Water Quality Data Management

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July 1992

Technical Report No. 59

Colorado Water Resources Research Institute

Colorado State University

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PREFACE

This report contains the author's master's thesis which was prepared under the direction of Dr. Neil Grigg with the assistance of Dr. Robert Ward and Dr. John Stednick, all of Colorado State University. The research addressed water quality data management activities in the United States and Colorado, and incorporates the results of a water quality data management survey of 200 water quality agencies that was undertaken in 1991. The report is designed to provide background information to assist in the interpretation of the survey results that are contained in Chapter 4 and Appendix C. Therefore, Chapter 2 reviews water quality legislation that has resulted in the generation and management of water quality data in the United States, and Chapter 3 contains a description of data management technologies and their applications to water quality data. Readers already familiar with water quality regulations or data management technologies may wish to skip one or both of these chapters.

A significant portion of the information contained in this report was contributed by personnel of numerous water quality agencies through their responses to the water quality data management survey, interviews and telephone conversations. The author is deeply appreciative of the time and cooperation of these individuals. The conclusions and generalizations contained within this paper should not be attributed to any particular respondent unless specifically quoted by name. Any errors of fact or interpretation are the author's.

This research was supported, in part, by Colorado State University and the Colorado Water Resources Research Institute (CWRRI). The author is grateful for the use of the facilities at the CWRRI and the support of its personnel, including Shirley Miller and Craig Woodring.

"The chess board is the world; the pieces are the phenomena of the universe; the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. But we also know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance."

Thomas Henry Huxley

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Chapter 1. Introduction

With the realization of the world's first global summit on the environment this summer, the fate of the earth's resources has finally been placed on an agenda at the table of most of the world's leaders. Decisions will be made at this summit concerning environmental management, which has been defined as "the influencing of human activities as they affect the quality of mankind's physical environment, especially the air, water, and terrestrial features (Sewell, 1975)."

Decision-making requires information, as illustrated by Grigg (1990):

> "It is easy to acknowledge the value of information in decision-making. All we have to do is envision a military commander before an attack; without good intelligence about both the friendly and opposing forces, the commander cannot make an effective decision. If the commander delays the decision too long to gather information, the opportunity for a victory may be lost. What the commander needs is access to the right amount of high information at the right time. This shows the need for the following aspects of decision information: amount, quality, timeliness, and clarity. All of them are important in planning."

This need for adequate, useful, and accessible information lies at the heart of data management. Effective data management will enhance decision-making efforts, while poor data management can result in inefficient and even erroneous conclusions.

This report addresses the issue of data management for water quality decision-making. Water quality management is a subset of environmental management, and its importance is reflected in the sobering statistics that over 3 million children died in 1991 from waterborne diseases, many of whom could have been saved with safe drinking water and improved sanitation (Easterbrook, 1992). The management of water quality is highly complex because of the variety of uses of water, sources of degradation, and technologies available. The task of making water quality management decisions is further complicated by the ongoing battle between water quantity and water quality, and the lack of natural economic incentives for upstream polluters to care about water quality downstream (Kneese and Bower, 1968). This complexity results in a critical need for efficient water quality data management.

Ward (1979) identifies five steps involving water quality data that contribute to the decision-making process: sample collection, laboratory analysis, data handling, data analysis, and information utilization. Data management is primarily concerned with the last three steps, although sample collection and laboratory analysis procedures certainly contribute to the adequacy and quality of data. The collection of representative samples, or samples that represent all possible samples within a population, and the use of proper procedures and quality assurance programs in laboratory analyses are instrumental in supplying water quality data that can be used with confidence (Stednick, 1991; Ward, 1979).

Water quality data are handled, analyzed and used for a variety of purposes, including regulatory and research activities. Numerous technologies are available to manage data, but efficient data management can still be difficult to attain because of institutional problems associated with the legal, organizational, and coordination problems between the parties involved (Palmlund, 1977). Financial constraints may also limit the acquisition of some data management technologies.

This report will present an assessment of water quality data management and its relation to legislation, agency function and responsibilities, and interagency coordination. This will be accomplished by reviewing legislation requiring water quality data, describing available water quality data management technologies, and assessing current water quality data management activities in the United States. In addition, an evaluation of current water quality data management in Colorado will be performed, and the results of the national assessment will be used to make recommendations for improvements to Colorado's water quality data management. Although this research focuses on data management activities in Colorado, it is intended that the research could be beneficial to any water quality agency.

To accomplish these objectives, the report is centered around a water quality data management survey conducted in 1991 as part of the research. Chapter 2 begins with a history of water quality regulations that have resulted in much of the current generation and management of water quality data in the United States and Colorado. The next chapter reviews data management technologies and their applications to water quality data. Chapter 4 describes water quality data management in the United States using data obtained from the survey. Existing water quality data management in Colorado is addressed in Chapter 5, followed by recommendations for future water quality data management in Colorado based on the discussions in the previous chapters, including the results of the water quality data management survey. Chapter 7 provides conclusions and recommendations for further research.

Chapter 2. History of Water Quality Regulations

A large amount of the water quality data used in the United States is generated in response to water quality regulations. This chapter relates the history of federal water quality legislation, followed by a discussion of water quality legislation in Colorado. These regulations have resulted in the variety of water quality activities that were included in the water quality data management survey discussed in Chapter 4.

Federal Water Quality Regulations

Evolution

Although many of the nation's major rivers and streams were seriously polluted by the 1900's, federal water quality legislation in the United States prior to 1972 was minimal (Nobel and Findley, 1977). In 1886, the first enacted federal statute related to water quality prohibited the deposit of refuse in New York Harbor, largely due to fears of fire damage if the waste were to ignite. The Department of the Army was given enforcement responsibilities, and in 1888, the jurisdiction of the act was extended to include adjacent and tributary waters of New York Harbor (Stednick, 1991).

Originally designed to protect navigation, the Rivers and Harbors Appropriations Act of 1899 was later used to control water pollution. Supreme Court decisions in the 1960's rendered pollution control as a goal of Section 13 of the statute, which prohibited the placement of refuse matter, except sewage and runoff, into navigable waters, and gave permit authority to the Department of the Army (Noble and Findley, 1977; Krenkel and Novotny, 1980).

The U.S. Public Health Service (USPHS) was formed in 1912 by the Public Health Service Act. Although authorized to investigate water pollution in navigable waters, the USPHS was not allowed to take any actions to correct water quality problems. The prevention of the spread of waterborne diseases, not the improvement of water quality, was the primary focus of the USPHS activities (Krenkel and Novotny, 1980; Stednick, 1991).

Until 1948, no other federal water quality legislation was enacted except the Oil Pollution Act of 1924. Designed to protect beaches and shellfish, this act made it unlawful to discharge oil to coastal waters (Krenkel and Novotny, 1980; Stednick, 1991). Several attempts were made to introduce water pollution control legislation after 1924, but all were unsuccessful until the Federal Water Pollution Control Act (FWPCA) was passed in 1948 (Noble and Findley, 1977).

FWPCA was the first major federal legislation concerning water pollution control, and its amendments have constituted all subsequent federal water quality control legislation. FWPCA provided federal grants to support state and local water pollution control programs, funded federal research into water pollution control approaches, and allowed limited federal loans for the construction of municipal treatment facilities. Federal water pollution control activities were restricted to interstate waters. The act was originally effective for five years, but was extended for another three years (Krenkel and Novotny, 1980; Noble and Findley, 1977).

Prior to 1948, states and local governments had most of the legal authority in water quality issues, and many states already had designated agencies for water pollution control. The major problem faced by these agencies was the funding of publicly owned treatment works (POTWs). Although FWPCA's enactment marked the beginning of major federal involvement in water pollution control activities, primary control of water pollution was still retained by the states (Krenkel and Novotny, 1980; Stednick, 1991).

The first permanent federal water pollution control legislation was enacted in 1956 with the passage of the Federal Water Pollution Control Act amendments. These amendments contained several provisions which provided a basis for future water quality control legislation, including the establishment of the administration of FWPCA under the Surgeon General of the USPHS and the creation of a Water Pollution Control Advisory Board. Research and training grants to states were increased, and as was funding for authorized POTW construction and upgrades. In addition, FWPCA authorized the collection and dissemination of water quality data relating to water pollution prevention and control, and the establishment of an associated database (Noble and Findley, 1977; Stednick, 1991; Krenkel and Novotny, 1980). This led to the development of STORET, a national water quality database that is still in use today. Implemented by the USPHS in 1964 (USEPA, 1990a), STORET is discussed in greater detail in Chapter 3 of this thesis.

FWPCA was further strengthened by the 1961 amendments, which transferred the administration of the act from the Surgeon General of the USPHS to the Secretary of Health, Education, and Welfare. Enforcement provisions were expanded to include navigable waters, so that both interstate and intrastate waters were covered by the act. Research and POTW construction grants were increased, and seven laboratories for water pollution control were added to the one established by the 1948 FWPCA. States continued to have primary control over water pollution control and prevention, and the federal government was to act in cooperation with state, interstate, and local interests (Stednick, 1991; Krenkel and Novotny, 1980; Noble and Findley, 1977).

In 1965, Congress passed the Water Quality Act, reflecting the change in attitude from the negative and corrective connotations of the term "pollution" to the new preventative attitude of "quality" (Stednick, 1991). A new agency, the Federal Water Pollution Control Administration, was formed to manage water quality control. The Administration was directly responsible to the assistant secretary of Health, Education, and Welfare, removing water pollution control completely from USPHS jurisdiction.

The Administration was moved from Health, Education, and Welfare to the U.S. Department of the Interior eight months later (Krenkel and Novotny, 1980).

The Water Quality Act also addressed water quality standards for the first time, requiring states to adopt water quality criteria and submit a plan for their implementation and enforcement. The approved criteria and plan were to serve as a state's water quality standards (Noble and Findley, 1977). The standards were to be based on designated uses and were to be set to enable states to determine whether or not abatement action should be taken (Gould, 1980). Although the act required states to perform water quality monitoring, there was no explanation of how it was to be performed, resulting in the initiation of regular water quality monitoring that varied between states. States that did not comply with the act's requirements could lose federal funds for POTW construction as well as lose their control over water quality management to the federal government (Ward, et. al., 1990).

Another statute was passed in 1966 which addressed comprehensive basin water quality planning. The Clean Waters Restoration Act authorized grants to establish state planning agencies for water quality control and improvement on a river basin basis, and included grants for research and development. Estuarine pollution was to be studied, as well as eutrophication and thermal pollution. In addition, the responsibility for the Oil Pollution Control Act was moved to the U.S. Department of the Interior (Noble and Findley, 1977; Krenkel and Novotny, 1980).

The issue of environmental protection was incorporated into the National Environmental Protection Act (NEPA) of 1969, which requires the preparation of environmental impact statements (EISs) for proposed projects which might significantly affect water quality and are to be constructed with federal funds or on federal lands. The EISs include not only potential water quality degradation information, but also alternatives to the proposed activity. NEPA also created the Council on Environmental Quality whose responsibilities include publishing national environmental policies and preparing an annual environmental quality report. This report contains information on environmental conditions and trends and the status of federal programs. Many states have State Environmental Protection Acts that often have stronger guidelines than the federal act (Stednick, 1991; Vranesh, 1987b).

In 1970, the Water Quality Improvement Act was enacted. This act changed the title of the Federal Water Pollution Control Administration to the Federal Water Quality Administration (FWQA). The act also replaced the Oil Pollution Control Act of 1924, and made the FWQA responsible for addressing oil pollution, thermal pollution, and hazardous wastes. The FWQA was transferred to the U.S. Environmental Protection Agency (USEPA), which was also created in 1970. The USEPA was charged with overseeing the regulation and enforcement of air quality, water quality, and solid and hazardous wastes (Krenkel and Novotny, 1980; Stednick, 1991).

Clean Water Act

FWPCA was again amended in 1972, 1977, 1983, and 1987, and these amendments are referred to collectively as the Clean Water Act (CWA) (Stednick, 1991). The 1987 amendments are also called the Water Quality Act of 1987. Several CWA sections are important to water quality data collection and use and are summarized in Table 1 (Gould, 1980; USGPO, 1988).

The 1972 amendments to the FWPCA represent one of the most powerful pieces of environmental quality legislation in the United States and demonstrated a change of direction in the approach to water quality issues. Previous legislation generally considered water pollution a problem only if detrimental effects were experienced or standards were violated, and the use of the waste-assimilating capacities of streams was accepted as a method of treatment. The 1972 amendments, however, reflected the new attitude that it was not acceptable to use the nation's waters for waste disposal. This approach resulted in one of the significant features of the act, the establishment of a goal of zero discharge of pollutants to the nation's waters by 1985. Recognizing that such a goal was not immediately attainable, an interim goal

Table 1. Summary of Sections of the Clean Water Act that Involve Water Quality Data

Section	Description
106(e)	Requires the states to monitor, compile, and analyze both surface and ground water quality data in order to obtain grants for pollution control programs
107-118	Authorizes funding of specific projects, research, and scholarships
201	Outlines facilities planning requirements, including the study and evaluation of alternative waste management techniques and the use of best practicable waste management technology
204(a)	Requires states to implement 208 plans to receive grants for POTWs
205(j)	Requires the states to develop plans for carrying out and funding programs receiving federal grants for state water quality management planning
208*	Outlines the procedures for preparing and submitting areawide waste treatment management plans
209	Required the preparation of Level B basin plans for all of the nation's river basins by January 1, 1980
301	Requires the establishment of technology-based effluent limitations for existing sources of pollution and sets the procedures for their development and implementation
302	Requires the establishment of water quality-based effluent limitations
303	Requires states to establish and periodically revise water quality standards for all waterways, including water quality criteria for toxic pollutants
303(d)	Requires states to prioritize waters in which water quality-based effluent limitations should be set, taking into account the uses of the water and severity of the pollution; states shall establish total maximum daily loads (TMDLs) for these waters, and estimate TMDLs for all other waters
303(e)	Requires states to submit a continuing planning process which includes effluent limitations and schedules of compliance, applicable elements of 208 and 209 plans, and TMDLs
304	Requires the USEPA Administrator to provide information and guidelines for achieving requirements of various sections of the act, including monitoring, reporting, and enforcement procedures
305(b)*	Requires states to prepare biennial water quality reports
306	Requires the USEPA to establish standards of performance for new sources of pollution
307(a)	Specifies the establishment of effluent standards for toxic pollutants
307(b)	Specifies the establishment of pretreatment standards for POTWs
308*	Requires owners or operators of point sources to monitor effluents and maintain records
314	Requires the states to prepare biennial assessments of publicly-owned lakes which are to be included in Section 305(b) reports
319*	Specifies the requirements of nonpoint source management programs, including the submittal of state assessment reports and management programs
320*	Establishes a national estuary program
402	Establishes and outlines NPDES
402(p)	Specifies the conditions for establishing regulations for stormwater discharges by October 1, 1992
404	Outlines the procedures for issuing permits for dredge and fill; delegates permit issuance authority to the Secretary of the Army of the USCOE
505	Provides for citizen participation in the enforcement of point source pollution

* Indicates sections which are discussed further in the text

was also set of achieving fishable and swimmable waters in the nation by 1983 (Gould, 1980; LWV, 1986).

Another major feature of the 1972 amendments was the establishment of the National Pollutant Discharge Elimination System (NPDES), a permit system designed to enforce effluent limitations and water quality standards. All point source discharges are required to obtain a permit either from the USEPA or from the state's permit-issuing agency if the state has taken over NPDES administration. The permits are issued on a facility-by-facility basis and specify maximum allowable amounts of applicable parameters, a schedule for compliance, and schedules for self-monitoring and reporting. The 1972 amendments also asserted that the "best available technology economically available" be considered rather than what acceptable water quality requirements might be when setting effluent limitations. Provisions were made, however, for the establishment of water quality-based effluent limitations when water quality standards could not be attained using technology-based limitations (Krenkel and Novotny, 1980; LWV, 1986; USGPO, 1988).

The addition of Section 208 was seen by many as the first major attempt at addressing the regionality of water quality problems (USEPA, 1976). It also represented a recognition that point source control alone would not solve all of the nation's pollution problems (Krenkel and Novotny, 1980). States were required to identify regions which had significant water quality control problems and designate an organization for each of these regions to develop an areawide waste treatment management plan for that region. This organization includes representatives from local governments and is responsible for carrying out the continuous areawide waste treatment management planning process. Plans are to incorporate information from 303(e) basin plans and 201 facilities plans, including, but not limited to: the identification of treatment facilities needed over a twenty-year period; construction priorities and schedules for these facilities; the identification of agencies whose involvement is necessary in carrying out the plan; the identification of processes, costs, and timing for carrying out the plan; the identification of economic, social, and environmental impacts of plan implementation; the identification of nonpoint sources of pollution, their effects, and methods for controlling these sources; and the identification of methods of controlling salt water intrusion where applicable. Nonpoint sources specifically addressed in Section 208 include agricultural-, silvicultural-, mining-, and construction activity-related sources (USGPO, 1988; Noble and Findley, 1977).

Point source monitoring and reporting obligations are stipulated in Section 308 and provide the basis for data gathered through NPDES. This section also allows the USEPA or the appropriate state regulating agency to have access to records maintained by owners or operators of point sources, inspect monitoring equipment, and sample effluents. Data gathered is to be available to the public or Congress unless it can be proven that the release of such information will divulge methods or processes entitled to protection as trade secrets (USGPO, 1988).

Monitoring and data assessment are done to prepare the biennial reports required by Section 305(b) (Ward, et. al., 1990). Referred to as the "305(b) process," the generation of these reports has become the principal means by which the nation's water quality status is assessed. States, territories, and interstate commissions develop surface and ground water monitoring programs and prepare a report for the USEPA which is in turn submitted to Congress. The USEPA also prepares a nationwide water quality assessment compiled from the data submitted by the states (USEPA, 1991b). In March 1992, the USEPA released the latest National Water Quality Inventory which was based on data collected during 1988 and 1989. This was the eighth report prepared under Section 305(b), and it reflects the increasingly comprehensive reports prepared by the states with each reporting cycle, partially because of the value of these reports in determining water quality management priorities (Holmes, 1992; 1990 National Water Quality Inventory, 1992).

The 1987 amendments included an emphasis on nonpoint source pollution with the addition of a policy to pursue the goals of the Clean Water Act through the control of both point and nonpoint sources of pollution. In addition, Section 319 was incorporated into the act, outlining requirements for nonpoint source management programs. Under Section 319, states are required to submit a management program to the USEPA Administrator which includes an identification of best management practices (BMPs) for reducing pollutant loadings, an identification of programs for implementing these BMPs, and a schedule for implementation and funding. The states are encouraged to develop these plans on a watershed-by-watershed basis and are allowed to develop plans in conjunction with other states where applicable (USGPO, 1988).

Another addition of the 1987 amendments was the National Estuary Program which was included in Section 320. This program is voluntary, although the act specifies estuaries that are to receive priority consideration under the program. Conservation and management plans for nominated estuaries can be developed using existing reports, data and studies through management conferences. Section 320 also authorizes funding for estuary research programs which include long-term trend assessment monitoring and a comprehensive water quality sampling program for the continuous monitoring of nutrients, chlorine, acid precipitation, dissolved oxygen, and potentially toxic pollutants (USGPO, 1988).

Safe Drinking Water Act

In 1974, Congress passed the Safe Drinking Water Act (SDWA), which addresses the quality of drinking water. Although the Clean Water Act addressed the quality of navigable waters, studies showed that many drinking water systems were seriously contaminated partially due to the unregulated underground disposal of wastes (Muzzey, 1986). The 1974 SDWA includes provisions for the federal regulation of drinking water systems, requires the USEPA to set national standards for contaminant levels in drinking water, and established a program for state regulation of underground injection wells and for the protection of sole source aquifers (Randle, 1986).

Progress on fulfilling the obligations of the 1974 SDWA was very slow, and in 1986, amendments were enacted which were designed to speed up the process. The amendments include requirements for the issuance of standards for specified contaminants, provide for increased protection for sole source aquifers and wellhead areas, and require the regulation of lead in drinking water systems. Statutory deadlines for the accomplishment of requirements of the act were also incorporated, allowing environmental groups to file citizen suits in the event that the USEPA continued to lag in its responsibilities. This aspect of the act has resulted in subjecting the USEPA to court-ordered deadlines for the proposal and promulgation of drinking water standards (Randle, 1986).

Part B of the SDWA addresses the identification and development of minimum national standards by the USEPA for contaminants in drinking water. The USEPA was required to establish maximum contaminant level goals (MCLGs) and national primary drinking water standards for a list of 83 contaminants by June 1989. In general, the primary drinking water standards are set as maximum contaminant levels (MCLs). MCLGs are generally determined on a health basis and should be set at levels that have no expected adverse human health effects with an adequate margin of safety. For some carcinogens, the MCLGs are zero, which are not necessarily feasible to attain. However, since MCLGs are merely goals, they are not enforceable. MCLs, on the other hand, are enforceable and therefore are set as close to corresponding MCLGs as feasible using the best available technologies and treatment techniques (Randle, 1986).

The USEPA is also required to establish a priority list of contaminants for which it will generate standards after it promulgates standards for the original 83 contaminants. In addition, the act defines national secondary drinking water standards which are to be set by the USEPA and are directed at aesthetic water quality problems which can discourage people from using the affected water system (Randle, 1986). Tables showing the status of proposed and promulgated drinking water standards as of March 1992 are included in Appendix A (Pontius, 1992).

The SDWA also includes provisions for the regulation or ban of underground injection wells, and for the development of programs to protect sole source aquifers and wellhead areas (Randle, 1986). In accordance with these activities and the standards compliance of Part B of the SDWA, public water systems must perform monitoring (Pontius, 1992). To reduce technical and management problems which might result if monitoring requirements are too varied, the USEPA has established the standardized monitoring framework shown in Figure 1. This framework is to be implemented January 1, 1993, and involves a nine-year compliance cycle composed of three three-year compliance periods. States are to schedule one-third of their drinking water systems to monitor during each year of the compliance period. Once a system is scheduled to monitor during a particular year of the three-year compliance period, it must monitor in the same year for the other compliance periods. Thus, a system scheduled to monitor in the first year of the first compliance period (1993) must monitor again in the first year of the second and third compliance periods (1996 and 1999). Although the intent of this standardized monitoring framework is to reduce the technical and managerial workload and make monitoring and vulnerability assessments more cost effective, the new monitoring requirements are more complex. This may actually necessitate improved laboratory capacities, monitoring methods, and financial resources (Pontius, 1991).

Other Federal Regulations

The 1976 Toxic Substances Control Act (TSCA) gives the USEPA the authority to require the testing of new and old chemical substances and to regulate these substances. The act is centered around premanufacture notification (PMN) to the USEPA of the identity of a chemical substance, its intended uses, and a description of required toxicological tests. The USEPA publishes the PMNs in the *Federal Register* and can restrict or prohibit the production or distribution of the chemical if it determines that the chemical may pose a risk to man or the environment (Miller, 1991).

The treatment, storage, and disposal of hazardous waste is addressed in the Resource Conservation and Recovery Act (RCRA) of 1976, which was amended in 1984 by the Hazardous and Solid Waste Amendments. RCRA affects generators and transporters of hazardous wastes as well as owners and operators of treatment, storage, and disposal (TSD) facilities. Primarily concerned with active facilities, RCRA includes ground water monitoring requirements for TSD facilities (Case, 1991).

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Asbestos Base requirement	One sample at each sampling point			No requirements			No requirements		
Waiver*	No samples required			Not applicable			Not applicable		
Inorganics Surface water base requirement	One sample at each sampling point each year			One sample at each sampling point each year			One sample at each sampling point each year		
Groundwater base requirement	One sample at each sampling point each year			One sample at each sampling point each year			One sample at each sampling point each year		
Waiver†	One sample at each sampling point								
VOCs Base requirement	Four quarterly samples at each sampling point								
Reduced monitoring*	One sample at each sampling point each year			One sample at each sampling point each year§			One sample at each sampling point each year§		
Waiver** Surface water	State discretion			State discretion			State discretion		
Groundwater	One sample at each sampling point						One sample at each sampling point		
Pesticides Base requirement	Four quarterly samples at each sampling point			Four quarterly samples at each sampling point			Four quarterly samples at each sampling point		
Reduced monitoring‡ Systems >3,300 people	Not applicable			Two samples at each sampling point			two samples at each sampling point		
Systems <3,300 people	Not applicable			One sample at each sampling point			One sample at each sampling point		
Waiver††	No samples required			No samples required			No samples required		
Unregulated contaminants Organics	Four quarterly samples at each sampling point			Not applicable			Not applicable		
Inorganics	One sample at each sampling point			Not applicable			Not applicable		
Waiver††	No samples required			Not applicable			Not applicable		

Compliance monitoring requirements for contaminants regulated as of Jan. 1, 1993. *(*Waivers from asbestos monitoring are available for all systems based on vulnerability assessment. †For all systems, states may waive the base monitoring requirements after 3 samples lower than the MCL are taken. ‡For all systems, reduced monitoring is allowed, provided initial monitoring is completed by Dec. 31, 1992, and no contamination was detected. §Groundwater systems may be allowed to reduce monitoring to one sample at each sampling point per three-year compliance period after no detection in three years of annual monitoring. **Waivers are allowed, provided initial monitoring is completed by Dec. 31, 1992, and no contamination was detected. ††Reduced monitoring is allowed for systems in which contamination has not been detected. ‡‡Waivers are allowed based on use or susceptibility assessment or both.)*

Figure 1. Compliance monitoring requirements for USEPA standardized monitoring framework. *Source: Pontius (1991)*

The environmental effects of surface coal mines including acid mine drainage and erosion control problems are the focus of the 1977 Surface Mining Control and Reclamation Act (SMCRA). The Office of Surface Mining Reclamation and Enforcement (OSMRE) was established under the U.S. Department of the Interior to provide regulatory, technical, and financial assistance in the administration of the provisions of the act. The act includes a permitting program for surface coal mining and reclamation operations. This permit includes a reclamation plan and environmental protection provisions which can include surface and ground water quality and quantity monitoring where applicable. SMCRA also created an abandoned mine land reclamation program which is funded by fees paid on each ton of coal produced from surface or underground mining. This program enables the reclamation of land and water resources that were damaged prior to 1977. States can serve as the regulatory authority of the act if they have a reclamation program approved by the U.S. Department of the Interior and have established an agency to operate the program. As of 1987, 25 states had their own regulatory programs, and 10 states had federal programs (OSMRE, 1987).

The 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) concerns the cleanup of the nation's hazardous waste sites. Also called "Superfund," CERCLA was revised in 1986 by the Superfund Amendments and Reauthorization Act (SARA). CERCLA addresses all environmental media, including air, surface water, ground water, and soil. Monitoring may be performed during preliminary assessments to establish the USEPA's National Priority List (NPL) of sites for priority cleanup funding. Data is also generated during the preparation of the required remedial investigation and feasibility studies, and during remediation activities to assess the degree of cleanup (Stoll, 1991).

To identify the causes and sources of acid precipitation and its effects, Congress passed the Acid Precipitation Act in 1980. A comprehensive study assessing the economic, physical, climatic, and social effects of the impacts of atmospheric carbon dioxide and synthetic fuel activities was to be prepared by the Office of Science and Technology Policy and the National Academy of Sciences. This study was encouraged to develop an international, worldwide assessment (Freedman, 1987).

Water Quality Regulation in Colorado

As in many other states and parts of the world, Colorado has historically been more concerned with water quantity than water quality. To illustrate this point, it has been documented in the Colorado legislative actions that water rights laws have been a component of almost every session of the Colorado legislature since statehood, but water quality has only recently been an infrequent topic with the legislature (Vranesh, 1987b).

Prior to the 1900's, Colorado common law principles were used to protect water quality. Because of the "beneficial use" requirement of the appropriation doctrine, water users could not generate and introduce waste products which would impair the water use of other appropriators. However, water quality could not be improved by altering water quantity, such as by diluting a stream to decrease concentrations of parameters (Vranesh, 1987b; Hobbs, 1980).

A mining law enacted in 1908 became the first Colorado statute used to protect water quality, although it was originally intended to prevent miners from disposing of tailings on another person's property. This law was later used to protect the uses of other water appropriators from mining practices (Vranesh, 1987b).

In 1953, several statutes were enacted which addressed water pollution and created the Colorado State Department of Public Health. The statutes made it unlawful to pollute any public waters containing fish, discharge any obnoxious substance into a stream, ditch, or flume, or deposit any oleaginous substance such as oil or petroleum into state streams. The duties of the Department of Public Health included the establishment and enforcement of water quality standards regarding sewage systems (Vranesh, 1987b).

Colorado's first comprehensive water quality law was the Colorado Water Pollution Control Act of 1966. The act established a Water Pollution Control Commission which was given the authority to establish water quality regulations and adopt standards conforming with FWPCA and the Water Quality Act of 1965. In keeping with the traditional emphasis on water quantity, however, the Commission was restricted from altering water rights for the purpose of controlling water pollution (Vranesh, 1987b; Hobbs, 1980).

The Colorado Water Quality Control Act of 1973 and its 1981 amendments follow closely the powerful FWPCA amendments. The Colorado act created a Water Quality Control Commission (WQCC) in the Colorado Department of Health (CDOH) with responsibilities that include classifying the state's waters, promulgating and regulating water quality standards, issuing waste discharge permits, and reviewing standards and regulations on a periodic basis. The classification of state waters takes into account factors such as ambient conditions, the source of pollution, present and designated uses, adjacent land use, the need for water quality protection, the type of water and its physical parameters, and the variability of these factors. In promulgating water quality regulations, the WQCC also considers the need for regulation, practicality of enforcement, streamflow and type of flow, and the class of water involved. These regulations establish water quality standards, prohibitions, and effluent limitations (Radosevich, et. al., 1976).

The act specifies that owners of point source discharge facilities must keep records, monitor their discharges, and compile reports on activities related to pollutant discharge. CDOH's Water Quality Control Division (WQCD) is given the right to enter and inspect facilities. In addition, the act includes provisions for hearing procedures, NPDES permitting, and violation, remediation, and penalty procedures (Radosevich, et. al., 1976).

Councils of Governments (COGs) were also created by the Colorado Water Quality Control Act to receive federal grants under Section 208 of the Clean Water Act for the preparation of the regional wastewater management plans. These COGs are planning agencies representing political subdivisions of Colorado with no regulatory authority. The WQCD conducts a continual planning process under Section 208, and the WQCC has sole responsibility for approving the regional plans (Hobbs, 1980).

The Colorado Mined Land Reclamation Act was enacted in 1978 by the Colorado Mined Land Reclamation Board. The objective of this act and the Colorado Surface Coal Mining Reclamation Act is to minimize the disturbances to surface and ground water quality both during and after mining operation and reclamation (Vranesh, 1987b).

In 1989, Colorado addressed the issue of the interrelation of water quality and quantity by enacting Senate Bill 181 (SB 181), which requires the state engineer and the Colorado Water Conservation Board to advise the WQCC regarding potential injuries to water rights due to proposed water quality regulations (LWVC, 1992). SB 181 also requires the State Engineer's Office (SEO) to enforce water quality standards and classifications that have been set by the WQCC if the SEO is the statutory regulatory agency. This mandate is significant, because the SEO has generally served as the state's water *quantity* agency, while the WQCD and the WQCC have dealt with water quality. In 1990, the SEO prepared a report that identified water quality activities that involved the SEO. These activities are summarized in Table 2 (SEO, 1990).

Recent activity in the Colorado legislature concerning water quality involves the reorganization of the Colorado Department of Natural Resources (CDNR) and CDOH. The proposed bill originally created a division of water quality in CDNR and transferred the WQCC to CDNR (CWC, 1992a). A revised version of this bill requires a study and report to the state General Assembly regarding the most efficient organizational placement of the water quality control program to enable protection of both water quality and water rights. The bill would also establish a Colorado Antidegradation Water Quality Program to protect water rights and developments on interstate waters. In addition, the bill includes a statement of intent to return administration of the SDWA program to the federal government if concerns about

Table 2. Colorado Statutes that Involve the State Engineer's Office

Statute	Description of Involvement
CRS 25-8-104, 202 & 204	Requires the WQCC to consult with the state engineer regarding possible injury to water rights resulting from the adoption of proposed water quality policies; also requires the state engineer to enforce water quality standards and classifications if the SEO is the statutory authority
CRS 25-11-103(7)	Requires the state engineer's approval of all leases or licenses for radiation sites
CRS 37-90.5-106	Addresses geothermal production and its effects on surface and ground water quality; the state engineer may issue a permit only after these effects are investigated
CRS 37-80-120(3)	Requires approval of the state engineer for substitution of water supply which must be of adequate water quality
CRS 37-90-107(5)	Requires the Ground Water Commission to approve proposed uses of designated ground water; deterioration of ground water quality must be addressed
CRS 37-90-137(2)	Requires the state engineer's approval for the drilling of any wells; the permit must incorporate provisions for preventing pollution
CRS 37-90-138(1)	Gives the state engineer regulatory authority for the drilling and construction of all wells in order to prevent the destruction of other water resources
CRS 37-91-101	Created the State Board of Examiners of Water Well and Pump Installation Contractors within the Division of Water Resources which is charged with regulating the drilling, construction and equipping of water wells to protect public health
CRS 37-91-110	Requires water well construction to protect against aquifer pollution
CRS 37-92-305(5)	Requires that the exchange or substitution of waters must incorporate waters of adequate quality to meet the needs of senior vested rights
Article III, Rio Grande Compact	Requires Colorado to monitor water quality from the Closed Basin for compliance with the Compact provisions

CRS = Colorado Revised Statute

increasing economic burdens on small communities and municipal water systems due to USEPA requirements are not addressed. As of May 1992, the bill had yet to be approved (CWC, 1992b).

Chapter 3. Literature Review of Data Management Technologies

As mentioned in Chapters 1 and 2, the extensive water quality legislation in the United States and Colorado require a vast amount of water quality data. The management of this data is critical to the successful attainment of not only the legislative goals, but those of society as well. There are a number of existing data management technologies available to users and generators of water quality data. This chapter reviews these technologies and their applications to water quality data.

USEPA Data Management Systems

The U.S. Environmental Protection Agency (USEPA) is charged with protecting and restoring the integrity of the nation's water resources and therefore collects and manages a large amount of information, including water quality data (USEPA, 1990a). Figures 2 and 3 provide an overview of the monitoring and data reporting requirements for several activities which involve the USEPA (USEPA, 1985). Under the "Required Data Reporting" column, databases such as STORET and PCS are mentioned. These and other computer databases have been developed and are maintained by several USEPA offices. Although most of these databases reside on the National Computer Center (NCC) IBM-3090 mainframe computer in Reston, Virginia, users can often communicate using a personal computer with communications software and a modem or direct line (USEPA, 1991a).

Because there is a charge to use the USEPA databases, users can get access in one of three ways. Federal agencies complete memorandums of understanding (MOUs) with the USEPA which sets up an

Purpose	Activity*	Type of Data Needed	Who Collects	Method	Required Data Reporting	Parameter Coverage	Data Uses: National Water Quality Assessment	Data Uses: Statewide Water Quality Assessment, 305(b)	Data Uses: Regional Oversight	Data Uses: Site-Specific Controls	Data Uses: Program Management, Wasteload Allocations	Data Uses: Program Management, Construction Grants	Data Uses: Check Water Quality Standards	Comments
Conduct Water Quality Assessments (Chapter 4)	Assess conditions and determine trends	Physical/ chemical	States	Fixed stations and monitoring surveys. Include toxics in fish flesh and sediments.	Enter appropriate data into STORET or "hard copies" to EPA. Report findings through 305(b) reports.	As needed to assess attainment of use	•	•	•		•	•	•	Source of "before" data for program management. Source of data to detect new or emerging problems Technical report discussing conditions, findings, trends, etc. strongly encouraged
		Biological	States	Biosurveys and bio-assays at fixed stations and as a part of intensive surveys. Include species ID and enumeration of fish.	Send abstract of findings to EPA, if requested by EPA and report findings through 305(b) reports.	Site specific	•	•	•		•	•	•	
Develop Water Quality-based Controls (Chapter 2)	Identify waters needing water quality-based controls and set priorities for controls	Physical/ chemical	States**	Fixed stations and intensive surveys. Also math modeling	Enter all data into STORET or "hard copies" of data to EPA	As needed	•	•	•	•	•	•	•	Source of "before" data for program management
		Biological	States**	Bioassays and bio-surveys (include species ID and enumeration of fish). Also math modeling.	Enter all data into STORET or "hard copies" of data to EPA	As needed		•	•	•	•	•	•	Source of "before" data for program management
	Review and revise (or reaffirm) water water quality standards	Physical/ chemical	States**	Use attainability studies, site-specific criteria, etc.	Enter all data into STORET or "hard copies" of data to EPA	As needed							•	
	Develop water quality-based controls (TMDLs/WLAs)	• Ambient physical, chemical, & biological • Effluent • Nonpoint source • Background	States**	Intensive surveys (including biological assessment sampling) and math models.	Enter all data into STORET or "hard copies" of data to EPA	As needed		•	•	•	•	•		
	Issue water quality-based permits, make construction grant decisions, implement non-point source controls	Not applicable												

*Technical guidance is available from EPA for each of these activities. For copies, contact the Regional Monitoring, Water Quality Standards, or Wasteload Allocation Coordinators
**Dischargers may also be required to collect data if stringent QA/QC program is in effect.

Figure 2. State monitoring and wasteload allocation programs. *Source: USEPA (1985)*

Purpose	Activity*	Type of Data Needed	Who Collects	Method	Required Data Reporting	Parameter Coverage	Data Uses: National Water Quality Assessment	Data Uses: Statewide Water Quality Assessment, 305(b)	Data Uses: Regional Oversight	Data Uses: Site-Specific Controls	Data Uses: Program Management, Wasteload Allocations	Data Uses: Program Management, Construction Grants	Data Uses: Check Water Quality Standards	Comments
Assess compliance with and effectiveness of controls (technology & water quality-based for point and nonpoint sources) (Chapter 3)	Monitor municipal and industrial sources & BMP sites for compliance.	Effluent &/or nonpoint source discharge	States Dischargers (DMR data)	Effluent monitoring as specified in permit.	Appropriate data into PCS PCS Inspections	As specified in the permit			•	•	•	•	•	
				Bioassay if specified in permit	Abstract of findings to EPA	As specified in the permit			•	•	•	•	•	
	Document protection of designated use	Ambient physical, chemical, & biological	Dischargers with possible assistance from States	Intensive survey (including biological assessments and effluent sampling) to document results of controls and impact on water quality after controls are in place. If problems are noted, re-examine controls	Enter data from representative stations into STORET or "hard copies" of data to EPA. Send abstract of findings to EPA, if requested by EPA	Same as "before" survey	•	•	•	•	•	•	•	Source of "after" data for program management Use water quality standards guidance Follow-up monitoring to assess attainment of designated uses. Technical report discussing conditions, findings, trends, etc. strongly encouraged
			Dischargers with possible assistance from States	Fixed stations as needed to document results of controls and impact on water quality	Enter all data into STORET or "hard copies" to EPA	Same as measured at downstream stations for "before" and "after" intensive surveys. Include parameters limited on permits.	•	•	•	•	•	•	•	Use water quality standards guidance Follow-up monitoring to assess attainment of designated uses

*Technical guidance is available from EPA for each of these activities. For copies, contact the Regional Monitoring, Water Quality Standards, or Wasteload Allocation Coordinators

Figure 3. State monitoring and wasteload allocation programs (cont.). *Source: USEPA (1985)*

account. These MOUs can be on made on a national or regional basis with each agency (Ott, 1992; Younger, 1992).

Private organizations or consultants desiring direct access can apply for an account through the National Technical Information Service (NTIS). If a phone line is required for access, users are responsible for paying for the installation. Subsequent billing of use is done through NTIS (Ott, 1992; Younger, 1992).

Each region of USEPA has an account with which to fund database use by state agencies with responsibilities involving USEPA data. Generally, each state has a primary agency that has such responsibilities, but the region account can fund more than one state agency if necessary. For example, the responsible agency in Colorado for most interaction with the USEPA's STORET database is the Colorado Department of Health (CDOH), but because of its involvement with Section 319 of the Clean Water Act, the Colorado Water Conservation Board is also on the regional account. Other agencies such as local entities and universities can also access USEPA databases through the regional account if their data is pertinent to USEPA activities and they complete a letter of agreement with the USEPA (Ott, 1992; Younger, 1992).

STOrage and RETrieval System (STORET)

The STOrage and RETrieval system (STORET) is a water information system maintained by the USEPA's Office of Information Resources Management and the Office of Water Regulations and Standards. STORET stores information contributed by federal, state, and other organizations regarding ambient, intensive survey, effluent, and biological water quality for both surface and ground waters. STORET includes over 700,000 sampling stations and covers about 11,000 water quality variables. Users submit data daily, and states submitting information follow quality control guidelines specified in Section

106 of the Clean Water Act. Data security is accomplished by allowing agencies to lock their information to limit outside access, and by permitting agencies to change only their own information (USEPA, 1990a).

Although STORET is useful for water quality analyses, its use has been rather cumbersome because of the multitude of computer languages used to perform data input and retrieval. Consequently, some STORET users minimized their use or potential users were discouraged from using the system. To address this problem, the USEPA has recently added a new user interface to STORET that provides a menu-driven system with full-screen editing capabilities (USEPA, 1989). In addition, the USEPA is in the midst of a modernization of STORET and other water quality databases, as discussed later (USEPA, 1992).

STORET is composed of four systems of data: the Water Quality System (WQS), the BIOlogical System (BIOS), the Fish Kill File (FK), and the Daily Flow System (DFS). The main component of STORET is the WQS which is maintained by the Office of Water Regulations and Standards and the Office of Information Resources Management. WQS contains two kinds of surface and ground water information: station information and sampling information. Station information includes station type, locational information, U.S. Geological Survey (USGS) Hydrologic Unit, reach number, and a narrative description. The reach number refers to the USEPA's Reach File database which is discussed later. Sampling information included in WQS includes where, when, and how samples were collected, parameters tested for, and testing results. Agencies submitting data are encouraged to follow USEPA quality control guidelines when collecting and analyzing data, and ranges of parameter measurements are used to test data as it is added to WQS. WQS also receives data periodically from the USGS WATSTORE database, which is described in a subsequent section of this chapter. Users can obtain text or graphical reports and can use linkage tools to format WQS data for use with other software such as SAS, dBASE, Lotus, and other USEPA databases (USEPA, 1990a).

