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Regulatory Water Quality Monitoring— A Systems Perspective

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REGULATORY WATER QUALITY MONITORING
- A SYSTEMS PERSPECTIVE -

by

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FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound monitoring data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report covers a systems approach to regulatory water quality monitoring and is intended to assist the monitoring systems manager to more efficiently distribute resources between sampling sites and laboratory resources to achieve better data distribution at a lesser cost. For further information contact the Monitoring Systems Research and Development Division at this Laboratory.

George B. Morgan
Director
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PREFACE

Any attempt to evaluate, improve or "optimize" a regulatory water quality monitoring network should begin with the question, "Why do we want to monitor?". A review of the monitoring literature will very quickly reveal that this question has not been adequately addressed. Instead, we answer questions such as, "How do I collect a water quality sample?"; "How do I determine the amount of mercury in a sample?"; or "How do I handle data?". We concentrate almost exclusively on determining how to monitor or how to collect data--very rarely do we examine why we monitor or how we are to utilize data and information in regulatory water quality management. As a result of this unbalanced situation, we are very good at collecting data but very poor at using data or the information they yield. A review of why this has been the case indicates that rarely has the regulatory monitoring system been viewed as a total system--from sample collection through information utilization for water quality management decision-making. In addition, the purposes of monitoring have been expanded in recent years which further complicates the situation.

As an initial step toward developing a more systematic, thorough, and balanced approach to regulatory monitoring, an overall systems perspective has been developed. The systems view of regulatory monitoring examines the monitoring purposes and monitoring activities (including data collection and utilization) and develops a monitoring system matrix. Such a matrix places past, present and future efforts at improving regulatory monitoring in proper perspective.

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ACKNOWLEDGEMENTS

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INTRODUCTION

Regulatory water quality monitoring is that monitoring performed by government agencies for the direct support of their water quality management efforts within the political jurisdiction of the governmental body. As the public demand for a cleaner environment has intensified, the governmental bodies have reacted with more comprehensive laws. This, in turn, has resulted in much more comprehensive regulatory water quality management programs. The monitoring systems that support this increasingly comprehensive management are becoming more complex both in terms of the purposes for monitoring and the activities involved in monitoring.

As monitoring purposes are expanded and new monitoring methodologies are developed, it is difficult to retain a clear perspective of the total monitoring system. In integrating the new purposes and activities into the existing monitoring system, an overall perspective of the total system must be maintained.

The purpose of this report is to describe and analyze the evolving regulatory monitoring system as it exists today and to develop an overall perspective of the total system. This involves a review of the regulatory monitoring purposes that have been identified over the past few years; a categorization and delineation of the monitoring activities associated with regulatory monitoring; and development of a regulatory monitoring system matrix which provides an overall perspective of the interaction between monitoring purposes and activities.

CONCLUSIONS

1. A general definition of the regulatory water quality monitoring system has been developed.

2. The definition provides a basis for more realistic management of the total regulatory monitoring system, including all the purposes and activities of such monitoring.

3. Water quality management strategies need to be tied more closely to monitoring strategies in the context of a total regulatory monitoring system.

4. The role of data utilization within a regulatory water quality monitoring system needs to be quantified.

5. In any attempt to develop regulatory water quality monitoring evaluation and/or certification procedures, the interaction of the purposes and activities involved in such monitoring must be considered.

6. The impact of new regulatory water quality management goals on regulatory monitoring should be carefully evaluated.

7. Before they are incorporated into an existing regulatory water quality monitoring system, new monitoring techniques and procedures should be carefully evaluated with respect to their effect on monitoring and management strategies.

8. The system view of regulatory monitoring developed in this report is based upon a subjective classification of monitoring purposes and activities. It should be considered a first cut at providing the basis upon which future attempts can be made for "optimizing" the regulatory water quality monitoring system.

RECOMMENDATIONS

As a means of further quantifying the regulatory water quality monitoring system, it is recommended that a regulatory water quality monitoring strategy be developed. The strategy should quantitatively spell out how monitoring purposes and monitoring activities can be integrated to form a total monitoring system. The integration of monitoring purposes and activities must include the development of guidelines for the design, operation and maintenance of all aspects of the system.

