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Regulatory Mandates for Ground-Water Monitoring

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The Need for Ground-Water Monitoring: Protection of a Resource at Risk

Ground water has been described as one of the world's most valuable natural resources. People around the world have long depended on ground water for many uses, but primarily for drinking water. In the United States alone, more than 125 million people — nearly half the population — depend on ground water for their drinking water supply. Approximately 80% of public water supply systems providing drinking water in the United States, including those of one third of the nation's largest cities, depend at least partly on ground water (U.S. EPA, 2004a). Additionally, 95% of all domestic water needs in rural areas is served by ground-water resources. Ground water is also used extensively in the western U.S. for irrigation, in the northern U.S. for residential and commercial heating, in the southern U.S. for cooling, and across the nation for various industrial purposes. National reliance on ground water has increased dramatically over the past few decades and will continue to increase as consumption and use of water increases in the future. This reliance will be underscored if surface-water shortages, caused by prolonged droughts, continue to occur and development of arid land continues at its current pace.

The need for the regulation of activities that pose a threat to the quality of ground water has become an overriding concern when communities face commercial and private development. In many areas of the world, this once-pristine, widely available resource is in a delicate balance between supply and demand. The quantity of useable ground water in any given area is closely linked to the quality of the water available for various uses. The apparent ignorance of humans about the finite nature of this resource has led to its exploitation, its abuse as a dumping ground for unwanted waste materials, and its excessive mining, particularly in the western United States. Since the mid-1970s, there have been increased efforts to protect this resource from further degradation and there are now regulatory mandates in place both to protect useable ground water and to clean up ground water that has suffered from the effects of short-sighted waste-management practices. However, efforts to protect the quantity of ground water continue to lag behind development. This promises to be a challenge to 21st century planners in North America and abroad.

In spite of numerous uses of ground water, there are limitations and constraints placed on the appropriation and quality of this resource. Both Federal and state legislators have attempted to address the evolving requirements for ground water that, in some cases, must be clean enough to drink and, in other cases, must be only relatively free of chemicals that could affect the performance of an industrial process. Legislation has addressed the problem of potential contamination from the use of ground water both as a resource and as a means of disposal. Additional constraints are being placed on this resource as Tribal Nations make demands for ground-water and surface-water quality that surpass requirements dictated by risk. Finally, legislation associated with Brownfields and Superfund call for the clean up of ground water that has been already contaminated.

This chapter discusses the role of ground-water monitoring within the framework of existing environmental and resource regulations, focusing on protection of the resource from over-development and contamination. It places the discussion in the context of the levels of protection that will keep this resource abundant and free of unhealthy contaminants.

Federal Regulatory Mandates for Ground-Water Monitoring

There exist a variety of federal agencies whose missions include the protection of ground water. Among them are the Nuclear Regulatory Commission, the Office of Surface Mining (OSM), the Department of Energy, the Department of Defense, and the U.S. Environmental Protection Agency (U.S. EPA). By far, the largest body of environmental regulations involving ground-water protection and requiring ground-water monitoring has been promulgated by the U.S. EPA. Copies of these regulations are readily available from a number of sources, but the primary sources are the U.S. EPA (www.epa.gov) and the Government Printing Office. The primary emphasis of the following discussion is on the Federal mandates for ground-water monitoring included in documents issued by the aforementioned agencies.

The major Federal regulatory programs that involve the implementation of ground-water monitoring include the following:

- The Resource Conservation and Recovery Act (RCRA) including the Hazardous and Solid Waste Amendments (HSWA) which, in turn, include the Underground Storage Tank (UST) Program
- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund") including the Superfund Amendments and Reauthorization Act (SARA)
- The Toxic Substances Control Act (TSCA)
- The Clean Water Act (CWA) and CWA Amendments
- The Safe Drinking Water Act (SDWA) and SDWA Amendments, including the Underground Injection Control (UIC) Program and the Wellhead Protection Program (WHPP)
- The Surface Mining Control and Reclamation Act (SMCRA)

Each of these pieces of legislation is described briefly, and the ground-water monitoring provisions of each program are summarized in the following sections.

Resource Conservation and Recovery Act

The RCRA (Public Law 94-580) was passed by the Congress in October 1976, as an amendment to the 1965 Solid Waste Disposal Act. Its purpose was to address the problem of how to safely dispose of the huge volumes of solid and hazardous waste generated nationwide each year (U.S. EPA, 1986). RCRA has evolved from a relatively limited program dealing with nonhazardous solid waste to a far-reaching program that focuses primarily on hazardous waste. Solid and hazardous waste generators, transporters, and owners or operators of treatment, storage, and disposal facilities (TSDFs) comprise the RCRA-regulated community. On November 8, 1984, the Congress passed the HSWA to RCRA, thereby greatly expanding the nature and complexity of activities covered under RCRA.