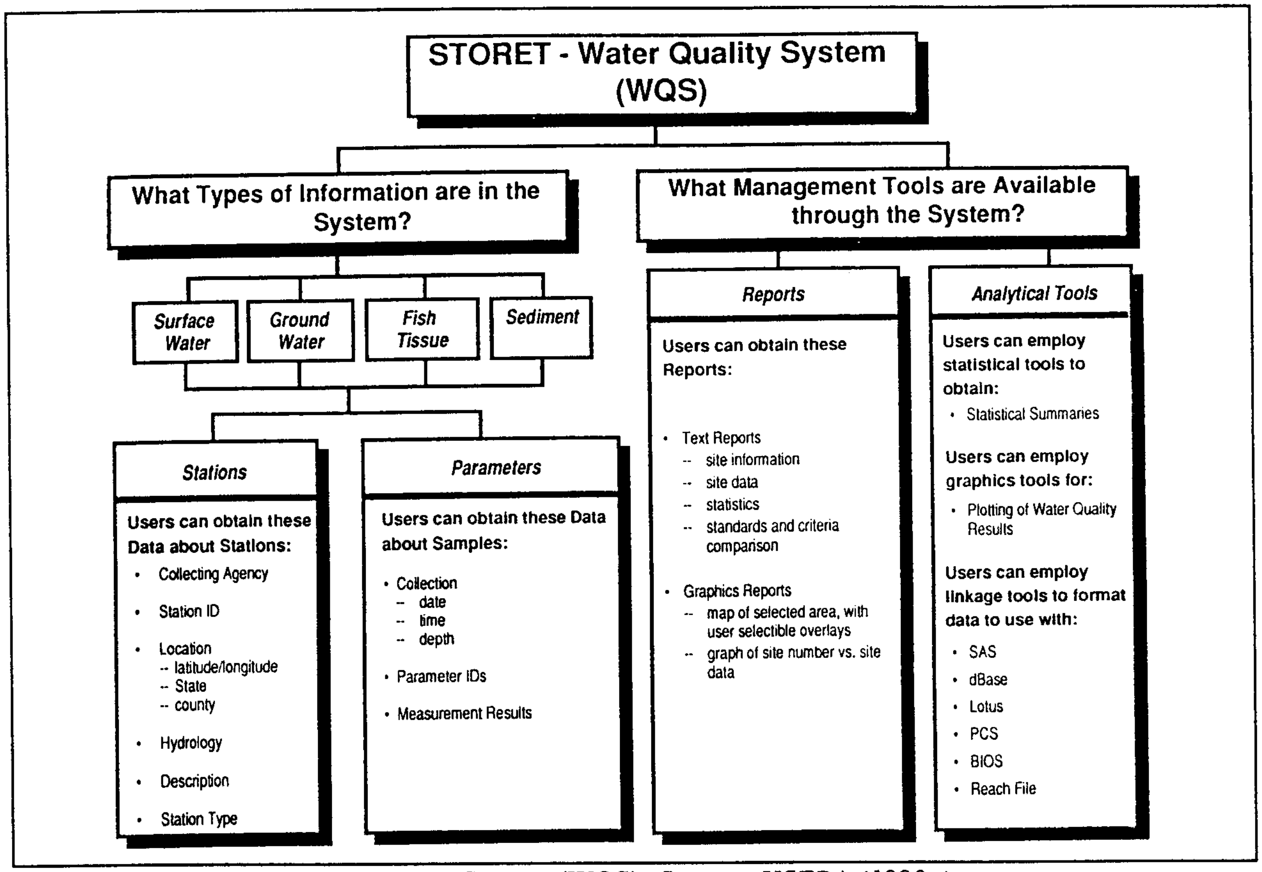

Figure 4. STORET Water Quality System (WQS). *Source: USEPA (1990a)*

BIOS is managed by the Office of Water Regulations and Standards. This database has biological information storage and analysis capabilities. Like WQS, BIOS contains site information and sampling information. Station information includes an agency code, station identification number, USGS Hydrologic Unit, locational information, and a narrative description. Sampling information specifies the sampling event and survey date and identifier, and contains a complete record of the observed biota including taxonomic identities and counts of observed organisms. Sampling gear, meteorological conditions, physical and chemical water conditions, and habitat descriptions may also be included in BIOS. In addition to linking to WQS and another USEPA database called PCS, BIOS can be linked to the National Oceanographic and Atmospheric Administration's taxonomic nomenclature file. Data is submitted daily by federal, state, interstate and international users. Users can obtain text or graphical reports and can employ tools to use BIOS data with other software systems such as SAS, dBASE, and Lotus (USEPA, 1990a).

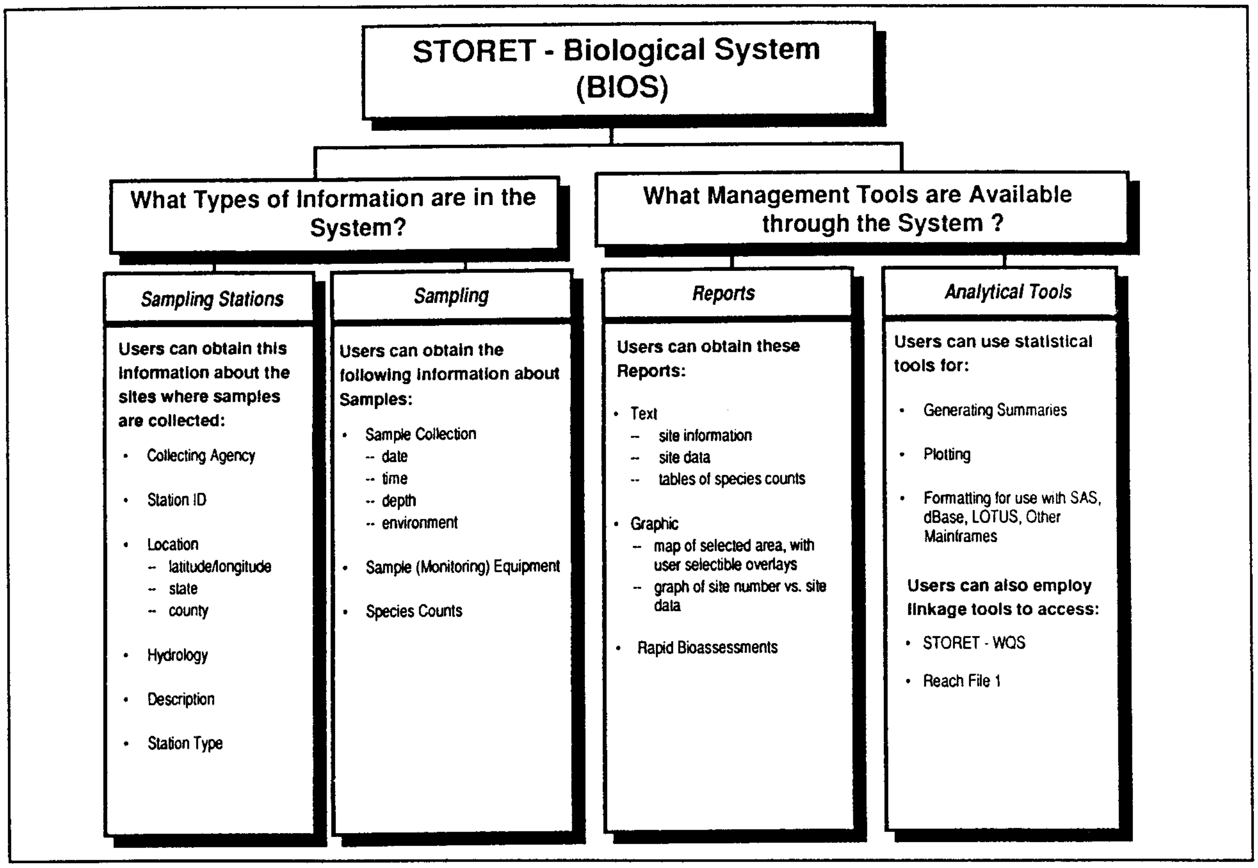

Figure 5. STORET Biological System (BIOS). *Source: USEPA (1990a)*

Developed and maintained by the Office of Water Regulations and Standards, the Fish Kill File (FK) contains a record of fish kills caused by pollution throughout the United States. This database was designed to assist in the determination of the causes of these occurrences. Information in FK includes location, circumstances, number and species of fish killed, primary land use surrounding the kill site, pollutants, and sources of pollutants. Input to FK was discontinued in 1986, but users can still obtain reports sorted by state, county, city, year, or pollution cause (USEPA, 1990a).

The DFS, maintained by the Office of Water Regulations and Standards, contains daily stream flow, water level, and water quality information collected at USGS gaging stations. This information is

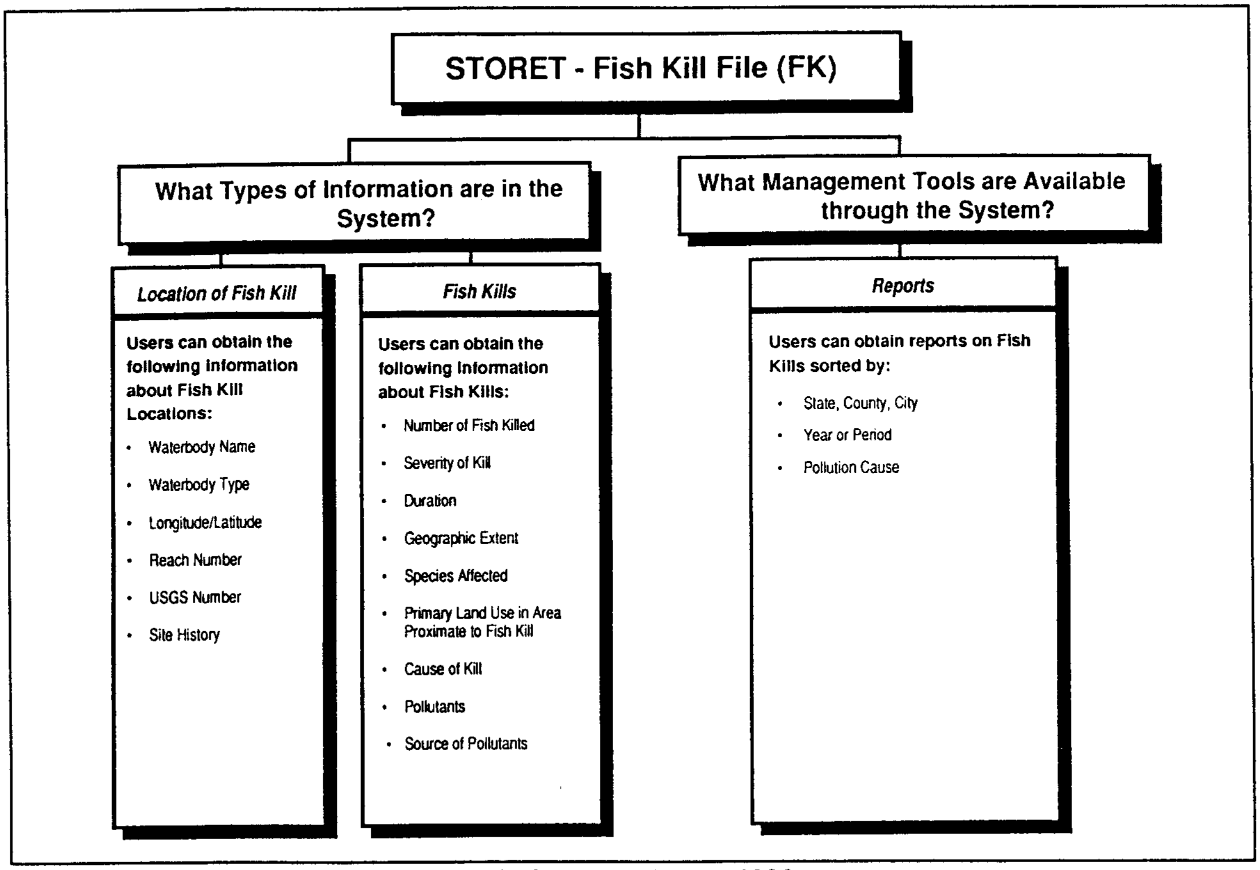

Figure 6. STORET Fish Kill File (FK). *Source: USEPA (1990a)*

essentially the same as the USGS' WATSTORE Daily Values File and includes data for almost 30,000 gaging sites. Flow information constitutes about 85 percent of the data, with the remaining data covering water level and water quality measurements of temperature, conductivity, dissolved oxygen, pH, chloride, and suspended sediment. DFS is updated twice a year, and users can obtain station summary reports, data reports by station, or flow analysis reports by station (USEPA, 1990a).

Ocean Data Evaluation System (ODES)

The other major USEPA database containing water quality data is the Ocean Data Evaluation System (ODES) which is maintained by the Office of Marine and Estuarine Protection with the intent of

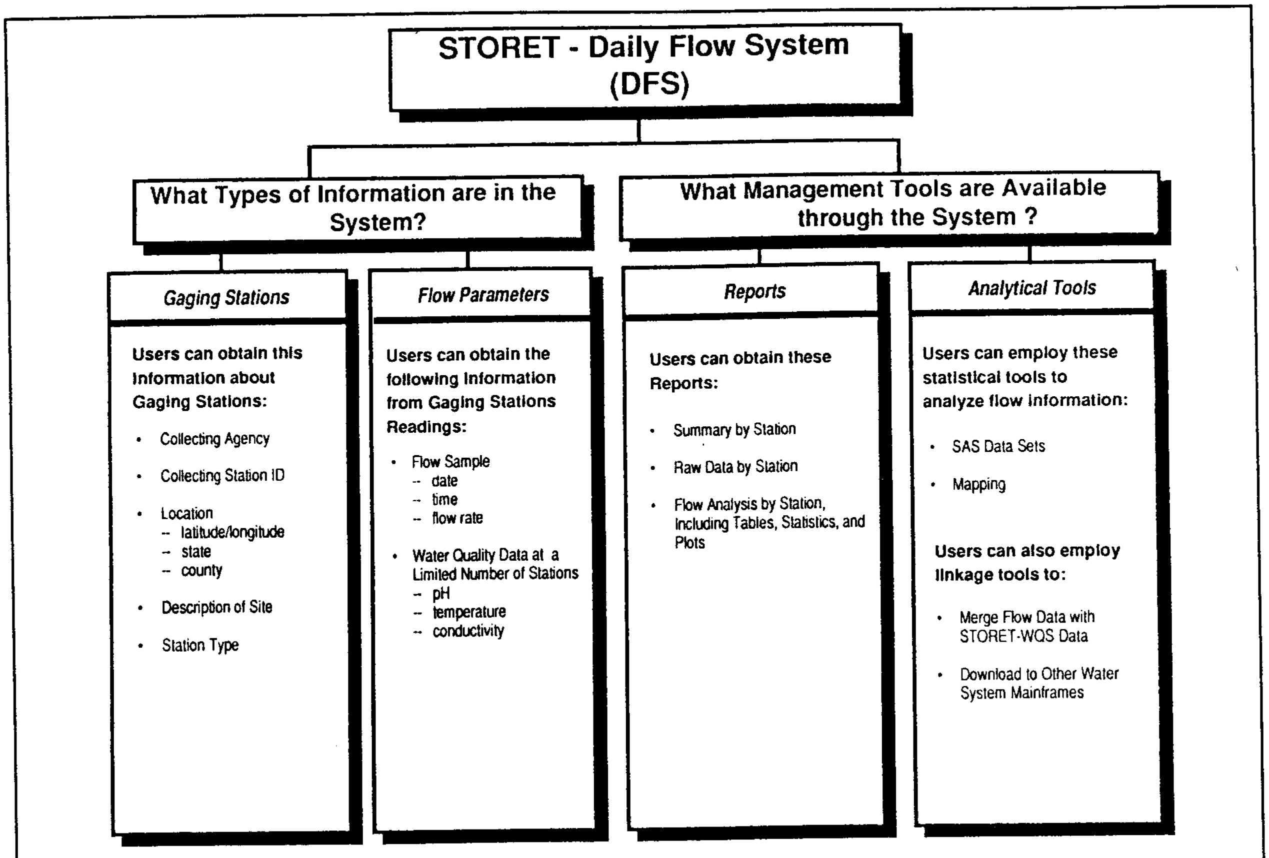

Figure 7. STORET Daily Flow System (DFS). *Source: USEPA (1990a)*

aiding agencies in meeting regulatory objectives by evaluating marine monitoring information. Quarterly input data comes from publicly owned treatment works (POTWs) complying with a number of USEPA programs including the 301(h) sewage discharge program, the National Pollutant Discharge Elimination System (NPDES) program, the 403(c) program, the ocean dumping program, and the National Estuary Program. Data is compatible with standard National Oceanographic Data Center formats and is verified prior to entry into ODES with a set of review and evaluation procedures. Database records include water quality data, physical, chemical, and biological characteristics, estuary information, oceanographic descriptions, and sediment pollutants. Spatial relationships between pollution sources, sampling locations, and other geographic features can be mapped, and graphs can be constructed showing spatial and temporal relationships of selected variables. Although the database is currently not linked to STORET (USEPA, 1990a), a STORET modernization begun in 1990 will integrate the STORET, BIOS and ODES databases (EPA News-Notes, 1992).

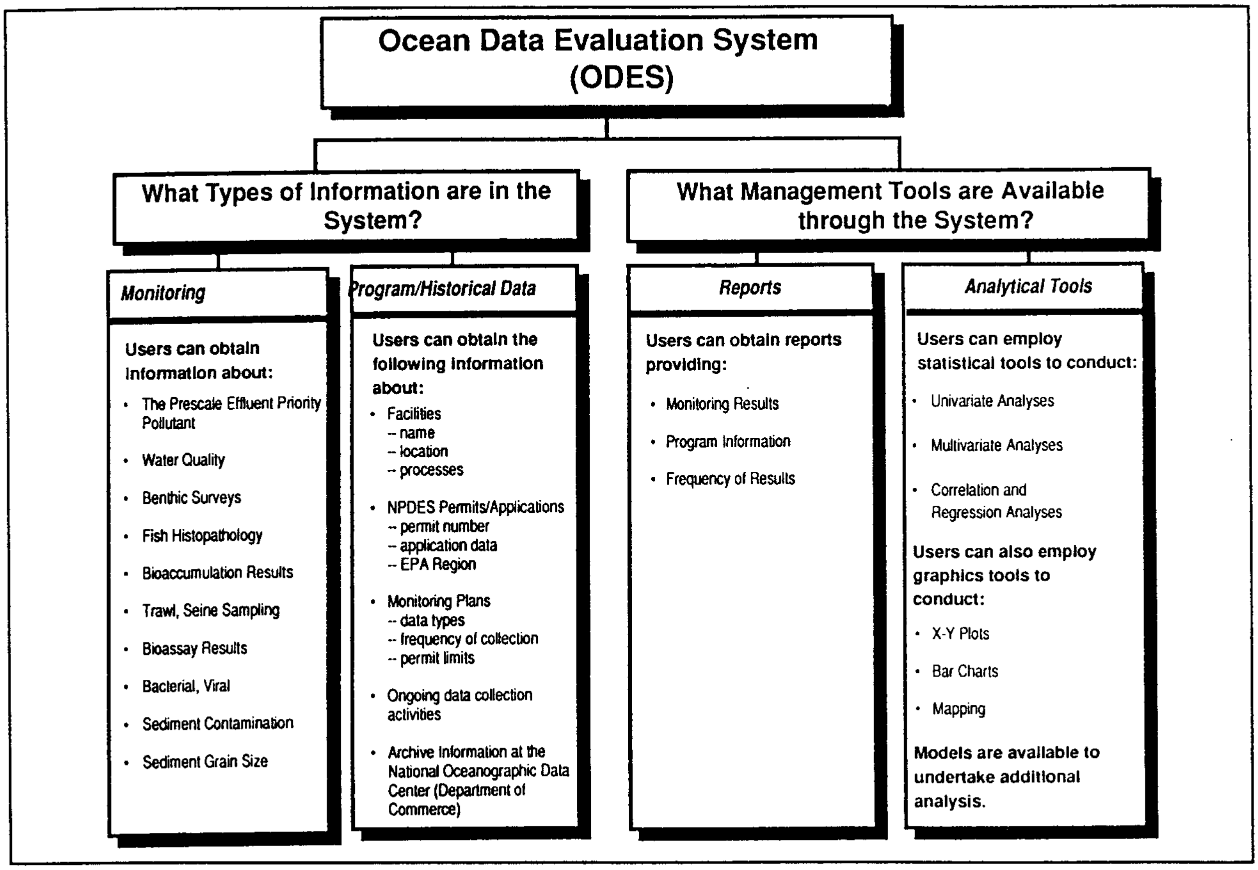

Figure 8. Ocean Data Evaluation System (ODES). *Source: USEPA (1990a)*

Reach File (RF)

The USEPA has other data files which are used by water quality agencies. Some of these can be linked to STORET through the Reach File (RF), a hydrographic database of surface water features of the United States developed by the Office of Water Regulations and Standards. All streams, lakes, reservoirs, coastlines, and estuaries are divided into segments called "reaches" which reference each other, allowing a hydrologic traversal of the nation's rivers and open waters. The unique segment identifiers have been incorporated into other USEPA databases including STORET, allowing linkages between databases. Reach information in the database include reach names, type, length, upstream and downstream connections, location, and descriptions of whole water bodies. The third version of RF (RF3) is currently being implemented and contains 3,000,000 individual reach components. In addition to incorporating all information from the previous two RF versions, RF3 includes the USGS Geographic Names Information System (GNIS) database and USGS 1:100,000 scale Digital Line Graph (DLG) data obtained from 48,000 quadrangle map files (USEPA, 1990a; Bondelid, 1991). Users can use RF3 data to generate reports, maps, and export files formatted for ARC/INFO, a geographic information system discussed later in this paper (USEPA, 1991a).

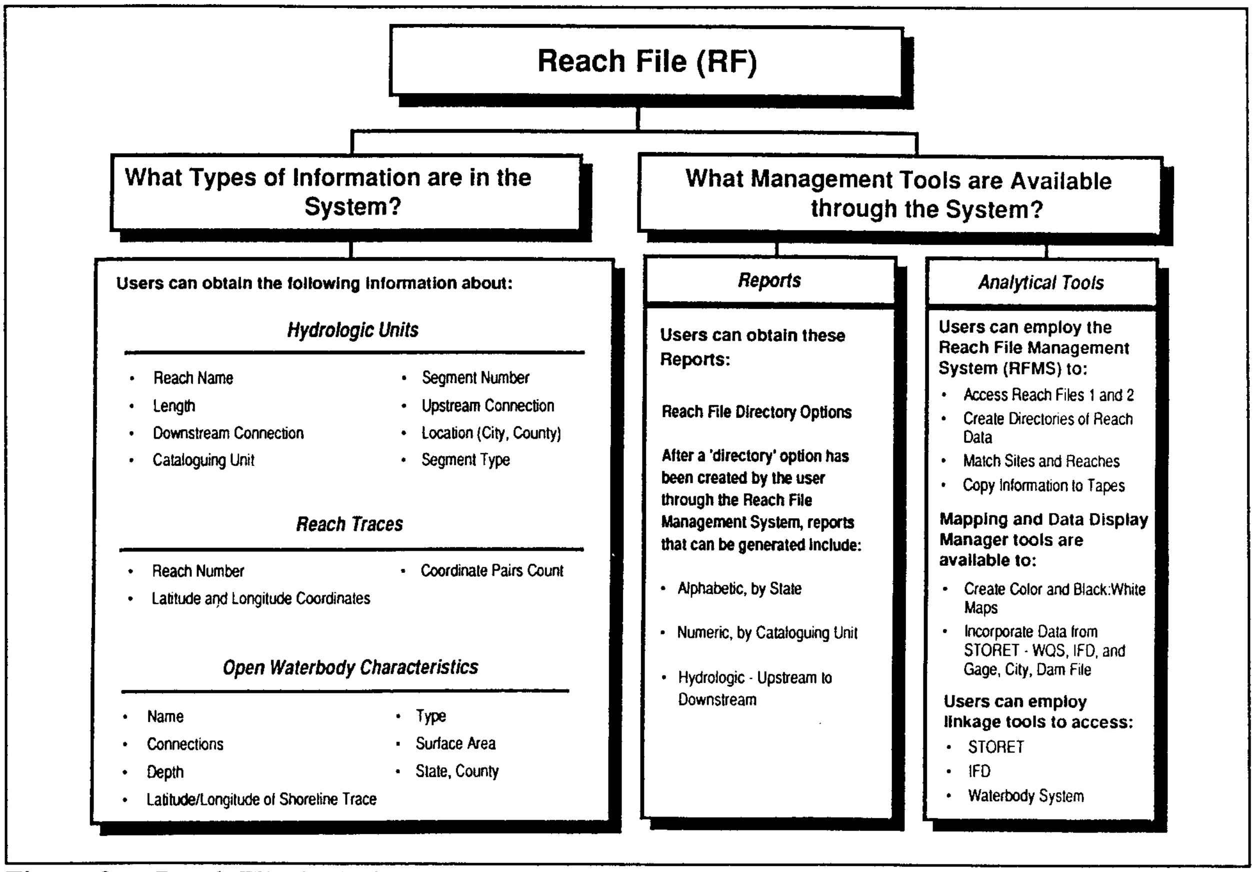

Figure 9. Reach File (RF). *Source: USEPA (1990a)*

Permit Compliance System (PCS)

The Permit Compliance System (PCS) is maintained by the Office of Water Enforcement and Permits and supports the NPDES program by tracking permit, compliance, and enforcement status of major regulated facilities. Compliance schedule reports and discharge monitoring reports (DMRs) containing compliance and status information are submitted to regulating agencies which enter the information into PCS. The regulating agencies also enter inspection and enforcement information. Using the NPDES permit number, PCS can track facility characteristics, permit conditions, discharge characteristics, inspections, compliance schedules, and enforcement actions. PCS can also be linked to other USEPA databases associated with NPDES permitting, including: the Industrial Facilities Discharge File (IFD) which contains facility, direct discharge, indirect discharger, and Superfund site information and which can be linked to STORET with the reach number; the Needs Survey, an inventory of POTWs needing construction or renovation; and the Grants Information and Control System (GICS), an information system that tracks the processing of wastewater treatment grant applications (USEPA, 1990a).

Federal Reporting Data System (FRDS)

The Office of Drinking Water maintains the Federal Reporting Data System (FRDS), a centralized database containing information about public water supplies (PWSs) and their compliance with the Safe Drinking Water Act (SDWA) of 1986. Information about both surface and ground water sources covered by the SDWA are contained in the database, including an identification number, location, violations, enforcement actions, and treatment. Although PWS owners and operators are required by the SDWA to submit monitoring information to the regulating agency, FRDS only includes the enforcement officials' assessments and quarterly reports of this data, not the data itself (USEPA, 1990a).

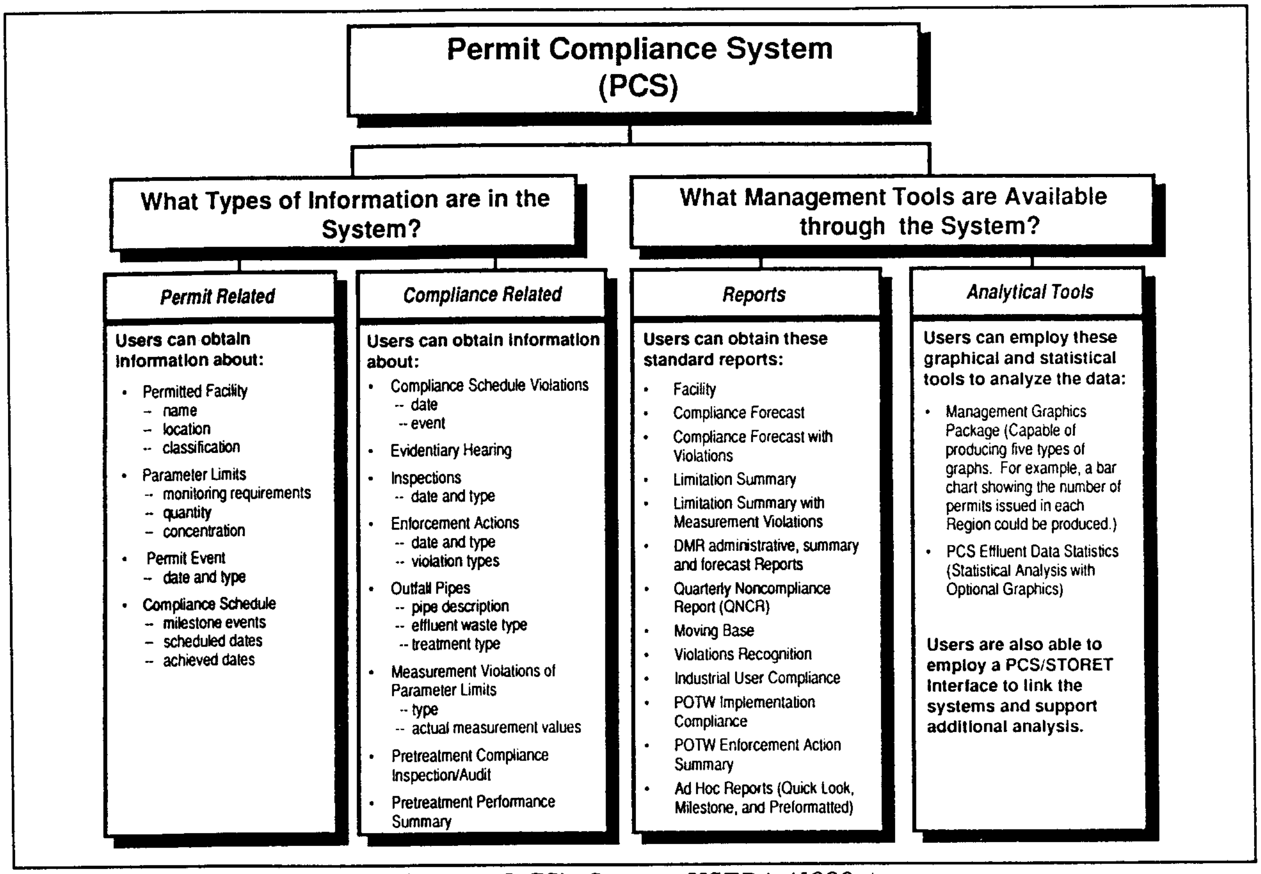

Figure 10. Permit Compliance System (PCS). *Source: USEPA (1990a)*

Waterbody System (WBS)

To assist the USEPA and the states in preparing the water quality assessments every two years as required by Section 305(b) of the Clean Water Act (CWA), the Office of Water Regulations and Standards maintains the Waterbody System (WBS) on the NCC mainframe. WBS was designed as a management tool for agencies preparing water quality assessments by providing a centralized database that improves data consistency and usefulness, and simplifies the preparation of state reports. WBS contains water quality assessment information entered by states, territories, and interstate commissions. These agencies use available monitoring data to prepare summary information that is entered into WBS, but the

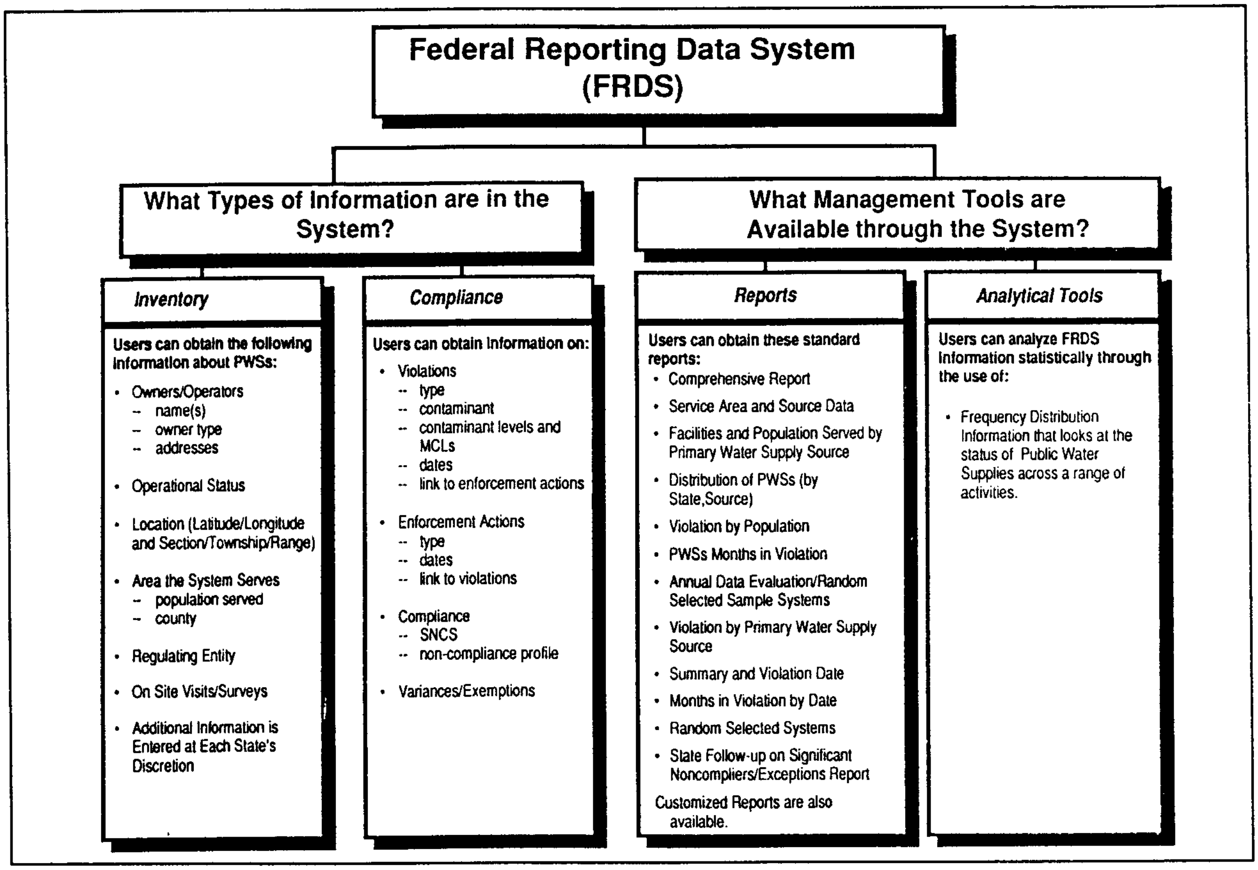

Figure 11. Federal Reporting Data System (FRDS). *Source: USEPA (1990a)*

monitoring data itself is not entered into WBS because the system does not have the capability to store, manipulate, or analyze the raw data (USEPA, 1990a; USEPA, 1991b). States can use a personal computer version of WBS (PC WBS), and can upload the PC WBS information onto the mainframe WBS (EPA WBS Report, 1990). WBS can be linked to STORET with Reach numbers, and to PCS with NPDES permit numbers. Addition and editing of information is restricted to states with approved contracts, although any NCC user can view information and generate reports (USEPA, 1990a).

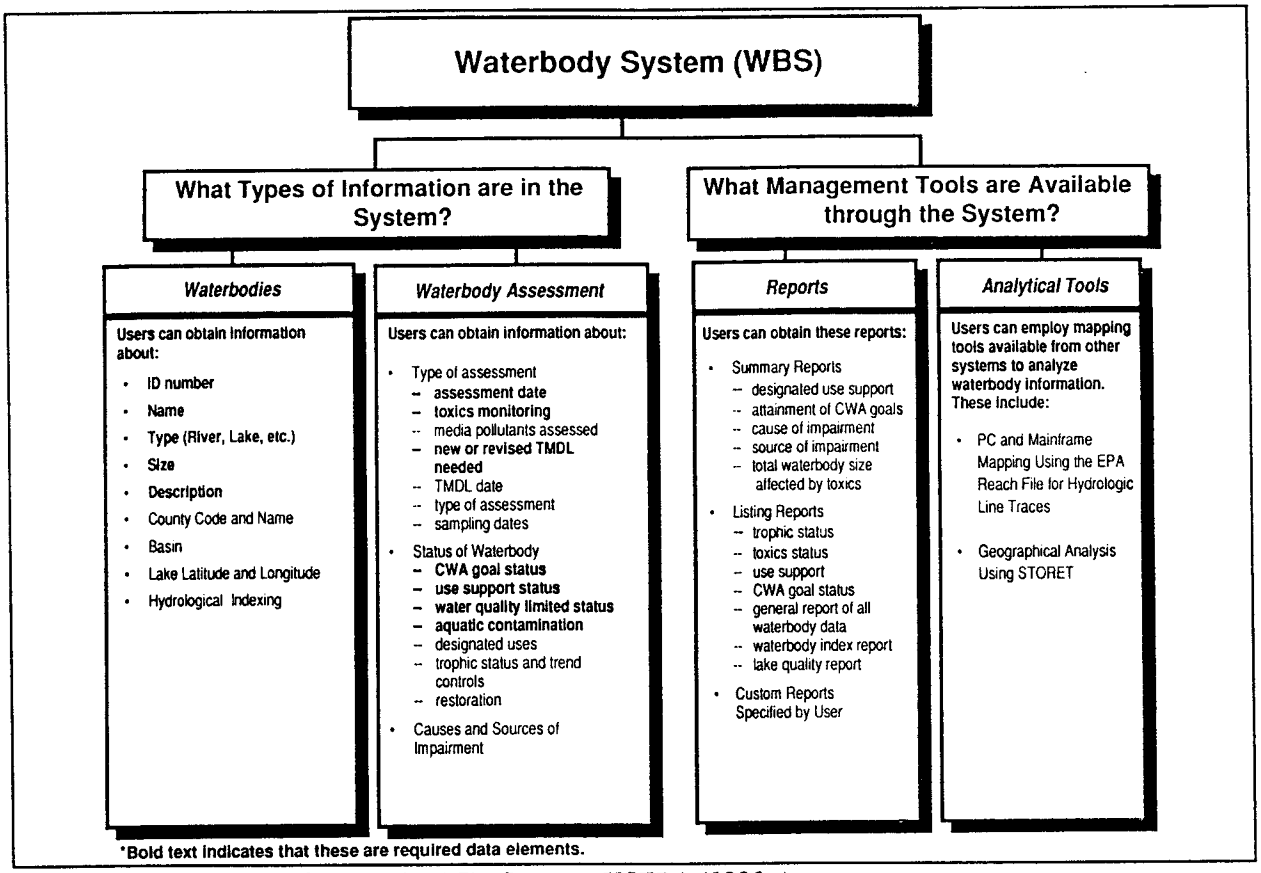

Figure 12. Waterbody System (WBS). *Source: USEPA (1990a)*

STORET/BIOS/ODES Modernization Project

The USEPA is currently modernizing STORET, BIOS, and ODES, its three largest water quality and biological monitoring databases. This modernization will result in a standardization of these databases in order to enhance data integration and information sharing. To assist in defining the functional and data needs of potential users of the database, the USEPA has conducted a series of joint application design sessions. The session participants have defined the following objectives of the STORET/BIOS/ODES modernization:

-- To meet the users' information needs

-- To provide a flexible platform to facilitate data integration and sharing

-- To provide serviceable, maintainable long-term system(s)

-- To enhance system ease of use

-- To provide adequate user training and concise, clear, user-friendly documentation

It is expected that the project will be completed by April 1997 (USEPA, 1992).

USGS Data Management Systems

The U.S. Geological Survey (USGS) is responsible for assessing the quantity and quality of the nation's earth resources (Hirsch, et. al., 1988). The Water Resources Division (WRD) of the USGS is specifically charged with providing information to best use and manage the nation's water resources. To accomplish this goal, the WRD collects and disseminates data, performs interpretive studies and water resources appraisals, and conducts research activities. The USGS maintains three major computerized data management systems to coordinate and disseminate much of the data used by the WRD: the WAter Data STOrage and REtrieval System (WATSTORE), the NAtional Water Data EXchange (NAWDEX), and the National Water Information System (NWIS). Data is also available in the USGS publication series entitled "U.S. Geological Survey Water-Data Reports" which is published by water year for each state (USGS, 1991). In addition, the USGS is in the process of establishing a National Water Information Clearinghouse (NWIC) (Water Fact Sheet).

WATer Data STOrage and REtrieval System (WATSTORE)

The WATer Data STOrage and REtrieval System (WATSTORE) was implemented in 1971 to improve data processing and management procedures. The USGS maintains and operates WATSTORE on its central computer system in Reston, Virginia, and data can be accessed through WRD district offices or through NAWDEX, which is discussed below (Kilpatrick, 1981; Edwards, 1987).

Most of the hydrological data collected by the USGS is stored in WATSTORE in several files and databases. These programs include the Station Header File, Daily Values File, Peak Flow File, Water Quality File, Ground Water Site Inventory, and the Water Use File. These files are shown in Table 3 (Kilpatrick, 1981; USGS).

Table 3. Description of Programs in WATSTORE

Program Name	Description
Station Header File	Indexes all sites for which data are stored by identification, location, and physical description
Daily Values File	Contains all water data parameters measured or observed daily or continually, including river stages, streamflow values, water temperature, specific conductance, sediment concentrations and discharges, etc.
Peak Flow File	Contains annual peak discharge and stage values at surface water sites
Water Quality File	Contains the results of water sample analyses describing the chemical, physical, biological, and radiochemical characteristics of surface and ground waters
Ground Water Site Inventory	Inventories data pertinent to ground water sources such as site location and identification, well construction data, and geohydrologic information
Water Use File	Contains summary data on the nation's water use

WATSTORE allows only limited access to the water quality file. However, this data is periodically transferred to STORET, where users can access the data. Output from WATSTORE can be in the form of tables, graphs, digital plots, statistical analyses, or machine-readable form for use with other computers or programs (Kilpatrick, 1981; USGS).