Development of a regulatory water quality monitoring strategy must be matched to the strategies employed by water quality management in using monitoring data for making decisions. This will require a thorough examination of data utilization within regulatory water quality management prior to development of monitoring strategies.

MONITORING PURPOSES

The need to monitor water quality for regulatory purposes is stated in most laws that establish water quality management programs. As new laws are passed dealing with additional aspects of water pollution or new approaches to water quality management, the purpose of regulatory monitoring is expanded to supply data and information on the additional aspects or for the new management approaches.

Within these legal classifications of monitoring purposes which, in general, relate to the "location" of the water (e.g., surface water, groundwater, etc.) there is a classification of regulatory monitoring purposes that stems from the need to obtain trends (means) in water quality for certain management functions (e.g., planning) and the need to obtain extremes in water quality for other functions (e.g., enforcement of water quality standards).

LEGAL CLASSIFICATION

A review of the evolution of regulatory monitoring reveals the continuing Federal attempt (through laws and studies) to more directly relate the purpose of monitoring to management goals. Passage of the Federal Water Quality Act of 1965 (P.L. 89-234) resulted in the first organized and systematic approach to water quality monitoring by newly created or reorganized State and local agencies across the United States. P.L. 89-234 established stream standards as the basis of water quality management; thus the monitoring that resulted was geared to instream conditions.

The stream standards resulting from P.L. 89-234 were established as levels of quality to be maintained. They did not reflect the fact that a statistical sampling program would be the source of information regarding compliance. This led to confusion as to the exact role of a monitoring program's input to management's decision-making process. In this particular case, monitoring was generally initiated to meet the legal requirements of the law rather than for clearly defined management decision-making purposes--a clearly defined data utilization strategy was missing.

Passage of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) shifted emphasis of regulatory water quality management from strictly stream standards to a combined stream and effluent standards basis. With such a change came the need for the agencies to monitor effluents as a means of verifying self-monitoring data reported to the Environmental Protection Agency (EPA). After a number of years of collecting background data on effluents, effluent standards based on historical records are beginning to be written in statistical terms that more clearly define the relationship between effluent monitoring (means and/or extremes) and regulatory water quality management decision-making.

Passage of the Safe Drinking Water Act of 1974 (P.L. 93-523) has drawn attention to the need to monitor groundwater quality and, in many cases, is pressuring agencies to initiate groundwater monitoring for regulatory water quality management purposes.

These three laws have established the need for regulatory monitoring programs to routinely monitor water quality in three general "locations"--surface water, groundwater and effluents. Each of the different locations requires a monitoring operation (or system) geared to its own specific characteristics. For example, the ready access of surface water is contrasted with the need for a well to access groundwater; the rapidly changing surface-water quality is contrasted with the relatively slowly occurring changes in groundwater quality; the self-monitoring requirements of effluent discharge permits require that effluent monitoring be more of a verification effort.

The above routine monitoring operations--routine in the sense that they have no designated termination date--are complemented, in most management agencies, by another type of monitoring referred to here as special surveys. Special surveys are defined as monitoring efforts which have a designed termination date. The purpose and forms of special surveys are extremely varied, as is the manner in which they are used in an overall monitoring strategy.

In an effort to more clearly define the use of special surveys and to better identify their use with water quality management goals, the EPA's Standing Work Group on Water Monitoring (1977) issued a report describing a basic water monitoring program. The proposed program would shift the emphasis on surface water and effluent monitoring by management agencies "from a fixed-station, single discharge approach to an intensive survey approach." This shifting of emphasis is consistent with the recognition over the past few years that the routine high frequency sampling needed to support an active enforcement of standards is very costly and often beyond the resources of the management agencies.

MEANS VERSUS EXTREMES

As water quality standards were initially written they were absolute, and enforcement action took place when the standard was violated. To determine if a standard was violated required data with very high sampling frequencies--the extremes in water quality were sought. The means (averages) of water quality were used to detect trends in water quality over time and distance.