The objectives of RCRA, as set forth by the Congress, are:

- The improvement of solid-waste disposal practices to protect human health and the environment
- The regulation of hazardous wastes, from initial generation to ultimate disposal
- The establishment of resource conservation as the preferred approach to solid and hazardous wastes management

Section 1003 of RCRA, which outlines these objectives, clearly indicates the applicability of the Act to ground-water protection, as does Section 1004, which defines the terms used in the Act.

To achieve RCRA's goals, three programs were established by U.S. EPA. The first program, termed Subtitle D, encourages states to formulate comprehensive solid-waste management plans, primarily for nonhazardous waste. The second program, Subtitle C, establishes a program to control hazardous waste from the time it is generated until its ultimate disposal — the so-called "cradle-to-grave" concept. The third program, Subtitle I, regulates certain underground storage systems.

RCRA Subtitle D

Subtitle D establishes a voluntary program under which participating states receive Federal financial and technical support to develop and implement solid-waste management plans. This program is primarily a planning tool used to clarify state, local, and regional roles in the management of solid waste. One of the objectives of this portion of the act is to identify those facilities that are "open dumps." Although originally there were no specific regulations within this program requiring the monitoring of ground water, the HSWA now contains rules governing land-disposal units. The current version has specific ground-water monitoring requirements.

RCRA Subtitle C

Subtitle C is the backbone of RCRA. It calls for the management of hazardous waste from the time it is generated until its ultimate disposal, through a complex system of standards applicable to generators and transporters of hazardous waste and to owners and operators of hazardous waste TSDFs. Subtitle C clearly defines what is considered a hazardous waste and what is not and defines the types of facilities that fall under these regulations. The purpose of these regulations is to protect human health and the environment, with an emphasis on the protection of ground water. EPA has set performance criteria that apply to most forms of land disposal including landfills, surface impoundments, waste piles, and land-treatment units. The siting, design, and operating specifications developed for hazardous waste facilities require that the owner and operator employ natural geologic or engineering design features and waste management practices that minimize adverse effects on ground water and surface water. The basic purposes of these requirements are to minimize the production of leachate and to avoid situations that could compromise the integrity of the facility's liner and final cover (landfills) or its natural ability to ameliorate waste migration (land-treatment facilities).

Subtitle C also has set forth requirements for the installation and operation of ground-water monitoring systems as a means of evaluating the performance of TSDFs. These ground-water monitoring requirements outline procedures for (1) installing ground-water monitoring systems, (2) developing a ground-water sampling and analysis program, and (3) preparing a ground-water quality assessment plan. Exempt from these requirements are those TSDFs which can demonstrate that there is a low potential for migration of hazardous waste from the facility via the uppermost aquifer to water-supply wells or surface water. Such a facility may apply for a waiver from ground-water monitoring requirements.

There are a number of parts to Subtitle C. Sections containing requirements for ground-water monitoring include:

Part 264: Regulations for Owners and Operators of Permitted Hazardous Waste Facilities

Part 265: Interim Status Standards for Owners and Operators of Hazardous Waste Facilities

Part 267: Interim Standards for Owners and Operators of New Hazardous Waste Management Facilities*

*This part was only temporary until Part 264 was finalized, but has never been removed from Subtitle C. Specific requirements under Part 267 are no longer applicable.

Part 270: Regulations for Federally Administered Hazardous Waste Permit Programs (Part B permits)

Part 271: Requirements for Authorization of State Hazardous Waste Programs

The regulatory scheme established under RCRA is to grant permits to all TSDFs that are in compliance with RCRA requirements. The standards set forth in Part 264 apply to these permitted facilities. Because there were thousands of facilities that applied for and were awaiting permits early in the administration of the program, RCRA provided the means to regulate nonpermitted facilities prior to their final permitting. New facilities waiting to be built or in the process of being built fall under Part 264. Established facilities operating without a final permit, but under the regulatory framework, fall under Part 265. The information needed to submit an application for status as a permitted facility is detailed under Part 270.

Most ground-water monitoring requirements included in Subtitle C apply to the water quality in the "uppermost aquifer," although, at some sites with known contamination, monitoring of other connected hydrogeologic units may be required to characterize the extent of the contaminant plume.