The water quality data from WATSTORE is also available in Compact Disc-Read Only Memory (CD-ROM) format from EarthInfo, Inc. Data is supplied by the USGS to EarthInfo, where it is sorted and indexed for distribution as the USGS Quality of Water database. Use of the database requires an IBM compatible personal computer and a CD-ROM drive. The database contains 35 station, analysis, and parameter characteristics which can be used to retrieve data. Available export formats include ASCII, dBASE, Lotus, card record, and binary (EarthInfo, 1991a; EarthInfo, 1991b).

NAtional Water Data EXchange (NAWDEX)

In 1971, the Federal Advisory Committee on Water Data presented the design characteristics for a national system to acquire, store, and disseminate water data which resulted in the establishment of the NAtional Water Data EXchange (NAWDEX) in 1976. NAWDEX is a program designed to assist water data users in finding and acquiring needed data and consists of member organizations that are involved with water data. A central Program Office in the WRD manages the NAWDEX system and coordinates the linkage between member organizations to enable the exchange of their water data holdings. Membership is voluntary and cost-free, although a memorandum of understanding is signed with the Program Office regarding the member's commitment to participate in NAWDEX (Edwards, 1987).

NAWDEX itself does not have water data, but it retains an index of the data held by members which is available in two computerized databases on its computer system in Reston, Virginia. The Water Data Sources Directory contains information regarding organizations that collect water data, including their identity, sources within the organization from which data can be obtained, geographic areas, and types of water data collected and available. The second database is the Master Water Data Index which identifies water data collection sites, their geographic location, the data-collecting organization, types of data available, the periods of record, available water data parameters, measurement frequency of the parameters, and the media for data storage. In addition to these databases, NAWDEX has direct access to the USGS' WATSTORE database and the USEPA's STORET system (Edwards, 1987).

To use the computer system, NAWDEX users are required to sign a memorandum of understanding regarding the conditions and fees for its use. Users are charged for the direct costs in fulfilling a data request plus a 5-1/2 percent surcharge (USGS).

National Water Information System (NWIS)

The original WATSTORE database was a centralized system which required a user to access data by dialing up the Amdahl central computer (Dolnack, 1992). In 1983, WATSTORE was supplemented with the National Water Information System-I (NWIS-I), a FORTRAN-based system which operated on PRIME minicomputers that were installed in most WRD offices. NWIS-I consists of a Daily Values File, Ground Water Site Inventory, Water Quality File, and Water Use File, which contain most of the data in WATSTORE. In addition, NWIS-I has a Unit Values File which includes data collected more frequently than daily (Schornick and Paschal, 1991; Yorke and Williams, 1991).

The principal advantage of the newer system is the quicker access to data available to WRD offices. Each office maintains the NWIS-I databases for that district which contains the data they collect. Data from NWIS-I is then transmitted to WATSTORE where it can be accessed by other WRD offices. Thus, users do not have to go to the centralized database to access local information, but retrieval of data from other offices is still accomplished by going through the centralized system (Yorke and Williams, 1991; Dolnack, 1992).

The USGS is in the process of developing and implementing NWIS-II, which should be fully operational by late 1993 (Yorke, 1992a). This single system will integrate WATSTORE, NAWDEX, and NWIS-I, and will provide the functions of the current systems. NWIS-II will also have added capabilities to process and manage additional chemical constituent, sediment, biological, and spatial data (Yorke and Williams, 1991).

The development of NWIS-II has involved the establishment of several organizational groups in the USGS. A Strategic Planning Group was formed in 1988 which consists of senior managers of the WRD. This group determined that software should be completely redesigned and rewritten instead of attempting to upgrade and convert existing software. In addition, the Strategic Planning Group is responsible for determining the scope of the project and approving each phase of the software development and implementation (Yorke and Williams, 1991).

In 1989, User Groups were formed to define user needs regarding data input, computation, storage, and retrieval. Composed of WRD scientists, the eight User Groups address surface water, ground water, water quality, sediment, water use, biology, spatial data, and non-USGS users of NAWDEX. A Quality Assurance and Configuration Management Unit assesses the design and performance of NWIS-II throughout its development and implementation, while a Design and Development Team is responsible for actual software design. The Operations and Management Unit maintains WATSTORE and NWIS-I during NWIS-II development, and will also be responsible for maintaining NWIS-II (Yorke and Williams, 1991).

A feature of the new system will again be a change in user access. Using the relational database INGRES on Data General workstations instead of the PRIME computers, users will have direct access to the databases of each office. The centralized system will eventually be eliminated, although a national archive will be retained on the master computer in Virginia (Yorke, 1992a; Yorke and Williams, 1991).

Table 4 lists some of the proposed components of NWIS-II (Schornick and Paschal, 1991). The network for the system is currently in place, and the databases are in the process of being fitted with the applications software. It is planned to implement the databases in phases, with Phase I scheduled for installation by April 1, 1993. This phase will include discrete data such as water quality, ground water, site, and biological information. Phase II should be installed by October 1, 1993 and will include water use data and continuous and automated data such as streamflow (Yorke, 1992a).

Table 4. Proposed Components of NWIS-II

Component	Information contained
Event data system	Activity records, and party, project and equipment information
Feature system	Describes the feature and its location; includes the capability of defining multiple data collection points; 2- or 3-dimensional grids or 1-dimensional transects can be used to locate sample collection or measurements
Sample collection and processing information	Provides for electronic login and tracking of samples from collection to return of sample values; allows the definition of multiple and varied samples (i.e., regular, replicate, split, or blank) at a feature at any given date or time
Sample and value characterization information	Includes sample type (air, water, sediment, etc.); water form; water salinity; water type (surface, ground, leachate, etc.); sample form; sample weight basis; sediment type; particle diameter and category; lithology; filter pore size; filter composition; sample QA/QC type (regular, blank, replicate, split, matrix spike, surrogate spike); soil type; substrate type; and tissue group
Constituent characterization information	Includes constituent name; IUPAC chemical name; synonyms; chemical abstract service number; general chemical group (nutrients, radiochemicals, general organics, etc.); chemical element/compound group (acids, actinides, calcium, aluminum, etc.); chemical/physical property (acidity, hardness, color, etc.); general physical factors (length, width, volume, etc.); water use type (instream, offstream); water use elements (withdrawal, delivery, release, return flow); water use category (public supply, commercial, irrigation, etc.); water use source (ground surface, transfer, reclaimed); water use extended data (goods produced, population, power production, etc.); water use measurement (meter, reports, pumping totalizer); channel characteristics; stream flow statistics; recurrence interval; frequency distribution; ground water categories (geophysical logs, discharge, hydraulic properties, etc.); biological sample fate (bioassay, biomass, cellular counts, etc.); biological sample description (aquatic invertebrate, bacteria, benthic invertebrate, etc.); biological level (collection, preservation, identification, tracking); and taxonomy

A future application of NWIS-II will be to integrate it with a geographical information system (GIS). The USGS is currently using ARC/INFO, but it is separate from the NWIS data, and retrieved data must be reformatted and then imported into ARC/INFO. The USGS is currently investigating options for selecting the GIS to be contracted for attachment to NWIS (Yorke, 1992b).

National Water Information Clearinghouse (NWIC)

In 1988, the USGS was directed by Congress to investigate the establishment of a national ground water clearinghouse for information dissemination on ground water issues. In the resulting report in 1989, the USGS identified national water information clearinghouse objectives and recommended that both surface and ground water quantity and quality information should be included in clearinghouse activities. The USGS and the Interstate Council on Water Policy subsequently conducted a series of workshops in 1990 and 1991 to solicit input from participants regarding their needs for a national water clearinghouse (Water Fact Sheet).

Currently, the National Water Information Clearinghouse (NWIC) is in the design phase with two pilot centers scheduled to be operational in 1992. Clearinghouse activities include program development, outreach and training, information dissemination, and data systems modernization. In regards to water quality data, the NWIC will incorporate an "easy access" system to improve access to WATSTORE and STORET. 39,000 water quality sites from STORET have been indexed, and their water quality data will be available through the NWIC. In addition, the Clearinghouse will use DIALOG to provide linkages with other water-related databases. Workstations are to be installed throughout the WRD to enhance the Clearinghouse's ability to analyze, access, and publish data (Water Fact Sheet).

Computer Software

The previous discussion has highlighted some nationwide databases that can be used both to store and manipulate water quality data. Many agencies also use commercial software to establish local databases or to analyze data obtained from the national databases. Software used for water quality applications generally includes spreadsheets, databases, statistical programs, water quality models, and geographic information systems.

Spreadsheets

Data storage and retrieval and simple graphical and statistical analyses of water quality data can be performed using spreadsheets. Spreadsheet software simulates a worksheet with columns of numbers by using matrices of rows and columns of cells. Each cell can contain labels, numeric values, or formulas. Labels are descriptive text which do not perform any function, while numeric values are actual data. Formulas contain the commands needed to perform calculations on the numeric values by specifying cells and operators. For example, a formula might say essentially, "This cell TIMES that cell." When numeric data is changed, the formulas can automatically perform recalculations. VisiCalc was the first spreadsheet in 1978, with common spreadsheets now including Lotus and QuattroPro (Ward, et. al., 1990; Freedman, 1991).

Databases

Databases are collections of related data that are created and maintained by database management systems (DBMSs). The software of the DBMS defines, constructs, and manipulates the database to perform desired applications. Because DBMSs have the ability to control storage redundancy, share data, restrict data access and provide for a variety of user interfaces, they are often suitable for environments where a centralized database may be used by a large number of users. DBMSs are generally more costly than traditional file processing software such as spreadsheets and are therefore not recommended if database and application requirements are simple or multiple access to data is not needed (Elmasri and Navethe, 1989). In addition, statistical programs often must be written and graphical capabilities are limited. RBase and dBASE are two commonly-used DBMSs for IBM-compatible systems (Ward, et. al., 1990).

Statistical Software

Another form of computer software frequently used with water quality data are statistical software packages such as the Statistical Analysis System (SAS) and Statistical Package for the Social Sciences (SPSS). Operating on IBM mainframes and VAXs, SAS includes data management, spreadsheets, graphics, statistical quality control, econometric and time series analysis, and mathematical, engineering, and statistical applications. SPSS runs on mainframes, minicomputers, and personal computers and performs statistical processes including regression, correlation, and variance analyses. Although statistical software packages can perform most desired statistical analyses, they are often supplemented with a DBMS to enhance their data management capability (Ward, et. al., 1990; Freedman, 1991).

Water Quality Models

Water quality models are decision-making tools which use mathematical relationships to describe natural processes. Stochastic models incorporate the variability of physical, chemical, and biological processes, while deterministic models are based on mean parameter values (Foree and Tapp, 1977). Models can enhance available monitoring data by providing a means to analyze that data and predict water quality conditions (McCutcheon, 1989).

Several types of data are used in modeling and are important to the usefulness of model results. A set of data describing mass and energy inputs to the model domain is needed to define boundary conditions. Another set of data is required to set initial conditions for dynamic or quasi-dynamic models to define the water quality conditions at the beginning of the simulation period. Calibration data are needed to set the model parameters and are used to compare observed conditions with those predicted by the model. Another independent set of data collected in the same manner as the calibration data are required to validate the model using the calibrated parameters. The actual measured validation data should compare adequately to data generated by the calibrated model (McCutcheon, 1989).

The selection of water quality models and modeling techniques is dependent upon the available data and the ability to collect adequate data to define boundary and initial conditions and to calibrate and validate the model. The usefulness of model results are therefore closely related to monitoring programs and proper data collection procedures (McCutcheon, 1989).

Geographic Information Systems

Geographic information systems (GISs) are computerized information systems that store and utilize spatially referenced data. As such, GISs can be considered as databases of spatial and non-spatial data that are combined with a set of operations for manipulating the data. According to Star and Estes (1990), there are five functional elements to a GIS: data acquisition, preprocessing, data management, manipulation and analysis, and product generation.

Data acquisition, the first and generally costly step of developing a GIS database, involves the identification and gathering of both spatial and non-spatial data (Star and Estes, 1990). Spatial water quality data includes well, point discharge, and stream locations as well as land use and soil types. Attributes such as date of data collection, parameter concentration, analytical method, and information sources are examples of non-spatial data.

Preprocessing procedures such as format conversion, data reduction and generalization, error detection and editing, merging, interpolation, and edge matching may be necessary to enter the gathered data into the GIS (Star and Estes, 1990). In the case of water quality data, unit conversions and STORET code number interpretations are types of preprocessing which may be required.

The functions of data management make the information obtained in the data acquisition and preprocessing phases available to system users while hiding the physical details of storage and retrieval from these users. This is done by creating a structured collection of the information called a database that is managed in a database management system (DBMS). As mentioned earlier, this system must be able to identify the contents of the database and provide data management functions such as the insertion of new data, the deletion of old data, and queries and modifications of existing data. The capability of handling multiple users and databases, maintenance of the independence of the database from the hardware, checks for uniformity of data entries, and minimization of redundancy of the stored data are other important features of the DBMS. Finally, the DBMS must provide security to prevent unauthorized or improper database modification while maintaining access to different kinds of users (Star and Estes, 1990).

Manipulation and analysis involve the analytic operations which work with the database contents to produce new information. In some cases, it may be necessary to link the GIS with another data analysis and processing system, requiring the transport of data from the GIS to the linked external system and back. Some of the procedures which are necessary to manipulate and analyze the data are: reclassification and aggregation; geometric operations such as rotation, translation, scaling, rectification, and registration; centroid determination; data structure conversion; spatial operations regarding connectivity and neighborhood analyses; measurements of distance and direction; statistical analyses including descriptive statistics and regression, correlation, and cross-tabulation; and modeling (Star and Estes, 1990). An example of some functions which a user may wish to have a GIS system perform or aid in performing include (Burrough, 1989):

-- *What is the value of function Z at position X?* This type of analysis would aid in the prediction of contaminant movements in surface and ground waters.

-- *What is the result of intersecting various kinds of spatial data? If necessary, reclassify objects having certain combinations of attributes.* The determination of areas of concern often entail the assessment of a combination of water quality parameters.

-- *What is the path of least cost, resistance, or distance along the ground from X to Y along pathway P?* Hydrologic routing and water facility locating could be accomplished with this type of function.

-- *Using the digital database as a model of the real world, simulate the effect of process P over time T for a given scenario S.* This function would especially aid water quality managers in selecting treatment, remediation, and planning techniques.

The final element of a GIS is product generation, the phase in which final outputs from the GIS are created. These outputs may be in the form of reports, tables, maps, or other graphic outputs and can be "hard copy" outputs such as paper or film products, or "soft copy" outputs such as images on computer displays (Star and Estes, 1990).

GISs basically incorporate raster or vector data structures. Raster data structures are cellular organizations of the spatial data and are referenced in arrays of columns and rows. The size of the raster elements limits geographic specificity because there different locations within a cell cannot be distinguished. Vector data structures, on the other hand, are based on a starting coordinate and an associated displacement and direction, enabling more precise locations of objects (Star and Estes, 1990). An example of a raster GIS is the U.S. Army Corps of Engineers' Geographic Resources Analysis Support System (GRASS), while Environmental Systems Research Institute's ARC/INFO GIS is a widely-used vector-based system.

Geographic Resources Analysis Support System (GRASS)

The Geographic Resources Analysis Support System (GRASS) resulted from pilot land analysis graphics systems begun in 1980 by the U.S. Army Corps of Engineers (USCOE) Environmental Division. This GIS provides the management tools necessary for complex land use planning and management by USCOE land-use planners (Westervelt, et. al., 1986; USCOE, 1991).

GRASS was first publicly released in 1985 and has since gone through several upgrades. A 1989 survey of GRASS users showed that the majority of users were federal agencies, although educational institutions and private firms were also significant users. Since GRASS was developed by the USCOE, it is public-domain software and is available to the public free of charge. While originally designed as a raster-based GIS, digitizing and data input have always been possible with a vector approach. The USCOE is attempting to expand the vector capabilities to develop a vector-based GIS (Goran and Finney, 1991; Westervelt, 1991).

GRASS has more than 300,000 lines of C program code for UNIX machines. It operates in a workstation environment, but can also be used on the Apple MacIntosh and IBM-compatible personal computers with special applications software (Westervelt, 1991).

Version 4.0, released in 1991, contains several sets of commands which can be summarized as shown in Table 5. Display commands manage monitor operations and facilitate data display on the display graphics monitor, including 2-dimensional and 3-dimensional display, profiles, histograms, pie charts, graphs, and screen dumps to hard copy. Raster analysis commands provide traditional raster GIS operations, including overlay (boolean, weighted, cellophane, or rulebase), full mathematical operations, filters, proximity analysis, measurements, clustering, import/export, line-of-sight, cost analysis, transformation to vector, rotation, patching, reclassification, network flow analysis, thinning, and elevation transformations. Vector commands allow limited vector GIS functions such as digitizing, editing, labeling, import/export, topological linking, display, patching, transformation to raster, grid generation, and contour labeling. Imagery commands manipulate multi-spectral images with programs for terrain correction, classification, filtering, and histograms. Site analysis commands provide for the analysis of geographical information through surface generation (interpolation), statistical comparisons, reclassification, transformation to raster and vector, coordinate registration, database searches and retrievals, proximity analysis, and import/export to a statistical package (Westervelt, 1991).

Table 5. Sets of GRASS Commands

Command Prefix	Command Description
g.	General data (file) management commands
d.	Display (monitor) graphics
p.	Paint paper graphics
r.	Raster data manipulation and analysis
v.	Vector data manipulation and analysis
s.	Site data manipulation and analysis
i.	Imagery (multi-spectral) data manipulation and analysis
m.	Manipulation of external data

ARC/INFO

Developed and distributed by the Environmental Systems Research Institute (ESRI), ARC/INFO is a vector-based GIS which is composed of an ARC system to store locational data, and a relational database management system called INFO that stores attribute data. Features are stored in ARC as sets of coordinates, although polygons are stored according to their topological relationships instead of as a series of coordinates to improve data storage efficiency. Attributes of points, arcs, and polygons are stored in attribute tables in the relational database, and the tables can be related to allow the viewing and analysis of a number of attributes at the same time. The ARC and INFO systems are fully integrated, so that data updates in one system can automatically update data in the other. The systems can also be operated independently, allowing the manipulation of only one data set (ESRI, 1989).

ARC/INFO performs six general functions for the user: geographic database generation and management; geographic analysis; geographic database manipulation; database query; graphic display and report generation; and user development and customization. The latter function is accomplished through the ARC Macro Language (AML), a standardized command and macro language that can be used on all hardware environments (ESRI, 1989).

Other software distributed by ESRI can be used to enhance the ARC/INFO system. ARC/INFO NETWORK provides network analysis capabilities for topographically interconnected linear features. Digital terrain modeling functions including cross-sectional and three-dimensional display, generating Thiessen polygons, and watershed determination are available through ARC/INFO Triangulated Irregular Network (TIN). ARC/INFO COGO links coordinate geometry software with GIS. ARC/INFO RDBI allows the integration of relational database systems such as ORACLE and INGRES with the feature attribute table in ARC/INFO (ESRI, 1989).

ARC/INFO is available on workstations and a version called PC ARC/INFO can run on IBM-compatible personal computers (ESRI; ESRI, 1989).

Manual and Other Data Management

Prior to the advent of computers, water quality data gathered from the field or laboratory was recorded on paper or in reports and filed in paper files, cabinets, or shelves (Ward, et. al., 1990). Although computer storage of data is now extremely common, manual data recording and storage still exists and continues to be a method of data management (Grigg, 1985).

Other forms of data management that do not fall into any of the previously-mentioned technologies include microfiche storage, reports, and other documents such as student theses.

Chapter 4. Description of Existing Water Quality Data Management in the United States

The previous discussions have provided a background for the information presented in this chapter. Using the results of a 1991 water quality data management survey undertaken as part of this research, this chapter highlights existing management of water quality data in the United States and its relation to water quality activities and legislation. The survey's implementation and results are presented. In addition, this chapter includes the results of a USEPA survey of drinking water systems and a USGS study on water quality data collection activities in Colorado and Ohio. Data management activities in California, Florida, Utah, and Wyoming are discussed in greater detail at the end of the chapter.

Water Quality Data Management Survey

In gathering available information on water quality data management in the United States, very little literature was located which provided adequate and useful information on current data management activities. The problems with the available literature generally fell into one or both of the following categories:

-- *Discussions of data management were too narrowly focussed.* Most of the literature referred to a specific project or a specific water quality management activity. For example, the Office of Drinking Water of the USEPA did a nationwide survey of information systems in state drinking water agencies, but this survey did not provide any information on other water quality management activities such as NPDES permitting or Superfund monitoring (89). Much of the remaining literature discussed project-specific data management which was a one-time activity. Since the purpose of this thesis was to assess ongoing data management, such information was not useful.

-- *Information was not current.* This was a critical problem with the literature search. Data management is a constantly evolving activity that changes with funding, technology, and need. Because of this, it was assumed that any information more than a few years old was essentially obsolete without verification.

Because of these problems, it was decided to undertake a nationwide water quality data management survey to accomplish the objective of assessing current management applications of water quality data by federal and state governments.

Survey Development

The survey was developed during the spring of 1991. A survey of water quality data needs for small watersheds done by the U.S. Geological Survey in 1979 was consulted to prepare an initial survey format (USGS, 1979). This initial format was modified considerably after review and discussion with faculty at Colorado State University.

The functional goals of the survey were: 1) to solicit enough information about an agency and its activities to enable a useful assessment of data management and its relation to water quality management activities; and 2) to encourage response by being easily filled out within an hour. To achieve these ends, a survey format was developed that was primarily of a "check-off" nature by listing the responses expected to be most common. A fill-in option of "other" was included for most categories of information sought. The advantage of using this format was that it was relatively easy to complete and it gave respondents an idea of the kind of information desired. On the other hand, the listed "check-off" items could bias responses if agencies ignored the "other" option and tried to fit all of their responses into listed categories even if it was inappropriate to do so.

The final survey consisted of a one-and-a-half page legal-sized format with a pre-printed return address that could be folded, stapled, and returned easily. A fax number was given to further increase ease of response, and the cover letter sent with the survey promised respondents a copy of a brief summary of the survey responses if they filled out the agency's name, address, contact person, and telephone number. A copy of this cover letter and a blank final survey form are in Appendix B.

There were six general categories of information regarding water quality data that the survey sought to obtain:

1) *Type of agency:* In general, the survey targeted government agencies because it was ultimately to be used to compare with state agency water quality management in Colorado. Thus, it was desired to classify respondents as federal agencies, state agencies, or other agencies. For the purposes of this survey, federal and state agencies were funded by the U.S. government or by the corresponding state respectively. All other organizations were considered "other" agencies, including educational institutions, private organizations, and local government agencies such as municipalities, counties, and regional agencies. A direct question to solicit this information was not included on the survey, so this categorization was generally accomplished using the agency name (i.e., *Florida Department of Environmental Regulation* was categorized as a *state agency*). Personal contact was made with some agencies if their type could not be discerned from the agency name.

2) *Type of water quality involvement:* Because ground water management and issues are often considerably different from surface water activities, it was anticipated that responsibilities for these activities might be divided into separate sections of an agency or even into separate agencies. It was also expected that data management activities could be very different for surface and ground water data. The first question on the survey therefore asked respondents to distinguish the type of water quality their agency was involved with: ground water, surface water, or other water quality. Clarification was requested if "other water quality" was indicated. Subsequent questions on the survey had three columns for responses so that one form could be used to fill out an agency's activities in all three classes while still distinguishing between activities which involved each type of water quality.

3) *Description of data storage and management:* Since this was the central theme of the research and the survey, the first section of the body of the survey solicited information about both software and hardware components of data storage and management. National databases which were expected to be in common usage for water quality data were the USEPA's STORET database and the USGS WATSTORE database. Use of the USGS' NWIS system was classified as WATSTORE.

The survey also separated out geographic information systems (GISs) as a category of software for data management because of its unique ability to combine spatial data with relational databases. ARC/INFO and GRASS were selected as "check-off" GISs, although it was not certain what GIS systems would be in common use because of the large variety of systems available and the relatively recent introduction of GIS applications in water quality management. However, since both ARC/INFO and GRASS have been functional GISs for at least ten years, it was expected that some agencies might be using these systems. For agencies using other GISs, there was an "Other" option which asked respondents to specify the GIS being used.

The next category of software was "other computerized software," which was to include any computerized software that did not fall under the previous three categories (i.e., STORET, WATSTORE, or GIS). It was anticipated that agencies would be using database and/or spreadsheet software to manage water quality data, so four "check-off" items were listed: dBASE and RBase, two database systems; and Lotus and QuattroPro, two spreadsheet systems. Again, an "other" option was available with a request for specification of the computerized system.

A "check-off" option for manual data management was listed to include data that is not stored in a computerized fashion, but is stored in files or cabinets. An "other" category for any data management systems that did not fall under any of the software or manual systems followed.

The next section asked respondents to describe the hardware used by their agency for water quality data management. Hardware was broken into four classifications: personal computers, mainframes, minicomputers or workstations, and other computers. Under personal computers, it was expected that most agencies would be using either IBM-compatible machines or MacIntosh computers. The mainframe and minicomputer or workstation hardware was expected to vary because of the large number of different systems available. Thus, the mainframe category listed only IBM mainframes and an "other" option, while the minicomputer or workstation category listed VAX and an "other" option. Again, specification was requested in all of the "other" classifications.

4) *Type of activities involving water quality data:* As discussed previously, there are a wide variety of activities involving water quality data that can be performed by an agency. Chapter 2 discussed legislation which can involve water quality data, and these activities were accounted for in the survey under subcategories of "Federal Standards Compliance" and "State Standards Compliance." Federal standards compliance activities included activities associated with the Clean Water Act (CWA), Safe Drinking Water Act (SDWA), National Environmental Policy Act (NEPA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Surface Mining Control and Reclamation Act (SMCRA). As noted in the discussion of the CWA in Chapter 2, there are many sections of the act which involve water quality data. Rather than list all of them, National Pollutant Discharge Elimination System (NPDES) permitting was specified with an "Other (please specify)" option. The SDWA was also broken into two options: federal drinking water standards, and other activities involving SDWA. At the end of the federal standards compliance list was an "other" option for any federal regulations not listed.

Since state standards could vary considerably between states, the state standards compliance activities included only wellhead protection programs, state drinking water standards, and other state activities not listed. Again, specification of the "other state activities" was requested.

Aside from complying with regulations, water quality data management can be performed in association with research and development activities. These activities were classified as follows: baseline or trend analysis, model development and verification, cause and effect studies, best management practice (BMP) assessments, public inquiries, project management, and other research and development activities.

To assess the importance of activities that agencies were responsible for, respondents were asked to rank the activities they were involved with in order of importance, with a "1" indicating the most important activity.

5) *Types of data used:* Because of the variety of activities which could involve agencies and the different management policies that these agencies could operate under, the data types used to manage water quality could also be highly variable. The types of data used could also affect the way the data is managed. Therefore, a section of the survey was devoted to ascertaining what types of water quality data were used by responding agencies. Data types were broken into the following classifications: discharge; temperature; pH; dissolved oxygen; major cations such as calcium, magnesium, sodium, etc.; nitrogen; phosphorus; suspended sediments or solids; biological oxygen demand (BOD) or chemical oxygen demand (COD); trace metals; pesticides and herbicides; volatile organic compounds (VOCs); bacteriological or viral; chlorophyll a or algae; radiological; and other data types.

It was also expected that, while agencies might collect a wide variety of data, certain data types would be essential to their activities and responsibilities. Respondents were therefore asked to rank the data types used in order of importance, with a "1" indicating the most important data type.

6) *Sources of data and interagency activities:* Although it was likely that many of the agencies would collect their own water quality data, this section of the survey sought to ascertain how frequently data was shared and integrated between agencies and other organizations. The first question asked respondents where they got their data from, with the following "check-off" options: the agency collects the data itself; data comes from private sources such as private

organizations and laboratories; data comes from HYDATA, a USGS publication; data comes from other agencies; data is obtained from STORET; data is obtained from WATSTORE; and data is obtained from other sources, with specification of the sources requested.

Two "yes or no" questions followed designed to assess the extent that the agency's data was used by others, and whether or not agencies had developed cooperative agreements for exchanging water quality data and information.

Once the survey was developed, a nationwide mailing list was needed of agencies that are involved with water quality. One mailing list of 198 names was obtained from the Office of Regulations and Standards of the USEPA. The Environmental Affairs Program of the Water Resources Division of the USGS provided a second mailing list of 462 names in dBASE format from the NAWDEX database. Both of these mailing lists were entered into dBASE IV so that mailing labels could be generated and responses compiled. Because there was some duplication of names on the two mailing lists, it is estimated that approximately 600 surveys were sent out in April and May of 1991.

Data Analysis

Responses to the survey were received throughout the summer of 1991. To organize these responses and facilitate later analysis, the dBASE format was expanded to include fields for all questions on the survey. The fields of the expanded database are shown in Table 6 along with their characteristics.

As surveys were returned, their responses were entered in the database. Several judgements were made in entering information into the database and are discussed below:

Table 6. Summary of Fields in Survey Database

Field	Field Name	Field Description	Type	Width
1	NWDX_AGCY	Code for NAWDEX	Character	5
2	AGENCY	Principal agency name	Character	40
3	DEPARTMENT	Secondary agency name	Character	40
4	FIRSTNAME	First name of contact person	Character	15
5	LASTNAME	Last name of contact person	Character	25
6	POSITION	Position held by contact person	Character	40
7	ADDRESS	Agency address (street)	Character	40
8	CITY	Agency address (city)	Character	20
9	STATE	Agency address (state)	Character	2
10	ZIPCODE	Agency address (zip code)	Character	10
11	TELEPHONE	Telephone number of contact person	Character	12
12	RESPONSE	Tracked survey responses	Logical	1
13	SUMMARY	Tracked agencies requesting a summary	Logical	1
14	STATE_AGCY	Sorted state agencies	Logical	1
15	FEDL_AGCY	Sorted federal agencies	Logical	1
16	EDUC_INST	Sorted educational institutions	Logical	1
17	OTHER_AGCY	Sorted other agencies	Logical	1
18	SURF_WTR	Indicated involvement with surface water	Logical	1
19	GRND_WTR	Indicated involvement with ground water	Logical	1
20	OTHER_WTR	Specified other water quality involvement	Character	30
21	STORET	Indicated data management using STORET	Logical	1
22	WATSTORE	Indicated data management using WATSTORE	Logical	1
23	GIS	Specified GIS used to manage data	Character	40
24	COMP_SWARE	Specified other computer software used to manage data	Character	40
25	MANUAL	Indicated manual data management	Logical	1
26	OTHER_MGMT	Specified other data management	Character	40
27	PC	Specified personal computers used to manage data	Character	40
28	MAINFRAME	Specified mainframe computers used to manage data	Character	40
29	MINI_WORK	Specified minicomputers/workstations used to manage data	Character	40
30	OTHER_COMP	Specified other computers used to manage data	Character	40
31	NPDES	Indicated involvement in NPDES permitting	Logical	1
32	OTHER_CWA	Specified involvement in other Clean Water Act activities	Character	40
33	FDWS	Indicated involvement in federal drinking water standards	Logical	1
34	OTHER_SDWA	Specified involvement in other Safe Drinking Water Act activities	Character	40
35	NEPA	Indicated involvement in NEPA	Logical	1
36	RCRA	Indicated involvement in RCRA	Logical	1
37	CERCLA	Indicated involvement in CERCLA	Logical	1
38	SMCRA	Indicated involvement in SMCRA	Logical	1
39	OTHER_FED	Specified involvement in other federal regulations	Character	40
40	WELLHEAD	Indicated involvement in wellhead protection activities	Logical	1
41	SDWS	Indicated involvement in state drinking water standards	Logical	1
42	OTHER_STAT	Specified involvement in other state regulations	Character	40
43	BASE_TREND	Indicated involvement in baseline/trend analyses	Logical	1
44	MODEL_DEV	Indicated involvement in model development and verification	Logical	1
45	CAUSE_EFF	Indicated involvement in cause/effect studies	Logical	1
46	BMP_EFF	Indicated involvement in BMP effectiveness studies	Logical	1
47	PUBLIC_INQ	Indicated involvement in public inquiries	Logical	1
48	PROJ_MGMT	Indicated involvement in project management activities	Logical	1
49	OTHER_RD	Specified involvement in other research/development activities	Character	40
50	DISCHARGE	Indicated use of discharge data	Numeric	1
51	TEMPERATUR	Indicated use of temperature data	Numeric	1
52	PH	Indicated use of pH data	Numeric	1
53	DO	Indicated use of dissolved oxygen data	Numeric	1
54	MAJ_CATION	Indicated use of major cations data	Numeric	1
55	NITROGEN	Indicated use of nitrogen data	Numeric	1
56	PHOSPHORUS	Indicated use of phosphorus data	Numeric	1
57	S_SED_SOL	Indicated use of suspended sediment/solids data	Numeric	1
58	BOD_COD	Indicated use of BOD/COD data	Numeric	1
59	TRACE_MET	Indicated use of trace metals data	Numeric	1
60	PEST_HERB	Indicated use of pesticides/herbicides data	Numeric	1
61	VOCS	Indicated use of volatile organic compounds data	Numeric	1
62	BACTI_VIR	Indicated use of bacteriological/viral data	Numeric	1
63	CHLOROPHYL	Indicated use of chlorophyll a or algae data	Numeric	1
64	RADIOLOGIC	Indicated use of radiological data	Numeric	1
65	OTHER_TYPE	Specified use of other data types	Character	40
66	AGENCY_COL	Indicated agency collected data itself	Logical	1
67	PRIV_SOURC	Indicated agency got data from private sources	Logical	1
68	HYDATA	Indicated agency got data from HYDATA	Logical	1
69	OTHR_AGCYS	Indicated agency got data from other agencies	Logical	1
70	STORET_SRC	Indicated agency got data from STORET	Logical	1
71	WATSTO_SRC	Indicated agency got data from WATSTORE	Logical	1
72	OTHER_SRC	Specified other sources of data	Character	40
73	UTILIZE	Indicated agency's data was used by others	Logical	1
74	COOP_AGREE	Indicated agency had cooperative agreements for sharing data	Logical	1

-- Agencies involved with more than one type of water quality (i.e., surface, ground, or other) were entered into the database with a record for each type of water quality. However, multiple responses from different people at the same agency regarding the same water quality type were consolidated into one record. Thus, each responding agency had at least one record and not more than three in the database.

When consolidating responses, all "check-off" items indicated by any of the agency's respondents were correspondingly given a logical "Y" entry in the database, and any numerical rankings were averaged between respondents.

-- Each region or district of an agency was considered a separate agency. Thus, each forest of the U.S. Forest Service that responded to the survey had a separate record in the database, as did each regional office of the USGS Water Resources Divisions.

-- Several agencies listed "drinking water" in the "other" category of water quality type. Since all of these agencies also indicated involvement in surface or ground water quality or both, it was assumed that drinking water supplies fell into one or both of those categories as well. Responses in the "drinking water" column were therefore consolidated with the responses in the surface and/or ground water columns.

-- It was assumed that all computer hardware used by agencies could be classified as personal computers, mainframe computers, or minicomputers and workstations. Agencies indicating use of "other computers" were contacted by telephone to ascertain which of these computer categories best characterized the hardware. For example, several agencies listed Local Area Networks (LANs) under "other computers," which were reclassified as workstations.

-- Ranking information for the water quality management activities and data types used was disregarded in the final analysis of the survey information, although a relative ranking was entered into the database for the "Types of Data Used" responses. Several valid comments were received with the surveys about the difficulty of ranking the importance of water quality activities and data due to the multitude and variety of projects that an agency might be involved with. For many agencies, it is conceivable that all data types or activities could be high priority at some time for some project and low priority at some time for another project.

Data types used by agencies were entered into the database with a ranking scale of 0-3. A "1" indicated the most important data used by an agency, and a "3" indicated the least important data. A "0" referred to data that was not used at all by the agency. If an agency listed numerical values outside of this range, the range was divided into thirds, and all data within the first third were assigned a "1." For example, if an agency ranked 12 data types from 1 to 12, the data types ranked by the agency as 1, 2, 3, and 4, were assigned values of "1" in the database. Agency values of 5, 6, 7, and 8, were assigned a "2," and the other four data types were given values of "3." All other data types were assigned a "0" because the agency did not indicate that it used the data.

In the final analysis, the database was merely searched for those data types that were used by agencies by eliminating all records with "0" entries for a particular data type and counting the remaining records. Thus, the importance ranking was not used.

-- Although the database was set up to distinguish educational institutions as an agency type, these organizations were incorporated into the "other agency" type for analysis purposes. This was done because the number of educational institutions was small compared to federal and state agencies, but comparable to the number of agencies listed under "other agencies."

-- In the section regarding data types used, a number of agencies listed one or more kinds of data under the "Other (please specify)" option. Some of these data fit into one of the other categories of data types for the purposes of this survey. For example, discharge data included flow and water level measurements. All nitrogen analyses including nitrates, nitrites, and ammonia were classified as nitrogen, and the phosphorus category included orthophosphorus data. Turbidity and bedload analyses were classified as suspended sediment and solids data. Trace metals included cyanide and major anions, while calcium, magnesium, sodium, and potassium were considered to be major cations.

-- Data management is a constantly evolving process. Several agencies noted that their data management systems were in the process of being changed, or changes were planned. If computer or software types were specified in the notation, they were included in the database as if the system were in place. A comment was added to the database to record the development status of the item. Where types were not specified, the system was classified in the "Other" category. For example, an agency indicating it would acquire a minicomputer in the near future but not specifying what the brand name was would be counted as using "Other minicomputers."

To analyze the data, the dBASE software was used to manipulate the database. A general analysis of the database was completed in October 1991 which provided an overall summary of the survey that was sent to survey respondents. A more detailed analysis of water quality activities and their relation to water quality data was also performed using the data generated by the general investigation. Although the results of this analysis are not pertinent to the conclusions of this thesis, the data is of potential use to water quality agencies. Therefore, a discussion of the analysis has been included in Appendix C.

The master database was first sorted by water quality type to create three files:

SURFACE	Contained all agencies involved with surface water quality
GROUNDWTR	Contained all agencies involved with ground water quality
OTHERWTR	Contained all agencies involved with other water quality

Each of these files was then sorted into the 53 files shown in Table 7 to create a total of 163 files (159 subfiles, SURFACE, GROUNDWTR, OTHERWTR, and the master file). A short dBASE program called COUNT was written that could be run on the subfiles to "count" the number of federal agencies, state agencies, other agencies, and educational institutions. This information was placed in a spreadsheet and used to generate the tables found later in this chapter.

General Summary of Survey Results

Of the approximately 600 surveys sent out, 226 surveys were returned. Although follow-up telephone calls were made to about one-third of the responders to clarify and verify responses, eight of the returned surveys were still unusable due to incompleteness and difficulty of contacting the responding parties. These responses have not been included in the analysis of the survey.

The 218 usable surveys consisted of responses from a total of 200 agencies in 48 states, one territory, and the District of Columbia. Table 8 contains a summary by state or territory of the number of responding agencies, and a list of the agencies by state is in Appendix D.