The need for high sampling frequencies for effective enforcement of stream standards when combined with the limited resources available, created problems in regulatory water quality monitoring. These problems led the EPA to fund several studies on the design of cost-effective monitoring systems for surveillance purposes (Beckers et al., 1972, and Beckers and Chamberlain, 1974).

These studies and others (Sherwani and Moreau, 1975, and Montgomery and Hart, 1974) revealed the extremely intense monitoring effort needed to obtain, in a routine manner, adequate information on extremes in water quality. Realizing that routine acquisition of data on extremes is impractical, there is a tendency for agencies to rely upon effluent monitoring data and special surveys for supporting enforcement actions. The special survey also helps in dealing with enforcement problems associated with nonpoint sources.

This shift in monitoring emphasis is reducing the routine monitoring portion of the monitoring system and augmenting the effort put into special surveys. By having the routine monitoring seek only means, the design of the network can be closely geared to the precision and confidence sought by the management agencies' decision-makers.

SUMMARY OF MONITORING PURPOSES

To summarize the above review of regulatory monitoring purposes, the purposes are categorized and listed as follows:

ROUTINE MONITORING

Surface Water
Means
Extremes
Groundwater
Means
Extremes
Effluent Verification

SPECIAL SURVEY

Scheduled
Multipurpose
Single-purpose
Unscheduled
Multipurpose
Single-purpose

The categories of monitoring purposes include most of the purposes of an agency. Even though many agencies do not routinely measure surface water extremes, some do have automatic monitoring networks that supply data on extremes. Routine monitoring of groundwater is little known relative to the use of such data for regulatory water quality management purposes. Effluent verification monitoring, though a small portion of the total monitoring system, validates a much larger source of data used for enforcement purposes, i.e., the self-monitoring data reported by permit holders.

Routine monitoring is categorized around the locations of the water due to the distinctive differences in the monitoring systems established for each type of water. Special surveys could likewise be categorized; however, as noted by the National Water Monitoring Panel (1975), special surveys bridge the gap between data bases generated by effluent monitoring and fixed-station monitoring and provide a definitive basis for understanding and describing the mechanisms, processes and interactions (surface and groundwater) that affect water quality.

Since special surveys are not routine, this operational aspect of their purposes serves as an ideal basis for categorization. Surveys that are scheduled in advance often meet planning and enforcement goals. Surveys that must take place on the spur of the moment are often exclusively enforcement oriented, caused by a pollution event. Since the specific purpose of a survey can vary, a further categorization can be distinguished by noting whether a survey is multipurpose or single-purpose.

Special surveys may be scheduled as one-time efforts or as a series of surveys. The Standing Work Group on Water Monitoring (1977) recommended that special surveys be scheduled "at least once within 5 years on every river, lake, estuary, bay or aquifer where waste loads are allocated or adverse water quality conditions have either been identified or are considered probable." Unscheduled surveys can occur at any time and involve any number of different situations. The National Water Monitoring Panel (1975) noted the need to plan for unscheduled events by allocating resources to special surveys that will take place due to these unscheduled events. Such unscheduled surveys must have a highly flexible mode of operation as compared to a scheduled survey.

A scheduled multipurpose survey has been defined as a basin status survey by the National Water Monitoring Panel (1975). Such surveys are often conducted to assess the total water quality picture of a basin. A scheduled single-purpose survey is oriented toward a more specific objective: load allocations, nonpoint sources of pollution, etc. Unscheduled multipurpose surveys deal with pollution situations where the cause and effects are poorly defined, while an unscheduled single-purpose survey deals with a more clearly defined pollution situation. With the latter survey, the purpose may be only to obtain evidence for enforcement action.

MONITORING ACTIVITIES

Monitoring purposes represent one dimension of the regulatory monitoring system. Another dimension is that associated with the operational activities involved in the acquisition and utilization of data. These activities begin with the collection of samples and end with the data being used to make regulatory management decisions. In between are a large number of activities associated with the processing of samples and data, analysis of data, reporting of the resulting information, etc.