Part 264: For facilities operating under a RCRA permit, there are generally three types of ground-water monitoring that may be required. The monitoring scheme is based on a phased approach, so that facilities that have not released contaminants into the ground water have different requirements than those that have released contaminants. The most rudimentary monitoring scheme is the Detection Monitoring Program (40 CFR 264.98). This program must consist of

> A sufficient number of wells, installed at appropriate locations and depths, to yield ground-water samples from the uppermost aquifer that:
>
> - Represent the quality of ground water that has not been affected by leakage from the regulated unit, and
> - Represent the quality of ground water passing the point of compliance (roughly the boundary of the waste management unit or units, such as individual or adjacent groups of impoundments or landfills).
>
> (40 CFR 264.97)

The Part 264 regulations essentially require that each TSDF must have installed detection-monitoring wells both hydraulically upgradient and hydraulically downgradient of the limit of the waste management area. The number, location, depth, and construction details of the upgradient wells must be sufficient to yield ground-water samples, which are representative of background water quality in the uppermost aquifer beneath the facility. The number, location, depth, and construction details of downgradient wells must ensure that these wells can detect any wastes that migrate from the waste management area to the uppermost aquifer. Both upgradient and downgradient wells must be cased in a manner that maintains the integrity of the well, screened and packed with sand to enable the collection of ground-water samples, and the annular space above the sampling depth sealed to prevent contamination of samples and ground water. Regulations require a minimum of one upgradient well and three downgradient wells. Monitoring is required during the active life of the facility, during its closure period, and during any postclosure period that is applicable.

The ground-water sampling and analysis plan developed for compliance with Part 264 regulations must include procedures and techniques for sample collection, sample preservation, analytical procedures, and chain of custody control. The owner and operator must monitor ground water in all wells for a period of 1 yr, on a quarterly basis. Samples must be analyzed for three separate sets of indicator parameters including:

- Parameters characterizing the suitability of the ground water as a drinking water supply, including all water quality parameters mandated for analysis under the SDWA (Table 1.3)
- Parameters establishing ground-water quality, including chloride, iron, manganese, phenols, sodium, and sulfate
- Parameters used as indicators of ground-water contamination, including pH, specific conductance, total organic carbon, and total organic halogens

After the first year, all monitoring wells must be sampled and the samples analyzed, such that all parameters used to establish ground-water quality are sampled and analyzed annually and parameters used as indicators of ground-water contamination are sampled and analyzed semiannually.

Part 264 also requires owners and operators of TSDFs to determine the extent to which wastes may have entered the uppermost aquifer in the event that a statistically significant change in the concentrations of the monitored chemical parameters indicates a release from the regulated unit during the Detection Monitoring Program. This second phase of monitoring is called the Compliance Monitoring Program (40 CFR 264.99). The Compliance Monitoring Program applies to units in which there is a reason to believe that concentrations of certain chemicals in the ground water exceed the established ground-water protection standards (40 CFR 264.92). The U.S. EPA Regional Administrator has a certain amount of discretion in identifying the parameters to be monitored, as set forth in the permit.

If the Compliance Monitoring Program establishes that there is a release of a type and magnitude to be of concern at the compliance point of the facility, then a Corrective Action Program must be implemented (40 CFR 264.100). The Corrective Action Program requires that the owner or operator remove or treat the wastes that are causing the release, so that the ground-water quality complies with the ground-water protection standards. In this program, the primary purpose of the ground-water monitoring network is to monitor the effectiveness of the corrective action. Ground-water cleanup criteria are usually determined either by the individual states or within a state on a case-by-case basis. In all cases, the cleanup criteria must be as stringent as, or more stringent than, various standards set by the Federal government.

After the TSDF ceases operation, the ground-water monitoring network may still be required to monitor the facility during the closure and postclosure periods. The closure period usually runs from the time the facility receives the final volume of waste until all activities at the facility cease (40 CFR 264.112 and 264.113). Postclosure monitoring, usually a period of 30 yr after closure, is required at facilities in which all of the waste or waste constituents are not removed from the facility at closure. This applies primarily to landfills and land-treatment facilities, but can also apply to surface impoundments that are closed with waste constituents remaining in the ground (40 CFR 264.117). Certain demonstrations can be made to reduce the duration of the postclosure monitoring period. Table 1.1 lists the citations associated with Part 264 ground-water monitoring requirements.