189 of the 200 responding agencies reported that they were involved with surface water quality, while 144 of the 200 agencies work with ground water quality. "Other" water quality, or water quality activities that did not fall under the general surface or ground water classifications, involved 36 of the

Table 7. Subfiles Created For the General and Detailed Survey Analyses

Name of Subfile*	Field Sorted On	Description of Contents
Data Management System Subfiles (30 Files)		
STORETS, STORETG, STORETO	STORET	All agencies managing data with STORET
WATSS, WATSG, WATSO	WATSTORE	All agencies managing data with WATSTORE
GISS, GISG, GISO	GIS	All agencies managing data with geographic information systems
COMPS, COMPG, COMPO	COMP_SWARE	All agencies managing data with other computer software
MANUALS, MANUALG, MANUALO	MANUAL	All agencies managing data manually
OMGMTS, OMGMTG, OMGMTO	OTHER_MGMT	All agencies using other data management systems
PCS, PCG, PCO	PC	All agencies using personal computers
MFS, MFG, MFO	MAINFRAME	All agencies using mainframe computers
MINIS, MINIG, MINIO	MINI_WORK	All agencies using minicomputers or workstations
OCOMPS, OCOMPG, OCOMPO	OTHER_COMP	All agencies using other computers
Water Quality Activities Subfiles (57 Files)		
NPDESS, NPDESG, NPDESO	NPDES	All agencies involved with NPDES permitting
OCWAS, OCWAG, OCWAO	OTHER_CWA	All agencies involved with other Clean Water Act activities
FDWSS, FDWSG, FDWSO	FDWS	All agencies involved with federal drinking water standards
OSDWAS, OSDWAG, OSDWAO	OTHER_SDWA	All agencies involved with other Safe Drinking Water Act activities
NEPAS, NEPAG, NEPAO	NEPA	All agencies involved with NEPA activities
RCRAS, RCRAG, RCRAO	RCRA	All agencies involved with RCRA activities
CERCLAS, CERCLAG, CERCLAO	CERCLA	All agencies involved with CERCLA activities
SMCRAS, SMCRAG, SMCRAO	SMCRA	All agencies involved with SMCRA activities
OFEDS, OFEDG, OFEDO	OTHER_FED	All agencies involved with other federal regulations
WELLS, WELLG, WELLO	WELLHEAD	All agencies involved with wellhead protection activities
SDWSS, SDWSG, SDWSO	SDWS	All agencies involved with state drinking water standards
OSTATS, OSTATG, OSTATO	OTHER_STAT	All agencies involved with other state regulations
BTRENDS, BTRENDG, BTRENDO	BASE_TREND	All agencies involved with baseline/trend analyses
MODELS, MODELG, MODELO	MODEL_DEV	All agencies involved with model development and verification
CAUSES, CAUSEG, CAUSEO	CAUSE_EFF	All agencies involved with cause/effect studies
BMPS, BMPG, BMPO	BMP_EFF	All agencies involved with BMP effectiveness assessments
PUBLICS, PUBLICG, PUBLICO	PUBLIC_INQ	All agencies involved with public inquiries activities
PROJS, PROJG, PROJO	PROJ_MGMT	All agencies involved with project management activities
ORDS, ORDG, ORDO	OTHER_RD	All agencies involved with other research and development activities
Data Types Used Subfiles (48 Files)		
DISCHS, DISCHG, DISCHO	DISCHARGE	All agencies using discharge data
TEMPS, TEMPG, TEMPO	TEMPERATUR	All agencies using temperature data
PHS, PHG, PHO	PH	All agencies using pH data
DOS, DOG, DOO	DO	All agencies using dissolved oxygen data
MAJCATS, MAJCATG, MAJCATO	MAJ_CATION	All agencies using major cations data
NITROS, NITROG, NITROO	NITROGEN	All agencies using nitrogen data
PHOSPHS, PHOSPHG, PHOSPHO	PHOSPHORUS	All agencies using phosphorus data
SUSPS, SUSPG, SUSPO	S_SED_SOL	All agencies using suspended sediment/solids data
BODS, BODG, BODO	BOD_COD	All agencies using BOD or COD data
TRACES, TRACEG, TRACEO	TRACE_MET	All agencies using trace metals data
PESTS, PESTG, PESTO	PEST_HERB	All agencies using pesticides or herbicides data
VOCS, VOCG, VOCO	VOCS	All agencies using VOCs data
BACTIS, BACTIG, BACTIO	BACTI_VIR	All agencies using bacteriological or viral data
CHLOROS, CHLOROG, CHLOROO	CHLOROPHYL	All agencies using chlorophyll a or algae data
RADIOS, RADIOG, RADIOO	RADIOLOGIC	All agencies using radiological data
ODATAS, ODATAG, ODATAO	OTHER_TYPE	All agencies using other data types
Sources of Data Subfiles (18 Files)		
AGENCYS, AGENCYG, AGENCYO	AGENCY_COL	All agencies that collect data themselves
PRIVS, PRIVG, PRIVO	PRIV_SOURC	All agencies that get data from private sources
HYDATAS, HYDATAG, HYDATAO	HYDATA	All agencies that get data from HYDATA
OAGCYS, OAGCYG, OAGCYO	OTHR_AGCYS	All agencies that get data from other agencies
STORS, STORG, STORO	STORET_SRC	All agencies that get data from STORET
WATSTOS, WATSTOG, WATSTOO	WATSTO_SRC	All agencies that get data from WATSTORE
OSRCS, OSRCG, OSRCO	OTHER_SRC	All agencies that get data from other sources
Interagency Activity Subfiles (6 Files)		
UTILS, UTILG, UTILO	UTILIZE	All agencies whose data is used by others
COOPS, COOPG, COOPO	COOP_AGREE	All agencies that use cooperative agreements for sharing data

* The last letter of each subfile name corresponds with the water quality type (i.e., "S" for surface water, "G" for ground water, or "O" for other water)

Table 8. Summary of Responding Agencies by State or Territory

State	Federal Agencies	State Agencies	Other Agencies	Total Agencies	State	Federal Agencies	State Agencies	Other Agencies	Total Agencies
Alabama	0	0	0	0	Montana	3	1	0	4
Alaska	4	0	3	7	Nebraska	1	1	4	6
Arizona	5	4	1	10	Nevada	2	1	0	3
Arkansas	0	2	0	2	New Hampshire	0	1	0	1
California	2	11	19	32	New Jersey	1	1	2	4
Colorado	2	3	3	8	New Mexico	4	0	0	4
Connecticut	0	1	0	1	New York	1	1	1	3
Delaware	0	0	0	0	North Carolina	1	1	0	2
Distr. of Columbia	2	1	0	3	North Dakota	1	1	0	2
Florida	2	1	6	9	Ohio	2	3	0	5
Georgia	2	0	0	2	Oklahoma	0	1	0	1
Hawaii	1	1	2	4	Oregon	1	0	4	5
Idaho	3	1	0	4	Pennsylvania	0	2	2	4
Illinois	1	2	0	3	Puerto Rico	0	2	0	2
Indiana	0	1	0	1	Rhode Island	0	2	0	2
Iowa	1	1	0	2	South Carolina	2	2	1	5
Kansas	0	2	1	3	South Dakota	2	1	0	3
Kentucky	0	1	0	1	Tennessee	1	1	0	2
Louisiana	2	1	0	3	Texas	2	3	2	7
Maine	0	3	1	4	Utah	3	1	0	4
Maryland	1	3	1	5	Vermont	0	1	1	2
Massachusetts	0	2	0	2	Virginia	1	1	0	2
Michigan	0	1	1	2	Washington	1	1	2	4
Minnesota	0	3	1	4	West Virginia	1	1	0	2
Mississippi	1	1	0	2	Wisconsin	0	1	2	3
Missouri	0	1	0	1	Wyoming	2	0	1	3

agencies. Included in this category were atmospheric and precipitation water quality, marine and estuary quality, stormwater and wastewater effluent quality, biological assessments, and leachate water quality at landfills.

Responses were also broken down according to agency type. Table 9 shows a breakdown of the responding agencies by agency type and kind of water quality data involvement. Subsequent information in Tables 10, 13, and 17 through 25 give percentages of these numbers of agencies that indicated positive responses to survey questions. It should be noted that the summation of percentages vertically in a table will not necessarily add up to 100 percent because agencies often selected more than one option.

Table 9. Summary of Responding Agencies by Agency Type and Water Quality Type

Water Quality Type	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface Water Quality	60	74	55	189
Ground Water Quality	45	57	42	144
Other Water Quality	12	15	9	36

Data Management Systems

The data management systems listed in Table 10 are displayed in order of the highest percentage of use according to water quality type and agency type. WATSTORE was used more by federal agencies than STORET for data management, while state agencies used STORET more than WATSTORE. This result was anticipated, since most of the federal agencies were contacted through the USGS NAWDEX mailing list, which would make them likely candidates for using a USGS system. The USEPA mailing list, on the other hand, was almost exclusively state and other agencies, and by the same reasoning, these agencies would be likely to be using a USEPA database system.

Telephone contact was made with most of the agencies using geographic information systems to ascertain how many of these agencies were actually using GIS as an ongoing database. In general, agencies were using GIS for special projects and studies, but almost all agencies had plans for eventually using the GIS as a long-range database. Of the agencies using GIS, ARC/INFO was the most widely used, especially by state and federal agencies. Other GISs being used included SPANS, GRASS, MOSS, and in-house developed software. Table 11 shows the percentages of agencies using GIS that were using the different types of systems.

Table 10. Summary of Data Management Systems Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
WATSTORE	57%	Other comp software	92%	Other comp software	80%	Other comp software	75%
Manual Files	52%	STORET	73%	Manual files	65%	Manual files	59%
GIS	50%	Manual files	59%	GIS	24%	STORET	50%
STORET	48%	GIS	39%	STORET	22%	GIS	38%
Other comp software	46%	WATSTORE	26%	WATSTORE	15%	WATSTORE	32%
Other mgmt systems	2%	Other mgmt systems	1%	Other mgmt systems	4%	Other mgmt systems	2%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
WATSTORE	73%	Other comp software	79%	Other comp software	81%	Other comp software	67%
GIS	60%	Manual files	54%	Manual files	57%	Manual files	53%
Manual files	49%	STORET	47%	GIS	26%	GIS	44%
Other comp software	38%	GIS	44%	STORET	17%	WATSTORE	36%
STORET	27%	WATSTORE	26%	WATSTORE	10%	STORET	32%
Other mgmt systems	2%	Other mgmt systems	4%	Other mgmt systems	2%	Other mgmt systems	3%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Other comp software	50%	Other comp software	73%	Other comp software	78%	Other comp software	69%
WATSTORE	50%	Manual files	60%	Manual files	67%	Manual files	56%
GIS	50%	STORET	40%	STORET	0%	GIS	25%
Manual files	42%	GIS	20%	WATSTORE	0%	STORET	22%
STORET	17%	WATSTORE	0%	GIS	0%	WATSTORE	17%
Other mgmt systems	0%	Other mgmt systems	0%	Other mgmt systems	0%	Other mgmt systems	0%

As can be seen in Table 10, many agencies used computer software other than WATSTORE, STORET, and GISs to manage data. Generally, the most common database software was dBASE, and the most widely-used spreadsheet program was Lotus. Table 12 lists the most-used computer software as a percentage of the total agencies using computer software.

A large number of agencies continue to maintain data manually. Most agencies also had computerized systems, but 22 agencies listed manual data management as their only form of managing water quality data. Other data management systems not listed in the survey were used by a small number of agencies and included microfiche and microfilm storage, reports, studies, and theses.

Table 11. Summary of Geographic Information Systems Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
ARC/INFO	90%	ARC/INFO	90%	ARC/INFO	54%	ARC/INFO	83%
MOSS	10%	GRASS	10%	Other GIS	46%	Other GIS	11%
GRASS	3%	Other GIS	7%	GRASS	8%	GRASS	7%
SPANS	0%	SPANS	0%	SPANS	8%	MOSS	4%
Other GIS	0%	MOSS	0%	MOSS	0%	SPANS	1%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
ARC/INFO	96%	ARC/INFO	100%	ARC/INFO	64%	ARC/INFO	92%
GRASS	4%	GRASS	8%	Other GIS	36%	GRASS	6%
MOSS	4%	MOSS	0%	GRASS	9%	Other GIS	6%
SPANS	0%	SPANS	0%	SPANS	9%	MOSS	2%
Other GIS	0%	Other GIS	0%	MOSS	0%	SPANS	2%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
ARC/INFO	100%	ARC/INFO	100%	ARC/INFO	0%	ARC/INFO	100%

Note 1. Percentages shown are percent of agencies using geographic information systems (GISs).
Note 2. Table only shows GIS that was used by at least one agency type in each category of water quality.

Computers

Table 13 summarizes the agency responses regarding computer types used according to water quality type and agency type. The lists are shown in order of highest percentage of use.

Personal computers were used by most agencies. IBM or IBM-compatible computers were the most-commonly used type of personal computer, as can be seen in Table 14. Interestingly, almost all of the agencies using MacIntosh computers were also using IBM-compatibles. Only 4 agencies indicated they were using only MacIntosh personal computers, while over 100 agencies were only using IBM-compatible personal computers.

The types of mainframe computers used was widely varied and are shown in Table 15. Over half of the agencies using mainframes were using IBMs. 65 percent of the agencies using IBM mainframes were also using the USEPA's STORET, which is centralized on an IBM mainframe computer. In

Table 12. Summary of Other Computer Software Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Other software	39%	dBASE	72%	Lotus	50%	dBASE	55%
dBASE	36%	Lotus	60%	Other software	43%	Lotus	47%
QuattroPro	14%	Other software	26%	dBASE	41%	Other software	34%
Lotus	11%	QuattroPro	16%	QuattroPro	25%	QuattroPro	19%
Oracle	11%	RBase	13%	RBase	9%	RBase	10%
SAS	7%	SAS	6%	SAS	7%	SAS	6%
Ingres	7%	Reflex	3%	Paradox	7%	Oracle	5%
RBase	4%	Oracle	3%	Oracle	5%	Paradox	3%
Reflex	0%	Paradox	1%	Reflex	0%	Ingres	2%
Paradox	0%	Ingres	1%	Ingres	0%	Reflex	1%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Other software	47%	dBASE	60%	Lotus	41%	dBase	46%
dBASE	29%	Lotus	51%	dBASE	35%	Lotus	43%
Lotus	24%	Other software	33%	Other software	32%	Other software	35%
Oracle	12%	RBase	9%	QuattroPro	24%	QuattroPro	13%
Ingres	12%	QuattroPro	9%	RBase	12%	RBase	8%
SAS	6%	Oracle	4%	Paradox	9%	Oracle	5%
RBase	0%	SAS	2%	Oracle	3%	Paradox	4%
QuattroPro	0%	Paradox	2%	SAS	3%	SAS	3%
Paradox	0%	Ingres	2%	Ingres	0%	Ingres	3%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Other software	67%	Lotus	50%	dBASE	43%	Other software	43%
dBase	17%	dBase	40%	Lotus	43%	Lotus	39%
Lotus	17%	RBase	40%	Other software	43%	dBASE	35%
SAS	17%	Other software	30%	RBase	14%	RBase	22%
RBase	0%	QuattroPro	10%	SAS	14%	SAS	13%
QuattroPro	0%	SAS	10%	QuattroPro	0%	QuattroPro	4%

Note 1. Percentages shown are percent of agencies using other computer software.
Note 2. Table only shows software which was used by at least one agency type in each category of water quality.
Note 3. "Other software" includes in-house software, and programs other than dBASE, RBase, Lotus, QuattroPro, Oracle, Reflex, SAS, Paradox, or Ingres.

addition, over half of the agencies indicating usage of PRIME or Data General mainframes were using WATSTORE. As discussed in Chapter 3, NWIS-I made WATSTORE accessible with PRIME computers, and the NWIS-II upgrades will include converting to usage of Data General systems.

A variety of minicomputers and workstations were also used by agencies. Federal agencies almost overwhelmingly indicated usage of PRIME or Data General systems. Only 8 of the 33 agencies using PRIME or Data General computers were not USGS agencies, and 25 of the agencies were using

Table 13. Summary of Computers Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Personal computers	65%	Personal computers	92%	Personal computers	87%	Personal computers	82%
Minis/workstations	53%	Mainframes	58%	Mainframes	40%	Mainframes	50%
Mainframes	50%	Minis/workstations	32%	Minis/workstations	24%	Minis/workstations	37%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Minis/workstations	64%	Personal computers	91%	Personal computers	90%	Personal computers	82%
Personal computers	62%	Mainframes	58%	Mainframes	31%	Mainframes	48%
Mainframes	51%	Minis/workstations	42%	Minis/workstations	17%	Minis/workstations	42%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Personal computers	67%	Personal computers	93%	Personal computers	78%	Personal computers	81%
Minis/workstations	67%	Mainframes	60%	Mainframes	44%	Mainframes	56%
Mainframes	58%	Minis/workstations	33%	Minis/workstations	22%	Minis/workstations	42%

Table 14. Summary of Personal Computers Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
IBM compatibles	100%	IBM compatibles	97%	IBM compatibles	94%	IBM compatibles	97%
MacIntosh	28%	MacIntosh	19%	MacIntosh	19%	MacIntosh	21%
Other	3%	Other	7%	Other	4%	Other	5%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
IBM compatibles	100%	IBM compatibles	98%	IBM compatibles	92%	IBM compatibles	97%
MacIntosh	36%	MacIntosh	19%	MacIntosh	18%	MacIntosh	23%
Other	0%	Other	6%	Other	3%	Other	3%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
IBM compatibles	100%	IBM compatibles	93%	IBM compatibles	71%	IBM compatibles	90%
MacIntosh	50%	MacIntosh	14%	MacIntosh	29%	MacIntosh	28%
Other	0%	Other	7%	Other	14%	Other	7%

Note 1. Percentages shown are percents of agencies using personal computers.

WATSTORE for data management. Table 16 summarizes the breakdown of minicomputer and workstation usage.

Table 15. Summary of Mainframe Computers Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
PRIME	30%	IBM	79%	IBM	73%	IBM	61%
IBM	27%	Other	21%	Other	14%	Other	16%
Data General	27%	Data General	2%	VAX	9%	Data General	9%
Amdahl	10%	VAX	2%	Amdahl	5%	PRIME	9%
Other	10%	PRIME	0%	Data General	0%	Amdahl	4%
VAX	0%	Amdahl	0%	PRIME	0%	VAX	3%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
IBM	30%	IBM	79%	IBM	69%	IBM	61%
PRIME	30%	Other	21%	Other	23%	Other	19%
Data General	17%	Data General	3%	Amdahl	8%	PRIME	12%
Amdahl	13%	PRIME	3%	Data General	0%	Data General	7%
Other	13%	Amdahl	0%	PRIME	0%	Amdahl	6%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
PRIME	43%	IBM	78%	IBM	50%	IBM	55%
IBM	29%	Other	22%	VAX	25%	PRIME	20%
Amdahl	14%	Data General	11%	Other	25%	Other	20%
Other	14%	PRIME	11%	Data General	0%	Data General	5%
Data General	0%	VAX	0%	PRIME	0%	VAX	5%
VAX	0%	Amdahl	0%	Amdahl	0%	Amdahl	5%

Note 1. Percentages shown are percents of agencies using mainframe computers.
Note 2. Table only shows mainframes that were used by at least one agency type in each category of water quality.
Note 3. "Other" mainframe computers were computers other than IBM, Data General, PRIME, Amdahl, or VAX.

Water Quality Activities

Tables 17, 18 and 19 summarize the activities involving water quality data by agency type for surface water quality agencies, ground water quality agencies, and other water quality agencies respectively. Activities are shown in order of highest percentage of agency involvement.

A number of activities were listed by survey respondents under the "Other (please specify)" options in this survey section. Other CWA activities cited included 208 planning, ambient water quality monitoring, water quality assessments, 404/401 activities, nonpoint source control, and clean lakes programs. Lead rules and raw water quality standards were agency activities listed under the Other

Table 16. Summary of Minicomputers and Workstations Used by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
PRIME	63%	VAX	42%	VAX	77%	VAX	33%
Data General	47%	Other	33%	Other	31%	PRIME	30%
VAX	9%	Sun	25%	Sun	8%	Data General	23%
Sun	0%	PRIME	4%	PRIME	0%	Other	17%
Other	0%	Data General	4%	Data General	0%	Sun	10%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
PRIME	69%	VAX	46%	VAX	71%	PRIME	35%
Data General	41%	Sun	33%	Other	29%	VAX	32%
VAX	10%	Other	25%	Sun	14%	Data General	22%
Sun	0%	PRIME	4%	PRIME	0%	Sun	15%
Other	0%	Data General	4%	Data General	0%	Other	13%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
PRIME	63%	Sun	60%	VAX	100%	PRIME	33%
Data General	63%	VAX	40%	Other	50%	Data General	33%
VAX	0%	PRIME	0%	PRIME	0%	VAX	27%
Sun	0%	Data General	0%	Data General	0%	Sun	20%
Other	0%	Other	0%	Sun	0%	Other	7%

Note 1. Percentages shown are percents of agencies using minicomputers or workstations.
Note 2. Table only shows minicomputers or workstations that were used by at least one agency type in each category of water quality.
Note 3. "Other" minicomputers or workstations were computers other than Data General, PRIME, Sun, or VAX.

SDWA activities category. Other federal regulations involving survey respondents included the National Shellfish Sanitation Program and National Forest Service plans, standards, and guidelines development.

A variety of activities were mentioned under other state regulations, including state ambient water, surface water, ground water and wastewater quality standards, as well as state coastal, nonpoint source, and salinity control regulations. Other research and development activities included data storage and processing activities, questionnaires, biological monitoring, stormwater retrofit design, and special studies.

Research and development activities such as baseline/trend analysis, cause and effect studies, and public inquiry activities tended to involve more agencies than most of the regulatory activities. The dominant surface water regulatory activity was NPDES permitting, while state and federal drinking water standards tended to be the primary regulatory activity of ground water quality agencies.

Table 17. Summary of Activities Involving Water Quality Data by Agency Type for Surface Water Quality

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Baseline/trend anal	78%	NPDES permitting	77%	Baseline/trend anal	64%	Baseline/trend anal	72%
Cause/eff studies	63%	Baseline/trend anal	74%	Cause/eff studies	55%	Public inquiries	63%
Public inquiries	57%	Public inquiries	74%	Public inquiries	55%	Cause/eff studies	61%
Model development	55%	Cause/eff studies	65%	NPDES permitting	53%	NPDES permitting	57%
BMP eff assessmts	55%	Model development	62%	Fed'l drkg wtr stds	51%	Model development	54%
Project management	45%	Project management	61%	State drkg wtr stds	47%	BMP eff assessmts	51%
NPDES permitting	37%	Fed'l drkg wtr stds	57%	Model development	42%	Project management	50%
Fed'l drkg wtr stds	37%	State drkg wtr stds	57%	Project management	42%	Fed'l drkg wtr stds	49%
NEPA	37%	BMP eff assessmts	57%	BMP eff assessmts	40%	State drkg wtr stds	46%
State drkg wtr stds	32%	Other state regs	45%	NEPA	22%	NEPA	30%
CERCLA	28%	CERCLA	38%	RCRA	16%	CERCLA	27%
RCRA	25%	RCRA	34%	Other CWA regs	15%	RCRA	26%
Other state regs	10%	NEPA	30%	Wellhead protection	13%	Other state regs	24%
SMCRA	7%	Other CWA regs	22%	Other state regs	13%	Other CWA regs	14%
Wellhead protection	5%	Wellhead protection	22%	CERCLA	11%	Wellhead protection	14%
Other CWA regs	3%	SMCRA	16%	SMCRA	5%	SMCRA	10%
Other res & devel	3%	Other res & devel	5%	Other res & devel	2%	Other res & devel	4%
Other SDWA regs	2%	Other SDWA regs	1%	Other SDWA regs	0%	Other SDWA regs	1%
Other fed'l regs	2%	Other fed'l regs	0%	Other fed'l regs	0%	Other fed'l regs	1%

Table 18. Summary of Activities Involving Water Quality Data by Agency Type for Ground Water Quality

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Baseline/trend anal	64%	Fed'l drkg wtr stds	72%	State drkg wtr stds	64%	Baseline/trend anal	60%
Cause/eff studies	60%	State drkg wtr stds	70%	Baseline/trend anal	57%	State drkg wtr stds	58%
Public inquiries	60%	Public inquiries	63%	Fed'l drkg wtr stds	50%	Fed'l drkg wtr stds	56%
Model development	58%	Wellhead protection	60%	Cause/eff studies	50%	Public inquiries	56%
Fed'l drkg wtr stds	42%	Baseline/trend anal	58%	Wellhead protection	48%	Cause/eff studies	49%
State drkg wtr stds	38%	CERCLA	47%	Public inquiries	43%	Wellhead protection	47%
Project management	38%	RCRA	46%	Model development	33%	Model development	41%
RCRA	33%	Project management	46%	Project management	26%	Project management	38%
CERCLA	33%	Cause/eff studies	40%	NPDES permitting	21%	CERCLA	32%
Wellhead protection	31%	NPDES permitting	35%	BMP eff assessmts	21%	RCRA	31%
BMP eff assessmts	31%	Model development	33%	NEPA	12%	NPDES permitting	28%
NPDES permitting	24%	BMP eff assessmts	28%	Other CWA regs	10%	BMP eff assessmts	27%
NEPA	24%	NEPA	21%	RCRA	10%	NEPA	19%
SMCRA	9%	Other state regs	19%	CERCLA	10%	SMCRA	10%
Other res & devel	4%	SMCRA	18%	Other state regs	7%	Other state regs	10%
Other CWA regs	2%	Other CWA regs	9%	SMCRA	2%	Other CWA regs	7%
Other SDWA regs	0%	Other res & devel	7%	Other res & devel	2%	Other res & devel	5%
Other fed'l regs	0%	Other fed'l regs	2%	Other SDWA regs	0%	Other fed'l regs	1%
Other state regs	0%	Other SDWA regs	0%	Other fed'l regs	0%	Other SDWA regs	0%

Table 19. Summary of Activities Involving Water Quality Data by Agency Type for Other Water Quality

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Baseline/trend anal	83%	NPDES permitting	53%	Baseline/trend anal	67%	Baseline/trend anal	64%
Cause/eff studies	67%	Cause/eff studies	53%	NPDES permitting	44%	Cause/eff studies	53%
Model development	42%	Public inquiries	53%	Project management	44%	Model development	39%
Public inquiries	25%	Baseline/trend anal	47%	Model development	33%	NPDES permitting	36%
Project management	25%	Model development	40%	Cause/eff studies	33%	Public inquiries	36%
NPDES permitting	8%	Project management	33%	BMP eff assessmts	33%	Project management	33%
Wellhead protection	8%	Fed'l drkg wtr stds	27%	NEPA	22%	BMP eff assessmts	19%
All other activities	0%	NEPA	27%	Other state regs	22%	Other state regs	17%
		Other state regs	27%	Public inquiries	22%	NEPA	17%
		BMP eff assessmts	27%	Other res & devel	22%	Fed'l drkg wtr stds	14%
		CERCLA	20%	Fed'l drkg wtr stds	11%	CERCLA	11%
		State drkg wtr stds	20%	RCRA	11%	Wellhead protection	11%
		RCRA	13%	CERCLA	11%	State drkg wtr stds	11%
		Wellhead protection	13%	SMCRA	11%	RCRA	8%
		Other CWA regs	7%	Wellhead protection	11%	SMCRA	6%
		SMCRA	7%	State drkg wtr stds	11%	Other res & devel	6%
		Other fed'l regs	7%	Other CWA regs	0%	Other CWA regs	3%
		Other SDWA regs	0%	Other SDWA regs	0%	Other fed'l regs	3%
		Other res & devel	0%	Other fed'l regs	0%	Other SDWA regs	0%

Types of Data Used

Data types used by agency type for surface water quality, ground water quality, and other water quality are listed in order of highest percentage of use in Tables 20, 21 and 22 respectively. Surface water quality agencies used pH, temperature, and suspended sediment or solids data the most, while the most frequently-used ground water quality data was trace metals or major cations data. BOD, COD, chlorophyll a, and algae data were among the least-used data for both surface and ground water quality agencies. Several agencies listed data types that did not fall in any of the first fifteen categories and were therefore categorized as "other" data types. These data included alkalinity, biological assessment, conductivity, aesthetic, chlorides, and sulfides data.

Table 20. Summary of Data Types Used by Agency Type for Surface Water Quality

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Susp sed/solids	92%	pH	92%	Temperature	85%	Temperature	88%
Discharge	90%	Temperature	89%	pH	80%	pH	88%
pH	90%	Susp sed/solids	89%	Susp sed/solids	80%	Susp sed/solids	87%
Temperature	88%	Trace metals	89%	Trace metals	80%	Dissolved oxygen	85%
Dissolved oxygen	88%	Dissolved oxygen	88%	Nitrogen	78%	Trace metals	83%
Major cations	82%	Phosphorus	86%	Dissolved oxygen	76%	Nitrogen	81%
Nitrogen	82%	Nitrogen	82%	Discharge	75%	Discharge	80%
Phosphorus	78%	Pesticides/herbicides	80%	Major cations	75%	Phosphorus	79%
Trace metals	77%	Bacteriolog/viral	80%	Phosphorus	71%	Major cations	78%
Bacteriolog/viral	68%	Major cations	78%	Pest/herbicides	67%	Pest/herbicides	72%
Pest/herbicides	67%	BOD/COD	78%	Bacteriolog/viral	62%	Bacteriolog/viral	71%
BOD/COD	55%	Discharge	77%	VOCs	55%	BOD/COD	63%
VOCs	53%	VOCs	72%	BOD/COD	51%	VOCs	61%
Radiological	43%	Chlorophyll/algae	70%	Chlorophyll/algae	45%	Chlorophyll/algae	54%
Chlorophyll/algae	42%	Radiological	47%	Radiological	35%	Radiological	42%
Other data types	8%	Other data types	24%	Other data types	15%	Other data types	16%

Table 21. Summary of Data Types Used by Agency Type for Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Major cations	89%	Nitrogen	81%	Major cations	81%	Trace metals	83%
Trace metals	87%	Trace metals	81%	Trace metals	81%	Major cations	81%
pH	82%	VOCs	81%	Nitrogen	76%	Nitrogen	80%
Nitrogen	82%	Pest/herbicides	79%	Pest/herbicides	71%	Pest/herbicides	78%
Pest/herbicides	82%	pH	77%	pH	62%	pH	74%
VOCs	73%	Major cations	75%	VOCs	62%	VOCs	73%
Phosphorus	71%	Bacteriolog/viral	60%	Bacteriolog/viral	57%	Bacteriolog/viral	58%
Temperature	67%	Radiological	53%	Temperature	52%	Temperature	56%
Dissolved oxygen	62%	Temperature	51%	Radiological	50%	Radiological	54%
Radiological	60%	Phosphorus	47%	Susp sed/solids	48%	Phosphorus	53%
Bacteriolog/viral	58%	Susp sed/solids	46%	Phosphorus	43%	Susp sed/solids	44%
Discharge	42%	Discharge	35%	BOD/COD	31%	Dissolved oxygen	40%
BOD/COD	42%	Dissolved oxygen	33%	Discharge	29%	Discharge	35%
Susp sed/solids	40%	BOD/COD	32%	Dissolved oxygen	26%	BOD/COD	35%
Chlorophyll/algae	27%	Chlorophyll/algae	16%	Chlorophyll/algae	24%	Chlorophyll/algae	22%
Other data types	4%	Other data types	7%	Other data types	14%	Other data types	8%

Table 22. Summary of Data Types Used by Agency Type for Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
pH	75%	Susp sed/solids	80%	Susp sed/solids	78%	pH	69%
Major cations	75%	Trace metals	80%	Temperature	67%	Trace metals	67%
Nitrogen	58%	pH	73%	Dissolved oxygen	67%	Major cations	64%
Discharge	50%	Nitrogen	73%	Trace metals	67%	Nitrogen	64%
Phosphorus	50%	Phosphorus	73%	Discharge	56%	Phosphorus	61%
Trace metals	50%	BOD/COD	73%	pH	56%	Susp sed/solids	61%
Temperature	33%	Pest/herbicides	73%	Nitrogen	56%	Discharge	56%
Dissolved oxygen	33%	Bacteriolog/viral	73%	Phosphorus	56%	Temperature	56%
Pest/herbicides	33%	Temperature	67%	BOD/COD	56%	Pest/herbicides	56%
Susp sed/solids	25%	Major cations	67%	Pest/herbicides	56%	BOD/COD	53%
BOD/COD	25%	VOCs	67%	VOCs	56%	Dissolved oxygen	50%
VOCs	17%	Discharge	60%	Bacteriolog/viral	56%	Bacteriolog/viral	50%
Bacteriolog/viral	17%	Dissolved oxygen	53%	Major cations	44%	VOCs	47%
Chlorophyll/algae	17%	Chlorophyll/algae	53%	Other data types	33%	Chlorophyll/algae	33%
Radiological	17%	Radiological	53%	Chlorophyll/algae	22%	Radiological	33%
Other data types	0%	Other data types	20%	Radiological	22%	Other data types	17%

Sources of Data

A summary of agency responses regarding data sources according to agency type and water quality type is shown in Table 23, with data sources listed in order of highest percentage of use. The survey erroneously listed HYDATA as a source of data; this option was intended to be HYDRODATA, which is equivalent to the CD-ROM Quality of Water database mentioned in Chapter 3. Consequently, none of the agencies indicated that they obtained data from HYDATA, and it is therefore not included in the table. It is noted also that none of the responding agencies indicated they were using HYDRODATA. This is most likely because this database could be categorized under WATSTORE since it contains essentially the same data.

Most agencies collected their own data, and other agencies were generally the second-most frequent data source. A higher percentage of federal agencies got data from WATSTORE than from STORET, while the opposite was true for state agencies. As discussed earlier regarding data management systems, this was partially due to the sources of the mailing lists used.

Table 23. Summary of Data Sources by Agency Type and Water Quality Type

Surface Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Agency itself	93%	Agency itself	95%	Agency itself	91%	Agency itself	93%
WATSTORE	52%	Other agencies	66%	Other agencies	44%	Other agencies	53%
Other agencies	47%	STORET	49%	WATSTORE	16%	WATSTORE	34%
STORET	30%	Private sources	38%	STORET	15%	STORET	33%
Private sources	18%	WATSTORE	32%	Private sources	11%	Private sources	24%
Other sources	2%	Other sources	14%	Other sources	4%	Other sources	7%

Ground Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Agency itself	93%	Agency itself	95%	Agency itself	93%	Agency itself	94%
WATSTORE	62%	Other agencies	72%	Other agencies	40%	Other agencies	56%
Other agencies	51%	STORET	46%	STORET	17%	WATSTORE	40%
STORET	24%	Private sources	40%	WATSTORE	17%	STORET	31%
Private sources	22%	WATSTORE	39%	Private sources	14%	Private sources	27%
Other sources	2%	Other sources	16%	Other sources	2%	Other sources	8%

Other Water Quality Agencies

Federal Agencies		State Agencies		Other Agencies		All Agencies	
Agency itself	100%	Agency itself	100%	Agency itself	89%	Agency itself	97%
Other agencies	67%	Other agencies	80%	Other agencies	22%	Other agencies	61%
WATSTORE	58%	STORET	53%	Private sources	11%	WATSTORE	39%
Private sources	17%	WATSTORE	47%	Other sources	11%	STORET	28%
STORET	17%	Private sources	33%	STORET	0%	Private sources	22%
Other sources	8%	Other sources	13%	WATSTORE	0%	Other sources	11%

Interagency Activities

The last section of the survey questioned respondents about sharing data and cooperative agreements. As can be seen in Table 24, almost all of the data used by responding agencies is used by other agencies as well. This result indicates that data management should take into consideration potential uses of the data outside of a particular agency. Data management systems should include provisions for assuring or documenting data quality and should be capable of generating data that is compatible with other data management systems.

Table 25 shows the percentages of agencies that have cooperative agreements for sharing data. The lower percentages in this table indicate that not all agencies that share data have established agreements for sharing that data. However, the results indicate that a significant number of the responding agencies do consider data sharing to be important enough to warrant the use of cooperative agreements. As mentioned in Chapter 3, both the USEPA and USGS use memorandums of understanding or similar agreements to allow access to their national databases.

Table 24. Percentage of Agencies Whose Data is Utilized by Other Agencies by Agency Type and Water Quality Type

Water Quality Type	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface Water Quality	87%	95%	89%	90%
Ground Water Quality	89%	98%	90%	93%
Other Water Quality	92%	93%	89%	92%

Table 25. Percentage of Agencies with Cooperative Agreements by Agency Type and Water Quality Type

Water Quality Type	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface Water Quality	78%	73%	60%	71%
Ground Water Quality	82%	77%	60%	74%
Other Water Quality	83%	80%	78%	81%

Conclusions of the General Survey Analysis

Table 26 shows a summary of the data obtained from the general survey analysis for federal, state, and all agencies according to water quality type. The "other agency" category was not included because the variety of agencies that fell into that category made any conclusions difficult. However, it should be noted that the category of "all" responding agencies does include "other agencies." "Other water quality" is also not shown in the table because the many different water quality types included in this category involved too few agencies to provide any conclusive results.

Table 26. Summary of General Survey Analysis

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	60	74	189
Most-used data management	WATSTORE (57%) Manual (52%)	Comp sware (92%) STORET (73%)	Comp sware (75%) Manual (59%)
Most-used GIS[1]	ARC/INFO (90%)	ARC/INFO (90%)	ARC/INFO (83%)
Most-used computer software[2]	dBASE (36%) QuattroPro (14%)	dBASE (72%) Lotus (60%)	dBASE (55%) Lotus (47%)
% using personal computers	65%	92%	82%
% using mainframes	53%	58%	50%
% using minicomputers/workstations	50%	32%	37%
Most-frequent activities	Baseline/trnd anal (78%) Cause/eff studies (63%)	NPDES permitting (77%) Baseline/trnd anal (74%)	Baseline/trnd anal (72%) Public inquiries (63%)
Most-used data types	Susp sed/sol (92%) Discharge (90%)	pH (92%) Temperature (89%)	Temperature (88%) pH (88%)
Most-used data sources	Agency itself (93%) WATSTORE (52%)	Agency itself (95%) Other agencies (66%)	Agency itself (93%) Other agencies (53%)
% whose data is used by others	87%	95%	90%
% with cooperative agreements	78%	73%	71%
Ground Water Quality Agencies			
Total number of agencies	45	57	144
Most-used data management	WATSTORE (73%) Manual (52%)	Comp sware (79%) STORET (73%)	Comp sware (67%) Manual (53%)
Most-used GIS[1]	ARC/INFO (96%)	ARC/INFO (100%)	ARC/INFO (92%)
Most-used computer software[2]	dBASE (29%) Lotus (29%)	dBASE (60%) Lotus (51%)	dBASE (46%) Lotus (43%)
% using personal computers	62%	91%	82%
% using mainframes	64%	58%	56%
% using minicomputers/workstations	51%	42%	42%
Most-frequent activities	Baseline/trnd anal (64%) Cause/eff studies (60%)	Fed'l drnkg wtr stds (72%) State drnkg wtr stds (70%)	Baseline/trnd anal (60%) State drkg wtr stds(58%)
Most-used data types	Major cations (89%) Trace metals (87%)	Nitrogen; VOCs (81%) Trace metals (81%)	Trace metals (83%) Major cations (81%)
Most-used data sources	Agency itself (93%) WATSTORE (62%)	Agency itself (95%) Other agencies (72%)	Agency itself (94%) Other agencies (56%)
% whose data is used by others	89%	98%	93%
% with cooperative agreements	82%	77%	74%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

The percentages shown in Table 26 have been taken from the values shown in previous tables in this chapter. It should be noted that the percentages given for "most-used GIS" represent the percentage of agencies that indicated they were using GIS that were using the listed system. For example, 50 percent of the federal surface water agencies indicated they were using GIS, and 90 percent of those agencies were using ARC/INFO. Thus, the latter value is shown in the table next to the "most-used GIS." A similar procedure was followed for displaying percentages of most-used computer software. Note also that when listing the most-used computer software, the "other" category shown in Table 12 was not considered because it actually included a variety of computer software that was not counted separately.

Table 26 shows that state agencies tended to be using data management systems to a greater extent than federal agencies. The predominantly-used system for federal agencies was WATSTORE, but an equal or higher percentage of state agencies were using STORET to manage data. As explained previously, this phenomena can be explained by the fact that almost all of the federal agencies responding to the survey were contacted through a USGS mailing list.

Although state agencies were using STORET more than WATSTORE, they also were using other computer software more than STORET. In fact, comments received from several survey respondents indicated that some state agencies were so frustrated with the cumbersome nature of the system that, even though they interacted with STORET to some extent, they had developed their own software or adapted other computer programs to minimize that interaction (Haage, 1991; Rasmussen, 1992; Gowan, 1991a; Eichmiller, 1991).

At least 50 percent of federal agencies and 40 percent of state surface and ground water quality agencies were using GIS, and an overwhelming number of these agencies were using ARC/INFO. Although ARC/INFO is a relatively costly and complex system, the predominant use of the system by agencies using GIS suggests a large potential for data integration. Telephone conversations with numerous agencies using ARC/INFO and other GISs indicated that most were planning to expand their applications of the system to water quality management issues. GISs are generally used initially for special projects, but many agencies would like to expand their use as ongoing database management systems (Comer, 1991; Flexner, 1991; Hastings, 1991; Anderson, 1991; Orlob, 1991; Rupert, 1991; Tooley, 1991; Snethen, 1991; Kuehn, 1991).

The predominant computer software used by all agencies was dBASE, although the percentage of federal agencies using this software was considerably less than state agencies. Lotus was generally the most-used spreadsheet software. The fairly widespread use of dBASE and its compatibility with GISs such as ARC/INFO indicates an encouraging potential for data sharing.

Most state agencies and over half of all federal agencies were using personal computers, and almost all of these agencies were using IBM-compatible computers. This suggests the importance in developing and enhancing data management software that is appropriate for IBM-compatible personal computers.

Generally, fewer agencies were using mainframes than personal computers, and minicomputers and workstations were used by even less agencies. However, conversations with several agencies indicated that the use of workstations was increasing, and they were often being obtained to replace mainframe systems (Flexner, 1991; Rupert, 1991; Tooley, 1991; Bloem, 1991).

The predominant water quality activity among responding agencies was baseline and trend analysis. Federal agencies tended to be more involved in research and development activities than regulatory activities. On the other hand, the highest percentage of state surface water agencies were involved with NPDES permitting, and federal and state drinking water standards involved the highest percentage of state ground water agencies.

The most-used data types for surface water quality agencies were suspended sediments and solids, temperature, and pH. Major cations, nitrogen, and pH were the data types used most frequently by ground water agencies.

Over 90 percent of all agencies collected water quality data themselves, but a significantly high percentage of state agencies also indicated that they obtained data from other agencies. This suggests a need for data and software compatibility. Over 70 percent of all agencies had cooperative agreements for data sharing, indicating that a considerable number of agencies found data sharing to be important enough to warrant a formal or informal understanding between parties.

Other Inventories of Water Quality Data Management Activities

Two recent studies of water quality data activities in the United States were located. A 1991 USEPA survey specifically addressed drinking water information systems in all 50 states, while a USGS inventory concerned water quality data gathered in Colorado and Ohio. Both of these surveys are summarized below.

Survey of State Drinking Water Information Systems

In 1991, the USEPA's Office of Drinking Water (ODW) published the *Inventory of State Drinking Water Information Systems*. This report contains the results of telephone interviews conducted by ODW with state drinking water staff in all 50 states, and was designed to assist states in finding out what kinds of drinking water information systems are used in other states. Such data could help states that are trying to expand the functions of their information systems, improve their interface with the USEPA's FRDS database, develop a new system, or contact other states about their systems. The responses were compiled on standard forms that are included in the report. These forms describe the types of information systems used by states to manage their drinking water data, hardware and software used with these systems, types of data, system functions, system users, and contacts. Figure 13 shows a schematic of the inventory form used by the ODW. A summary of the inventory responses is also included in Appendix E (USEPA, 1991c).

