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FRANK R. BURDEN, IAN McKELVIE, ULRICH FÖRSTNER, AND ALEX GUENTHER

ENVIRONMENTAL MONITORING HANDBOOK

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PREFACE

When I was first asked to compile a handbook of environmental monitoring, I felt that there were many people who were far more experienced than I was in this field. However, I had been found from a Web site for which I was responsible, one that organized both students and staff across a number of Faculties of Monash University with the purpose of providing a course on environmental monitoring. My own knowledge of the area was wide but shallow, but through the adventures of academic life, I had formed an interest in a wide variety of the topics covered in this book, my own expertise being in data analysis and modeling, although often applied to areas far removed from environmental monitoring.

It was clear to me that there was a place for a book that elucidated the role and practice of environmental monitoring both for the expert and for those needing to expand their knowledge or to learn of the difficulties of gathering noisy data and making enough sense of them to present to regulators and legislators. If environmental monitoring is not carried out in a deep and exacting scientific manner, then it is likely that no action will be taken when it is needed for lack of firm evidence.

The first task was to decide on the general format of the book, and an updated version of the ancient lore of earth, air, fire, and water had an appeal (with fire being the analysis that tempers the data). Hence the book came to be divided into four parts under the guidance of a part editor, except for the last part, which was my responsibility. The part editors have a wide experience in their respective fields and they have persuaded and cajoled the chapter authors from around the world to submit a contribution, knowing that most of them are busy people with many calls on their time. The response was very positive and led to submissions that were all refereed and corrected independently. The four parts comprise (under more modern titles and reordered) the atmosphere, (both global and local), water, soils and sediments, and finally, a short chapter on data analysis. The range of possible subjects for inclusion is very broad so there are necessarily some areas that receive little or no treatment and others that are dealt with more comprehensively. The chosen topics have been written by 42 authors who are respected in their field, and the whole handbook consists of 27 chapters. Since the writers come from a wide variety of international backgrounds, there is a range of styles, which lends a different flavor to each chapter. It is hoped that this will stimulate readers to dip into chapters with subjects that may be rather far from their usual fare and thereby help to stimulate a cross-fertilization of ideas across the environmental monitoring community. It also should provide a reference book for analytical laboratories as well as an introduction to environmental monitoring techniques for graduate students.

It would be nice to think that this will become a definitive book. It may be for the present and may last until the technology changes and/or the regulations and legislation change. However, these changes will not happen in all areas or all at one time, so the material in this book should last a considerable time. Furthermore, many of the chapters deal with some fundamental issues of sampling and record keeping that will remain at the heart of the subject for much longer.

The production of this book has been a long haul, and I am eternally grateful to the part editors for bearing with my barrage of e-mails and for patiently and expertly providing the final manuscripts for this book. I also must thank the authors for taking time off from their own lives and work to contribute to the book. The submissions have been of high quality, and I commend them to our readers.

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WATER

CHAPTER 1
WATER QUALITY GUIDELINES

Barry T. Hart

INTRODUCTION

Most countries now have water resources management policies aimed at achieving sustainable use of their water resources by protecting and enhancing their quality while maintaining economic and social development. Achieving this objective requires that the needs and wants of the community for each water resource are defined and that these resources are protected from degradation. These community needs generally are called the *environmental values* (or *beneficial uses*) of the water body and can include water for drinking, swimming, fishing, recreation, agricultural food production, and/or ecosystem protection.

Water quality guidelines (or *criteria*) are the scientific and technical information used to provide an objective means for judging the quality needed to maintain a particular environmental value. Knowledge-based management decisions made on the basis of this scientific knowledge are far more preferable than those resulting from pressure by narrowly focused lobby groups.

A number of water quality guideline compilations are now available (e.g., USEPA, 1986a; CCREM, 1991; ANZECC, 1992). With few exceptions, these are broadly similar in their approach and in the threshold values they recommend. However, the recently released Australian and New Zealand water quality guidelines mark a radical departure from the conventionally derived water quality guidelines (ANZECC/ARMCANZ, 2000a). The key elements of these new guidelines are that they are risk-based, focus on ecological issues rather than single indicators, provide information for an increased number of ecosystem types, and require more site-specific information.