Part 265: Part 265 of RCRA addresses facilities that are under interim status. This applies to existing TSDFs that are waiting to obtain a final permit. The ground-water monitoring requirements under Part 265 are much narrower in scope than those under Part 264 and are explained under 40 CFR 265.91 through 265.93. For interim status, a facility needs

TABLE 1.1

Ground-Water Monitoring Citations for RCRA Part 264

Citation	Description
40 CFR 264.97	General ground-water monitoring requirements
40 CFR 264.98	Detection Monitoring Program
40 CFR 264.99	Compliance Monitoring Program
40 CFR 264.100	Corrective Action Program
40 CFR 264.112	TSDF closure
40 CFR 264.117	TSDF postclosure
40 CFR 264.221	Design and operation of surface impoundments
40 CFR 264.228	Closure and postclosure of surface impoundments
40 CFR 264.310	Closure and postclosure of landfills

only to perform one type of ground-water monitoring, similar in some respects to the detection monitoring of Part 264. However, unlike Part 264 requirements, there is no phased approach, and if a release from the facility is detected by the monitoring system, a Ground-Water Quality Assessment Program is implemented (40 CFR 265.93). There are no provisions that clearly spell out the procedures, once in the Ground-Water Quality Assessment Program, to determine whether ground-water remediation is required. Table 1.2 lists the citations associated with Part 265 ground-water monitoring requirements.

Part 270: Owners and operators of hazardous waste management facilities are required to file a Part A and Part B permit application to receive their facility permit to operate. A Part A notification serves to notify the U.S. EPA Regional Administrator of the existence of the facility and the wastes that are associated with it. A Part B permit application requires the generation of a substantial amount of information about the facility and the activities that take place at the facility. As part of a Part B application for owners of landfills, surface impoundments, waste piles, and land treatments units, information regarding the protection of the ground water is necessary (40 CFR 270.14 and 270.97).

Part 271: Part 271 of RCRA deals with the authorization of state programs. The regulations require that states seeking authority for their programs have regulations similar to those promulgated under RCRA for TSDFs (40 CFR 271.12 and 271.128).

RCRA Subtitle I

In 1985, the U.S. EPA estimated that as many as 100,000 to 300,000 USTs could be leaking their contents to the environment and polluting ground water (U.S. EPA, 1985). To address this problem, the Congress created a program under HSWA, entitled Subtitle I, to prevent the leakage of stored products from USTs. These amendments to RCRA were

TABLE 1.2

Ground-Water Monitoring Requirements for RCRA Part 265

Citation	Description
40 CFR 264.90 through 264.94	Ground-water monitoring program
40 CFR 264.112	Closure of Interim Status TSDF
40 CFR 264.117 and 264.118	Postclosure of Interim Status TSDF
40 CFR 264.221	Interim Status surface impoundments
40 CFR 264.301	Interim Status landfill design
40 CFR 264.310	Interim Status landfill closure and postclosure

significant in that they marked the first time that RCRA regulations were applied to raw product as well as to waste. Subtitle I is limited to regulating the underground storage of petroleum or hazardous chemicals, while Subtitle C regulates the underground storage of hazardous wastes.

Although there is no specific language in Subtitle I that requires the monitoring of ground water, there are references to a tank owner having the ability to detect releases. Subtitle I also authorizes the Federal and state personnel to monitor the surrounding soils, air, surface water, and ground water (U.S. EPA, 1985). There is also specific language in a number of state UST programs that ground-water monitoring wells shall be installed adjacent to each new and existing tank or tank field.

Final rules covering technical standards and requirements for new and existing USTs containing petroleum and hazardous chemicals took effect in December 1988. The purposes of these rules are to regulate the vast numbers of underground tanks and to minimize the environmental impact of leakage from these tanks by implementing early detection techniques, ground-water monitoring, and physical protection of the tanks themselves. The use of ground-water monitoring wells is one of the specified methods that can achieve the required monthly monitoring for releases from these tanks.

The schedule for technically upgrading and monitoring requirements for existing tanks is dependent on the tank age. However, after 1993, all existing tanks were required to perform monthly leak-detection monitoring, by means of in-tank gaging, vapor monitoring, interstitial monitoring, or ground-water monitoring.

Tanks that are confirmed to be leaking must initiate corrective action. The rules do not specify the types of measurements or site assessment techniques that must be employed. However, it is implied that soil and ground-water samples should be obtained. If there has been a confirmed release that requires corrective action, then a corrective action plan must be submitted, which will address the remediation of soil and ground water, as required, and the means to verify the success of these actions. It is important to note that many states and local municipalities have additional requirements that may regulate the monitoring or remediation of a petroleum hydrocarbon release.