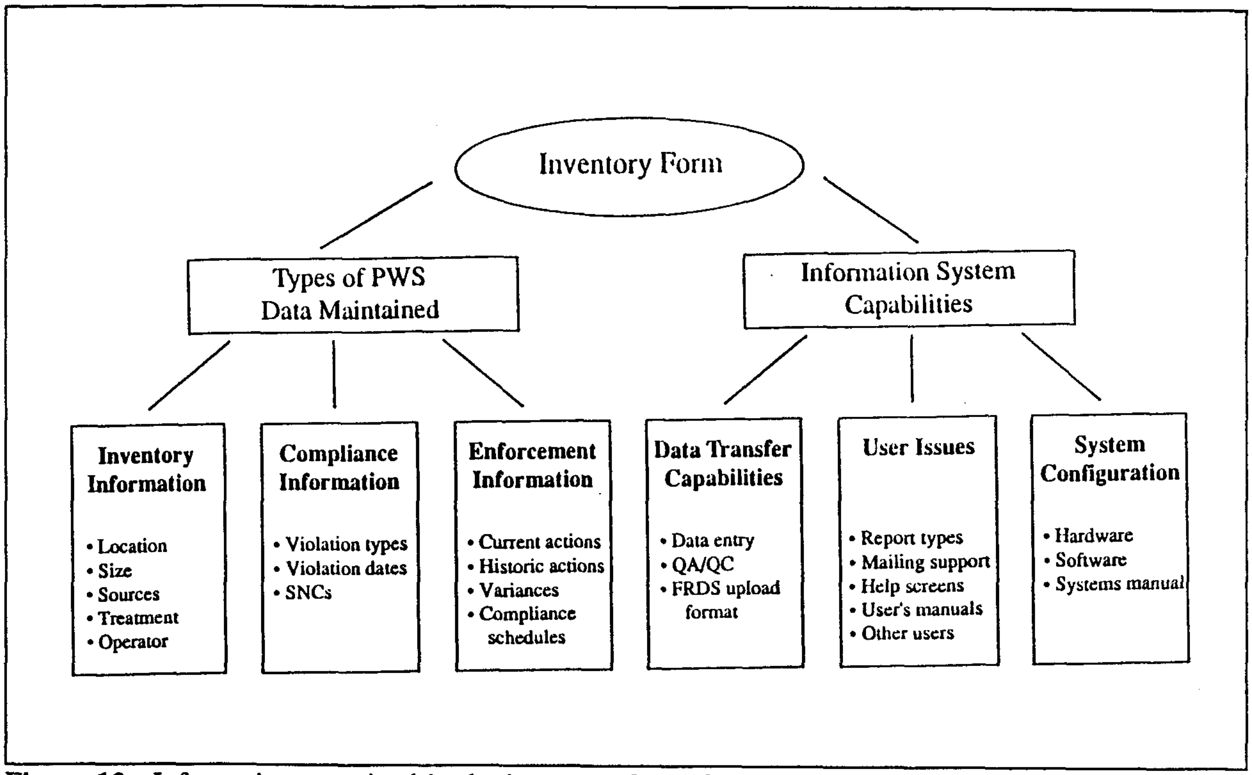

Figure 13. Information contained in the inventory form. *Source: USEPA (1991c)*

Inventory of Water Quality Data Collection Activities in Colorado and Ohio

The USGS undertook a three-phase study of 1984 water quality data collection activities in Colorado and Ohio. The intent of this study was to evaluate the adequacy of existing water quality data and its usefulness for regional and national water quality assessments. Phase I involved an inventory of water quality data collection programs, while Phase II looked at the quality assurance of field and laboratory practices that produce data. Phase III included an evaluation of the adequacy of a database compiled of qualifying data screened from Phases I and II for applying to regional and national water quality issues, as shown in Figure 14 (Norris, et. al., 1992).

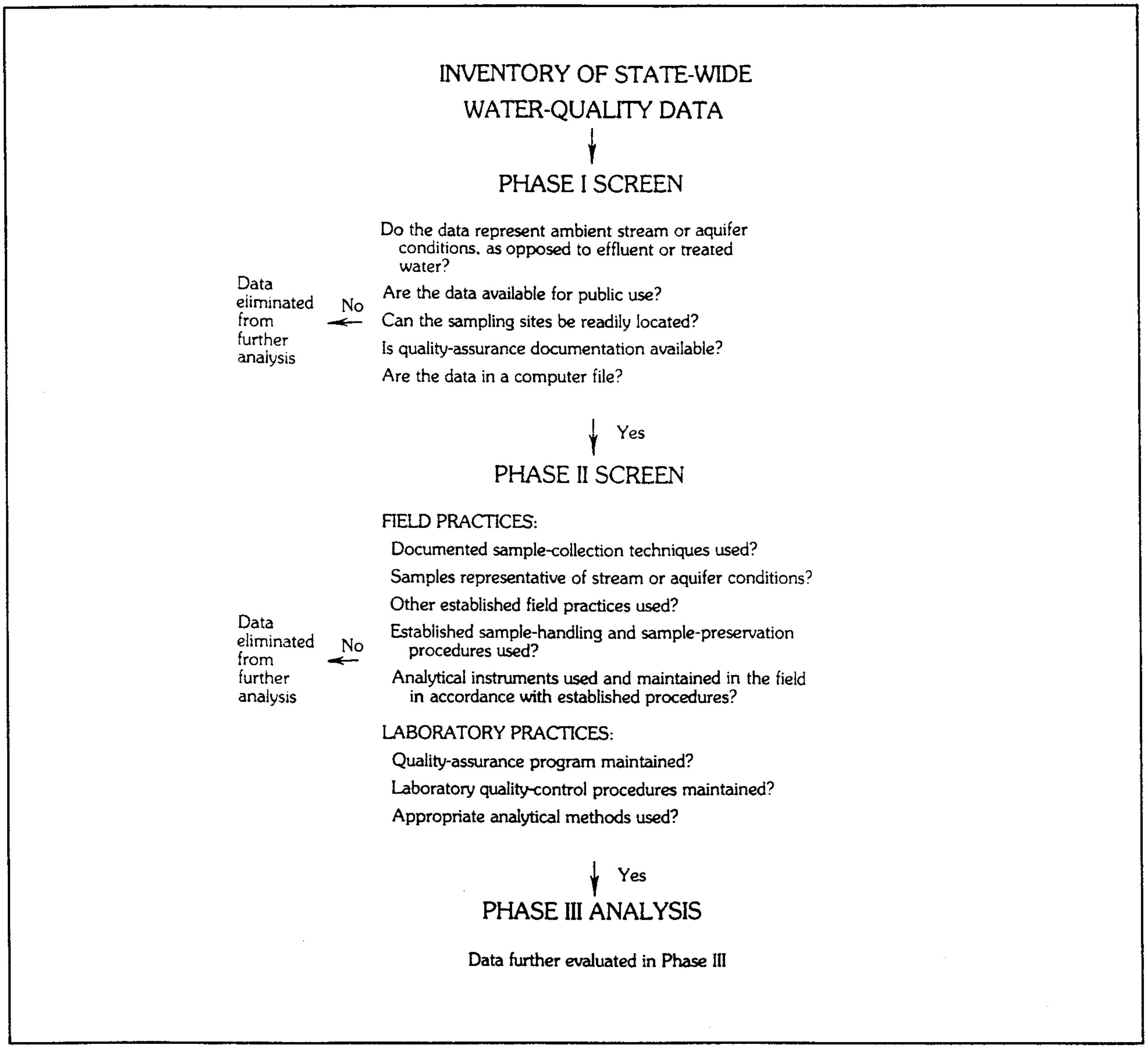

Figure 14. Inventory and screening process. *Source: Norris, et. al. (1992)*

In Phase I, the USGS contacted organizations identified through membership in state water organizations, participation in the USGS' Federal-State cooperative program, participation in NAWDEX, and by state publications. 115 water quality data collection programs in 48 organizations in Colorado were identified, while Ohio had 88 programs in 42 organizations. A questionnaire was completed for each program which solicited information on the program's scope, objectives, and cost. In addition, respondents indicated the kind of data collected, number of sites for collection, frequency of data collection, method of data storage and publication, and laboratory and quality assurance information (Hren, et. al., 1987).

Phase I identified more than 338,000 reported water quality samples in Colorado in 1984, and about 1.2 million samples in Ohio. As seen in Figure 15, most of these samples were surface water samples, and were collected for permit requirements which included NPDES permitting and SDWA requirements. Figure 16 shows the distribution of types of samples that were not collected for permitting activities for surface water and ground water. The physical properties group of samples was the largest group collected for surface waters and included measurements such as pH, temperature, dissolved oxygen, turbidity, alkalinity, and specific conductance. Samples collected for trace elements, major metals, priority pollutants, pesticides, and biota such as bacteria, algae, invertebrates, and other organisms generally represented higher percentages of collected ground water samples than surface water samples (Hren, et. al., 1987).

The responses were evaluated against the screening criteria shown in Figure 14 to determine if the data collected could be used for addressing national and regional water quality issues. About 34 percent of surface water samples and 27 percent of ground water samples collected in Colorado satisfied all of the screening criteria, while only 5 percent of surface water samples and 1 percent of ground water samples collected in Ohio met all criteria. The most limiting criteria in both states were criteria 1 (ambient conditions) and 5 (computerized data). The study noted that computerization of data would only result in an 8 percent increase in usable data in Colorado, while Ohio would more than double its database (Hren, et. al., 1987).

The data which passed the screening criteria in Phase I was collected by 44 water quality programs in Colorado and 29 programs in Ohio. This data was further evaluated in Phase II. The USGS completed field- and laboratory-practices questionnaires for each of the programs which focused on quality assurance practices. The field-practices questionnaire requested the following information: the types of constituents

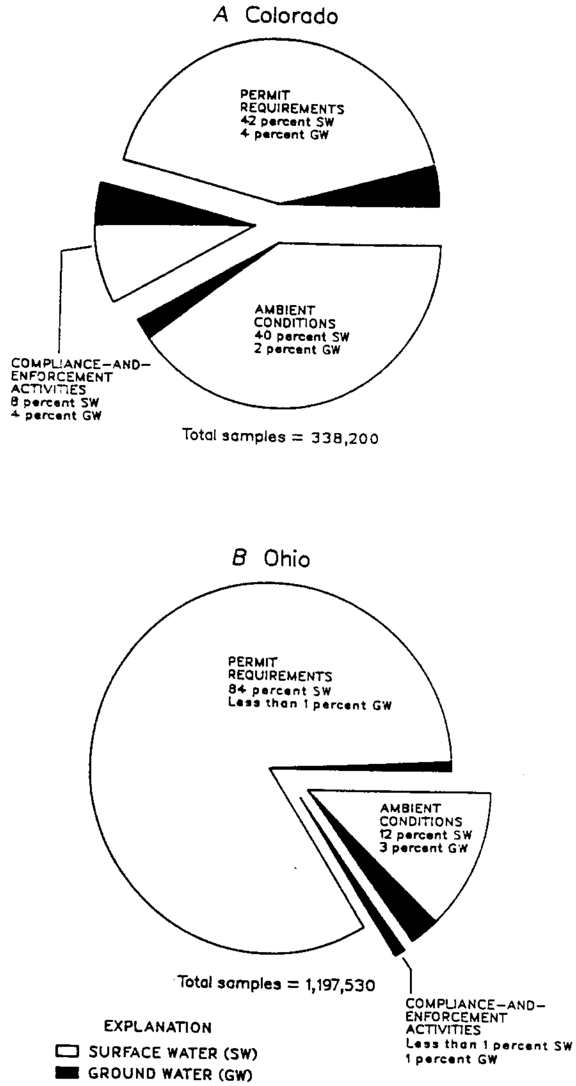

Figure 15. Water quality samples collected in Colorado and Ohio in 1984. *Source: Hren, et. al. (1987)*

analyzed or measured; the computer database used for data storage; whether field practices used were documented; what laboratories were used to analyze the samples and when; the location of sampling sites and the purpose of the sampling at those sites; procedures for obtaining representative samples; and the field practices and procedures used for specific constituents, including sample-collection procedures, sample handling and preservation, and the use and maintenance of field instruments. The laboratory-practices questionnaire addressed the use of 11 specific quality control practices, interlaboratory and

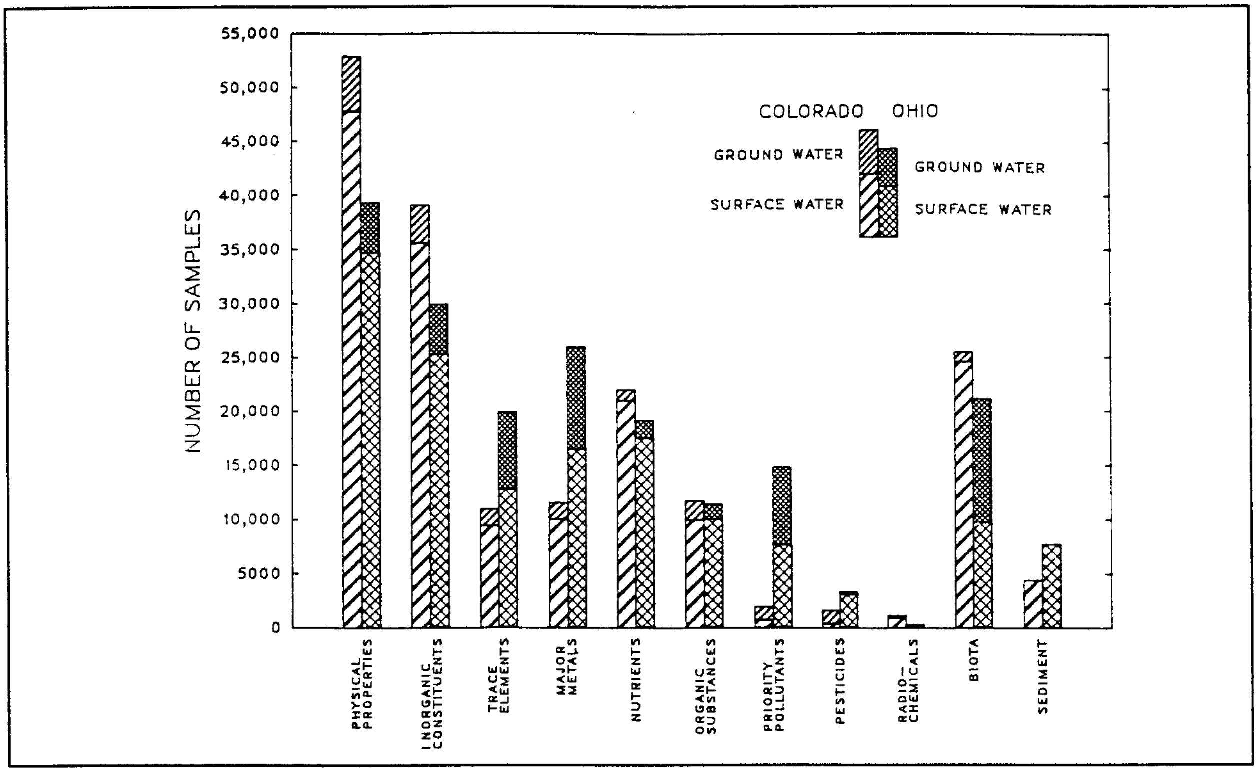

Figure 16. Major property and constituent groups of 1984 water quality samples. *Source: Hren, et. al. (1987)*

intralaboratory testing, the specific physical, chemical, and microbiological methods of analysis used, the period during which these methods were used, and when changes of method were made, if any (Childress, et. al., 1989).

To evaluate the responses, the eight criteria shown in Figure 14 were used. Figure 17 shows the results of the evaluation for surface water analyses and measurements. Of the 161,000 surface water analyses and measurements evaluated for Colorado in Phase II, only about 23,900 passed all criteria. 34,400 of the 75,800 samples evaluated for Ohio passed the screening of Phase II. Most of the data that did not meet the Phase II screening was constrained by criterion 2 (representative samples). About 69 percent of the Colorado ground water samples and all of the Ohio ground water samples passed the Phase II screening (Childress, et. al., 1989).

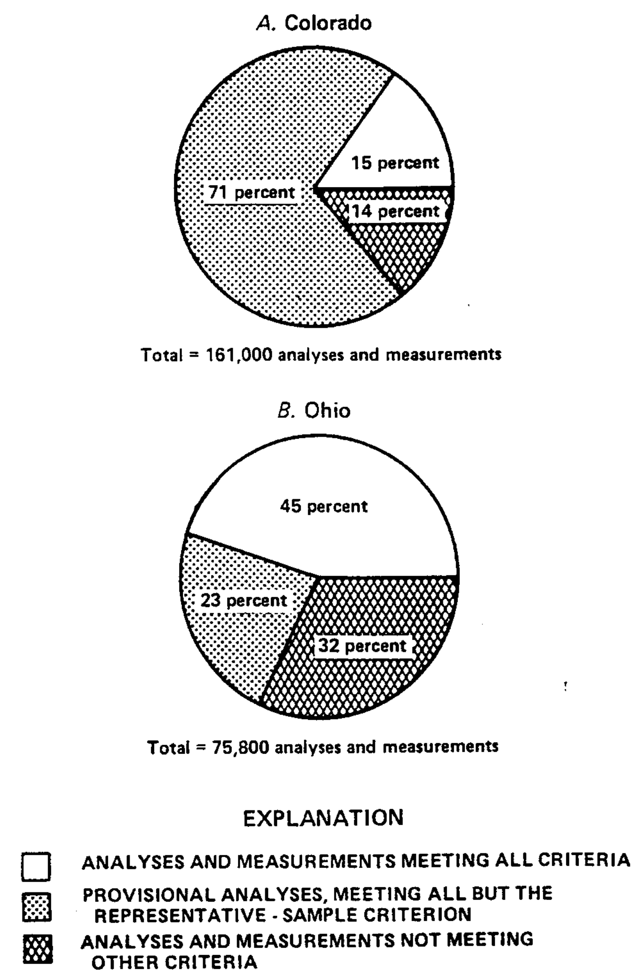

Figure 17. Phase II surface water screening results for Colorado and Ohio. *Source: Childress, et. al. (1989)*

Data for parameters and properties that broadly characterize water quality such as dissolved oxygen, pH, specific conductance, and alkalinity constituted most of the data that passed both Phase I and Phase II screens, while few trace constituent analyses data passed the screens. Thus, the study concluded after Phase II that qualifying data appeared to be available for traditional water quality issues such as sanitary quality and salinity, but more recent water quality issues such as toxic and trace metals contamination lacked adequate available water quality data (Childress, et. al., 1989).

In addition, the Phase II screening was applied to the data that did not meet the computer storage criterion of Phase I, but none of this data passed all of the Phase II criteria. The study therefore also concluded that field and laboratory quality assurance needs should be addressed before investing in the computerization of data (Childress, et. al., 1989).

The data which passed both the Phase I and the Phase II screening was evaluated in Phase III by looking at the spatial distribution of sampling sites, the number of measurements of different constituents at sampling sites, and the availability of additional information to support the water quality data in order to perform an assessment of current conditions and trends. Only selected constituents were addressed in Phase III, as shown in Table 27. Surface water data from lakes and reservoirs were not included (Norris, et. al., 1992).

Table 27. Water Quality Constituents Evaluated in Phase III

	Colorado		*Ohio*	
Constituent	Surface Water	Ground Water	Surface Water	Ground Water
Dissolved solids	X	X		
Suspended sediment	X			
Dissolved oxygen	X		X	
Total-coliform bacteria		X		
Nitrate as nitrogen		X		X
Uranium		X		
Total phosphorus			X	
Total-recoverable lead			X	
Fecal-coliform bacteria			X	
Phenols				X
Total-recoverable iron				X
Total-recoverable manganese				X

To assess current water quality conditions, it was assumed that the five-year period from 1980 to 1984 represented such conditions. At least 10 surface water analyses or one ground water analysis was required during that period to effectively determine current surface or ground water conditions, respecitvely. Of the surface water quality data collection sites that met the Phase II criteria, 26 percent

(123 sites) of Colorado and 12 percent (36 sites) of Ohio sites satisfied the requirement for existing condition analysis (Norris, et. al., 1992).

At least quarterly observations over five years (i.e., 20 observations) of selected constituents and concurrent streamflow data were required during the period 1977-1984 for the assessment of surface water quality trends. Only 6 percent (36 sites) and 4 percent (17 sites) of Colorado and Ohio surface water data collection sites passing Phase II screens respectively met these conditions (Norris, et. al., 1992).

The definition of ground water quality changes and trends required at least one observation per year collected over five years during the period of 1972 to 1984. In Colorado, only 1 percent (10 sites) of the Phase II-screened ground water data collection sites satisfied this requirement, while 13 percent (23 sites) of these sites in Ohio had adequate data (Norris, et. al., 1992).

Phase III study results noted that most of the data collection sites which satisfied all of the study criteria throughout the phases were centered around small areas with known or suspected water quality problems or high water use. An unbiased assessment of regional existing water quality conditions could not be done in large areas of both Colorado and Ohio because of insufficient data types and data collection sites, and poor areal distribution of sites. Very few sites in either state had qualifying data for evaluating changes in water quality. Finally, it was noted that although data did not meet the screening criteria for regional and national water quality assessments, this did not necessarily indicate that the data did not meet the needs for which it was originally collected (Norris, et. al., 1992).

Water Quality Data Management in Other Selected States

In reviewing the responses to the water quality data management survey, it was apparent that some states had already paid considerable attention to the management of their water quality data. The water quality data management systems of these states are briefly summarized here.

California

California has developed a Statewide Water Quality Information System (SWQIS) which is a computerized water quality database that is administered by the California State Water Resources Control Board (SWRCB) (SWRCB, 1985). The system is used to input data into STORET (Daniels, 1991) and serves as a central repository for water quality and related data in California. The database includes station data characterizing the sampling location and data information describing sampling conditions and the results of the sample analysis. Water quality data are separated into effluent and ambient data. Effluent data includes water quality information for influent or effluent waters to industrial, municipal, or agricultural processes, and is divided into two categories: 1) discharger self-monitoring data, and 2) all other data. Ambient water quality data concerns marine, lake, river, and ground water quality, and is divided into surface and ground water categories. Statistical or mathematical analyses and data plots can be output from SWQIS upon request (SWRCB, 1985).

SWQIS is available to employees of the SWRCB, other state agencies, and individuals, agencies, or organizations working with state agencies on water quality projects. Data is available to other entities including private consultants for a fee (SWRCB, 1985).

Another database developed by California is the California Data Exchange Center (CDEC) database. This system is maintained by the California Department of Water Resources (CDWR) and contains hydrologic, climatic, and water quality data from over 50 agencies. As of April 1991, the information in the database included data collected from 115 remote data stations which transmit river stages, precipitation amounts, snow water content, temperature, and water quality data over California's microwave system. The database also contains climatic data collected with the Geostationary Operational Environmental Satellite (GOES) network. CDWR personnel access the CDEC database directly through computer terminals, and outside users can gain access with modems and telephone lines. Data can be retrieved on an hourly, daily, monthly, historic, or event basis from single sites or by groups of data stations (CDWR, 1991).

California has also recently established the California Environmental Protection Agency (Cal EPA), which now oversees several environmental agencies, including the SWRCB. Cal EPA is eventually to be modeled after the USEPA, but currently is handling funding, while the agencies under it remain independent and autonomous. However, Cal EPA is the lead agency in the planned development of a new state water quality database from which data would be entered into STORET. A committee of all California water quality agencies is to be formed to develop the database, with implementation estimated in approximately two years (Rasmussen, 1992).

Florida

Florida has numerous agencies that gather and use water quality data, including district agencies, counties, and cities in addition to state-level agencies. Because of this, all agencies that gather and generate water quality data are required to store data in STORET themselves. The Florida Department of Environmental Regulation (FDER) is responsible for providing assistance and training on the use of STORET to these agencies, and also uploads or retrieves data for those agencies that have inadequate financial or staff capabilities to facilitate direct interaction with STORET. FDER has established a STORET Bulletin Board System (BBS) which provides information on training, allows the downloading or uploading of STORET files, and provides access to the data system by outside users (Gowan, 1990). Some of the files available on the BBS to assist STORET users in Florida include STORET.HELP files from the STORET system, short informative files and documents on how to interact with STORET, STORET data sets, public-domain software which can be used to create STORET data sets for uploading, and custom retrievals in formats for use with other computer software (Gowan, 1991b).

FDER attempted to develop its own in-house water quality database several years ago. However, because users were not very involved in the database development, it was not widely accepted and is currently not used at all (Gowan, 1991a).

FDER's Drinking Water Section has also developed a "PWS Data Base" system which is written in COBOL and resides on a UNISYS 2200. Data from the system is written onto magnetic tape and sent to the USEPA for input into FRDS. Data entry can be done remotely or locally with on-line telecommunications hookups or direct connections. The database includes fields found in FRDS as well as additional fields. The system flags MCL violations, missed reports, and public water systems in significant non-compliance, as well as allows for the input and alteration of monitoring limits. Sampling values are input into the system, and quality assurance is achieved by having MCL violations flash on the screen during the data input. Using Data Ease software, FDER has written programs for producing standard reports (USEPA, 1991c).

Utah

The Utah Department of Environmental Quality's (UDEQ) Division of Drinking Water has developed a database system which runs on a NIXDORF minicomputer that is connected to seven workstations. The system was purchased in 1980 with word processing, spreadsheet, and graphics capabilities. Database development was done in-house and was written in Editor. The database includes sample results from private laboratories, and state laboratory bacteriological and chemical sample results. It was anticipated that all sample data would be electronically transferred to the database by the middle of 1991. Almost all of the data fields in FRDS are included in the system as well as additional data. Data files from the minicomputer are sent to the UDEQ's PRIME mainframe computer for transfer via modem to FRDS. Source specific data is also entered on an annual basis into STORET, but UDEQ generally accesses its own data instead of retrieving data from STORET (USEPA, 1991c; Bousfield, 1991a; Bousfield, 1991b).

Wyoming

Wyoming has developed a computerized data storage and analysis system called the Water Resources Data System (WRDS). The Wyoming State Engineer's Office provides funding which allows the Wyoming Water Research Center (WWRC) to maintain and administer the system. The data and computer programs reside on the University of Wyoming's CDC Cyber 840 computer which can be accessed with a personal computer and modem to users with a dial-up mainframe account. The system is also connected to the Bitnet computer communications network to facilitate electronic data transfer (WWRC, 1988).

WRDS consists of six databases, including a water quality database that contains ground and surface water data for daily and grab samples from approximately 16,000 water quality monitoring sites. Data is input from major data sources such as the USGS and U.S. Soil Conservation Service. Data is verified before being input by consulting both published and digital data and through personal contact with collecting agencies. Output formats include hard copy printouts and plots, computer files, floppy disks, magnetic tapes, microfiche, and 35mm color slides (WWRC, 1988).

The WRDS is also a user assistance center for the USGS NAWDEX system, and can access WATSTORE. In addition to data retrieval, the system allows limited data entry to Wyoming state agencies (WRRC, 1988).

Chapter 5. Description of Existing Water Quality Data Management in Colorado

The secondary objective of this thesis is to relate the national water quality data management assessment with data management activities in Colorado. To provide a background for the recommendations made in Chapter 6, this chapter describes existing water quality data management activities in Colorado.

Colorado Department of Health (CDOH)

In Colorado, the agency responsible for protecting water quality and administering federal and state water quality regulatory programs is the Colorado Department of Health (CDOH). The politically-appointed nine members of the Colorado Board of Health adopt rules and regulations regarding the state's public health laws, including policies for primary drinking water regulations, hazardous and solid waste disposal, and sewage disposal systems. Within CDOH, the Office of the Environment's Water Quality Control Division and Hazardous Materials and Waste Management Division are the two principal branches which work with water quality data (WQCD, 1988; WQCD, 1991; CDOH, 1991a).

Water Quality Control Division

The Water Quality Control Division (WQCD) serves as staff to the Water Quality Control Commission (WQCC), a nine-member group appointed by the governor which is responsible for setting

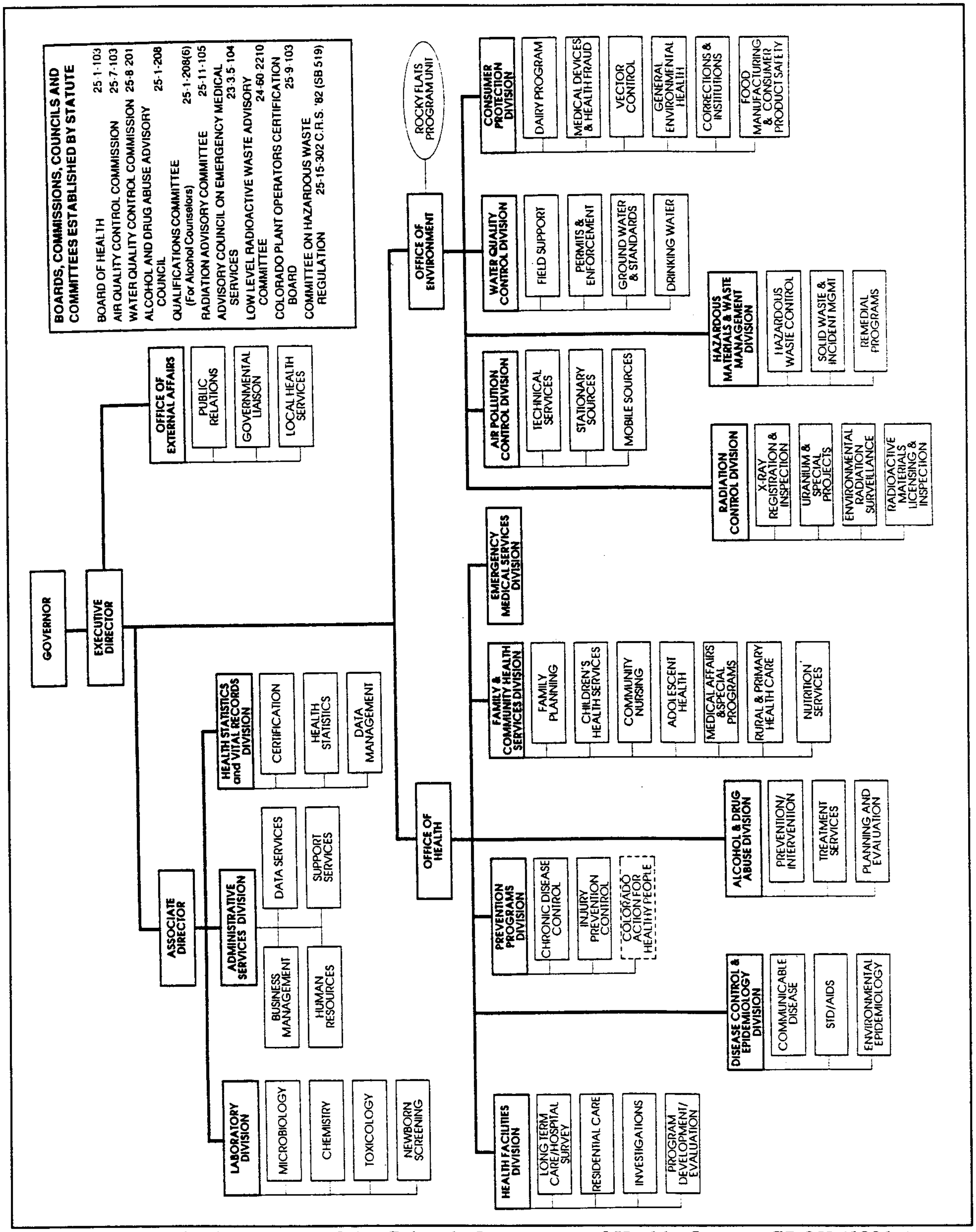

Figure 18. Organizational chart of the Colorado Department of Health. *Source: CDOH (1991a)*

surface and ground water quality policies in Colorado. The Colorado Water Quality Control Act (Senate Bill 10) specified that the member appointments should represent regional and varying interests in water issues in the state, with at least two members coming from west of the Continental Divide (CDOH, 1991a; LWVC, 1992).

The policies set forth by the WQCC are administered and regulated by the WQCD. The division is responsible for issuing permits for the discharge of pollutants into the state's surface and ground waters, and for enforcing the federal Safe Drinking Water and Clean Water Acts and the Colorado Water Quality Control Act (LWVC, 1992; CDOH, 1991a; WQCD, 1991).

Several sections of the WQCD collect, receive, and manage water quality data. The Drinking Water Program Section maintains and enforces the Primary Drinking Water Regulations (CDOH, 1991a). Water systems submit water quality data either directly or through the certified water quality labs which perform the water quality tests. CDOH personnel estimate that each year about 2000 entities submit data on a monthly to five-year basis, depending on the type of data submitted. Little is done with the submitted data, although the Drinking Water Section does enter information into the USEPA's FRDS database through a Wang VS workstation. This database consists of an inventory of the entities submitting data, and any violations and subsequent actions taken. Through FRDS, the state can identify water systems in significant noncompliance and work with them to bring them into compliance to avoid the $25,000 fine imposed by the USEPA. The only water quality data collected by the Drinking Water Section which is consistently entered into a computerized database is the volatile organics (VOCs) data which is being sent once every six months on a floppy disk to the USEPA. This data is being used by the USEPA to help them develop VOC standards. Water quality data is kept in manual files and is available to other agencies and entities on request (Rogers, 1992).

National Pollutant Discharge Elimination System (NPDES) permits are issued and enforced by the Permits and Enforcement Section. Permit terms are set using monitoring information provided by field staff. In addition, permittees are required to submit data in the form of discharge monitoring reports (DMR's). Approximately 45 percent of the permits and their associated limitations are entered in the USEPA's PCS data system. Water quality data for these permits is routinely entered on a monthly, quarterly, or annual basis. Although data is received for the remaining 55 percent of the permits, the DMR's are not current, and the respective permit limits are not listed in PCS. The Permits and Enforcement Section enters limits into PCS as the permits are reviewed every five years. The section expects to get increasingly involved in pretreatment and sludge activities and anticipates entering data from these operations into PCS (Shukle, 1992; CDOH, 1991a).

The Ground Water and Standards Section of CDOH assists the WQCC in setting standards for surface and ground waters in Colorado. In addition, the section is responsible for Section 201 certifications, site approvals for wastewater treatment facilities, Section 208 planning, and the development and review of areawide water quality management plans. The section is composed of two units: the Ground Water Unit and the Water Quality Standards Unit.

The Ground Water Unit's goal is to protect ground water quality for beneficial uses through the development of a comprehensive program. The Ground Water Unit also technically supports activities of other CDOH divisions involving the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Uranium Mill Tailings Remedial Action Programs (UMTRAP) (CDOH, 1991a).

The comprehensive ground water program involves the classification of the ground waters of the state based on current and potential uses of ground water (CDOH, 1991a). The first set of classifications was adopted by the WQCC on September 9, 1991. Entitled "Classifications and Water Quality Standards for Ground Water," an interim narrative standard was adopted for all unconfined ground water in the following areas (WQCC, 1991):

-- The Lower South Platte River Basin Alluvium and Terrace Gravel System

-- The Arkansas River Basin Alluvium and Terrace Gravel System

-- The San Luis Valley Aquifer System

-- The High Plains Aquifer System

-- The Denver Basin Aquifer System

The Ground Water Unit is also in the process of developing a ground water quality database system called QUALDAT. The system operates in a dBASE III Plus or dBASE IV compatible environment and currently includes ten databases as summarized below (CDOH, 1991b):

QUALINFO	Contains general information on the sampling event, including well location, well owner, agency collecting and reporting data, laboratory used, etc.
QINORNM	Contains inorganic non-metal ground water quality data
QINORMET	Contains inorganic metal ground water quality data
QUALORG	Contains organic ground water quality data
QUALORG2	Contains organic ground water quality data
QUALPEST	Contains pesticide ground water quality data
QUALPES2	Contains pesticide ground water quality data
QUALRAD	Contains radiological ground water quality data
QUALCOM	Contains comments about any inorganic, organic, pesticide, or radiological parameters

The system currently contains primarily special studies data. Only ambient data is input into the master database, although all submitted data may be entered in the future with additional fields to keep ambient water quality data separate. The latest version of QUALDAT allows data entry into these database formats, on-screen viewing, and data output. Search capability is currently limited to well permit numbers assigned by the State Engineer's Office (SEO) of the Colorado Department of Natural Resources (CDNR), location (Section, Township, Range), and by county. A new version of the database will be distributed in the fall of 1992 with the Nonpoint Source Task Force Report. The new version will condense QUALDAT to five databases and will have an editing capability (Crick, 1992a; CDOH, 1991b; Crick, 1992b).

QUALDAT is distributed by the Ground Water Unit to interested parties on a floppy disk that contains all of the database formats. Users are encouraged to return disks with data to the Ground Water Unit, where they are entered into the master database system. To date, QUALDAT has been given to approximately 30 to 35 agencies, but very little data has been received back by CDOH. The distribution in the fall through the Nonpoint Source Task Force will send the database to another 50 agencies (CDOH, 1991b; Crick, 1992a; Crick, 1992b).

The Ground Water Unit is working with other entities to set up routine input of their water quality data into the database. Such data includes monitoring data from the Hazardous Materials and Waste Management Division of CDOH, noncomputerized data from the CDNR's Mined Land Reclamation Division, and water quality data from the Drinking Water Section of the WQCD (Crick, 1992a).

The Ground Water Unit is also serving as the lead agency in the development of the Colorado Wellhead Protection Program. In this capacity, it is responsible for designing, implementing, and technically supporting a state plan which is in compliance with USEPA guidelines (WQCD, 1991).

Also part of the Ground Water and Standards Section, the Water Quality Standards Unit provides technical assistance to the WQCD in the development of stream classifications and standards by collecting and analyzing data on water quality. Ambient water quality data is collected on a weekly, bimonthly, or monthly basis via a network of 100 monitoring stations located on streams throughout the state. This data is input into the USEPA's STORET database. The Unit also performs special projects, such as the development of the Colorado Ammonia Model in conjunction with the University of Colorado. This model is used by CDOH to assess permit limits on a monthly basis by incorporating discharge information (CDOH, 1991a; Farrow, 1992).

Radiation Control Division

The mission of the Radiation Control Division is to reduce health risks from all sources of ionizing radiation. To accomplish this, the division conducts monitoring programs of facilities involved with nuclear materials among other activities. Current projects involve the Rocky Flats Plant, the Fort Saint Vrain Nuclear Generating Plant, and uranium mines, mills, and affected communities (CDOH, 1991a). Water quality data collected for these projects is primarily from surface and drinking waters of streams and reservoirs, but some ground water is also sampled. New data is acquired almost daily, but the division does not have a computerized database for storing the data. Data is filed away and is difficult to access. Consequently, requests for data are usually filled by selling copies of reports, which can be expensive to the purchaser. The division would like to eventually enter the data into a database such as dBASE for easier access, manpower is currently limited (Terry, 1992).

Hazardous Materials and Waste Management Division

The Hazardous Materials and Waste Management Division (HMWMD) manages the disposal of hazardous and nonhazardous wastes to minimize resulting health and environmental impacts. The division is responsible for administering the Resource Conservation and Recovery Act (RCRA) program and the Uranium Mill Tailings Remedial Action Program (UMTRAP), is involved in Comprehensive

Environmental Response, Compensation and Liability Act (CERCLA) lawsuits in the state, and participates in the Superfund program (WQCD, 1991; CDOH, 1991a).

The division collects water quality data specific to facilities being studied. This data is often used to assess background and current water quality conditions when determining the extent of contamination. Models are used to evaluate the transport and fate of contaminants and ground water flow, but there is no consistency of model use. The division does not maintain any water quality database. Water quality data is filed after a specific study is completed. HMWMD did recently purchase a workstation and the geographic information system ARC/INFO, which should be operational soon (Campbell, 1992).

The division is attempting to coordinate with the CDNR's SEO to identify sensitive ground water areas. As discussed later, the SEO is responsible for issuing well permits. In the past, the SEO has only been concerned with quantity, but attention is increasing towards identifying areas of potential contamination for consideration when granting permits (Vranka, 1992).

Colorado Department of Natural Resources (CDNR)

The Colorado Department of Natural Resources (CDNR) is responsible for administering and coordinating programs and activities dealing with natural resources of the state including water (LWVC, 1992). The primary divisions within CDNR which interact with water quality data are the Division of Water Resources (State Engineer's Office) and the Colorado Mined Land Reclamation Division (CMLRD).

Division of Water Resources/State Engineer's Office

The Colorado Constitution specifies that the unappropriated water of all natural streams within the state is owned by the public and is subject to appropriation and use according to the Constitution and the

State Water Laws (Colorado Revised Statutes). The governor-appointed state engineer is responsible for administering and distributing these public waters according to Colorado water rights laws. The state engineer also regulates ground water through the issuance of well permits. The state engineer serves as the director of the Division of Water Resources, which is divided into seven divisions that generally correspond with the major river basins in Colorado. Division engineers appointed by the state engineer for each water division are responsible for administering waters within their divisions. Each division engineer also appoints a water commissioner to assist in enforcing orders of the division or state engineer and to serve as a contact with the public for water administration (LWVC, 1992; CWC, 1991; Vranesh, 1987a).

The State Engineer's Office (SEO) has a statutory responsibility to collect and record data to facilitate water rights administration. Flow data is often collected by irrigators, ditch riders, or local water commissioners using Parshall flumes or current and depth gauges. This data is recorded on a daily basis in field books maintained by water commissioners or assistant division engineers. The field books are submitted to division engineers on a regular basis and are microfilmed and stored in the state archives. These archives contain data which date back to 1911 (Vranesh, 1987a).

The SEO maintains a computerized water rights database that was developed in 1972 as the Colorado Water Data Bank Project by Colorado State University (CSU) and the SEO. This database was intended to include not only water rights information, but also data pertaining to climate, gaging stations, ditch diversions, reservoirs, dams, wells, stock ponds, and water quality (Longenbaugh and McMillin, 1974). Although the database was transferred from CSU to the SEO several years ago, water quality data is still not included in the database (Longenbaugh, 1992). The system is capable of retrieving information in a dBASE-compatible format and includes fields for water district, stream identification number, designated use, date of adjudication, and quantity of water allocated (Colorado Water Rights Data Bank).

Since 1984, the SEO has operated a satellite-linked water resources monitoring system which collects real-time data from over 250 automated stations. In addition to measuring flow data, the system monitors inflow, outflow, and stage elevation at some Colorado reservoirs. Future plans for the system include the monitoring of water quality parameters such as conductivity, water temperature, dissolved oxygen, and turbidity (Kaliszewski, 1990; CWC 1991).

