the national systems should be generally accessible for use by water users and the general public.

Establishment of national information systems

138. (1) The Minister must, as soon as reasonably practicable, establish national information systems regarding water resources.
 (2) The information systems may include, among others -
 (a) a hydrological information system;
 (b) a water resource quality information system;
 (c) a groundwater information system; and
 (d) a register of water use authorisations.

Objectives of national information systems

139. The objectives of national information systems are -
 (a) to store and provide data and information for the protection, sustainable use and

- management of water resources;
- (b) to provide information for the development and implementation of the national water resource strategy; and
- (c) to provide information to water management institutions, water users and the public -
 - (i) for research and development;
 - (ii) for planning and environment impact assessments;
 - (iii) for public safety and disaster management; and
 - (iv) on the status of water resources.

Provision of information

141. The Minister may require in writing that any person must, within a reasonable given time or on a regular basis, provide the Department with any data, information, documents, samples or materials reasonably required for -
- (a) the purposes of any national monitoring network or national information system; or
 - (b) the management and protection of water resources.

Access to information

142. Information contained in any national information system established in terms of this Chapter must be made available by the Minister, subject to any limitations imposed by law, and the payment of a reasonable charge determined by the Minister.

Regulations for monitoring, assessment and information

143. The Minister may make regulations prescribing -
- (a) guidelines, procedures, standards and methods for monitoring; and
 - (b) the nature, type, time period and format of data to be submitted in terms of this Chapter.

Part 3: Information on floodlines, floods and droughts

Part 3 requires certain information relating to floods, droughts and potential risks to be made available to the public. Township layout plans must indicate a specific floodline. Water management institutions must use the most appropriate means to inform the public about anticipated floods, droughts or risks posed by water quality, the failure of any dam or any other waterworks or any other related matter. The Minister may establish early warning systems to anticipate such events.

Floodlines on plans for establishment of townships

144. For the purposes of ensuring that all persons who might be affected have access to information regarding potential flood hazards, no person may establish a township unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by floodwaters on average once in every 100 years.

Duty to make information available to public

145. (1) A water management institution must, at its own expense, make information at its disposal available to the public in an appropriate manner, in respect of -
- (a) a flood which has occurred or which is likely to occur;
 - (b) a drought which has occurred or which is likely to occur;
 - (c) a waterwork which might fail or has failed, if the failure might endanger life or property;
 - (d) any risk posed by any dam;
 - (e) levels likely to be reached by floodwaters from time to time;
 - (f) any risk posed by the quality of any water to life, health or property; and
 - (g) any matter connected with water or water resources, which the public needs to know.
- (2) The Minister may, where reasonably practicable, establish an early warning system in relation to the events contemplated in subsection (1).

Appendix B: Water Act Chapter 14	B -1
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Other related WRC reports available:

Management of water-related microbial diseases

DWAF and WRC

The purpose of this guideline series is to provide awareness building and management information on the nature and prevention of important water-related microbial diseases.

The purpose of volume one in the series, "Disease characteristics", is to introduce and describe the basic facts of some important water-related diseases, in terms of:

- how they can be recognised (presenting symptoms)
- how they are transmitted
- the role of water in the transmission routes
- how they can be prevented
- what management options may be exercised in reducing their incidence and risk of transmission.

Note: It is not the purpose of this guide to go into details of differential diagnosis or treatment. These details may be found in medical texts and handbooks.

This guide is primarily an awareness building guide to educate the upcoming generation in the need for: (1) disinfected drinking water, (2) safe waste disposal, (3) good personal and kitchen hygiene, and (4) protection of water resources from faecal pollution.

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