Comprehensive Environmental Response, Compensation and Liability Act

The CERCLA, more popularly known as Superfund, was passed by the Congress in December 1980 to deal with threats posed to the public by abandoned waste sites. With the SARA of 1986, CERCLA assumed a greater role in the cleanup of hazardous waste sites. The main objectives of CERCLA, as established by the Congress, are:

- To develop a comprehensive program to set priorities for cleaning up the worst existing hazardous waste sites
- To make responsible parties pay for those cleanups wherever possible
- To set up a Hazardous Waste Trust Fund for the twofold purpose of performing remedial cleanups in cases where responsible parties could not be held accountable and responding to emergency situations involving hazardous substances
- To advance scientific and technical capabilities in all aspects of hazardous waste management, treatment, and disposal (U.S. EPA, 1987a)

There are several steps involved in completing a Superfund cleanup. The initial report of the existence of a site may come from a private individual or a facility manager, either to EPA's National Response Center or to a local or state official. After EPA learns of the site, it conducts a site assessment, during which it collects all available background information to determine the potential hazards posed by the site. In the preliminary assessment step, EPA not only tries to identify the size of the problem and the types of wastes at the site, but also attempts to identify any and all PRPs associated with the wastes. If the preliminary assessment reveals evidence that the site may pose a significant threat to human health or the environment, then a site inspection is performed to define more precisely which media have been impacted, which contaminants are present at the site (and at what levels), contaminant migration potential, and threats posed by the site to drinking water, soil, and air quality. The site-inspection step may involve the installation of short-term ground-water monitoring points. The site is scored and then ranked using the EPA Hazard Ranking System. If the ranking is high enough to place the site on the National Priorities List (NPL), then the next phase of the site investigation, site characterization, is warranted. As of April 2004, 1,238 waste sites had been listed on the NPL by EPA, with another 65 sites proposed for the list (U.S. EPA, 2004b). This is increased from 1,010 sites as of January 1990. However, EPA estimated that in 1980, there were 9,000 "problem" hazardous waste sites. In 1989, more than 30,000 sites had been entered into EPA's computerized database (CERCLIS).

The ultimate objective of placing sites on the NPL is their permanent cleanup. As of April 2004, 583 sites on the NPL were listed as "construction completed," with the remainder listed as "deleted" (267) or "construction needed or ongoing" (388). To identify a cleanup strategy that best suits a particular situation, each of the sites on the NPL undergoes a Remedial Investigation/Feasibility Study (RI/FS). The RI/FS is a process of site characterization and remedy evaluation, which facilitates the selection of remedial measures that will most effectively eliminate, reduce, or control risks to human health and the environment. Ground-water monitoring is a critical element of the RI, as it is necessary to establish the nature and extent of ground-water contamination at the site and whether or not ground water serves as a pathway for waste constituents to migrate away from the site. The FS is often heavily dependent on the data gathered during the RI, so that the optimal remedial technology (or combination of technologies) may be implemented at the site. Ground-water monitoring is also a critical factor in evaluating whether the remedial activities implemented at the site are successful in abating ground-water contamination.

Guidance documents available from U.S. EPA set forth the procedures that should be followed to conduct a RI in support of a FS (U.S. EPA, 1988). The focus of the RI effort depends on the quality of the existing data, key site problems, the need to provide sufficient technical data to support the FS, and enforcement needs. These factors dictate the study parameters and the types and amount of sampling that will be sufficient to meet the needs of the study. Therefore, unlike RCRA, CERCLA does not set up any specific ground-water monitoring program requirements — the investigator must address each site individually. Although the purpose of the RI is to characterize the hydrogeologic setting and any contamination present at the site, there are several other important aspects to conducting a ground-water monitoring program that are required for the FS.

The collection of data that will help in the evaluation of remedial technology alternatives is essential during the RI. These data may not directly aid in the definition of the problem, but could predict interactions between water quality and certain alternatives. For example, although the level of iron present in the ground water is not an essential piece of information to establish the presence or extent of ground-water contamination, it may be useful in the FS portion of the project. If air stripping is proposed in the FS as a candidate remedial technology, then the concentrations of iron must be known to devise methods of preventing scale buildup on the air-stripping unit, which would reduce its effectiveness.

Ground-water monitoring is also essential during the cleanup of a contaminated site. After a remedy has been implemented at a site, ground-water conditions must be monitored to assess the effectiveness of remediation efforts and, ultimately, to determine when the remediation effort can be discontinued and the site can be declared clean.