The system uses pre-existing stream, diversion, and reservoir gaging stations which are installed with remote data collection hardware connected to on-site sensors that may be a float or pressure transducer, or a direct discharge meter. The remote site data collection hardware includes a data collection platform (DCP) which has a sensor interface module capable of handling up to 16 sensors, a UHF transmitter, and a microprocessor which allows the programmable input of data measurement and transmission scheduling, and which provides for data manipulation and storage. A shaft encoder that communicates directly with the DCP is also included in the remote hardware to convert incremental stage values. Other components of the remote data collection hardware are an environmentally secure enclosure, antenna, battery, solar panel, and cables (Kaliszewski, 1990).

The DCPs generally store eight hours of data collected at 15-minute, 30-minute, or user-specified intervals. The eight hours of stored data are transmitted at four-hour intervals to provide replicate data in case a transmission is missed. The DCPs also can transmit real-time alarm warnings when they detect streamflow conditions which exceed programmed levels. In addition, some DCPs also transmit meteorological and water quality data (Kaliszewski, 1990).

Transmission receive hardware is located at the Direct Readout Ground Station at the SEO's office in the Centennial Building in Denver. This component of the system includes a parabolic dish, downconverter, receiver, amplifier, multiplexor, and programmable demodulators (Kaliszewski, 1990).

A Digital Equipment Corporation (DEC) VAX 11/750 located in the Centennial Building serves as the central computer for the system and has program, data storage, data exchange, backup, archiving, system control, and printing capabilities. Thirty-two asynchronous input/output ports allow terminal communications in the Centennial Building, modem communications over telephone lines, and voice synthesizer units for the SEO's WATERTALK system, which is discussed later (Kaliszewski, 1990).

The operation of the central computer is controlled with DEC virtual memory system (VMS) software. Applications used for the system are written in FORTRAN programming language. The primary software application used is HYDROMET, which was developed by Sutro Corporation and enhanced by the SEO. This package contains a series of programs which allow for transmission receive, raw data processing, data conversions, data archiving, data retrieval, and system diagnostics. Specifically, the following applications are available to the user DAYFILES, ARCHIVES, ANNUAL, PLOT, SCHEMATICS, and DIAGNOSTICS. In addition, enhancement software has been developed for HYDROMET, including SMSEQPT, RECORD, and LOG. These applications are described in Table 28 (Kaliszewski, 1990).

All of the seven division offices and some of the water commissioners access the main system with a personal computer and a modem. Field personnel program and test the DCPs with small hand-held terminals and can also access the main computer system with a modem (Kaliszewski, 1990).

The final element of the satellite-linked water resources monitoring system is the Geostationary Operational Environmental Satellite (GOES) which serves as the communications link for data transmissions. The National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service operates GOES and has satellites in an equatorial, geostationary orbit that allows for a continuous line-of-site to be maintained with remote transmitters and the Direct Ground Readout Station (Kaliszewski, 1990).

To ensure database integrity, the remote hardware/sensor interface are calibrated by a hydrographer on a two- to four-week basis. In addition, normal data ranges are entered for each station, and data values which fall outside of these ranges are flagged. These flagged values are not used in calculating mean

Table 28. Description of Software Applications in HYDROMET

Application	Description
DAYFILES	Performs raw data processing, data conversions, shift applications, and archiving of the real-time data for a given station
ARCHIVES	Computes and stores mean daily values for a given data type for a given station
ANNUAL	Provides a yearly summary of mean daily values for a given data type for a given station, and also summarizes monthly total, mean, minimum and maximum values in a format which matches that established by the USGS
PLOT	Allows the graphical display of data values versus time
SCHEMATICS	Allows the graphical display of relative locations of monitoring stations with their most recent data
DIAGNOSTICS	Gives a detailed daily summary of the operating characteristics of a network of stations, such as missed transmissions, parity errors, remote battery power, and database quality flags
Enhancement Software	
SMSEQPT	A computerized inventory and tracking system for the remote data collection hardware
RECORD	Facilitates the development of hydrologic records
LOG	Monitors transmission activity to detect unauthorized transmissions which could cause interference problems

daily values. The number of flags for each station are reported by the computer every day (Kaliszewski, 1990).

Another computer accessory that is linked to the satellite-linked monitoring system is the SEO's WATERTALK, a telephone access system that outputs data to the user using computer-generated voice synthesis. Using the keypad of a touch-tone phone, up to four users at a time can access WATERTALK simultaneously to receive up-to-date flow conditions at key gaging stations in the state. During the runoff season in 1989-90, almost 2000 calls were handled per month. Additional information which is intended to be available through WATERTALK includes water quality data and planned reservoir releases (Kaliszewski, 1990).

The SEO maintains records of well permitting information which are archived on microfiche. Well information includes water division number, county, permit number, owner's name, water district number, location, street address, use, data permit granted, well yield, well depth, water level, annual appropriation, number of irrigated acres, and aquifer geology. The SEO also keeps driller's logs and other detailed information on microfiche (Vranesh, 1987a). A computerized database on dBASE contains some of this information. Although the SEO does not require that it be submitted for well permits, some permittees do submit water quality data. Currently, the SEO does not use this data and does not enter it in any database, although it may be added to the WQCD's QUALDAT in the future (Kraus, 1991). In addition, the WQCD intends to use SEO well information in developing the wellhead protection program (WQCD, 1991).

The SEO is in the process of purchasing and implementing a geographic information system (GIS). An initial application of the GIS will be to map the Colorado River Basin to aid in Colorado River management. The GIS would be used to assess the availability of Colorado River water for possible leasing to California, and would include data on surface and ground water quality and quantity, water rights, consumptive use, and irrigated lands. Attempts would be made to integrate maps and data with other agencies involved in the Colorado River Basin (Kraus, 1992).

An additional use of the GIS would be to manage the well permits database. Ground water well data would be mapped, and the well permitting process could be documented. The SEO has contracted to use the Global Positioning System (GPS) to locate wells, and this data would also be input into the GIS (Kraus, 1992).

In 1989, the amendments to the Colorado Water Quality Control Act required interagency coordination regarding the impacts of water quality regulations on water rights. Consequently, the SEO and the Colorado Water Conservation Board serve in an advisory capacity to the WQCC and WQCD (WQCD, 1991; LWVC, 1992). This was discussed in detail in Chapter 2.

Colorado Mined Land Reclamation Division

The Colorado Mined Land Reclamation Division (CMLRD) is responsible for minimizing impacts to surface and ground waters during mining and land reclamation activities. Water quality data is collected and managed by the division in association with state reclamation permits and coal mining operations (WQCD, 1991; Humphries, 1992).

CMLRD's Minerals Program uses water quality data for two principle activities: permit administration and enforcement. The permits are issued according to a state reclamation regulation and stipulate sampling schedules, parameters, and reporting requirements. Permit conditions vary depending on the type of activity being regulated, location, and the presence of nearby water users that could be affected by the activity. Both surface and ground water data is collected by CMLRD, and sampling is generally done weekly or annually by permittees. Reports are submitted monthly, quarterly, or annually, depending on permit requirements. Because of a shortage of manpower, data is generally placed in the permit file with little review unless there is need for enforcement actions. Some data may be copied for NPDES permits if the facility being regulated is also subject to discharge regulation (Humphries, 1992).

CMLRD has authority to take enforcement actions if there are off-site impacts of a permitted operation. In this case, the Minerals Program performs water quality sampling at the point of enforcement, and solicits additional information from the permittee if such information is available. There is no computerized database of any of the data used by the Minerals Program (Humphries, 1992).

Due to a new state regulation, the Minerals Program will manage the monitoring of mine sites for the protection of ground waters in the near future. There are no other plans for a modification of data management (Humphries, 1992).

CMLRD also collects data from coal mining operations in Colorado. Federal regulations require every coal mine to submit an annual hydrologic report which contains tabulated water quality data summarizing sampling done throughout the year. CMLRD prepares an annual report from these coal mine reports which assesses water quality impacts due to coal mining operations. Until recently, these reports have been shelved and nothing further has been done with the water quality data. CMLRD is now in the process of entering data from the annual reports into a computerized database managed by the U.S. Department of the Interior's Office of Surface Mining Reclamation and Enforcement (OSMRE) (Renner, 1992). This database was originally developed by the state of Wyoming and is written in Oracle. OSMRE is developing the database as part of the technical support it offers to states that are regulating coal mines and hopes to operate the database on a nation-wide basis in the future. Currently, Wyoming is using the database independently, and Colorado's data is the only water quality data in the national database (Kannawin, 1992). The database contains information such as lab parameters, location of sampling, constituents sampled and their measurements, and method of data collection. Some of the water quality parameters included in the database are pH, temperature, specific conductance, total dissolved solids, phosphate, nitrates, bicarbonate, sulfate, calcium, magnesium, manganese and aluminum (Just, 1992).

Other Agencies and Projects

Numerous agencies below the state level assist CDOH in carrying out its water quality control responsibilities. The administration and enforcement of public health laws is performed in cooperation with CDOH and the WQCC by county, district, and regional health departments. These local health departments are created by boards of county commissioners, who also appoint the boards of health which administer the departments (Vranesh, 1987b).

Municipalities in Colorado also participate in activities involving water quality control such as the construction and improvement of facilities for sewage treatment. Municipalities are also allowed to treat water, and can drain or fill ponds on private property for water quality abatement purposes (Vranesh, 1987b).

Councils of Governments (COGs)

As mentioned in Chapter 2, the Councils of Governments (COGs) are regional agencies which prepare areawide water quality management plans for submittal to the WQCC in accordance with Section 208 of the Clean Water Act (Dahl, 1980). In preparing these plans, the COGs often collect, review, and analyze water quality data supplied by their local government members.

In addition to preparing 208 plans, the Denver Regional Council of Governments (DRCOG) also performs special studies. Most of the data acquired by DRCOG is obtained from its member associations which include cities, counties and wastewater facilities. The data is generally short-term in nature and does not go into any of the national databases. An exception to this was data gathered for the Clean Lakes Program which was entered into STORET. DRCOG maintains a computerized database in Paradox for the water quality data it collects, and statistical and computational analyses are performed on the data using QuattroPro spreadsheets (Clayshulte, 1992). DRCOG has considered GIS as a future data management system that would enable the regional agency to be a central repository of data for its member associations (Clayshulte, 1991).

Another regional agency, the Northwest Colorado Council of Governments (NWCCOG), is actively looking into developing a water quality model to enhance special studies and the development of its 208 plans (Wyatt, 1992). NWCCOG's jurisdiction includes six counties, with one located east of the Continental Divide on the "east slope" and the rest on the "west slope." NWCCOG is therefore in the midst of the controversies surrounding water in Colorado due to the increasing transmountain diversions from the west slope to the more populated east slope (Dahl, 1980).

To assist in resolving water use and water quality conflicts, NWCCOG has proposed to develop a water quality model which would serve as a decision-making tool. NWCCOG's intent is to have all of the pertinent interests in its region involved in the model's development so that ultimately all would agree to its validity. The model could then be used in the decision-making process to generate management scenarios (Wyatt, 1992).

Since the key to the model's development and acceptance is the input provided by local entities throughout the process, NWCCOG assembled a 12-member panel representing a variety of interests in its region to oversee the project. The SEO has also been involved in the project because it is interested in potentially applying a successful prototype of the model statewide. Unfortunately, the panel has already had difficulty in reaching a consensus on a technical consultant to develop the model and the project is currently at an impasse (Wyatt, 1992).

Interestingly, in the late 1970's NWCCOG did develop a water quality database to assist in preparing its 208 plans. The database included sampling data from nearly 100 sites, information regarding water quality violations, and natural geologic and land use data. A computer mapping firm integrated this data with base data that included soil types, slope, aspect, climate zones, subbasins, headwaters, and potential activity zones. The software was designed to enable regional or site-specific printouts or maps to be obtained by NWCCOG and its member associations. These outputs would assist the agencies in identifying sources of water pollution and means of managing water quality (Dahl, 1980).

This database was used to prepare NWCCOG's first 208 plan, but it has since seen little use due to personnel changes and the dissolution of the company which wrote the software. There also was little documentation on the system, but the magnetic tapes for the program were found recently, and they are currently being evaluated by the SEO to see if the program can be modernized to be used in an ARC/INFO or similar format (Wyatt, 1992).

NWCCOG does not currently have an official database, although they do put some data into dBASE and Lotus for evaluation. The actual data collection is done by member agencies as part of special studies, such as studies for the expansion of the Keystone ski resort and an antidegradation study for a small proposed reservoir in Eagle County (Wyatt, 1992).

South Platte NAtional Water Quality Assessment (NAWQA) Program

Recognizing the need to have a nationally consistent description of water quality conditions and trends, the USGS proposed The NAtional Water Quality Assessment (NAWQA) Program in 1985. This program involves the assessment of conditions, trends, and factors affecting water quality, with an emphasis on large-scale persistent concerns such as the effects of nonpoint sources of pollution and high densities of point sources. The program consists of investigations of study units, or hydrologic regions composed of river basins and aquifer systems. These investigations address study unit and local water quality issues. The results of the investigations are then used to make regional and national water quality assessments (Leahy, et. al., 1990; Wilbur and Alley, 1988).

A four-year pilot program was begun in 1986 which consisted of four surface water and three ground water projects representing a variety of conditions and environments. The pilot program was used to test the concepts of the NAWQA program, suggest revisions where necessary, and provide an estimate of the costs of a full-scale national program (Wilbur and Alley, 1988). In 1991, the full-scale program was begun with the implementation of studies in 20 study units. One of the selected study units was the South Platte River Basin in Colorado, Wyoming, and Nebraska (Dennehy, 1991).

A liaison committee was formed in 1991 which consists of entities with an interest in the basin's water management. Included are representatives from federal, state and local agencies, universities, and the private sector. The liaison committee is charged with exchanging information about regional and local water quality issues, identifying sources of data and information, assisting in the design and scope of the South Platte NAWQA study, and reviewing documents and reports (Dennehy, 1991).

As part of the investigation, water quality data has been gathered by the USGS by several means, including from the USGS' NWIS database, the USEPA's STORET database, CDOH's QUALDAT database, or by direct transmission on paper or magnetic tape to the NAWQA project team. A discussion of NWIS and STORET can be found in Chapter 3, and QUALDAT is described earlier in this chapter. Table 29 lists federal, state, and local agencies which have contributed data to the South Platte NAWQA study (Litke, 1992a).

Table 29. South Platte NAWQA Water Quality Data Sources

Agency Name	Means of Data Contribution to South Platte NAWQA Study
Federal Agencies	
U.S. Army Corps of Engineers	STORET
U.S. Bureau of Reclamation	NWIS
U.S. Department of Energy	Direct transmission
U.S. Environmental Protection Agency	NWIS, STORET
U.S. Forest Service	STORET, direct transmission
U.S. Geological Survey (Water Resources Division)	NWIS
State Agencies	
Colorado Department of Health	STORET, direct transmission
Nebraska Department of Environmental Control	STORET
Nebraska Game and Park Commission	STORET
Wyoming Department of Environmental Quality	STORET
Local Agencies	
Central Colorado Water Conservancy District	NWIS
Denver Regional Council of Governments	NWIS, direct transmission
Denver Water Department	NWIS, STORET, direct transmission
Lower South Platte Water Conservancy District	Direct transmission
Metro Wastewater Reclamation District	NWIS, STORET, direct transmission
North Front Range Water Quality Planning Association	QUALDAT
Northern Colorado Water Conservancy District	NWIS
Pikes Peak Regional Council of Governments	STORET
Twin Platte Natural Resources District	Direct transmission

NWIS = USGS' NWIS database
STORET = USEPA's STORET database
Direct transmission = Paper or magnetic tapes given directly to NAWQA project team
QUALDAT = CDOH's QUALDAT database

Usable data is being processed using PSTAT, a statistical package. The USGS has set strict requirements for acceptable data which is based on several factors, including period of record, number of samples, and methodology of sampling and analysis. USGS personnel estimate that approximately 80 percent of the gathered data does not meet the criteria and cannot be used for the South Platte NAWQA assessment (Litke, 1992b).

South Platte River Basin Water Database Research

The South Platte River Basin is the also the subject of ongoing research at Colorado State University sponsored by the Colorado Water Resources Research Institute. This research will result in the preparation of a feasibility-stage planning document which will serve as the first phase in the development of a centralized water database for the basin. To accomplish the project objectives, interviews with prospective system users will be conducted to ascertain their concerns and needs regarding database development and management. In addition, the study will investigate existing water databases in Colorado and other states (Gates, 1990).

A secondary product of the research will be a brief assessment of water-related data in the basin, including water balance, water quality, economic, and water rights information. The condition, reliability, source, confidentiality and accessibility of the data will be included in the assessment (Gates, 1990).

Chapter 6. Recommendations for Colorado's Water Quality Data Management

Chapter 4 related current water quality data management in the United States, while a detailed description of water quality data collection, management, and use in Colorado was the highlight of Chapter 5. This chapter presents recommendations for Colorado's water quality data management based on the discussions in these previous chapters.

Issues in Colorado's Water Quality Data Management

As noted in Chapter 5, an extensive amount of water quality data is being collected and used by numerous agencies in Colorado. Some problems with current water quality data management practices identified by this research include:

-- *Lack of a centralized database.* Colorado does not have its own centralized water quality database. Therefore, national databases such as STORET or WATSTORE serve as the means of general access to state water quality data. However, only a few sections of the CDOH input water quality data on a regular basis into national databases. The Water Quality Standards Unit of CDOH's Water Quality Control Division is the only state agency that regularly contributes water quality data to STORET. Although California also has one agency which interacts with STORET, that agency maintains a centralized database through which it receives data from many other water quality agencies in the state. STORET receives data from the centralized database, and therefore contains data from all of the contributing agencies.

The only other national information systems which regularly receive data from Colorado are the USEPA's PCS and FRDS databases. Both of these databases are primarily "tracking" systems that do not contain actual water quality data.

-- *Lack of management of data collected.* The discussion in Chapter 5 noted that a large amount of collected water quality data ends up on shelves in files where it is not evaluated or used unless water quality violations are encountered. For example, the Drinking Water Section of CDOH's Water Quality Control Division collects water quality data from water systems throughout Colorado, but the only actual water quality data entered into a computerized database pertains to volatile organic compounds. Although the section uses the national FRDS database, that system only accommodates assessments of water quality data. Thus, most of the data gathered by the Drinking Water Section is filed away. A similar fate befalls data gathered by CDOH's Radiation Control Division and the Hazardous Materials and Waste Management Division, as well as the CDNR's State Engineer's Office and Mined Land Reclamation Division.

-- *Lack of integration of water quantity and water quality data.* The historical separation of water quantity and water quality in Colorado is becoming increasingly difficult to maintain because of the interrelation between these two issues. Changes in water quantity can affect water quality, and methods for altering water quality can affect water quantity.

The current organizational structure of the Colorado state agencies does not facilitate easy integration of water quality and quantity issues. Water quality control is centered in CDOH, while water rights are handled by CDNR. Although personnel in both agencies speak of a desire to share data, the separation of the two agencies makes such data sharing more difficult than it appears it should be. For example, the Permits and Enforcement Section of CDOH's Water Quality Control Division has requested diversion data from CDNR's State Engineer's Office because the water quantity data would assist them in setting permit limitations. Although CDOH has received positive verbal responses to their request, they have not received any actual data (Shukle, 1992). Conversely, the original intent of the SEO's Colorado Water Data Bank was to include water quality data from CDOH in the database (Longenbaugh and McMillin, 1974). However, in the twenty years since the database was established, CDOH has not supplied the SEO with any water quality data to develop that portion of the database (Longenbaugh, 1992).

An Alternative for Colorado's Water Quality Data Management

The problems noted above with water quality data management in Colorado can make the acquisition and use of water quality data a time-consuming and sometimes costly guessing game. One apparently simple answer would be the development of a centralized water quality and quantity database, but as mentioned in Chapter 1, the institutional problems between the parties that should participate in the database could make such an effort very complex. Chapter 5 noted the difficulties experienced by NWCCOG in developing an acceptable water quality model on just a regional level. Coordinating such an effort on a state level could be even more complicated.

A study of environmental data systems undertaken in 1973 by Colorado State University for CDNR identified three important guidelines for designing an information system (CSU, 1973):

1) The database must be useful to the decision-maker

2) The database must fit within Colorado's state budget

3) The database must be compatible with data collection and use technologies

A fourth criteria can be added regarding the need for agency cooperation and support. This was one of the major factors in the subsequent disinterest in implementing the recommendations of that report (Dyer, 1992).

It is not within the scope of this paper to actually design a centralized water quality database system for Colorado, but recommendations are made regarding the initiation of an effort that could satisfy these four criteria based on the background provided in the previous chapters.

Step 1: Secure funding from the state legislature to pursue the development of a centralized water quality database. This step will require the initiative of an agency or organization that will be committed throughout the initial phases to organizing and researching the database development. One of the first tasks of this entity will be to prepare a proposal to secure funding from the state legislature to pursue the steps outlined below.

Because the initiating organization should be able to coordinate the effort on a statewide basis, an agency at the state level could be an appropriate choice. However, both CDOH and CDNR, the two state agencies most involved with water quality issues, have regulatory functions which may discourage some entities from participating in the database development. In addition, many state agencies in Colorado are currently being faced with reduced budgets. It is therefore recommended that the Colorado Water Resources Research Institute (CWRRI) serve as the initiating organization.

Step 2: Establish a project task force. The large number of organizations using water quality data and the variety of usage of that data has been evident throughout this paper. The development of a useful centralized water quality data system by a single agency will not be easy because of this diversity. Therefore, a task force or consensus approach is recommended as a means of addressing Criteria 1 (useful database) and 4 (agency support and cooperation) cited previously. Because the database will be a statewide system, representatives from state agencies such as CDOH and CDNR should participate in the task force. Furthermore, the specific divisions, sections, and units of both of these agencies discussed in Chapter 5 should each have members on the task force.

To facilitate integration of the proposed database with existing databases at the federal, regional and local level, the task force should also include members from appropriate organizations. For example, USEPA representatives familiar with STORET, PCS, and FRDS should participate on the task force. USGS task force members should include those involved with WATSTORE, NWIS, NAWDEX, and NAWQA. At the local and regional level, municipalities and councils of governments could become involved on the task force. Table 30 lists agencies which were identified in Chapter 5 as maintaining some involvement in water quality data in Colorado. This list is far from complete but provides a preliminary indication of some potential task force members.

The coordination and assembly of the task force will require the designation of a lead agency which would most likely be the agency that undertakes Step 1. It may be possible to initially organize the task force by tapping into existing committees, such as the Nonpoint Source Task Force or its subcommittees, or the Wellhead Protection advisory group. The responsibilities of the task force would primarily be to facilitate the development process of the database by defining the project's objectives and needs. The task force would therefore be involved in organizing, implementing, and reviewing the workshops discussed in Step 3, reviewing the research of Step 4, and securing the needed financial support in Step 5.

Table 30. Potential Task Force Members Identified in Chapter 5

Federal agencies
- U.S. Environmental Protection Agency
- U.S. Geological Survey

State agencies
- Colorado Department of Health
  - Water Quality Control Division
    - Drinking Water Program Section
    - Permits and Enforcement Section
    - Ground Water and Standards Section
  - Radiation Control Division
  - Hazardous Materials and Waste Management Division
- Colorado Department of Natural Resources
  - Division of Water Resources (State Engineer's Office)
  - Mined Land Reclamation Division

Other organizations
- Councils of Governments
  - Denver Regional Council of Governments
  - Northwest Colorado Council of Governments
- Colorado Water Resources Research Institute
- Colorado State University

Step 3: Conduct a series of workshops to solicit input on user needs. Earlier discussions in Chapters 3, 4, and 5 have related the processes underway for the USEPA's modernization of the STORET, BIOS, and ODES databases, the USGS' development of NWIS-II and the NWIC, Cal EPA's planned development of a statewide water quality database, and the above-mentioned NWCCOG water quality model design. All of these projects incorporate a fundamental database development aspect: the importance of input in the early stages by potential users of the data system. This importance is illustrated by the discussion in Chapter 4 relating Florida's unsuccessful water quality database system that did not adequately include user input during its development.

The USGS' inventory of water quality data collection activities detailed in Chapter 4 identified 115 programs in 48 organizations in Colorado that collected water quality data. A list of water quality data sources for the South Platte NAWQA study, another USGS project, includes several additional

Colorado agencies that were not included in the inventory study. It is evident that the number and diversity of organizations that could potentially use the database would necessitate input for database design from as many of these entities as possible. Consequently, a series of workshops should be conducted in various regions of the state, and personal interviews could be conducted with potential users as well.

Issues that should be addressed in the workshops include:

-- *Data compatibility with existing databases.* Colorado currently has three databases at the state level which could potentially be integrated with the centralized water quality and quantity database: QUALDAT, the ground water quality database being developed by CDOH; the SEO's Colorado Water Data Bank; and the SEO's satellite-linked water resources monitoring system. Since both of the first two databases are in dBASE-compatible format, the selected database would also ideally be compatible with dBASE.

One of the significant results of the water quality data management survey was the fact that almost all agencies indicated their data was used by others. In addition, a large percentage of agencies obtained their data from other agencies, particularly at the state level. Thus, it can be concluded that the coordination of data with other federal, state, regional, and local agencies would be a potential need of a centralized Colorado water quality and quantity database. The need for data compatibility with USEPA, USGS, and other databases should therefore be addressed.

Colorado also has several interstate water bodies, and the management of these waters could involve data sharing outside of Colorado. Thus, data compatibility with data management systems of other agencies should also be a consideration in developing the database. The results of the water quality data management survey indicated that the predominantly-used software amongst state agencies was dBASE and Lotus, and this should be considered when choosing the database system.

-- *Assurance of data quality.* Almost all state and federal agency surface water quality data collected is subject to quality assurance guidelines, but such is not the case with data collected by local and regional entities or with ground water quality data (Childress, et. al., 1989). To ensure the utility of the data in the database, a structured organization should be set up to analyze and verify data prior to its input into the system.

-- *Data accessibility, confidentiality, and security.* The water quality data management survey results indicated that most water quality agencies use IBM-compatible personal computers. Thus, a centralized database that could be accessed by such hardware could potentially be the most useful. In addition, relatively user-friendly and cost-effective data retrievals would be desirable.

Data confidentiality issues could be major concerns for some organizations due to the accessibility of the database by regulatory agencies such as CDOH and the USEPA. Data alterations by unauthorized parties should also be prevented.

-- *Location of the centralized system.* Modems and telecommunications lines essentially allow the centralized database to be accessible from almost any location. Because of the institutional conflicts sometimes present between CDOH and CDNR and the regulatory nature of these agencies as well, it may be preferable to locate the centralized system at a neutral location. Wyoming's choice of the Wyoming Water Research Center appears to be successful, and a corresponding potential location in Colorado would be at the CWRRI.

-- *Output needs for the centralized system.* One of the criticisms of CDOH's QUALDAT ground water quality database is the difficulty of data retrievals from the system. It is essential for the water quality and quantity database to facilitate data retrievals that will give users the information they need. Thus, desired outputs should be defined by the task force at the outset of the database design.

Aside from generating summary reports, discussions with several individuals involved with water quality data in Colorado indicate that they would like to be able to have graphical capabilities for displaying data. Since many decision-makers are not technically oriented, graphical displays can enhance communication greatly.

-- *Potential for using a geographic information system (GIS).* Colorado is at a unique point in its data management development to address the development of a statewide water quality and quantity database. Currently, both CDNR's State Engineer's Office and CDOH are in the process of acquiring and implementing GISs for use in addressing water management issues. The graphics and database capabilities of GISs make them candidates for data management systems, as discussed in Chapter 3. Because both agencies appear to have already made a financial commitment to implement GIS, the additional funding needed to develop a GIS into a centralized database would need to cover primarily manpower costs if careful planning were done in choosing the GIS. Ideally, a consensus of the task force would be used to select the most appropriate GIS for both agencies. However, the existing time frame for GIS selection at CDNR and CDOH may not be sufficient to allow the formation of the task force and attainment of a consensus.

The survey results of Chapter 4 indicate that of agencies using GIS to manage water quality data, the most widely-used software is ARC/INFO. ARC/INFO is compatible with dBASE formats, which would allow integration with the state databases mentioned earlier. Disadvantages of using ARC/INFO lie in its large cost (upwards of $10,000 for a basic package) and its relatively complex command structure. However, it may be possible to provide an interface with ARC/INFO that would allow users that do not have ARC/INFO to extract data from the database in ASCII or dBASE formats without the graphical enhancements.

Step 4: Perform research into potential database management systems. Several alternatives for the centralized system can be readily identified from the previous discussions in this paper and should be researched further regarding their feasibility in being developed into the needed system. These alternatives include:

-- *Building the database on an existing system in Colorado.* CDOH's QUALDAT, the SEO's Colorado Water Data Bank, and the SEO's satellite-linked monitoring system should be studied as candidates for expansion into a centralized water quality data system.

-- *Using a database system that has been developed elsewhere.* As mentioned in Chapter 4, some states such as California have already developed centralized water quality databases. These databases should be evaluated regarding their potential application in Colorado.

-- *Creating a completely new system.* The requirements for creating an entirely new database should be researched. In order to enhance data integration capabilities, it is recommended that databases incorporating dBASE-compatible formats be investigated, as well as ARC/INFO. This suggestion is made based on the results of the water quality data management survey, in which dBASE was the predominant software used to manage water quality data, and ARC/INFO was the most-used GIS.

In addition, some of the issues discussed in the workshops should be further researched. For example, different methods of assuring data quality, maintaining data confidentiality, and providing data security should be investigated. Research activities should also address ongoing projects which might provide useful information for or tie into the database development. Such projects include the South Platte NAWQA study, the feasibility study being prepared at CSU for the South Platte Basin database, and the SEO's planned application of GIS to the Colorado River System. The reader is referred to Chapter 5 for further discussion of these projects.

Step 5: Secure a financial commitment from the state legislature. After reviewing the input from the workshops and research, the task force should put together a proposal regarding the recommended centralized system and estimated costs for the design, implementation, and maintenance of the system. Once approved by the task force, this proposal should be used to approach the state legislature for ongoing funds to support the system's implementation and maintenance.

Chapter 7. Conclusions

Federal and state regulations require the management of a large amount of water quality data. Over 20 sections of the Clean Water Act alone concern the collection and use of water quality data, and the USEPA has developed a standardized monitoring framework to assist states in complying with the extensive monitoring required by the Safe Drinking Water Act. In addition to these regulatory activities, water quality data is generated and used to support the development of remediation plans, make operational decisions, and perform research.

To manage this vast amount of data, a number of technologies are available, ranging from national databases such as the USEPA's STORET and the USGS' WATSTORE, to manual data management. Computer software such as spreadsheets, databases, statistical software, water quality models, and geographic information systems are also available.

Most water quality agencies in the United States are using one or more of these technologies to handle the extensive data collected to comply with regulations and perform research and development activities. The water quality data management survey of 200 agencies conducted as part of this research indicated that almost all agencies use some form of computerized data management. IBM-compatible personal computers were the most widely-used hardware. Amongst the national databases, state agencies tended to use STORET more that WATSTORE, while the opposite was true for federal agencies. State agencies also used other computer software such as dBASE and Lotus more than STORET.

A significant percentage of both federal and state agencies were using GISs, and almost all of those agencies were using ARC/INFO. In most cases, GIS was currently being used for special projects, but many agencies were also planning to expand their use to include ongoing water quality database management.

The survey results also indicated that federal agencies tended to be more involved in research and development activities than in regulatory activities, while state agencies were primarily involved in activities concerning NPDES permitting or drinking water standards. Suspended sediments and solids, temperature, and pH were the predominantly-used data types by surface water agencies. The most-used data types by ground water agencies were major cations, nitrogen, and pH.

Almost all of the agencies responding to the survey collected water quality data themselves, but a significant number of agencies also obtained data from other agencies. In addition, virtually all respondents indicated that their data was used by other entities, and a large number of agencies had formal or informal agreements for data sharing. This stresses the importance of ensuring data quality from data collection and analysis to data management because data collected by an agency for a specific purpose could ultimately be used by other agencies for to meet a variety of other needs.

Water quality data is gathered and used by many agencies in Colorado, including the Colorado Department of Health (CDOH) and Colorado Department of Natural Resources (CDNR) at the state level. There is no centralized database in Colorado, so general access to state water quality data must be achieved through national databases such as WATSTORE or STORET. Unfortunately, a large amount of the water quality data collected in Colorado does not make it into any computerized database. In addition, there is little integration of water quantity and quality data.

It is recommended that Colorado develop a statewide centralized water quality and quantity database. A task force composed of federal, state, and local agencies involved with water quality data in Colorado should be established to design and develop the database. A series of workshops conducted regionally throughout the state would provide a means for input on data needs and concerns by potential database users. Some issues which should be addressed in these workshops include: data compatibility with existing databases, the assurance of data quality, data accessibility, confidentiality and security, location of the centralized system, output needs for the centralized system, and the potential for using a GIS. Research should be conducted into the feasibility of building the database on an existing system in Colorado, adapting a database system that is in use elsewhere to Colorado, or creating an entirely new system. Once the task force has reached a consensus about project objectives and direction, a proposal should be made to the state legislature requesting ongoing funding for the implementation and maintenance of the system. It is suggested that the Colorado Water Resources Research Institute serve as the initiating agency in the database investigation and task force development.

Recommendations for Further Research

Because all of the survey responses were entered into a database with fields representing all of the items questioned, the following potential relationships regarding water quality data could be investigated:

1) data management systems and activities involving water quality data
2) data management systems and types of water quality data used
3) data management systems and sources of data
4) data management systems and interagency activities
5) activities involving water quality data and types of water quality data used
6) activities involving water quality data and sources of data
7) activities involving water quality data and interagency activities
8) types of water quality data used and sources of data

During the course of this research, it became apparent that time constraints would restrict the full analysis of the database. Appendix C contains an analysis of relationships 1, 5, 6, and 7. Further research could look at the remaining relationships.

As noted in Chapter 4, data management is constantly changing and survey data could quickly become out of date. By the time further analysis of the survey database could be completed, the results might not indicate current data management activities. Another use of the water quality data management survey could therefore be to investigate the actual rate of change of data management. This could be accomplished by undertaking another data management survey within the next five years and comparing results. Such an investigation could not only indicate how fast things change, but also what the trends are towards future water quality data management.

If another water quality data management survey were undertaken, some additional information could be sought regarding the organizational structure of state agencies that deal with water quality data. As one survey respondent pointed out, some states have designated a single lead agency for water quality data, while others have numerous agencies that handle water quality data. In addition, the financial mechanisms for handling data management varies between states, and it would be interesting to determine if any particular mechanism were more efficient or effective.

As noted in Chapter 4, conclusions were not made about responses in the "other" categories of the survey. It was found that because the survey was not designed to look specifically at items which were classified as "other," insufficient data was gathered, and the responses in these categories tended to cover a wide range of issues. For example, "other water quality" included atmospheric and precipitation water quality, marine and estuary water quality, stormwater and wastewater effluent quality, biological assessments, and leachate water quality at landfills. While each of these are important water quality issues, separate studies would have to be done to adequately address related water quality data management. Similarly, the survey focussed on federal and state agencies, but numerous local, regional, private, and educational organizations also use water quality data. In addition, sufficient information about specific activities such as nonpoint source pollution and stormwater management was not solicited by the survey. Future research could address water quality data management for these activities or assess management by other types of agencies.

There are many specific issues regarding water quality data that this research did not address. For example, quality assurance and quality control concerns were not covered in detail, nor were methodologies for data collection and analysis. Each of these items is also extremely important to obtaining and preserving the utility of water quality data. Means of maintaining adequate data quality in data management systems, especially if they are accessed by a number of users, should be researched. In addition, the use of citizen volunteers to perform water quality data collection is an alternative approach to water quality modeling that is beginning to play a role in some state water quality assessment programs (USEPA, 1990b). Future investigations into this concept could evaluate its effects on water quality data management.

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Appendix A. Status of Proposed and Promulgated Drinking Water Standards

	Standards				Best Available Technology	
Contaminant	Regulation	Status	MCLG *mg/L*	MCL *mg/L*	Conventional Processes	Specialized Processes
Organics						
Acrylamide	Phase II	Final	zero	TT	Polymer addition practices	
Adipates[di(ethylhexl)adipate]	Phase V	Proposed	0.5	0.5		GAC; PTA
Alachlor	Phase II	Final	zero	0.002		GAC
Aldicarb	Phase II	Final	0.001	0.003		GAC
Aldicarb sulfone	Phase II	Final	0.001	0.002		GAC
Aldicarb sulfoxide	Phase II	Final	0.001	0.004		GAC
Atrazine	Phase II	Final	0.003	0.003		GAC
Benzene	Phase I	Final	zero	0.005		GAC; PTA
Carbofuran	Phase II	Final	0.04	0.04		GAC
Carbon tetrachloride	Phase I	Final	zero	0.005		GAC; PTA
Chlordane	Phase II	Final	zero	0.002		GAC
2,4-D	Phase II	Final	0.07	0.07		GAC
Dalapon	Phase V	Proposed	0.2	0.2		GAC
Dibromochloropropane(DBCP)	Phase II	Final	zero	0.0002		GAC; PTA
p-Dichlorobenzene	Phase I	Final	0.075	0.075		GAC; PTA
o-Dichlorobenzene	Phase II	Final	0.6	0.6		GAC; PTA
1,2-Dichloroethane	Phase I	Final	zero	0.005		GAC; PTA
1,1-Dichloroethylene	Phase I	Final	0.007	0.007		GAC; PTA
cis-1,2-Dichloroethylene	Phase II	Final	0.07	0.07		GAC; PTA
trans-1,2-Dichloroethylene	Phase II	Final	0.1	0.1		GAC; PTA
Dichloromethane (methylene chloride)	Phase V	Proposed	zero	0.005		PTA
1,2-Dichloropropane	Phase II	Final	zero	0.005		GAC; PTA
Dinoseb	Phase V	Proposed	0.007	0.007		GAC
Diquat	Phase V	Proposed	0.02	0.02		GAC
Endothall	Phase V	Proposed	0.1	0.1		GAC
Endrin	Phase V	Proposed	0.002	0.002		GAC
Epichlorohydrin	Phase II	Final	zero	TT	Polymer addition practices	
Ethylbenzene	Phase II	Final	0.7	0.7		GAC; PTA
Ethylene dibromide(EDB)	Phase II	Final	zero	0.00005		GAC; PTA
Glyphosate	Phase V	Proposed	0.7	0.7		GAC
Heptachlor	Phase II	Final	zero	0.0004		GAC
Heptachlor epoxide	Phase II	Final	zero	0.0002		GAC
Hexachlorobenzene	Phase V	Proposed	zero	0.001		GAC
Hexachlorocyclopentadiene	Phase V	Proposed	0.05	0.05		GAC; PTA
Lindane	Phase II	Final	0.0002	0.0002		GAC
Methoxychlor	Phase II	Final	0.04	0.04		GAC
Monochlorobenzene	Phase II	Final	0.1	0.1		GAC; PTA
Oxamyl(vydate)	Phase V	Proposed	0.2	0.2		GAC
PAHs[benzo(a)pyrene]†	Phase V	Proposed	zero	0.0002		GAC
Pentachlorophenol	Phase II	Proposed	zero	0.001		GAC
Phthalates[di(ethylhexyl) phthalate]‡	Phase V	Proposed	zero	0.004		GAC
Picloram	Phase V	Proposed	0.5	0.5		GAC
Polychlorinated byphenyls (PCBs)	Phase II	Final	zero	0.0005		GAC
Simazine	Phase V	Proposed	0.004	0.004		GAC
Styrene	Phase II	Final	0.1	0.1		GAC; PTA
2,3,7,8-TCDD(dioxin)	Phase V	Proposed	zero	5E-08		GAC
Tetrachloroethylene	Phase II	Final	zero	0.005		GAC; PTA
Toluene	Phase II	Final	1	1		GAC; PTA
Toxaphene	Phase II	Final	zero	0.005		GAC
2,4,5-TP(silvex)	Phase II	Final	0.05	0.05		GAC
1,2,4-Trichlorobenzene	Phase V	Proposed	0.009	0.009		GAC; PTA
1,1,1-Trichloroethane	Phase I	Final	0.2	0.2		GAC; PTA
1,1,2-Trichloroethane	Phase V	Proposed	0.003	0.005		GAC; PTA
Trichloroethylene	Phase I	Final	zero	0.005		GAC; PTA
Total trihalomethanes§	Interim	Final		0.1	AD; PR; discontinue pre-Cl_2	
Vinyl chloride	Phase I	Final	zero	0.002		PTA
Xylenes (total)	Phase II	Final	10	10		GAC; PTA
Inorganics						
Antimony	Phase V	Proposed	0.003	0.01/0.005	C–F**	RO
Arsenic	Interim			0.05		
Asbestos (fibers/1 >10 μm)	Phase II	Final	7 MFL	7 MFL	C–F;** DF; DEF; CC	
Barium	Phase II	Final	2	2	LS**	IX; RO
Beryllium	Phase V	Proposed	zero	0.001	C–F**; LS**	AA; IX; RO
Cadmium	Phase II	Final	0.005	0.005	C–F;** LS**	IX; RO
Chromium (total)	Phase II	Final	0.1	0.1	C–F;** LS (Cr III)**	IX; RO
Copper	Lead and copper	Proposed	1.3	1.3	CC; SWT	
Cyanide	Phase V	Proposed	0.2	0.2	Cl_2	IX; RO
Fluoride	Fluoride	Final	4	4		AA; RO
Lead	Lead and copper	Final	zero	TT	CC; PE; SWT; LSLR	
Mercury	Phase II	Final	0.002	0.002	C–F (influent <10 μg/L);** LS**	GAC; RO (influent ≤10 μg/L)
Nickel	Phase V	Proposed	0.1	0.1	LS**	IX; RO
Nitrate (as N)	Phase II	Final	10	10		IX; RO
Nitrite (as N)	Phase II	Final	1	1		IX; RO

Figure 19. USEPA Drinking Water Standards and Best Available Technologies for Regulated Contaminants. *Source: Pontius (1992)*

	Standards				Best Available Technology	
Contaminant	Regulation	Status	MCLG *mg/L*	MCL *mg/L*	Conventional Processes	Specialized Processes
Nitrate + nitrite (both as N)	Phase II	Final	10	10		IX; RO
Selenium	Phase II	Final	0.05	0.05	C–F (Se IV);** LS**	AA; RO
Sulfate	Phase V	Proposed	400/500	400/500	C–F	IX; RO
Thallium	Phase V	Proposed	0.0005	0.002/0.001		AA; IX
Radionuclides						
Beta-particle and	Interim	Final	zero	4 mrem	C–F	
photon emitters	Rad	Proposed	zero	4 mrem	C–F	IX;RO
Alpha emitters	Interim	Final	zero	15 pCi/L	C–F	
	Rad	Proposed	zero	15 pCi/L	C–F	RO
Radium-226 + 228	Interim	Final	zero	5 pCi/L	C–F	
Radium-226	Rad	Proposed	zero	20 pCi/L	LS**	IX; RO
Radium-228	Rad	Proposed	zero	20 pCi/L	LS**	IX; RO
Radon	Rad	Proposed	zero	300 pCi/L		Aeration
Uranium	Rad	Proposed	zero	20 μg/L	C–F**; LS**	AX; LS
Microbials						
Giardia lamblia	SWTR	Final	zero	TT	C–F; SSF; DEF; DF; D	
Legionella	SWTR	Final††	zero	TT	C–F; SSF; DEF; DF; D	
Standard plate count	SWTR	Final††	NA	TT	C–F; SSF; DEF; DF; D	
Total coliforms	TCR	Final	zero	‡‡	D	
Turbidity	SWTR	Final	NA	PS	C–F; SSF; DEF; DF; D	
Viruses	SWTR	Final††[5]	zero	TT	C–F; SSF; DEF; DF; D	

*Abbreviations used in this table: AA—activated alumina; AD—alternative disinfectants; AX—anion exchange; CC—corrosion control; C–F—coagulation–filtration; Cl_2—chlorination; D—disinfection; DEF—diatomaceous earth filtration; DF—direct filtration; GAC—granular activated carbon; IX—ion exchange; LS—lime softening; LSLR—lead service line removal; PE—public education; PR—precursor removal; PS—performance standard 0.5–1.0 ntu; PTA—packed-tower aeration; RO—reverse osmosis; SWT—source water treatment; TT—treatment technique

†USEPA is considering establishing MCLGs and MCLs for six additional PAHs classified as probable human carcinogens—benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indenopyrene.