This chapter seeks to define the information and knowledge required by water managers and environmental protection agencies in deciding whether a particular water body has good or bad water quality. The important role of water quality guidelines in the water resources management process is covered first. The types of water quality guidelines are then discussed, focusing first on the human uses of water (e.g., drinking, recreation, and irrigation). The main part of the chapter relates to guidelines for aquatic ecosystem protection.

USE OF GUIDELINES IN THE SUSTAINABLE MANAGEMENT OF WATER RESOURCES

The sustainable use of a water resource involves managing both the quantity and quality of the resource. This chapter will focus mainly on water quality aspects and only briefly cover other aspects of water resources management. A later section contains a short discussion of flow and habitat considerations.

Before considering in detail the water resource management process and the role of water quality guidelines in this process, a number of important and highly relevant considerations are highlighted.

- Water environments are naturally quite variable systems, particularly in flow and ecosystem types. Therefore, any process that seeks to manage a water resource adequately must be responsive, flexible, and adaptable (Walters, 1986).
- A key objective of modern water management is to maintain the ecological integrity of the resource. However, the knowledge base and mechanisms to underpin this new ecosystem-based management approach are poorly developed (Boon et al., 1992; Sparks, 1995; Hart et al., 1999).
- It is now generally well recognized that most water bodies are closely linked to their catchment and that activities within the catchment can influence the quality of such water bodies (lake, reservoir, river, or estuary). Thus integrated catchment and waterways management is essential if the quality of particular water resources is to be maintained in the future.
- Water resource management must address community needs and wishes, and to achieve this, the community must be involved in the management process. Technical and scientific information is essential but not sufficient for the successful management of rivers.
- Water management involves difficult trade-off decisions often between incompatible objectives, such as ecosystem protection and additional water for irrigation. It is vital that the decision-making process is as transparent as possible if such decisions are to be accepted by the community.

Figure 1.1 shows the main steps involved in the water resource management process (Hart et al., 1999). These are discussed briefly below.

Knowing the system. A good scientific and technical understanding of the aquatic system is essential if it is to be managed effectively. In particular, information is needed about the condition of the catchment, the water resource itself, the present water quality and stressors* likely to degrade the quality, and uses of the water resource.

Management goals. Clearly, it is essential in any management process to decide why the system is being managed. At the highest level, the goal of managing a natural resource is to improve community well-being through sustainable use and protection of the natural environment. Effective management of a nation's water and aquatic resources is crucial to the continued viability of society.

Environmental values (or beneficial uses). Identification of the community needs and wishes for the water resource (e.g., agricultural water supply, swimming, fishing, and protection of the ecosystem) provides the first step in defining the environmental values of a particular water body. The major environmental values considered in most guideline documents are

- Ecosystem protection
- Drinking water supply
- Recreational water use
- Agricultural water use (e.g., irrigation, stock watering, aquaculture)
- Water for industry

*Stressors are the physical, chemical, or biologic factors that can cause an adverse effect on an aquatic ecosystem. Toxic stressors include heavy metals and toxic organic compounds, salinity, and pH. Nontoxic stressors include nutrients, turbidity and suspended particulate matter, organic matter, flow, and habitat.

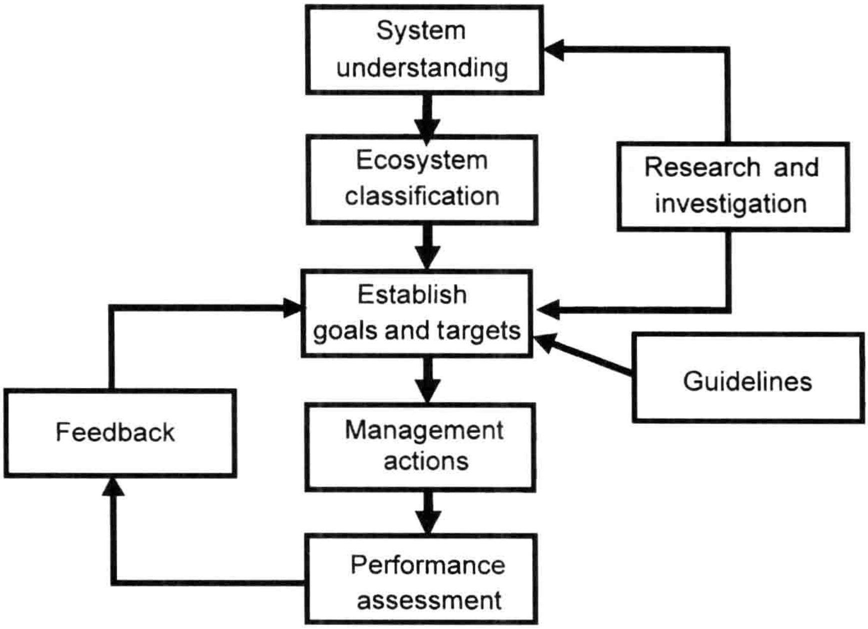

FIGURE 1.1 Water resources management framework.
(Modified from Hart et al., 1999.)