There are many ways that the monitoring activities could be categorized. The approach chosen here is to broadly divide the activities into data acquisition and data utilization. The division is chosen to indicate that both major groups of activities are equally important to the effectiveness of a total monitoring system. In the past, most research and operational efforts have been placed in the data acquisition area. This has resulted in systems more oriented toward acquiring data than to utilizing the data. This analysis of monitoring activities will treat both data collection and data utilization equally.

DATA ACQUISITION

Operationally, on a routine basis, data acquisition consists of sample collection and laboratory analysis. However, prior to sample collection, the sampling locations, frequency of sampling, parameters measured, etc., must be determined by network design. Thus when defined in categories, data acquisition consists of, in order, network design, sample collection, and laboratory analysis.

Network design has received considerable research attention since the early 1970's. Ward (1973) and Montgomery and Hart (1974) discuss the design of stream monitoring networks which detect means in quality; as noted earlier, Beckers and Chamberlain (1974) examine the design of stream monitoring networks which measure extremes; Todd et al. (1976) discuss the design of groundwater monitoring networks; Cohen et al. (1975) present a design procedure for effluent monitoring; and Kittrell (1969) discusses the factors to consider in the design of a special stream survey. Sherwani and Moreau (1975) discuss network design for a range of monitoring purposes.

A review of the above and other literature on the subject reveals the need for extensive knowledge of an area if station locations and parameters measured are to be dealt with in a quantitative manner. Obtaining such extensive information is often too costly, thus precluding use of the more sophisticated design methodologies. The network design, in such cases, is often placed in the hands of personnel who are quite familiar with the water quality situation. There are a number of basic statistical procedures which can assist in the determination of sampling frequencies if some information is available on past variances in water quality (Ward et al., 1976).

The sample collection activity involves taking field measurements, collecting the sample at the most representative point, using proper methods of collecting and preserving the samples for transportation to the laboratory. The exact procedures to use depend upon the type of water being sampled, the parameters to be measured, the types of analyses used in the laboratory, etc. Huibregtse and Moser (1976) present guidelines for sampling and sample preservation for a number of different situations and cite numerous references on the subject.

Laboratory analysis is a complex activity in that it involves the analysis for numerous water quality parameters with numerous alternative procedures. In addition, the operational procedures (handling and flow of samples) in the laboratory, the quality control and the recording of the data are major laboratory analysis activities. Although quality control has received more attention in the laboratory, it is equally important in all monitoring system activities.

Considerable effort has been put into the development of standard laboratory analysis procedures (American Public Health Association, 1976; Federal Interagency Work Group on Designation of Standards for Water Data Acquisition, 1972; and the U.S. Environmental Protection Agency, 1974). All aspects of laboratory analysis have been examined recently by Tracor Jitco, Inc. (1976) and the EPA's Water Supply Quality Assurance Work Group (1976) in the development of procedures for evaluating and certifying laboratories.

Assimilating the large amount of information on data acquisition and designing a data acquisition system are not easy tasks; however, an even larger problem in establishing a sound data acquisition portion of a total monitoring system is the lack of a corresponding level of information on data utilization. It is difficult to design a well balanced, smoothly operating monitoring system if there is any part of the system that is not well defined.

Data Utilization

The relatively small number of studies in the area of data utilization for regulatory water quality management purposes is probably indicative of the difficulty in dealing with the subjective nature of the decision-making involved. During the data utilization portion of a monitoring program, objective pieces of data are converted into information which is then used in a rather subjective manner to assist decision-making.

The conversion of data into information involves basically two categories of activities. First, the data must be stored in such a manner that they are properly screened and verified and are easy to retrieve and manipulate. Second, data analysis technique must be chosen such that the information generated: 1) matches the ability of the data to yield such information with confidence, and 2) matches the expectations of the decision-makers.

Beyond the conversion of data to information, data utilization includes a category of activities which ensure that the information is utilized in the manner for which the entire monitoring system was designed and by which it justifies its existence. Thus, data utilization consists of three major categories of activities: 1) data handling, 2) data analysis, and 3) information utilization.