‡USEPA is considering regulating butylbenzl phthalate.

§The sum of the concentrations of bromodichloromethane, dibromochloromethane, tribromomethane, and trichloromethane

**Coagulation–filtration and lime softening are not BAT for small systems for variances unless treatment is already installed.

††Final for systems using surface water; also being considered for groundwater systems

‡‡No more than 5 percent of the samples per month may be positive. (For systems collecting fewer than 40 samples per month, no more than 1 sample per month may be positive.)

Figure 20. USEPA Drinking Water Standards and Best Available Technologies for Regulated Contaminants (cont.). *Source: Pontius (1992)*

Contaminant	Regulation	Status	SMCLs*
Aluminum	Phase II	Final	0.05 to 0.2
Chloride	Interim	Final	250
Color	Interim	Final	15 color units
Copper	Interim	Final	1
Corrosivity	Interim	Final	Noncorrosive
Fluoride	Fluoride	Final	2
Foaming agents	Interim	Final	0.5
Hexachlorocyclopentadiene	Phase V	Proposed	0.008
Iron	Interim	Final	0.3
Manganese	Interim	Final	0.05
Odor	Interim	Final	3 TON
pH	Interim	Final	6.5–8.5
Silver	Phase II	Final	0.10
Sulfate	Interim	Final	250
Total dissolved solids (TD)	Interim	Final	500
Zinc	Interim	Final	5

*Units of measure are milligrams per litre unless noted otherwise.

Figure 21. USEPA Secondary Standards. *Source: Pontius (1992)*

Appendix B. Water Quality Data Management Survey and Cover Letter

WATER QUALITY DATA MANAGEMENT SURVEY

This survey has been designed to assemble information regarding water quality data collection, use, and management, especially by state agencies. Your responses to the following questions are greatly appreciated. Please feel free to attach additional sheets if more space is necessary, or include applicable reports or papers, if any are available.

Please indicate what kind of water quality your agency is concerned with:

_____ Ground Water   _____ Surface Water   _____ Other (please specify)

Data Storage and Management

Please indicate which of the following data storage and management systems are used by your agency:

Data Management System	Ground Water Quality Data	Surface Water Quality Data	Other Water Quality Data
EPA STORET Database	____	____	____
USGS WATSTORE Database	____	____	____
Geographic Information Systems			
ARC/Info	____	____	____
GRASS	____	____	____
Other (please specify):			
____________________	____	____	____
Other Computerized Software			
DBase	____	____	____
RBase	____	____	____
Lotus	____	____	____
QuattroPro	____	____	____
Other (please specify):			
____________________	____	____	____
____________________	____	____	____
Manual Files	____	____	____
Other (please specify):			
____________________	____	____	____

What kind(s) of hardware are used with your data management system?

Personal Computers
_____ IBM/Compatible
_____ MacIntosh
_____ Other (please specify): ____________________

Other (Please specify):____________________
____
____

Mainframes
_____ IBM
_____ Other (please specify): ____________________

Minicomputers/Workstations
_____ VAX
_____ Other (please specify): ____________________

Identification of Activities Involving Water Quality Data

Please indicate which items from the following list involve your agency, ranking each in order of importance (i.e., 1 = most important). If your agency is involved in both ground and surface water quality, please fill out each column appropriately. If you specified another water quality involvement above, please fill out the "Other" column.

Activity	Ground Water Quality	Surface Water Quality	Other Water Quality
Federal Standards Compliance			
Clean Water Act			
NPDES Permitting	____	____	____
Other (please specify):			
____________________	____	____	____
Safe Drinking Water Act			
Federal Drinking Water Standards	____	____	____
Other (please specify):			
____________________	____	____	____
National Environmental Policy Act (NEPA)	____	____	____
Resource Conservation and Recovery Act (RCRA)	____	____	____
CERCLA (Superfund)	____	____	____
Surface Mining Control and Reclamation Act (SMCRA)	____	____	____
Other (please specify):			
____________________	____	____	____
State Standards Compliance			
Wellhead Protection Program	____	____	____
State Drinking Water Standards	____	____	____
Other (please specify):			
____________________	____	____	____
Research and Development			
Base-line/Trend Analysis	____	____	____
Model Development and Verification	____	____	____
Cause/Effect Studies	____	____	____
BMP Effectiveness Assessments	____	____	____
Public Inquiries	____	____	____
Project Management	____	____	____
Other (please specify):			
____________________	____	____	____

Types of Data Used

Which of the following data do you use for ground water, surface water, and other water quality activities? Please rank in order of importance (i.e., 1 = most important).

Constituent Categories	Ground Water Quality	Surface Water Quality	Other Water Quality	Constituent Categories	Ground Water Quality	Surface Water Quality	Other Water Quality
Discharge	____	____	____	BOD/COD	____	____	____
Temperature	____	____	____	Trace Metals	____	____	____
pH	____	____	____	Pesticides/Herbicides, etc.	____	____	____
Dissolved Oxygen	____	____	____	Volatile Organics (VOCs)	____	____	____
Major Cations				Bacteriological/Viral	____	____	____
(Ca, Mg, Na, K, etc.)	____	____	____	Chlorophyll a, Algae, etc.	____	____	____
Nitrogen	____	____	____	Radiological	____	____	____
Phosphorus	____	____	____	Other (please specify):			
Suspended Sediment/Solids	____	____	____	________________	____	____	____

Sources of Data and Interagency Activities

Where does your agency get its data from?

____ Your agency collects it
____ Private sources
____ HYDATA
____ Other (please specify)
____ Other agencies
____ EPA STORET Database
____ USGS WATSTORE Database

Do other public or private entities utilize data collected by your agency? ____ Yes ____ No

Does your agency have any cooperative agreements for exchanging water quality data and information? ____ Yes ____ No

Thank you very much for completing this questionnaire. Please fill out the agency information below to receive a copy of the summary of this survey. If you would like to discuss this survey further, please call Laurel Saito at (303) 491-6308.

Agency Name:____

Address:____

Contact Person:____________________ Telephone:____________________

Please FAX the completed questionnaire to Ms. Laurel Saito at (303) 491-2293. Or, fold and staple the questionnaire so that the following address is shown and attach proper postage.

Colorado State University

Colorado Water Resources
Research Institute
Fort Collins, Colorado 80523

MEMORANDUM

TO: State and Federal Water Quality Agencies

FROM: Laurel Saito, Graduate Student, Colorado State University
Neil S. Grigg, Director, Colorado Water Resources Research Institute

DATE: April 24, 1991

SUBJECT: Water Quality Data Management Survey

Legislation and recent environmental awareness have increased the need for water quality data. We are currently involved in a research project which is assessing water quality data management, especially by federal and state agencies. To aid in this assessment, a survey has been designed to gather information about current water quality data collection, use, and management practices.

Your participation is vital to the success of this survey. If you will take a few minutes to fill out the questionnaire and return it to us along with any report that you believe will aid in our assessment, we will respond by sending you a copy of the summary we will prepare as a result of this survey. This summary should be available in August, 1991.

Please return this survey by *May 17, 1991*. You may FAX the completed questionnaire to Ms. Laurel Saito at CWRRI at (303) 491-2293. Or, you may return the questionnaire to:

Water Quality Data Management Survey
Colorado Water Resources Research Institute
410 University Services Building
Colorado State University
Fort Collins, CO 80523

We will be conducting some telephone followups after May 17. If you would like to discuss this survey or need additional information, please call Ms. Laurel Saito at (303) 491-6308.

Thank you in advance for your time and cooperation.

Appendix C. Results of Detailed Analysis of Water Quality Activities

Because all of the survey responses were entered into a database with fields representing all of the items questioned, the following potential relationships regarding water quality data could be investigated:

1) data management systems and activities involving water quality data
2) data management systems and types of water quality data used
3) data management systems and sources of data
4) data management systems and interagency activities
5) activities involving water quality data and types of water quality data used
6) activities involving water quality data and sources of data
7) activities involving water quality data and interagency activities
8) types of water quality data used and sources of data

Time constraints restricted the ability to perform all of the analyses because, as mentioned earlier, the ongoing update of data management systems could change the results of the survey within a short amount of time. It was decided that one of the most useful ways of looking at the survey's data would be through water quality activities because most agencies can identify specific activities they are involved in. These different activities could have different data use and management needs. Thus, the detailed survey analysis looked at relationships 1, 5, 6, and 7.

The detailed analysis used the water quality activity subfiles shown in Table 6 in Chapter 4 and followed essentially the same procedure as the general survey analysis. Each of the subfiles was sorted into 34 smaller files by data management system, data types used, sources of data, and interagency activities. For example, the NPDESS subfile containing surface water agencies involved with NPDES permitting was sorted to create 34 new files. The process was repeated for NPDESG and NPDESO to create a total of 105 files relating to NPDES permitting (102 new files, NPDESS, NPDESG, and NPDESO). COUNT was then run on the new files and the data was put into a spreadsheet.

Tables 31 through 43 summarize the results of the detailed analyses for each water quality activity. Each table summarizes the data for federal, state, and all agencies according to water quality type. The "other agency" category was not included because the variety of agencies that fell into that category made any conclusions difficult. However, the category of "all" responding agencies does include "other agencies."

"Other water quality" is not shown in the tables because the number of agencies involved was too small to be significant. For the same reason, tables are not shown for SMCRA operations and water quality activities that fell into "other" categories. These activities include: other Clean Water Act activities, other Federal Drinking Water Act activities, other federal regulations, other state regulations, and other research and development activities.

The percentages shown in these tables generally reflect the percentages of agencies involved in a particular water quality activity that responded positively to the data item unless otherwise indicated. For example, a notation of "75%" after "Computer software" indicates that 75 percent of the agencies involved in the activity being summarized in the table were using computer software.

When looking at these percentages, it should be noted that many agencies indicated involvement in more than one activity and were not necessarily managing data in the same way, using the same data types, or getting data from the same sources for all activities. However, because of the organization of the survey, it was not possible to sort out these differences by activity for each agency. Thus, the numbers in the tables should only be interpreted as percentages of agencies that are involved in an activity that are also using the indicated item, but that use is not necessarily for the purpose of that particular activity.

The percentages shown in Tables 31 through 43 for "Most-used GIS" represent the percentages of agencies that indicated they were using GIS that were using the listed system. For example, 50 percent of the federal agencies involved with NPDES permitting indicated they were using GIS, and 91 percent of those agencies were using ARC/INFO. Thus, the latter value is shown in Table 31 next to the most-used GIS. A similar procedure was followed for displaying percentages of most-used computer software. Note also that when listing the most-used computer software, the "other" category was not considered because it actually included a variety of computer software that was not counted separately.

Conclusions of the Detailed Analysis of Water Quality Activities

The activities evaluated in this analysis can be broken into two general categories: regulatory activities, and research and development activities. Regulatory activities include NPDES permitting, federal and state drinking water standards, NEPA, RCRA, CERCLA, and wellhead protection. Baseline/trend analysis, model development, cause and effect studies, BMP effectiveness assessments, public inquiries, and project management fall under the research and development classification.

For all activities, state agencies were using predominantly computer software and STORET to manage surface water quality data. However, federal agencies involved with surface water regulatory activities used mostly manual data management, STORET, or computer software, while WATSTORE and GIS were the principal means of data management for federal agencies involved with surface water research and development.

Table 31. Summary of Survey Results for NPDES Permitting Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	22	57	108
Most-used data management	Comp sware (73%) Manual (59%)	Comp sware (89%) STORET (82%)	Comp sware (86%) Manual (62%)
Most-used GIS[1]	ARC/INFO (91%)	ARC/INFO (82%)	ARC/INFO (77%)
Most-used computer software[2]	dBASE (25%) Lotus (19%)	dBASE (82%) Lotus (71%)	Lotus (59%) dBASE (58%)
% using personal computers	82%	95%	90%
% using mainframes	55%	67%	60%
% using minicomputers/workstations	36%	28%	26%
Most-used data types	Susp sed/sol (95%) Diss oxygen (91%) pH (86%)	Diss oxygen (98%) Susp sed/sol (98%) pH (96%)	Diss oxygen (94%) Susp sed/sol (94%) Temperature (91%)
Most-used data sources	Agency itself (95%) Other agencies (68%)	Agency itself (96%) Other agencies (68%)	Agency itself (96%) Other agencies (61%)
% whose data is used by others	91%	95%	92%
% with cooperative agreements	68%	77%	71%
Ground Water Quality Agencies			
Total number of agencies	11	20	40
Most-used data management	Comp sware (64%) WATSTORE (64%)	Comp sware (75%) Manual (60%)	Comp sware (78%) Manual (53%)
Most-used GIS[1]	ARC/INFO (80%)	ARC/INFO (100%)	ARC/INFO (92%)
Most-used computer software[2]	dBASE (29%) Oracle (29%)	dBASE (67%) Lotus (53%)	dBASE (48%) Lotus (45%)
% using personal computers	82%	100%	95%
% using mainframes	55%	80%	58%
% using minicomputers/workstations	36%	30%	25%
Most-used data types	Maj cats; Nitrogen (82%) pH; Phosphorus (73%) Tr met; Pest/herb (73%)	Nitrogen (90%) VOCs (90%) pH; Trace metals (85%)	Trace metals (83%) VOCs (83%) Nitrogen; Pest/herb(80%)
Most-used data sources	Agency itself (100%) Other agencies (64%)	Agency itself (100%) Other agencies (80%)	Agency itself (100%) Other agencies (65%)
% whose data is used by others	91%	100%	95%
% with cooperative agreements	64%	85%	70%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 32. Summary of Survey Results for Federal Drinking Water Standards Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	22	42	92
Most-used data management	Manual (59%) STORET (59%)	Comp sware (93%) STORET (81%)	Comp sware (80%) Manual (62%)
Most-used GIS[1]	ARC/INFO (88%)	ARC/INFO (94%)	ARC/INFO (90%)
Most-used computer software[2]	dBASE (42%) Lotus (25%)	dBASE (74%) Lotus (62%)	dBASE (58%) Lotus (51%)
% using personal computers	73%	93%	87%
% using mainframes	50%	69%	54%
% using minicomputers/workstations	36%	38%	32%
Most-used data types	Susp sed/sol (100%) Diss oxygen (95%) pH (95%)	Trace metals (95%) pH (93%) Temp; Bacti/viral (90%)	Susp sed/sol (90%) pH (89%) Trace metals (88%)
Most-used data sources	Agency itself (95%) Othr agcys; STORET (45%)	Agency itself (98%) Other agencies (64%)	Agency itself (97%) Other agencies (52%)
% whose data is used by others	91%	100%	93%
% with cooperative agreements	68%	79%	66%
Ground Water Quality Agencies			
Total number of agencies	19	41	81
Most-used data management	Manual (68%) WATSTORE (53%)	Comp sware (85%) Manual (54%)	Comp sware (75%) Manual (57%)
Most-used GIS[1]	ARC/INFO (83%)	ARC/INFO (100%)	ARC/INFO (93%)
Most-used computer software[2]	dBASE (33%) Lotus (33%)	dBASE (60%) Lotus (46%)	dBASE (48%) Lotus (46%)
% using personal computers	79%	93%	88%
% using mainframes	53%	59%	49%
% using minicomputers/workstations	37%	41%	32%
Most-used data types	Major cations (79%) Trace metals (74%)	VOCs (98%) Pest/herbicides (90%) Trace metals (88%)	Trace metals (84%) VOCs (81%) Pest/herbicides (81%)
Most-used data sources	Agency itself (95%) Other agencies (63%)	Agency itself (98%) Other agencies (71%)	Agency itself (96%) Other agencies (60%)
% whose data is used by others	89%	100%	94%
% with cooperative agreements	74%	78%	69%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 33. Summary of Survey Results for NEPA Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	22	22	56
Most-used data management	Manual (64%) STORET (59%)	STORET (86%) Comp sware (77%)	Comp sware (80%) STORET (61%)
Most-used GIS[1]	ARC/INFO (67%)	ARC/INFO (100%)	ARC/INFO (78%)
Most-used computer software[2]	dBASE (27%) Lotus; Oracle (27%)	dBASE (100%) Lotus (76%)	dBASE (65%) Lotus (57%)
% using personal computers	77%	95%	88%
% using mainframes	64%	77%	70%
% using minicomputers/workstations	32%	32%	32%
Most-used data types	Susp sed/sol (91%) pH (86%) Disch; Diss oxygen (82%)	Susp sed/sol; DO (95%) Nitrogen (95%) Phosphorus (95%)	Susp sed/sol (93%) Diss oxygen (89%) Temperature; pH (88%)
Most-used data sources	Agency itself (91%) Othr agcys; WATSTOR (45%)	Agency itself (95%) Other agencies (82%)	Agency itself (93%) Other agencies (63%)
% whose data is used by others	82%	95%	88%
% with cooperative agreements	73%	86%	71%
Ground Water Quality Agencies			
Total number of agencies	11	12	28
Most-used data management	WATSTORE (73%) Comp sware (64%)	STORET (67%) Comp sware; Manual (67%)	Comp sware (71%) Manual (50%)
Most-used GIS[1]	ARC/INFO (83%)	ARC/INFO (100%)	ARC/INFO (85%)
Most-used computer software[2]	dBASE (29%) Oracle (29%)	dBASE (88%) Lotus (50%)	dBASE (55%) Lotus (45%)
% using personal computers	100%	100%	100%
% using mainframes	64%	67%	61%
% using minicomputers/workstations	36%	42%	32%
Most-used data types	Nitrogen; Pest/herb (82%) Maj cat; Phosphorus (73%) Trace metals (73%)	Nitrogen (100%) VOCs; Phosphorus (92%) Major cations (92%)	Nitrogen (86%) Major cations (86%) Pest/herb; VOCs (82%)
Most-used data sources	Agency itself (91%) Othr agcys; WATSTOR (73%)	Agency itself (100%) Other agencies (92%)	Agency itself (96%) Other agencies (75%)
% whose data is used by others	91%	100%	96%
% with cooperative agreements	73%	92%	75%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 34. Summary of Survey Results for RCRA Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	15	25	49
Most-used data management	Manual (67%) Comp sware (67%)	STORET (96%) Comp sware (88%)	Comp sware (78%) STORET (71%)
Most-used GIS[1]	ARC/INFO (75%)	ARC/INFO (83%)	ARC/INFO (77%)
Most-used computer software[2]	dBASE (20%) INGRES (20%)	dBASE (86%) Lotus (82%)	dBASE (63%) Lotus (61%)
% using personal computers	80%	100%	92%
% using mainframes	53%	72%	67%
% using minicomputers/workstations	40%	28%	35%
Most-used data types	Susp sed/sol (100%) Diss oxygen (93%) ph; Nitrogen; Phosph (87%)	Trace metals; Temp (100%) Nitrogen; Phosph (100%) Diss oxygen (100%)	Susp sed/sol (96%) Diss oxygen (96%) Temp; Phosphorus (94%)
Most-used data sources	Agency itself (100%) Othr agcys; STORET (67%)	Agency itself (96%) Other agencies (84%)	Agency itself (96%) Other agencies (73%)
% whose data is used by others	100%	96%	94%
% with cooperative agreements	73%	88%	73%
Ground Water Quality Agencies			
Total number of agencies	15	26	45
Most-used data management	WATSTORE (73%) Comp sware (67%)	Comp sware (73%) STORET (62%)	Comp sware (71%) Man; GIS; STOR (49%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (91%)
Most-used computer software[2]	dBASE; Oracle (20%) INGRES (20%)	dBASE (68%) Lotus (63%)	dBASE (50%) Lotus (47%)
% using personal computers	80%	92%	87%
% using mainframes	67%	65%	64%
% using minicomputers/workstations	53%	38%	40%
Most-used data types	Major cations (93%) Trace metals (87%) VOCs (87%)	Nitrogen; VOCs (88%) pH; Trace metals (85%) Pest/herbicides (85%)	VOCs (87%) Maj cats;Pest/herb (82%) Nitr; Tr met; pH (82%)
Most-used data sources	Agency itself (100%) Othr agcys; WATSTOR (73%)	Agency itself (100%) Other agencies (81%)	Agency itself (100%) Other agencies (73%)
% whose data is used by others	93%	100%	98%
% with cooperative agreements	73%	92%	80%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 35. Summary of Survey Results for CERCLA Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	17	28	51
Most-used data management	Manual (71%) STORET (59%)	STORET (96%) Comp sware (89%)	Comp sware (78%) STORET (75%)
Most-used GIS[1]	ARC/INFO (78%)	ARC/INFO (92%)	ARC/INFO (83%)
Most-used computer software[2]	dBASE; Lotus (22%) INGRES (22%)	dBASE (84%) Lotus (84%)	Lotus (68%) dBASE (65%)
% using personal computers	65%	100%	86%
% using mainframes	53%	79%	71%
% using minicomputers/workstations	41%	29%	33%
Most-used data types	Susp sed/sol (94%) Diss oxygen (88%) pH (88%)	Trace metals (100%) Diss oxygen (100%) Temperature (100%)	Susp sed/sol (96%) Diss oxygen (96%) pH (94%)
Most-used data sources	Agency itself (100%) STORET (53%)	Agency itself (100%) Other agencies (82%)	Agency itself (100%) Other agencies (67%)
% whose data is used by others	100%	100%	98%
% with cooperative agreements	65%	86%	73%
Ground Water Quality Agencies			
Total number of agencies	15	27	46
Most-used data management	WATSTORE (73%) Comp swr; GIS; Manual (60%)	Comp sware (78%) STORET (59%)	Comp sware (72%) Manual (52%)
Most-used GIS[1]	ARC/INFO (89%)	ARC/INFO (100%)	ARC/INFO (91%)
Most-used computer software[2]	dBASE (22%) Lot; Orcl; SAS; INGR (11%)	dBASE (71%) Lotus (62%)	dBASE (55%) Lotus (48%)
% using personal computers	80%	96%	89%
% using mainframes	73%	67%	67%
% using minicomputers/workstations	60%	37%	41%
Most-used data types	Major cations (93%) Nitrogen; Tr met (87%) Pest/herb; VOCs (87%)	Nitrogen; VOCs (93%) Pest/herbicides (85%) pH; Trace metals (85%)	VOCs (89%) Nitrogen (87%) Pest/herbicides (85%)
Most-used data sources	Agency itself (100%) Other agencies (73%)	Agency itself (100%) Other agencies (78%)	Agency itself (100%) Other agencies (72%)
% whose data is used by others	93%	100%	98%
% with cooperative agreements	73%	89%	78%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 36. Summary of Survey Results for Wellhead Protection Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	3	16	26
Most-used data management	Comp sware (100%) Manual (67%)	Comp sware (88%) STORET (75%)	Comp sware (92%) Manual (62%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (100%)
Most-used computer software[2]	dBASE; Lotus (33%) RBase; Oracle (33%)	dBASE (79%) Lotus (50%)	dBASE (63%) Lotus (46%)
% using personal computers	100%	88%	85%
% using mainframes	100%	63%	65%
% using minicomputers/workstations	33%	25%	27%
Most-used data types	Disch;Susp sed/sol;pH (100%) Temp;Maj cat;Tr met (100%) DO;VOCs;Bacti/vir (100%)	Trace metals (100%) Bacti/viral (100%) Major cations (94%)	Trace metals (100%) Bacti/viral (100%) pH;Maj cat;VOCs (92%)
Most-used data sources	Agency itself (100%) Othr agcys;WATSTORE (67%)	Agency itself (100%) Other agencies (69%)	Agency itself (96%) Other agencies (54%)
% whose data is used by others	100%	100%	100%
% with cooperative agreements	67%	75%	69%
Ground Water Quality Agencies			
Total number of agencies	14	34	68
Most-used data management	WATSTORE (79%) Comp swr; GIS; Manual (57%)	Comp sware (82%) STORET; Manual (50%)	Comp sware (76%) Manual (53%)
Most-used GIS[1]	ARC/INFO (88%)	ARC/INFO (100%)	ARC/INFO (93%)
Most-used computer software[2]	dBASE (25%) Lotus (25%)	dBASE (64%) Lotus (46%)	dBASE (46%) Lotus (46%)
% using personal computers	93%	94%	91%
% using mainframes	79%	62%	56%
% using minicomputers/workstations	36%	35%	29%
Most-used data types	Major cations (93%) Nitrogen (86%) Trace metals (86%)	Trace metals (91%) Pest/herbicides (91%) VOCs (91%)	Trace metals (90%) Pest/herbicides (88%) Nitrogen; VOCs (81%)
Most-used data sources	Agency itself (93%) WATSTORE (79%)	Agency itself (100%) Other agencies (71%)	Agency itself (97%) Other agencies (60%)
% whose data is used by others	93%	100%	97%
% with cooperative agreements	86%	79%	72%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 37. Summary of Survey Results for State Drinking Water Standards Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	19	42	87
Most-used data management	Manual (63%) STORET (58%)	Comp sware (93%) STORET (81%)	Comp sware (79%) Manual (62%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (94%)	ARC/INFO (96%)
Most-used computer software[2]	dBASE (50%) Lotus (25%)	dBASE (74%) Lotus (59%)	dBASE (61%) Lotus (51%)
% using personal computers	63%	93%	85%
% using mainframes	47%	62%	51%
% using minicomputers/workstations	32%	33%	29%
Most-used data types	Susp sed/sol (100%) Discharge (100%) Phosphorus (100%)	Phosphorus (100%) Trace metals (95%) pH (93%)	Phosphorus (100%) Trace metals (91%) pH (91%)
Most-used data sources	Agency itself (95%) Other agencies (58%)	Agency itself (98%) Other agencies (67%)	Agency itself (97%) Other agencies (56%)
% whose data is used by others	84%	100%	92%
% with cooperative agreements	63%	79%	67%
Ground Water Quality Agencies			
Total number of agencies	17	40	84
Most-used data management	Manual (59%) WATSTORE; Comp swr (53%)	Comp sware (83%) Manual (58%)	Comp sware (77%) Manual (56%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (94%)
Most-used computer software[2]	dBASE (33%) Lotus (33%)	dBASE (55%) Lotus (42%)	Lotus (45%) dBASE (42%)
% using personal computers	82%	90%	87%
% using mainframes	65%	60%	51%
% using minicomputers/workstations	47%	43%	33%
Most-used data types	Major cations (88%) Trace metals (82%)	VOCs (95%) Trace metals (90%) pH; Pest/herbicides (88%)	Trace metals (87%) VOCs (82%) Major cations (82%)
Most-used data sources	Agency itself (100%) Other agencies (71%)	Agency itself (98%) Other agencies (70%)	Agency itself (98%) Other agencies (61%)
% whose data is used by others	94%	100%	95%
% with cooperative agreements	82%	78%	71%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 38. Summary of Survey Results for Baseline/Trend Analysis Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	47	55	137
Most-used data management	WATSTORE (66%) GIS (62%)	Comp sware (93%) STORET (80%)	Comp sware (75%) Manual (59%)
Most-used GIS[1]	ARC/INFO (90%)	ARC/INFO (92%)	ARC/INFO (85%)
Most-used computer software[2]	dBASE (36%) Lotus (32%)	dBASE (75%) Lotus (63%)	dBASE (58%) Lotus (50%)
% using personal computers	60%	100%	83%
% using mainframes	51%	64%	54%
% using minicomputers/workstations	62%	33%	42%
Most-used data types	Susp sed/sol (96%) pH (96%) Discharge (94%)	Temperature (96%) Diss oxygen (96%) pH (96%)	Temperature (94%) pH (93%) DO; Susp sed/sol (91%)
Most-used data sources	Agency itself (98%) WATSTORE (57%)	Agency itself (100%) Other agencies (76%)	Agency itself (98%) Other agencies (59%)
% whose data is used by others	91%	98%	95%
% with cooperative agreements	79%	84%	78%
Ground Water Quality Agencies			
Total number of agencies	29	33	86
Most-used data management	WATSTORE (86%) GIS (72%)	Comp sware (85%) Manual (58%)	Comp sware (72%) GIS (52%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (93%)
Most-used computer software[2]	dBASE (33%) Lotus;Oracle;INGRES (17%)	dBASE (61%) Lotus (61%)	dBASE (50%) Lotus (42%)
% using personal computers	59%	100%	84%
% using mainframes	59%	58%	55%
% using minicomputers/workstations	79%	39%	49%
Most-used data types	Major cations (100%) Trace metals (97%) pH (93%)	Major cations (88%) Trace metals (88%) Nitrogen (88%)	Major cations (92%) Trace metals (91%) Nitrogen (87%)
Most-used data sources	Agency itself (93%) WATSTORE (66%)	Agency itself (100%) Other agencies (79%)	Agency itself (95%) Other agencies (60%)
% whose data is used by others	100%	100%	99%
% with cooperative agreements	90%	91%	85%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 39. Summary of Survey Results for Model Development and Verification Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	33	46	102
Most-used data management	WATSTORE (67%) GIS (58%)	Comp sware (91%) STORET (87%)	Comp sware (78%) STORET (62%)
Most-used GIS[1]	ARC/INFO (95%)	ARC/INFO (95%)	ARC/INFO (90%)
Most-used computer software[2]	dBASE (39%) Lotus (22%)	dBASE (74%) Lotus (67%)	dBASE (66%) Lotus (54%)
% using personal computers	61%	98%	85%
% using mainframes	55%	67%	61%
% using minicomputers/workstations	64%	43%	46%
Most-used data types	Susp sed/sol (97%) pH (97%) Discharge (97%)	Diss oxygen (98%) Phosphorus (96%) pH; Temperature (96%)	Diss oxygen (95%) pH (94%) Temperature (94%)
Most-used data sources	Agency itself (97%) WATSTORE (58%)	Agency itself (100%) Other agencies (80%)	Agency itself (98%) Other agencies (62%)
% whose data is used by others	100%	98%	97%
% with cooperative agreements	85%	85%	81%
Ground Water Quality Agencies			
Total number of agencies	26	19	59
Most-used data management	WATSTORE (92%) GIS (77%)	Comp sware (89%) STORET (68%)	Comp sware (75%) GIS (59%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (94%)
Most-used computer software[2]	dBASE (31%) Lotus; Oracle (15%)	dBASE (59%) Lotus (53%)	dBASE (50%) Lotus (32%)
% using personal computers	58%	100%	81%
% using mainframes	54%	68%	56%
% using minicomputers/workstations	77%	47%	54%
Most-used data types	Major cations (100%) Trace metals (100%) Pest/herbicides (100%)	Trace metals (95%) Major cations (89%) VOCs;Pest/herb;Nitrogen (84%)	Trace metals (95%) Maj cats;Nitrogen (92%) Pest/herbicides (92%)
Most-used data sources	Agency itself (92%) WATSTORE (73%)	Agency itself (100%) Other agencies (84%)	Agency itself (95%) Other agencies (64%)
% whose data is used by others	100%	100%	100%
% with cooperative agreements	88%	95%	86%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 40. Summary of Survey Results for Cause and Effect Study Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	38	48	116
Most-used data management	WATSTORE (76%) GIS (61%)	Comp sware (92%) STORET (81%)	Comp sware (77%) Manual (57%)
Most-used GIS[1]	ARC/INFO (96%)	ARC/INFO (95%)	ARC/INFO (87%)
Most-used computer software[2]	dBASE (28%) Lotus (22%)	dBASE (73%) Lotus (66%)	dBASE (56%) Lotus (51%)
% using personal computers	58%	98%	83%
% using mainframes	50%	69%	59%
% using minicomputers/workstations	66%	38%	45%
Most-used data types	Susp sed/sol (95%) pH; Diss oxygen (95%) Discharge (95%)	Diss oxygen (98%) pH (96%) Temperature (96%)	Diss oxygen (94%) Temperature (94%) pH (93%)
Most-used data sources	Agency itself (97%) WATSTORE (61%)	Agency itself (100%) Other agencies (77%)	Agency itself (97%) Other agencies (59%)
% whose data is used by others	97%	98%	97%
% with cooperative agreements	82%	90%	81%
Ground Water Quality Agencies			
Total number of agencies	27	23	71
Most-used data management	WATSTORE (93%) GIS (74%)	Comp sware (91%) STORET; Manual (57%)	Comp sware (73%) GIS (56%)
Most-used GIS[1]	ARC/INFO (95%)	ARC/INFO (100%)	ARC/INFO (90%)
Most-used computer software[2]	dBASE (33%) Lotus (25%)	dBASE (57%) Lotus (52%)	dBASE (46%) Lotus (37%)
% using personal computers	56%	100%	80%
% using mainframes	59%	74%	59%
% using minicomputers/workstations	78%	57%	56%
Most-used data types	Major cations (100%) Trace metals (100%) Pest/herb;Nitr;pH (96%)	Nitrogen (91%) Major cations (91%) Trace metals (87%)	Major cations (94%) Trace metals (93%) Nitrogen (92%)
Most-used data sources	Agency itself (93%) WATSTORE (63%)	Agency itself (100%) Other agencies (91%)	Agency itself (94%) Other agencies (62%)
% whose data is used by others	100%	100%	100%
% with cooperative agreements	89%	87%	79%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 41. Summary of Survey Results for BMP Effectiveness Assessment Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	33	42	97
Most-used data management	STORET (64%) Comp sware (52%)	Comp sware (93%) STORET (88%)	Comp sware (77%) STORET (66%)
Most-used GIS[1]	ARC/INFO (79%)	ARC/INFO (91%)	ARC/INFO (81%)
Most-used computer software[2]	Lotus (47%) dBASE (41%)	dBASE (79%) Lotus (49%)	dBASE (65%) Lotus (48%)
% using personal computers	76%	100%	90%
% using mainframes	52%	71%	59%
% using minicomputers/workstations	45%	33%	35%
Most-used data types	Susp sed/sol (91%) Discharge (88%) pH;Temp;Diss oxyg (85%)	Diss oxygen (100%) Phosphorus (100%) Susp sed/sol (100%)	Susp sed/sol (94%) Temperature (93%) Diss oxygen (92%)
Most-used data sources	Agency itself (97%) WATS;STOR;Othr agcys(45%)	Agency itself (100%) Other agencies (71%)	Agency itself (99%) Other agencies (59%)
% whose data is used by others	91%	98%	94%
% with cooperative agreements	73%	86%	76%
Ground Water Quality Agencies			
Total number of agencies	14	16	39
Most-used data management	WATSTORE (86%) GIS; Comp sware (64%)	Comp sware (94%) STORET; Manual (75%)	Comp sware (85%) Manual (62%)
Most-used GIS[1]	ARC/INFO (89%)	ARC/INFO (100%)	ARC/INFO (89%)
Most-used computer software[2]	dBASE (22%) Oracle (22%)	dBASE (67%) Lotus (67%)	dBASE (52%) Lotus (42%)
% using personal computers	79%	100%	92%
% using mainframes	64%	75%	62%
% using minicomputers/workstations	71%	38%	44%
Most-used data types	Pest/herbicides (93%) Trace metals (96%) Maj cats;Nitrogen (96%)	Pest/herbicides (94%) Major cations (94%) Trace metals; VOCs (94%)	Pest/herbicides (95%) Trace metals (90%) Major cations (90%)
Most-used data sources	Agency itself (93%) WATSTORE;Othr agcys (50%)	Agency itself (100%) Other agencies (88%)	Agency itself (97%) Other agencies (67%)
% whose data is used by others	93%	100%	97%
% with cooperative agreements	79%	94%	77%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 42. Summary of Survey Results for Public Inquiry Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	34	55	119
Most-used data management	WATSTORE (76%) GIS (71%)	Comp sware (91%) STORET (80%)	Comp sware (79%) Manual (59%)
Most-used GIS[1]	ARC/INFO (96%)	ARC/INFO (91%)	ARC/INFO (89%)
Most-used computer software[2]	dBASE (39%) Lotus (22%)	dBASE (74%) Lotus (64%)	dBASE (59%) Lotus (49%)
% using personal computers	59%	96%	83%
% using mainframes	53%	62%	56%
% using minicomputers/workstations	65%	35%	40%
Most-used data types	Susp sed/sol (100%) Diss oxygen (100%) pH (97%)	Diss oxygen (95%) pH (95%) Phosph; Temp (93%)	pH (94%) Temperature (93%) Diss oxygen (93%)
Most-used data sources	Agency itself (97%) WATSTORE (65%)	Agency itself (100%) Other agencies (73%)	Agency itself (97%) Other agencies (57%)
% whose data is used by others	100%	100%	98%
% with cooperative agreements	79%	87%	79%
Ground Water Quality Agencies			
Total number of agencies	29	36	81
Most-used data management	WATSTORE (93%) GIS (85%)	Comp sware (83%) Manual (56%)	Comp sware (72%) GIS (58%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (98%)
Most-used computer software[2]	dBASE (29%) Lotus (21%)	dBASE (60%) Lotus (53%)	dBASE (48%) Lotus (40%)
% using personal computers	56%	100%	81%
% using mainframes	56%	64%	58%
% using minicomputers/workstations	78%	42%	48%
Most-used data types	Major cations (100%) Trace metals (100%) Nitrogen; pH (96%)	Nitrogen (89%) VOCs (86%)	Major cations (93%) Trace metals (90%) Nitrogen (88%)
Most-used data sources	Agency itself (96%) WATSTORE (67%)	Agency itself (100%) Other agencies (78%)	Agency itself (96%) Other agencies (59%)
% whose data is used by others	100%	100%	100%
% with cooperative agreements	89%	86%	81%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

Table 43. Summary of Survey Results for Project Management Activities

	Federal Agencies	State Agencies	All Agencies
Surface Water Quality Agencies			
Total number of agencies	27	45	95
Most-used data management	WATSTORE (63%) Manual (59%)	Comp sware (91%) STORET (80%)	Comp sware (78%) Manual (63%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (88%)	ARC/INFO (87%)
Most-used computer software[2]	dBASE (42%) Lotus (33%)	dBASE (76%) Lotus (61%)	dBASE (61%) Lotus (53%)
% using personal computers	59%	96%	83%
% using mainframes	56%	60%	60%
% using minicomputers/workstations	59%	38%	41%
Most-used data types	Susp sed/sol (96%) Diss oxygen;pH (93%) Temp; Discharge (93%)	Diss oxygen (93%) pH (93%) Phosphorus (93%)	pH (94%) Temperature (94%) Major cations (92%)
Most-used data sources	Agency itself (96%) WATSTORE;Othr agcys (56%)	Agency itself (100%) Other agencies (71%)	Agency itself (97%) Other agencies (59%)
% whose data is used by others	89%	100%	94%
% with cooperative agreements	74%	82%	76%
Ground Water Quality Agencies			
Total number of agencies	17	26	54
Most-used data management	WATSTORE (88%) GIS (82%)	Comp sware (88%) STORET (50%)	Comp sware (80%) GIS (56%)
Most-used GIS[1]	ARC/INFO (100%)	ARC/INFO (100%)	ARC/INFO (93%)
Most-used computer software[2]	dBASE (33%) Lotus (33%)	dBASE (57%) Lotus (48%)	dBASE (44%) Lotus (40%)
% using personal computers	53%	100%	83%
% using mainframes	59%	65%	61%
% using minicomputers/workstations	94%	65%	72%
Most-used data types	Major cations (100%) Trace metals; pH (100%) Nitrogen (100%)	Nitrogen (92%) Major cations (88%)	Major cations (94%) Nitrogen (93%) Trace metals (89%)
Most-used data sources	Agency itself (100%) WATSTORE (65%)	Agency itself (100%) Other agencies (77%)	Agency itself (98%) Other agencies (63%)
% whose data is used by others	100%	100%	100%
% with cooperative agreements	82%	88%	80%

[1]Percent of agencies using GIS using this system
[2]Percent of agencies using computer software using these programs

For ground water, state agencies use computer software the most for almost all activities. Federal agencies used WATSTORE predominantly for all activities, and GIS was a strong second for research and development activities. This high usage of GIS for research-oriented efforts corresponds with conversations with survey respondents which indicated that most current GIS usage is for special projects. Regulatory activities are often ongoing in nature, while many short-term projects could be considered research-related.