Since these uses may change with time, the water quality management process must be sufficiently adaptive to allow the goals to change in step with community values. There is no simple method for determining management goals. The process must be interactive and should involve at least the community, resource managers, and researchers.

Objectives or targets. Each environmental value requires a certain level of water quality to be maintained. The water quality to sustain environmental values may be defined by establishing water quality objectives that become the goals for management action. This is a complex process that depends on such factors as feasibility and costs of achieving the desired water quality and the lost opportunity costs to the community if these environmental goals are not reached. The objectives usually aim either

- To *protect* waterway values (e.g., those which do not allow waste discharge, no sand extraction, and those which apply restrictions on catchment activities) or
- To *restore* waterway values (e.g., works programs to prevent existing erosion of banks, stabilize beds, revegetate banks, and restore catchment buffer strips)

Key indicators of quality. These water quality objectives are established in terms of key indicators of quality that provide a means of identifying and measuring change in the environmental values. They can include physical, chemical, radiologic, microbial, or biological measures of water quality. Broadly, three types of indicators of environmental quality exist:

- Indicators that are *normally present* in the water and can be monitored usefully for a change in concentration, quantity, or quality (e.g., salinity and nutrient and heavy metal concentrations)

- Indicators that are *not normally present* but which if detected in certain concentrations or quantities can be used to identify a change (e.g., concentrations of pesticides and other toxic organic compounds)
- Indicators that are normally present but the *absence of which* reflects a change

Guidelines. These provide an objective means for judging the quality needed to maintain a particular environmental value. Normally they are described in terms of the key indicators of quality (but see page 1.12 for a new way to define water quality guidelines).

Management actions. Water quality objectives defined by the preceding process will require actions to maintain and/or attain the desired quality and therefore achieve the environmental values identified by the community. Programs or strategies that might be developed to achieve these objectives could include control of waste discharges, water quality protection, catchment revegetation, nutrient reduction, river rehabilitation, resnagging of a river, and the provision of adequate environmental flows.

Performance assessment. There is now increased pressure on water management agencies to assess their performance and report the results publicly. This requires that an effective monitoring program is put in place and that there is an appropriate feedback mechanism to confirm that the various management goals are being met or that they need to be revised (ANZECC/ARMCANZ, 2000b). In the past, performance has been judged on the basis of whether threshold physicochemical indicator (e.g., dissolved oxygen, nutrients, pH, heavy metals) concentrations are achieved or not. In situations where protection of the ecosystem is the goal, monitoring of the biota is a more direct indicator of whether the goal has been achieved than measuring a physicochemical surrogate. For more details on indicators of ecosystem health, see Loeb and Spacie (1994), Davis and Simon (1995), Norris et al. (1995), and Wright et al. (2000).

Research. The ecological understanding of most aquatic environments is inadequate, this being particularly so for rivers and streams (Boon et al., 1992; Cullen et al., 1996; Lake, 2000). Obtaining the required information will demand sustained and focused long-term ecological research on these ecosystems. Where possible, these studies should be multidisciplinary and catchment-based and done as collaborative partnerships between researchers and managers.

WATER QUALITY GUIDELINES FOR HUMAN USES

Guidelines have been established for all the major uses of water. In this section we cover those relating to human uses: drinking water, agricultural water (including aquaculture), and water for recreational and aesthetic uses. Guidelines for ecosystem protection are covered in later Sections.

Drinking Water

Drinking water should be safe to use and aesthetically pleasing. The quality of drinking water is focused primarily on the protection of human health, and for this reason, drinking water guidelines mostly have been established by health authorities, e.g., the World Health Organization (WHO, 1984) and the Australian National Health and Medical Research Council (NH&MRC/ARMCANZ, 1996).

These authorities list guideline values for a wide range of indicators, including