Data Handling

The conversion of data into information begins with data handling. The initial step is to acquire (make arrangements to receive) all the data that are available and relevant to the water quality being managed by the agency. Data generated outside the agency (e.g., EPA, United States Geological Survey (USGS), local agencies, and effluent permittees) would enter the monitoring system at this point.

Besides data on water quality, there are many other types of information that are frequently needed and used in water quality management. The Joint Committee on Water Quality Management Data (1967) established ten categories (e.g., data on the status of compliance with regulations, data on the type and design of wastewater treatment plants, data on the personnel and fiscal resources used to conduct water quality management, etc.).

Once data are received, they are evaluated and verified for accuracy. This is often done in the process of putting the data into a storage system, especially if the data are to be stored on a computer. The Joint Committee on Water Quality Management Data (1967) discusses the alternatives available for storing and retrieving data.

The increasing availability and efficiency of computers with respect to storage and retrieval of data are attracting the attention of many agencies. The Commonwealth of Pennsylvania (1974) is using a modified form of the Joint Committee on Water Quality Management Data's (1967) list of categories to develop a complete computer-based water quality management information handling system.

Haseman et al. (1975) describe the basic components needed in a computerized data handling system for water quality management. They list three levels of data use: (1) listing, (2) summary and report, and (3) mathematical models for sophisticated decision-making.

Michigan has also developed a computer-based data handling system; however, it deals only with water quality data. It is tied closely to STORET, the EPA's computer system for storing and retrieving data. The Michigan system is described by Guenther et al. (1973).

The EPA's STORET system is available to all State and local agencies for storage and retrieval of their water quality data and its use is expanding. Having many agencies use a common system has many advantages from an overall efficiency point-of-view.

Beyond having valuable and accurate data stored in a readily available system, data handling includes the means of reporting and disseminating raw data to other agencies and organizations. The purposes of such reporting and dissemination of raw data is to assist other agencies and organizations in their data acquisition efforts, thereby increasing the value and utilization of all data collected through reduction in the duplication of acquisition efforts.

Data Analysis

Data handling and data analysis are closely related since many data analyses require the rapid manipulation of large amounts of data. Even with the data stored in an accommodating system, the multiplicity of parameters which determine water "quality", the ever-changing nature of water, and the broad scale of management combine to create a formidable obstacle to obtaining precise information from the data during this analysis activity.

There are a number of broad categories of techniques which can be used to analyze water quality data. The more general techniques (basic statistics, indices, etc.) are most often used for a broad-scale (time and/or space) analysis of water quality conditions. When a specific water quality problem is identified (one parameter, one source, one river, etc.), the more specific types of data analysis techniques (time series analysis, modeling, etc.), are more applicable as normally more data are taken to solve the problem (through special or intensive surveys).

The particular type of analysis used will depend upon many factors besides the data handling procedures. The type of data (often low sampling frequency) collected by many agencies restricts the analysis that can be used and, consequently, the level of information achieved by the monitoring system. The form of the decision-making body (layman or professional) may influence the data analysis technique as well as the type of problems being encountered. The statistical training of the personnel and the facilities available for performing the analysis will influence the analysis as well as the purpose of monitoring.

Literature describing the types of data analysis applicable to regulatory water quality monitoring data is rather limited. There are many studies that describe the use of statistics with high frequency water quality data and special survey data, but few that deal specifically with data collected for regulatory purposes--relatively low frequency data.

To illustrate the type of literature available, a few publications will be cited. Cochran (1963) in a sampling textbook describes the range of basic statistics that can be used to analyze data. Brown et al. (1970) and Landwehr and Deininger (1976) describe water quality indices. Samson et al. (1970) in a textbook describe the basics of statistical quality control, while Deininger (1971) relates quality control concepts to water quality data. Wastler (1969) discusses techniques available for analyzing the time series aspects of water quality data. Thomann (1972) reviews the available approach for water quality modeling while Gross (1975) presents a bibliography of water quality modeling efforts.

Each of the categories of data analysis techniques has many variations depending upon the characteristics of the data and the type of information sought. As a result, design of a total monitoring system requires a clear definition of the information sought which must, in turn, be balanced against the type of data available. The careful balancing of the information expectations and available data around the analysis techniques is an area needing more attention, particularly with respect to regulatory water quality monitoring.