In general, a higher percentage of state agencies indicated usage of some data management system than federal agencies. Lotus and dBASE were the most commonly-used computer software.

Almost all state agencies used personal computers, with less usage of mainframes and even fewer minicomputers or workstations. Federal agencies involved with regulatory activities also followed this pattern, but those involved with research activities generally showed almost equal usage of all three types of computers. This was an interesting result and may be related to the higher usage of GIS by federal agencies involved with research, since ARC/INFO and other GISs operate best on mainframes or workstations.

The only significant difference noted between federal and state surface water agencies in terms of data types was that federal agencies tended to use suspended sediment and solids data for almost all activities, but this was not generally the predominant data type used by state surface water agencies. Federal agencies also used discharge data more frequently than state agencies. The most-used data types for both federal and state surface water agencies were: dissolved oxygen, pH, trace metals, temperature, nitrogen, and phosphorus. Bacteriological and viral data was used by a significant number of state agencies involved with drinking water standards. In terms of ground water quality, both federal and state agencies generally used the following data types the most: pH, nitrogen, phosphorus, trace metals, major cations, pesticides and herbicides, and VOCs.

State agencies involved in surface or ground water for all activities collected most of their data themselves, with other agencies as the secondary source of data. Federal agencies also collected data themselves, but the next dominant source was often WATSTORE. This was especially true for ground water research and development activities.

Finally, almost all agencies indicated their data was used by others. Interestingly, the usage of cooperative agreements was generally higher for agencies involved with research-oriented activities than for regulatory agencies.

Appendix D. Summary of Agencies Responding to Survey

Alabama

Federal Agencies: None

State Agencies: None

Other Agencies: None

Alaska

Federal Agencies:
- U.S. Forest Service, Alaska Region Regional Office
- U.S. Forest Service, Chatham Area Tongass National Forest
- U.S. Forest Service, Institute of Northern Forestry
- U.S. Geological Survey, Water Resources Division

State Agencies: None

Other Agencies:
- City and Borough of Sitka, Water and Wastewater
- Matanuska Susitna Borough - MSB, Department of Planning or Public Works
- Municipality of Anchorage, Department of Solid Waste Services

Arizona

Federal Agencies:
- U.S. Forest Service, Apache-Sitgreaves National Forest
- U.S. Forest Service, Coronado National Forest
- U.S. Forest Service, Kaibab National Forest
- U.S. Forest Service, Tonto National Forest
- U.S. Soil Conservation Service

State Agencies:
- Department of Environmental Quality
- Department of Environmental Quality, Surface Water Quality Program
- Department of Environmental Quality, Water Assessment Section
- Game and Fish Department

Other Agencies:
- Central Arizona Water Conservation District

Arkansas

Federal Agencies: None

State Agencies:
Department of Heath, Bureau of Environmental Health Services
Department of Pollution Control and Ecology

Other Agencies: None

California

Federal Agencies:
U.S. Forest Service, Klamath National Forest
U.S. Forest Service, Pacific Southwest Experiment Station

State Agencies:
Department of Fish and Game
Department of Water Resources, Sacramento
Department of Water Resources, Southern District
Regional Water Quality Control Board, Central Coast Region
Regional Water Quality Control Board, Los Angeles Region
Regional Water Quality Control Board, North Coast Region
Regional Water Quality Control Board, San Diego Region
Regional Water Quality Control Board, Santa Ana Region
Water Resources Control Board, Division of Water Quality
Water Resources Control Board, Division of Water Rights
Water Resources Control Board, Monitoring and Assessment Unit

Other Agencies:
City of Los Angeles, Department of Water and Power
City of Los Angeles, Hyperion Treatment Plant
City of San Diego, Water Utilities/Production Division
Desert Water Agency
Fern Valley Water District
Imperial Irrigation District
Joseph M. Long Marine Laboratory, Institute of Marine Sciences
Los Alisos Water District
Monterey County Water Resources Agency
Orange County Environmental Management Agency, Environmental Resources Division
San Francisco Water Department, Water Quality Division
Santa Cruz County, Flood Control and Water Conservation District
Santa Margarita Water District
United Water Conservation District
University of California, Department of Civil Engineering
University of California, Department of Land, Air, and Water Resources
University of California, Division of Environmental Studies - Tahoe Research Group
University of California, Marine Pollution Studies Lab
University of California, Sea Grant Extension Program

Colorado

Federal Agencies:
Department of the Army, Rocky Mountain Arsenal
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Health, Water Quality Control Division
Mined Land Reclamation Division
Water Conservation Board

Other Agencies:
City of Arvada, Water Quality/Environmental Services
Denver Regional Council of Governments
Denver Water Department, Quality Control

Connecticut

Federal Agencies: None

State Agencies:
Department of Environmental Protection, Bureau of Water Management and Planning

Other Agencies: None

Delaware

Federal Agencies: None

State Agencies: None

Other Agencies: None

District of Columbia

Federal Agencies:
U.S. Bureau of Land Management
U.S. Forest Service, Watershed and Air Management

State Agencies:
Environmental Control Division, Water Hygiene Branch

Other Agencies: None

Florida

Federal Agencies:
U.S. Geological Survey, Tampa
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Environmental Regulation

Other Agencies:
Brevard County, Office of Natural Resources Management
Broward County, Office of Natural Resources Protection
City of Hallandale Utilities
Englewood Water District
Old Plantation Water Control District
Southwest Florida Water Management District, Tampa Permitting Department

Georgia

Federal Agencies:
U.S. Forest Service, Southern Region
U.S. Geological Survey, Water Resources Division

State Agencies: None

Other Agencies: None

Hawaii

Federal Agencies:
U.S. Geological Survey

State Agencies:
Department of Health

Other Agencies:
City and County of Honolulu, Honolulu Board of Water Supply
County of Kauai, Department of Water

Idaho

Federal Agencies:
U.S. Department of Energy, Idaho Operations Office
U.S. Forest Service, Caribou National Forest
U.S. Forest Service, Salmon National Forest

State Agencies:
Department of Health and Welfare, Div of Environmental Quality, Water Quality Bureau

Other Agencies: None

Illinois

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Environmental Protection Agency
State Water Survey

Other Agencies: None

Indiana

Federal Agencies: None

State Agencies:
Geological Survey, Department of Natural Resources

Other Agencies: None

Iowa

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Natural Resources

Other Agencies: None

Kansas

Federal Agencies: None

State Agencies:
Biological Survey
Department of Health and Environment

Other Agencies:
Kansas City Board of Public Utilities, Engineering and Technical Services

Kentucky

Federal Agencies: None

State Agencies:
Division of Water, Standards and Specifications Section

Other Agencies: None

Louisiana

Federal Agencies:
U.S. Forest Service, Southern Forest Experiment Station
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Environmental Quality, Office of Water Resources

Other Agencies: None

Maine

Federal Agencies: None

State Agencies:
Department of Conservation, Geological Survey
Department of Environmental Protection, Water Bureau-Div of Env Eval & Lake Studies
Department of Marine Resources

Other Agencies:
Cobbossee Watershed District

Maryland

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of the Environment
Department of the Environment, Ecological Assessment Section
Highway Administration

Other Agencies:
Baltimore County, Department of Environmental Protection and Resource Management

Massachusetts

Federal Agencies: None

State Agencies:
Division of Water Pollution Control, Technical Services Branch
Metro District Commission, Division of Watershed Management

Other Agencies: None

Michigan

Federal Agencies: None

State Agencies:
Department of Natural Resources, Surface Water Quality Division

Other Agencies:
Clinton River Watershed Council

Minnesota

Federal Agencies: None

State Agencies:
Department of Health
Department of Transportation, Environmental Engineering Unit
Pollution Control Agency

Other Agencies:
Ramsey County, Department of Public Works

Mississippi

Federal Agencies:
U.S. Geological Survey, Mississippi District-Water Resources Division

State Agencies:
Office of Pollution Control Laboratory

Other Agencies: None

Missouri

Federal Agencies: None

State Agencies:
Department of Natural Resources

Other Agencies: None

Montana

Federal Agencies:
U.S. Bureau of Land Management, Montana State Office
U.S. Forest Service, Lolo National Forest
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Health and Environmental Sciences, Water Quality Bureau

Other Agencies: None

Nebraska

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Natural Resources Commission

Other Agencies:
City of Lincoln, Lincoln Water System
Twin Platte Natural Resources District
University of Nebraska, Conservation and Survey Division
University of Nebraska, Water Resources Center

Nevada

Federal Agencies:
U.S. Bureau of Land Management, State Field Office
U.S. Geological Survey, Water Resources Division

State Agencies:
Division of Environmental Protection, Planning and Standards

Other Agencies: None

New Hampshire

Federal Agencies: None

State Agencies:
Department of Environmental Services, Water Supply and Pollution Control Division

Other Agencies: None

New Jersey

Federal Agencies:
U.S. Geological Survey, New Jersey District

State Agencies:
Department of Environmental Protection, Div of Water Res-Bureau of Monitoring Mgmt

Other Agencies:
Delaware River Basin Commission
Morris County Municipal Utility Authority

New Mexico

Federal Agencies:
U.S. Bureau of Land Management, New Mexico State Office
U.S. Bureau of Land Management, Socorro Resource Area
U.S. Forest Service, Gila National Forest
U.S. Forest Service, Lincoln National Forest

State Agencies: None

Other Agencies: None

New York

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Environmental Conservation

Other Agencies:
Monroe County Water Authority

North Carolina

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Division of Environmental Management

Other Agencies: None

North Dakota

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Health, Division of Water Quality

Other Agencies: None

Ohio

Federal Agencies:

U.S. Environmental Protection Agency, Environmental Monitoring Systems Lab
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Agriculture
Department of Natural Resources, Scenic Rivers Program
Environmental Protection Agency, Division of Water Quality Planning and Assessment

Other Agencies: None

Oklahoma

Federal Agencies: None

State Agencies:
Department of Health, State Environmental Laboratory Service

Other Agencies: None

Oregon

Federal Agencies:
U.S. Forest Service, Pacific Northwest Region

State Agencies: None

Other Agencies:
City of Portland, Portland Water Bureau
Douglas County Water Resources Survey
Oregon State University, College of Forestry
Oregon State University, Oregon Water Resources Research Institute

Pennsylvania

Federal Agencies: None

State Agencies:
Department of Environmental Resources
Department of Environmental Resources, Pennsylvania Geological Survey

Other Agencies:
Allegheny County Health Department, Division of Public Drinking Water and Waste Mgmt
Susquehanna River Basin Commission

Puerto Rico

Federal Agencies: None

State Agencies:
Electric Power Authority, Environmental Protection and Quality Assessment
Environmental Quality Board

Other Agencies: None

Rhode Island

Federal Agencies: None

State Agencies:
Department of Environmental Management
Department of Health, Division of Drinking Water Quality

Other Agencies: None

South Carolina

Federal Agencies:
U.S. Department of Energy, Westinghouse Savannah River Company
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Health and Environmental Control
Department of Health and Environmental Control, Bureau of Water Pollution Control

Other Agencies:
Spartanburg Water System

South Dakota

Federal Agencies:
U.S. Geological Survey, EROS Data Center
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Environmental and Natural Resources, Ground Water Quality Program

Other Agencies: None

Tennessee

Federal Agencies:
U.S. Department of Energy, Oak Ridge National Laboratory

State Agencies:
Department of Health and Environment, Division of Water Pollution Control

Other Agencies: None

Texas

Federal Agencies:
International Boundary and Water Commission, U.S. Section
U.S. Geological Survey, Water Resources Division

State Agencies:
Water Commission
Water Commission, District 4, Duncanville Office
Water Development Board, Ground Water Section

Other Agencies:
Lower Colorado River Authority, Water Resources Management
San Antonio River Authority

Utah

Federal Agencies:
U.S. Forest Service, Manti-Lasal National Forest
U.S. Forest Service, Wasatch-Cache National Forest
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Environmental Quality, Division of Drinking Water

Other Agencies: None

Vermont

Federal Agencies: None

State Agencies:
Department of Health, Water Supply Program

Other Agencies:
River Watch Network

Virginia

Federal Agencies:
U.S. Geological Survey, National Water Data Exchange (NAWDEX)

State Agencies:
Water Control Board

Other Agencies: None

Washington

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Department of Ecology

Other Agencies:
Washington State University, Department of Civil and Environmental Engineering
Washington State University, Washington Water Research Center

West Virginia

Federal Agencies:
U.S. Geological Survey, Water Resources Division

State Agencies:
Division of Natural Resources, Water

Other Agencies: None

Wisconsin

Federal Agencies: None

State Agencies:
Department of Natural Resources

Other Agencies:
Dairyland Power Cooperative
Southeast Wisconsin Regional Planning Commission

Wyoming

Federal Agencies:
U.S. Bureau of Land Management, Wyoming State Office
U.S. Geological Survey, Water Resources Division

State Agencies: None

Other Agencies:
City of Casper, Wyoming Board of Public Utilities

Appendix E. Summary of Responses to USEPA's 1991 Inventory of Drinking Water Information Systems

	Maintains MCL & Monit. Violations	Maintains Enforcement Actions	Provides Mailing Support	Maintains Compliance Schedules	Determines SNCs	FRDS Upload Format	Key Software	Current Hardware Platform	State Contact
Alabama	MCL & Mont.	Yes	Yes	No	In Development	DTF	Pace	Wang VS 73-60	Michael McCary (205) 271-7927
Alaska	MCL & Mont.	Yes	Yes	Yes	Yes	DTF	Advanced Revelation	PC Network	Doug Martinson (907) 273-4275
Arizona	Data tracked manually					DTF*	dBASE III+ & ORACLE	PC Network & Honeywell DPS6	Robert Andrews (602) 257-2205
Arkansas	MCL & Mont.	No	Yes	Yes	Yes	Hardcopy & ASCII Files	Basic	Wang VS5000	Harold Seifert (501) 661-2623
California	MCL & Mont.	Yes	Yes	In Development	In Development	DTF	Focus	IBM Mainframe	Mark Ratlam (415) 540-2186
Colorado	MCL & Mont.	Yes	Limited	No	No	Card & DTF*	dBASE IV	PC	Dave Rogers (303) 331-4554
Connecticut	MCL & Mont.	Limited	No	Yes	In Development	DTF*	dBASE III	PC Network	Joy Zocco (203) 566-5049
Delaware	MCL & Mont.	Limited	No	No	No	DTF	FRDS-DE	PC Network	Jack Pingree (302) 739-5410
Florida	MCL & Mont.	Yes	Yes	Yes	Yes	DTF	COBOL	UNISYS 2200	Kerma Sudy (904) 487-1762
Georgia	MCL & Mont.	Limited	Yes	Limited	No	DTF	INFO & Clipper	Prime 2755 & PC Network	Paul Arnold (404) 656-4807

* DTF uploading capability is achieved by use of FRDS-DE, a system developed by EPA.

Figure 22. State Drinking Water Information System Summary. *Source: USEPA (1991c)*

	Maintains MCL & Monit. Violations	Maintains Enforcement Actions	Provides Mailing Support	Maintains Compliance Schedules	Determines SNCs	FRDS Upload Format	Key Software	Current Hardware Platform	State Contact
Hawaii	MCL & Mont.	Limited	No	No	No	DTF*	dBASE III+	PC	Linda Bauer (808) 543-8258
Idaho	MCL & Mont.	Yes	Yes	No	Yes	DIF	dBASE III	PC Newtwork	Renee Hardy (208) 334-5870
Illinois	MCL & Mont.	Yes	Yes	Yes	No	DIF	COBOL	IBM 3090	Charles Bell (217) 785-4653
Indiana	MCL & Mont.	Yes	Yes	Yes	No	DIF	dBASE IV	PC Network	Linda Edwards (317) 233-4190
Iowa	MCL & Mont.	Yes	Yes	Yes	No	DIF	IDMS Database	IBM 3090	Tamie Calef (515) 281-8956
Kansas	Data tracked manually					Card	Wordperfect	PC Network	Jean Hertold (913) 296-5518
Kentucky	MCL & Mont.	Yes	Yes	Limited	No	DIF	COBOL & SAS	IBM 3090	Vicki Ray (502) 564-3510
Louisianna	MCL & Mont.	No	Limited	No	No	Card & MSIS	COBOL & Clipper	IBM Mainframe & PC Network	Leslie LoMon (504) 568-5109
Maine	MCL & Mont.	Yes	Yes	Yes	No	DTF*	dBASE III+	PC Network	Lynda Hadsell (207) 289-5683
Maryland	MCL & Mont.	Yes	No	No	No	DTF*	Lotus 123	PC	Hashem Pezeshki (301) 631-3715
Massachusetts	MCL & Mont.	Yes	Yes	No	Yes	DIF	ORACLE	PC Network	Karen Doherty (617) 292-5775
Michigan	MCL & Mont.	Limited	Yes	No	No	Card & DTF*	COBOL	Honeywell DPS-6	Karen Kalinowski (517) 335-8316
Minnesota	Data tracked manually					Card	dBASE IV	PC Network	Doug Mandy (612) 627-5179
Mississippi	MCL & Mont.	Limited	Limited	No	No	DTF*	FoxBASE	PC	Leland May (601) 960-7518

* DTF uploading capability is achieved by use of FRDS-DE, a system developed by EPA.

Figure 23. State Drinking Water Information System Summary (cont). *Source: USEPA (1991c)*

	Maintains MCL & Monit. Violations	Maintains Enforcement Actions	Provides Mailing Support	Maintains Compliance Schedules	Determines SNC's	FRDS Upload Format	Key Software	Current Hardware Platform	State Contact
Missouri	MCL & Monit.	Yes	No	No	Yes	DTF	SAS & dBASE	Mainframe & PC	Patty Purvis (314) 751-8330
Montana	MCL & Monit.	No	Yes	No	Yes	DTF	Advanced Revelation	PC Network	Jim Melstad (406) 444-2406
Nebraska	MCL & Monit.	Yes	Yes	Yes	No	DTF	dBASE III+	PC	Scott Peterson (402) 471-2541
Nevada	Limited MCL & Monit.	Limited	Limited	No	No	Card & DTF	dBASE III	PC	Larry Roundtree (702) 687-4750
New Hampshire	Limited MCL	Limited	Yes	No	No	DTF*	PACE	WANG VS 7110	Laurie Cullenof (603) 271-2923
New Jersey	MCL & Monit.	Yes	Yes	No	Yes	DTF	SAS	IBM 4381	Vickie Prill (609) 292-9979
New Mexico	MCL & Monit.	Yes	Yes	No	No	DTF	dBASE IV	PC	Richard Asbury (505) 524-6300
New York	MCL & Monit.	Yes	Limited	Yes	No	MSIS	IDMS	IBM Mainframe	Frank Faso (518) 458-6731
N. Carolina	MCL & Monit.	Yes	Yes	Yes	Yes	MSIS	COBOL	WANG VS1000	Martha Moore (919) 733-2321
N. Dakota	MCL & Monit.	Yes	Yes	No	Limited	DTF	dBASE IV	Minicomputer	Jim Allman (701) 224-4558
Ohio	MCL & Monit.	Yes	Yes	In Development	In Development	MSIS & DTF	COBOL	IBM 3090	Evelyn Young (614) 644-2752
Oklahoma	MCL & Monit.	Limited	Yes	Yes	No	Card & MSIS	IBM 4381 & PC Network	COBOL & dBASE III+	Mike Harrell (405) 271-7352
Oregon	MCL & Monit.	No	Yes	Yes	No	DTF	PC Network	dBASE III+	Mary Alvey (503) 229-5056
Pennsylvania	MCL & Monit.	Yes	Limited	No	No	DTF	COBOL	Wang 5000	Barry Greenawald (717) 787-0122

* DTF uploading capability is achieved by use of FRDS-DE, a system developed by EPA.

Figure 24. State Drinking Water Information System Summary (cont). *Source: USEPA (1991c)*

	Maintains MCL & Monit. Violations	Maintains Enforcement Actions	Provides Mailing Support	Maintains Compliance Schedules	Determines SNCs	FRDS Upload Format	Key Software	Current Hardware Platform	State Contact
Rhode Island	MCL & Mont.	Yes	Yes	Yes	Yes	Card & DTF*	4GL File Pro 16+	PC Network	Brian Barrett (401) 277-3336
S. Carolina	MCL & Mont.	Yes	Yes	Yes	Yes	MSIS & DTF	dBASE III+	PC Network	Melinda Mathias (803) 734-5310
S. Dakota	MCL & Mont.	Yes	Yes	No	Yes	DTF	ADABASE & dBASE	IBM 3090 PC Network	Rob Kittay (605) 773-4208
Tennessee	MCL & Mont.	Yes	Yes	No	Yes	DTF	FoxBASE	PC	Margaret Keck (615) 741-6636
Texas	MCL & Mont.	In Development	Limited	No	No	MSIS	COBOL	UNISYS 1100	Anthony Bennett (512) 458-7497
Utah	MCL & Mont.	Yes	Yes	No	Yes	DTF	EDITOR	Nixdorf 600/45	Ken Bousfield (801) 538-6159
Vermont	MCL & Mont.	Yes	Limited	No	No	DTF	1032	VAX 8550	Kim Jones (802) 863-7344
Virginia	No	No	Limited	No	No	DTF*	COBOL	IBM 4381	Evans Massie (804) 786-1756
Washington	MCL & Mont.	Yes	Yes	No	No	MSIS	ADABASE	IBM Mainframe	Peggy Johnson (206) 753-3528
West Virginia	MCL & Mont.	Yes	Yes	No	No	DTF*	dBASE III+	PC	Jan Griffith (304) 348-2981
Wisconsin	MCL & Mont.	Yes	Yes	No	No	DTF	ORACLE	IBM Mainframe	Sharon Burbach (608) 266-8696
Wyoming	MCL & Mont.	Yes	Yes	Yes	No	DTF	dBASE IV	PC Network	(See Inventory Form)

* DTF uploading capability is achieved by use of FRDS-DE, a system developed by EPA.

Figure 25. State Drinking Water Information System Summary (cont). *Source: USEPA (1991c)*

Appendix F. Data for the General Survey Analysis

TOTAL RESPONSES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	1.00	1.00	1.00	1.00
Ground water quality	1.00	1.00	1.00	1.00
Other water quality	1.00	1.00	1.00	1.00

STORET

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.48	0.73	0.22	0.50
Ground water quality	0.27	0.49	0.17	0.33
Other water quality	0.17	0.47	0.00	0.25

WATSTORE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.57	0.26	0.15	0.32
Ground water quality	0.73	0.26	0.10	0.36
Other water quality	0.50	0.00	0.00	0.17

GIS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.50	0.39	0.24	0.38
Ground water quality	0.60	0.44	0.26	0.44
Other water quality	0.50	0.20	0.00	0.25

OTHER COMPUTER SOFTWARE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.47	0.92	0.80	0.74
Ground water quality	0.38	0.79	0.81	0.67
Other water quality	0.50	0.67	0.78	0.64

MANUAL FILES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.52	0.59	0.65	0.59
Ground water quality	0.49	0.54	0.57	0.53
Other water quality	0.42	0.60	0.67	0.56

OTHER MANAGEMENT SYSTEMS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.02	0.01	0.04	0.02
Ground water quality	0.02	0.04	0.02	0.03
Other water quality	0.00	0.00	0.00	0.00

PC COMPUTERS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.65	0.92	0.87	0.82
Ground water quality	0.62	0.91	0.90	0.82
Other water quality	0.67	0.93	0.78	0.81

MAINFRAME COMPUTERS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.50	0.58	0.40	0.50
Ground water quality	0.51	0.58	0.31	0.48
Other water quality	0.58	0.60	0.44	0.56

TOTAL RESPONSES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	60	74	55	189
Ground water quality	45	57	42	144
Other water quality	12	15	9	36

STORET

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	29	54	12	95
Ground water quality	12	28	7	47
Other water quality	2	7	0	9

WATSTORE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	34	19	8	61
Ground water quality	33	15	4	52
Other water quality	6	0	0	6

GIS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	30	29	13	72
Ground water quality	27	25	11	63
Other water quality	6	3	0	9

OTHER COMPUTER SOFTWARE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	28	68	44	140
Ground water quality	17	45	34	96
Other water quality	6	10	7	23

MANUAL FILES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	31	44	36	111
Ground water quality	22	31	24	77
Other water quality	5	9	6	20

OTHER MANAGEMENT SYSTEMS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	1	1	2	4
Ground water quality	1	2	1	4
Other water quality	0	0	0	0

PC COMPUTERS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	39	68	48	155
Ground water quality	28	52	38	118
Other water quality	8	14	7	29

MAINFRAME COMPUTERS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	30	43	22	95
Ground water quality	23	33	13	69
Other water quality	7	9	4	20

MINICOMPUTERS/WORKSTATIONS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.53	0.32	0.24	0.37
Ground water quality	0.64	0.42	0.17	0.42
Other water quality	0.67	0.33	0.22	0.42

OTHER COMPUTERS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.00	0.00	0.00	0.00
Ground water quality	0.00	0.00	0.00	0.00
Other water quality	0.00	0.00	0.00	0.00

NPDES ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.37	0.77	0.53	0.57
Ground water quality	0.24	0.35	0.21	0.28
Other water quality	0.08	0.53	0.44	0.36

OTHER CLEAN WATER ACT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.03	0.22	0.15	0.14
Ground water quality	0.02	0.09	0.10	0.07
Other water quality	0.00	0.07	0.00	0.03

FEDERAL DRINKING WATER STANDARDS ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.37	0.57	0.51	0.49
Ground water quality	0.42	0.72	0.50	0.56
Other water quality	0.00	0.27	0.11	0.14

OTHER SAFE DRINKING WATER ACT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.02	0.01	0.00	0.01
Ground water quality	0.00	0.00	0.00	0.00
Other water quality	0.00	0.00	0.00	0.00

NEPA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.37	0.30	0.22	0.30
Ground water quality	0.24	0.21	0.12	0.19
Other water quality	0.00	0.27	0.22	0.17

RCRA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.25	0.34	0.16	0.26
Ground water quality	0.33	0.46	0.10	0.31
Other water quality	0.00	0.13	0.11	0.08

CERCLA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.28	0.38	0.11	0.27
Ground water quality	0.33	0.47	0.10	0.32
Other water quality	0.00	0.20	0.11	0.11

MINICOMPUTERS/WORKSTATIONS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	32	24	13	69
Ground water quality	29	24	7	60
Other water quality	8	5	2	15

OTHER COMPUTERS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0	0	0	0
Ground water quality	0	0	0	0
Other water quality	0	0	0	0

NPDES ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	22	57	29	108
Ground water quality	11	20	9	40
Other water quality	1	8	4	13

OTHER CLEAN WATER ACT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	2	16	8	26
Ground water quality	1	5	4	10
Other water quality	0	1	0	1

FEDERAL DRINKING WATER STANDARDS ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	22	42	28	92
Ground water quality	19	41	21	81
Other water quality	0	4	1	5

OTHER SAFE DRINKING WATER ACT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	1	1	0	2
Ground water quality	0	0	0	0
Other water quality	0	0	0	0

NEPA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	22	22	12	56
Ground water quality	11	12	5	28
Other water quality	0	4	2	6

RCRA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	15	25	9	49
Ground water quality	15	26	4	45
Other water quality	0	2	1	3

CERCLA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	17	28	6	51
Ground water quality	15	27	4	46
Other water quality	0	3	1	4

SMCRA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.07	0.16	0.05	0.10
Ground water quality	0.09	0.18	0.02	0.10
Other water quality	0.00	0.07	0.11	0.06

OTHER FEDERAL REGULATION ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.02	0.00	0.00	0.01
Ground water quality	0.00	0.02	0.00	0.01
Other water quality	0.00	0.07	0.00	0.03

WELLHEAD PROTECTION ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.05	0.22	0.13	0.14
Ground water quality	0.31	0.60	0.48	0.47
Other water quality	0.08	0.13	0.11	0.11

STATE DRINKING WATER STANDARDS ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.32	0.57	0.47	0.46
Ground water quality	0.38	0.70	0.64	0.58
Other water quality	0.00	0.20	0.11	0.11

OTHER STATE REGULATION ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.10	0.45	0.13	0.24
Ground water quality	0.00	0.19	0.07	0.10
Other water quality	0.00	0.27	0.22	0.17

BASELINE/TREND ANALYSIS ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.78	0.74	0.64	0.72
Ground water quality	0.64	0.58	0.57	0.60
Other water quality	0.83	0.47	0.67	0.64

MODEL DEVELOPMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.55	0.62	0.42	0.54
Ground water quality	0.58	0.33	0.33	0.41
Other water quality	0.42	0.40	0.33	0.39

CAUSE/EFFECT STUDY ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.63	0.65	0.55	0.61
Ground water quality	0.60	0.40	0.50	0.49
Other water quality	0.67	0.53	0.33	0.53

BMP EFFECTIVENESS ASSESSMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.55	0.57	0.40	0.51
Ground water quality	0.31	0.28	0.21	0.27
Other water quality	0.00	0.27	0.33	0.19

SMCRA ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	4	12	3	19
Ground water quality	4	10	1	15
Other water quality	0	1	1	2

OTHER FEDERAL REGULATION ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	1	0	0	1
Ground water quality	0	1	0	1
Other water quality	0	1	0	1

WELLHEAD PROTECTION ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	3	16	7	26
Ground water quality	14	34	20	68
Other water quality	1	2	1	4

STATE DRINKING WATER STANDARDS ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	19	42	26	87
Ground water quality	17	40	27	84
Other water quality	0	3	1	4

OTHER STATE REGULATION ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	6	33	7	46
Ground water quality	0	11	3	14
Other water quality	0	4	2	6

BASELINE/TREND ANALYSIS ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	47	55	35	137
Ground water quality	29	33	24	86
Other water quality	10	7	6	23

MODEL DEVELOPMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	33	46	23	102
Ground water quality	26	19	14	59
Other water quality	5	6	3	14

CAUSE/EFFECT STUDY ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	38	48	30	116
Ground water quality	27	23	21	71
Other water quality	8	8	3	19

BMP EFFECTIVENESS ASSESSMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	33	42	22	97
Ground water quality	14	16	9	39
Other water quality	0	4	3	7

PUBLIC INQUIRY ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.57	0.74	0.55	0.63
Ground water quality	0.60	0.63	0.43	0.56
Other water quality	0.25	0.53	0.22	0.36

PROJECT MANAGEMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.45	0.61	0.42	0.50
Ground water quality	0.38	0.46	0.26	0.38
Other water quality	0.25	0.33	0.44	0.33

OTHER RESEARCH AND DEVELOPMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.03	0.05	0.02	0.04
Ground water quality	0.04	0.07	0.02	0.05
Other water quality	0.00	0.00	0.22	0.06

DISCHARGE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.90	0.77	0.75	0.80
Ground water quality	0.42	0.35	0.29	0.35
Other water quality	0.50	0.60	0.56	0.56

TEMPERATURE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.88	0.89	0.85	0.88
Ground water quality	0.67	0.51	0.52	0.56
Other water quality	0.33	0.67	0.67	0.56

pH

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.90	0.92	0.80	0.88
Ground water quality	0.82	0.77	0.62	0.74
Other water quality	0.75	0.73	0.56	0.69

DISSOLVED OXYGEN

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.88	0.88	0.76	0.85
Ground water quality	0.62	0.33	0.26	0.40
Other water quality	0.33	0.53	0.67	0.50

MAJOR CATIONS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.82	0.78	0.75	0.78
Ground water quality	0.89	0.75	0.81	0.81
Other water quality	0.75	0.67	0.44	0.64

NITROGEN

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.82	0.82	0.78	0.81
Ground water quality	0.82	0.81	0.76	0.80
Other water quality	0.58	0.73	0.56	0.64

PUBLIC INQUIRY ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	34	55	30	119
Ground water quality	27	36	18	81
Other water quality	3	8	2	13

PROJECT MANAGEMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	27	45	23	95
Ground water quality	17	26	11	54
Other water quality	3	5	4	12

OTHER RESEARCH AND DEVELOPMENT ACTIVITIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	2	4	1	7
Ground water quality	2	4	1	7
Other water quality	0	0	2	2

DISCHARGE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	54	57	41	152
Ground water quality	19	20	12	51
Other water quality	6	9	5	20

TEMPERATURE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	53	66	47	166
Ground water quality	30	29	22	81
Other water quality	4	10	6	20

pH

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	54	68	44	166
Ground water quality	37	44	26	107
Other water quality	9	11	5	25

DISSOLVED OXYGEN

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	53	65	42	160
Ground water quality	28	19	11	58
Other water quality	4	8	6	18

MAJOR CATIONS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	49	58	41	148
Ground water quality	40	43	34	117
Other water quality	9	10	4	23

NITROGEN

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	49	61	43	153
Ground water quality	37	46	32	115
Other water quality	7	11	5	23

PHOSPHORUS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.78	0.86	0.71	0.79
Ground water quality	0.71	0.47	0.43	0.53
Other water quality	0.50	0.73	0.56	0.61

SUSPENDED SEDIMENT/SOLIDS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.92	0.89	0.80	0.87
Ground water quality	0.40	0.46	0.48	0.44
Other water quality	0.25	0.80	0.78	0.61

BOD/COD

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.55	0.78	0.51	0.63
Ground water quality	0.42	0.32	0.31	0.35
Other water quality	0.25	0.73	0.56	0.53

TRACE METALS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.77	0.89	0.80	0.83
Ground water quality	0.87	0.81	0.81	0.83
Other water quality	0.50	0.80	0.67	0.67

PESTICIDES/HERBICIDES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.67	0.80	0.67	0.72
Ground water quality	0.82	0.79	0.71	0.78
Other water quality	0.33	0.73	0.56	0.56

VOCs

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.53	0.72	0.55	0.61
Ground water quality	0.73	0.81	0.62	0.73
Other water quality	0.17	0.67	0.56	0.47

BACTERIOLOGICAL/VIRAL

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.68	0.80	0.62	0.71
Ground water quality	0.58	0.60	0.57	0.58
Other water quality	0.17	0.73	0.56	0.50

CHLOROPHYLL/ALGAE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.42	0.70	0.45	0.54
Ground water quality	0.27	0.16	0.24	0.22
Other water quality	0.17	0.53	0.22	0.33

RADIOLOGICAL

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.43	0.47	0.35	0.42
Ground water quality	0.60	0.53	0.50	0.54
Other water quality	0.17	0.53	0.22	0.33

PHOSPHORUS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	47	64	39	150
Ground water quality	32	27	18	77
Other water quality	6	11	5	22

SUSPENDED SEDIMENT/SOLIDS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	55	66	44	165
Ground water quality	18	26	20	64
Other water quality	3	12	7	22

BOD/COD

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	33	58	28	119
Ground water quality	19	18	13	50
Other water quality	3	11	5	19

TRACE METALS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	46	66	44	156
Ground water quality	39	46	34	119
Other water quality	6	12	6	24

PESTICIDES/HERBICIDES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	40	59	37	136
Ground water quality	37	45	30	112
Other water quality	4	11	5	20

VOCs

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	32	53	30	115
Ground water quality	33	46	26	105
Other water quality	2	10	5	17

BACTERIOLOGICAL/VIRAL

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	41	59	34	134
Ground water quality	26	34	24	84
Other water quality	2	11	5	18

CHLOROPHYLL/ALGAE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	25	52	25	102
Ground water quality	12	9	10	31
Other water quality	2	8	2	12

RADIOLOGICAL

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	26	35	19	80
Ground water quality	27	30	21	78
Other water quality	2	8	2	12

OTHER DATA TYPES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.08	0.24	0.15	0.16
Ground water quality	0.04	0.07	0.14	0.08
Other water quality	0.00	0.20	0.33	0.17

DATA COLLECTED BY AGENCY

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.93	0.95	0.91	0.93
Ground water quality	0.93	0.95	0.93	0.94
Other water quality	1.00	1.00	0.89	0.97

DATA SUPPLIED BY PRIVATE SOURCES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.18	0.38	0.11	0.24
Ground water quality	0.22	0.40	0.14	0.27
Other water quality	0.17	0.33	0.11	0.22

DATA SUPPLIED BY OTHER AGENCIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.47	0.66	0.44	0.53
Ground water quality	0.51	0.72	0.40	0.56
Other water quality	0.67	0.80	0.22	0.61

DATA SUPPLIED BY STORET

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.30	0.49	0.15	0.33
Ground water quality	0.24	0.46	0.17	0.31
Other water quality	0.17	0.53	0.00	0.28

DATA SUPPLIED BY WATSTORE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.52	0.32	0.16	0.34
Ground water quality	0.62	0.39	0.17	0.40
Other water quality	0.58	0.47	0.00	0.39

DATA SUPPLIED BY OTHER SOURCES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.02	0.14	0.04	0.07
Ground water quality	0.02	0.16	0.02	0.08
Other water quality	0.08	0.13	0.11	0.11

DATA UTILIZED BY OTHER AGENCIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.87	0.95	0.89	0.90
Ground water quality	0.89	0.98	0.90	0.93
Other water quality	0.92	0.93	0.89	0.92

COOPERATIVE AGREEMENTS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	0.78	0.73	0.60	0.71
Ground water quality	0.82	0.77	0.60	0.74
Other water quality	0.83	0.80	0.78	0.81

OTHER DATA TYPES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	5	18	8	31
Ground water quality	2	4	6	12
Other water quality	0	3	3	6

DATA COLLECTED BY AGENCY

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	56	70	50	176
Ground water quality	42	54	39	135
Other water quality	12	15	8	35

DATA SUPPLIED BY PRIVATE SOURCES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	11	28	6	45
Ground water quality	10	23	6	39
Other water quality	2	5	1	8

DATA SUPPLIED BY OTHER AGENCIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	28	49	24	101
Ground water quality	23	41	17	81
Other water quality	8	12	2	22

DATA SUPPLIED BY STORET

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	18	36	8	62
Ground water quality	11	26	7	44
Other water quality	2	8	0	10

DATA SUPPLIED BY WATSTORE

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	31	24	9	64
Ground water quality	28	22	7	57
Other water quality	7	7	0	14

DATA SUPPLIED BY OTHER SOURCES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	1	10	2	13
Ground water quality	1	9	1	11
Other water quality	1	2	1	4

DATA UTILIZED BY OTHER AGENCIES

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	52	70	49	171
Ground water quality	40	56	38	134
Other water quality	11	14	8	33

COOPERATIVE AGREEMENTS

	Federal Agencies	State Agencies	Other Agencies	All Agencies
Surface water quality	47	54	33	134
Ground water quality	37	44	25	106
Other water quality	10	12	7	29

List of Abbreviations

BBS	Bulletin board system
BIOS	BIOlogical System
BMP	Best management practice
BOD	Biochemical oxygen demand
Cal EPA	California Environmental Protection Agency
CDEC	California Data Exchange Center
CDNR	Colorado Department of Natural Resources
CDOH	Colorado Department of Health
CD-ROM	Compact Disc-Read Only Memory
CDWR	California Department of Water Resources
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMLRD	Colorado Mined Land Reclamation Division
COD	Chemical oxygen demand
COG	Council of Government
CSU	Colorado State University
CWA	Clean Water Act
CWC	Colorado Water Congress
DBMS	Database management system
DCP	Data collection platform
DEC	Digital Equipment Corporation
DFS	Daily Flow System
DMR	Discharge monitoring reports
DRCOG	Denver Regional Council of Governments
EIS	Environmental impact statement
ESRI	Environmental Systems Research Institute
FDER	Florida Department of Environmental Regulation
FK	Fish Kill File
FRDS	Federal Reporting Data System
FWPCA	Federal Water Pollution Control Act
FWQA	Federal Water Quality Administration
GIS	Geographic information system
GOES	Geostationary Operational Environmental Satellite
GRASS	Geographic Resources Analysis Support System
HMWMD	Hazardous Materials and Waste Management Division (CDOH)
LWV	League of Women Voters
LWVC	League of Women Voters of Colorado
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MOU	Memorandum of understanding
NAWDEX	NAtional Water Data EXchange
NAWQA	NAtional Water Quality Assessment
NCC	National Computer Center (USEPA)
NEPA	National Environmental Protection Act
NPDES	National Pollutant Discharge Elimination System
NTIS	National Technical Information Service
NWCCOG	Northwest Colorado Council of Governments
NWIC	National Water Information Clearinghouse
NWIS	National Water Information System
ODES	Ocean Data Evaluation System
ODW	Office of Drinking Water (USEPA)
OSMRE	Office of Surface Mining Reclamation and Enforcement
PCS	Permit Compliance System
PMN	Premanufacture notification
POTW	Publicly owned treatment work
PWS	Public water supply
RCRA	Resource Conservation and Recovery Act
RF	Reach File
RF3	Reach File Version 3
SAS	Statistical Analysis System
SB 181	Senate Bill 181 (Colorado)
SDWA	Safe Drinking Water Act
SEO	State Engineer's Office (CDNR)
SMCRA	Surface Mining Control and Reclamation Act
SPSS	Statistical Package for the Social Sciences
STORET	STOrage and RETrieval System
SWQIS	Statewide Water Quality Information System (California)
SWRCB	State Water Resources Control Board (California)
TSCA	Toxic Substances Control Act
TSD	Treatment, storage and disposal
UDEQ	Utah Department of Environmental Quality
USCOE	U.S. Army Corps of Engineers
USPHS	U.S. Public Health Service
USEPA	U.S. Environmental Protection Agency
USGPO	U.S. Government Printing Office
USGS	U.S. Geological Survey
VOC	Volatile organic compound
WATSTORE	WAter Data STOrage and REtrieval System
WBS	Waterbody System
WQCC	Water Quality Control Commission (CDOH)
WQCD	Water Quality Control Division (CDOH)
WQS	Water Quality System
WRD	Water Resources Division (USGS)
WRDS	Water Resources Data System (Wyoming)
WWRC	Wyoming Water Research Center