Information Utilization

Information utilization is the activity that takes the information from the data analysis activity and ensures that it is utilized. This involves a set of quantitative information distribution steps followed by a subjective evaluation of the information's usefulness. The latter subactivity is the beginning of a feedback loop in a regulatory monitoring system that provides for the adjustments needed to keep the system relevant.

Distribution of information involves determining where the points of use are, what types and quantities of information are needed at each point, and with what frequency the information is needed. In addition, the best means of injecting (report, oral presentation, action sheets, etc.) the information into its point-of-use needs to be identified.

In utilizing information for decision-making in a regulatory water quality management program, the points of decision are at various levels. At the lower levels, operational decisions are made as to whether a water quality change warrants investigation. Such decision can be based upon a given deviation from past trends. For example, three samples out of the past four being more than two standard deviations away from the historical mean could necessitate an investigation. Different types of investigative actions could be matched to different levels of deviation from expected values.

Another type or level of decision-making occurs at the program level (establishing management strategy within the agency). Here management resources are devoted to different programs depending upon the problems involved and the effectiveness of different programs to handle a problem. The monitoring information assists in identifying problems and priority ranking them. Often, compressing the information into an index is useful at this stage, not only for comparing problems, but for comparing the effectiveness of different programs for handling problems.

The planning of general policy or decision-making policy occurs at a point far removed from the monitoring operations. If data and information are to play a role in policy making, they must be reported in a format that fits the occasion. This often requires considerable ingenuity on the part of monitoring personnel in not only the analysis and compression of the data but, also, the reporting and presentation of the data and information.

At all levels of decision-making within water quality management where monitoring data are used, there are different philosophies or approaches which can be used to direct the manner in which decisions are made. The approach to decision-making used by an agency will affect the monitoring system. For example, in solving environmental problems, Lindblom (1973) suggests two broad management or decision-making approaches: (1) the traditional, conventionally scientific method and (2) a much more highly selective, incremental, tactically focused method. He argues that by using the second approach, the actions of an agency are more precisely defined, making it easier to accomplish the goals. The first approach results in too broad a definition of goals, poorly defined actions and, in the end, no true or accurate measure of whether the goals were accomplished.

House (1973), on the other hand, states:

> "The instinct is for each Federal, State or local agency to treat individual environmental problems as separate entities and to concentrate on short-range crises rather than long-range trends. This approach is inefficient, not only because of its tendency to duplicate efforts but, also, because it ignores the fact that pollution abatement problems are long term, intertwined and mutually dependent."

Each management agency establishes its own approach to decision-making either informally or formally. Whichever is chosen, the monitoring strategy as a whole, and the information utilization activity in particular, must reflect the information needs.

Beyond establishing quantitative information utilization procedures, the actual use of the information needs to be evaluated as a means of ensuring that the needed information is actually being produced by the monitoring system. Evaluating the information's usefulness will often consist of only a subjective appraisal by the decision-maker. Such evaluations should be made, however, and they should initiate a loop that encompasses the entire monitoring system.

SUMMARY OF MONITORING ACTIVITIES

In the data acquisition and utilization discussions, six categories of activities have been identified. These six categories are shown in their operational setting in Figure 1. Network design, as noted earlier, is not a routine operation, but is vital to the effective operation of the system. The five routine operational categories follow the flow of information through the monitoring system and tie the water quality being managed to the decisions made with respect to management. The monitored changes are the feedback loop in the system.

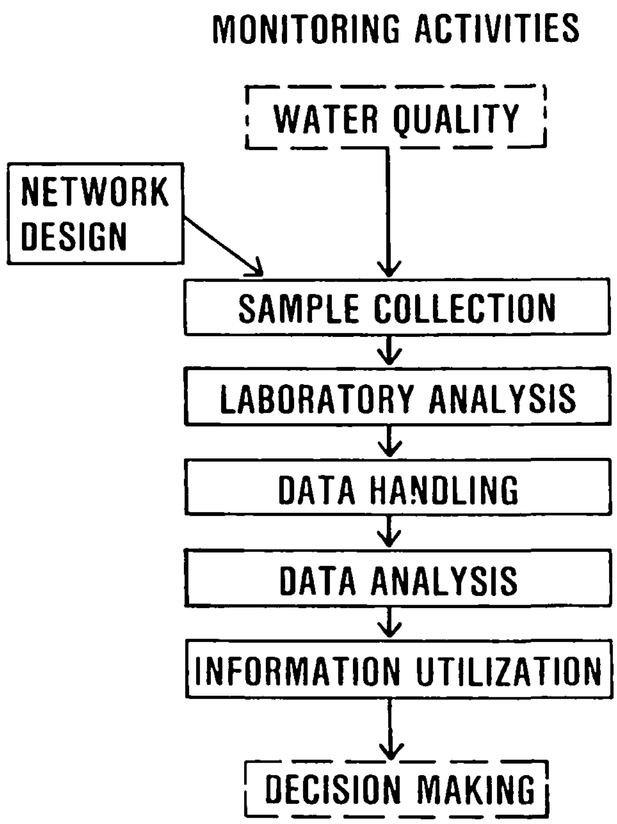

Figure 1. The monitoring system based on the operational activities involved in the flow of information through a monitoring program.

The six monitoring activity categories can be summarized in more of a functional manner as has been discussed previously. The number and diversity of the activities in the following list illustrates the complexity of the activity dimension of regulatory water quality monitoring.

NETWORK DESIGN

1. Station Location
2. Parameter Selection
3. Sampling Frequency

SAMPLE COLLECTION

1. Sampling Technique
2. Field Measurements
3. Sample Preservation
4. Sampling Point
5. Sample Transport

LABORATORY ANALYSIS

1. Analysis Techniques
2. Operational Procedures
3. Quality Control
4. Data Recording

DATA HANDLING

1. Data Reception
   a. Laboratory
   b. Outside Sources
2. Screening and Verification
3. Storage and Retrieval
4. Reporting
5. Dissemination

DATA ANALYSIS

1. Basic Summary Statistics
2. Regression Analysis
3. Water Quality Indices
4. "Quality Control" Interpretation
5. Time Series Analysis
6. Water Quality Models

INFORMATION UTILIZATION

1. Information Needs
2. Reporting Formats
3. Operational Procedures
4. Utilization Evaluation

Managing such a system is becoming more difficult as the complexity grows. Several studies in recent years have attempted to evaluate the entire monitoring activity dimension. The National Water Monitoring Panel (1975) presents a discussion on what a model state monitoring program would contain, while the Standing Work Group on Water Monitoring (1977) presented an overall monitoring strategy. Schnider and Shapiro (1976) developed a procedure for evaluating a monitoring program.

In all three studies, the lack of information on data utilization, as defined in this report, prevents a well-balanced approach to the total monitoring system. The lack of information on data utilization, as noted earlier stems mainly from a lack of emphasis in this area of monitoring, as compared to the emphasis placed on data collection. From a research point of view, data are often considered a subjective factor in monitoring and at the personal whim of the user. From a regulatory standpoint, however, the data collected by a management agency should be carefully related to its use.

MONITORING SYSTEM MATRIX

Two dimensions of regulatory water quality monitoring systems have been discussed: (1) monitoring purposes and (2) monitoring activities. These dimensions are considered critical to gaining an overall perspective of the monitoring system.

If the two dimensions are combined to form a monitoring system matrix, the interaction of purposes and activities can be more easily visualized. A monitoring system matrix is presented in Figure 2. The 5 major purposes of monitoring in Figure 2 combine with the 6 major activities of monitoring to create some 30 major combinations of monitoring purpose/activity that must be designed to fit into an overall system. Knowing that the interaction of each purpose/activity block with all the others occurs is one thing, but identifying (or quantifying) the interaction is another.

From an overall monitoring system management viewpoint, such interactions may best be dealt with from a common basis--basic resources of money, personnel, etc. Allocation of resources among the various monitoring purposes establishes the agencies' monitoring and, consequently, management strategy. For example, assuming equal output is obtained from each purpose for equal input of resources, an agency that allocated 60 percent of its monitoring budget to special surveys would be emphasizing this type of monitoring. Continuing the example, a further breakdown may have 20 percent for routine surface water monitoring, 15 percent for routine effluent monitoring, 50 percent for scheduled surveys and 10 percent for unscheduled surveys. Such a percentage breakdown more clearly establishes an agency's overall regulatory monitoring strategy relative to its purposes.

The allocation of resources among the monitoring activities could likewise be divided. In all probability, however, the percentage of a budget allocated to routine surface-water sample collection would not be the same as that allocated to routine effluent sample collection. A higher portion of effluent monitoring monies would be devoted to data utilization, since much of the data has no or little acquisition cost to the agency. Thus, each monitoring purpose would have its own percentage allocation to the monitoring activities.

If an allocation of resources to monitoring purposes and monitoring activities is to take place with a clear understanding of the total monitoring system, the system must be carefully defined. The monitoring system matrix in Figure 2 provides a generalized framework around which an agency can formulate a definition of its particular monitoring system. The framework, by considering data utilization in more detail, provides a more thorough perspective of a monitoring system than has generally been considered in the past.

Monitoring Purposes / Monitoring Activities	Routine Monitoring			Special Surveys	
	Surface	Ground	Effluent	Scheduled	Unscheduled
Network Design 1. Station Location 2. Parameter Selection 3. Sampling Frequency					
Sample Collection 1. Sampling Point 2. Field Measurements 3. Sampling Technique 4. Sample Preservation 5. Sample Transport					
Laboratory Analysis 1. Analysis Techniques 2. Operational Procedures 3. Quality Control 4. Data Recording					
Data Handling 1. Data Reception a. Laboratory b. Outside Sources 2. Screening and Verification 3. Storage and Retrieval 4. Reporting 5. Dissemination					
Data Analysis 1. Basic Summary Statistics 2. Regression Analysis 3. Water Quality Indices 4. Quality Control Interpret. 5. Time Series Analysis 6. Water Quality Models					
Information Utilization 1. Information Needs 2. Reporting Formats 3. Operational Procedures 4. Utilization Evaluation					

Figure 2. Monitoring System Matrix

Using the matrix as a basis for examining the balance of past research efforts on monitoring systems design and operation, some general conclusions can be drawn. The first three activities have received considerably more attention than the last three. Within the last three activities, data handling and analysis have received more attention than information utilization, an area that has received almost no attention.

Under purposes, surface water has historically received the most attention while effluent monitoring is currently receiving increasing attention as the permit system mandated by P.L. 92-500 takes full effect. Groundwater monitoring, on a routine basis within political boundaries, has received little attention relative to the importance given it under P.L. 93-523. Special surveys, until recently, have not received enough attention to clarify their exact role. Recent developments (Standing Work Group on Water Monitoring, 1977) may shift more emphasis to special surveys, thus providing a basis for refinement in their purpose, design and operation.

SUMMARY

Regulatory water quality monitoring systems have been and still are evolving very rapidly. Each agency approaches the job of regulatory monitoring from a different angle, thereby making generalizations difficult. However, from the national initiative in environmental control have come some basic monitoring purposes which have been described. In addition, there are some basic categories of activities associated with monitoring. A set of activity categories has been defined and discussed.

By combining the monitoring purposes and monitoring activities in a matrix format, it is possible to gain a perspective of the total regulatory water quality monitoring system. Such a perspective is very helpful in developing well-balanced monitoring programs and in identifying weak areas needing additional research and/or support.

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16. ABSTRACT

The purpose of this report is to describe and analyze the evolving regulatory monitoring system as it exists today and to develop an overall perspective of the total system. This involves a review of regulatory monitoring purposes that have been identified over the past few years; categorizing and delineating the monitoring activities associated with regulatory monitoring; and development of a regulatory monitoring system matrix which provides an overall perspective of the interaction between monitoring purposes and activities.

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