Toxic Substances Control Act

The TSCA (Public Law 94-469), enacted by the Congress in 1976, brought about significant changes in the day-to-day operation of the U.S. chemical industry. With TSCA, the U.S. EPA was given the power to prohibit or regulate the manufacture, processing, distribution, use, or disposal of chemical products that pose an unreasonable risk to human health or the environment. TSCA also provides the U.S. EPA with the authority to require premarket testing of a wide range of chemicals to evaluate the health effects that they may cause. To enable EPA to monitor the marketing of new chemicals, TSCA requires manufacturers to submit premanufacture notices on new chemical substances and to keep records identifying the new uses of existing chemicals. To be included in these records are data such as the amounts of chemicals produced, how and where the chemicals are stored and transported, any known or projected occupational exposures, and the methods used to dispose of the chemicals.

The U.S. EPA is authorized to take a variety of steps to protect against threats to human health or the environment by the introduction or unrestricted use of new chemicals. Such steps include publication of the chemical inventory, information gathering authority, and permitting access to manufacturing data, which could assist in the development of source inventories for ground-water protection planning and investigation. For example, any RCRA facility that handles hazardous wastes, which contain more than 50 ppm of polychlorinated biphenyls (PCBs) is regulated under both the RCRA and TSCA; initial ground-water monitoring for background data at PCB disposal sites is also required.

Clean Water Act

The CWA of 1972 (Public Law 92-500) and the CWA Amendments of 1977 (Public Law 95-217) established a major milestone in water pollution control law. At that time, the CWA was one of the most far-reaching Federal laws ever enacted. The objective of the CWA was to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” However, the language of the Act stresses the need to protect “navigable waters,” thus the major emphasis and the thrust of enforcement have been toward surface water. To the extent that surface water and ground water are hydraulically connected, protection of surface-water quality will also protect ground-water quality and vice versa. Several specific provisions of the CWA have served to enhance ground-water protection.

The potentially most effective means for controlling ground-water contamination under the CWA is found in Section 208, which provides for statewide and areawide planning for pollution control, including funding to set up and implement water-quality management planning programs. The water-quality management program required by Section 208 has served as a catalyst for the development of several state ground-water management programs. The most powerful means for controlling ground-water contamination under Section 208 requires water-quality management plans to include a process to control the disposal of pollutants on land or in subsurface excavations to protect ground- and surface-water quality. For example, where CWA funds are used to construct municipal sewage treatment plants that use land-application techniques, the municipality is required to design the plant to ensure protection of ground water (40 CFR 35, Appendix A). The primary responsibility for preparing plans and implementing programs is in the hands of state, regional, and local agencies. It is within U.S. EPA’s power to withhold approval of a plan or program that does not adequately provide for ground-water protection, but not within its power to act if the ground-water provisions of the plan are not implemented.

Section 304 of the CWA requires EPA to develop and issue guidelines for identifying and evaluating the nature and extent of nonpoint sources of pollutants. Guidelines have also been developed for processes, procedures, and methods to control pollution resulting from, among others, "the disposal of pollutants in wells or in subsurface excavations, saltwater intrusion resulting from reduction of freshwater flow from any cause, including extraction of ground water, and changes in movement, flow and circulation of any navigable waters or ground waters."

Section 402, which describes the National Pollutant Discharge Elimination System (NPDES), empowers the U.S. EPA to issue permits for the discharge of any point-source pollutant or combination of pollutants to navigable waters. Individual states may issue NPDES permits if they develop programs and are authorized by the EPA to do so. A trust fund that was the precursor to Superfund was set up to deal with problems stemming from NPDES discharges. However, no provision was made to deal with damages to land resources resulting from contamination by hazardous wastes. One specific requirement for approval of a state NPDES program is that the state must provide for control of the disposal of pollutants into wells.

Finally, Sections 104 and 106 provide for the establishment and funding of national and state programs to equip and maintain both surface-water and ground-water surveillance systems. This is the strongest provision relating specifically to ground-water monitoring, but the systems that are authorized under this program would be primarily large-scale in nature. In addition, while the authority exists under Section 106 for the use of funds to establish regional or statewide ground-water monitoring networks, most money has been channeled to surface-water programs at the state level.

The formation of the National Contingency Plan for dealing with emergencies from hazardous waste was an important offshoot of the Clean Water Act. This plan remains the guiding principle behind the implementation of Superfund.

Safe Drinking Water Act

The SDWA (Public Act 93-523) was passed by the Congress in 1974 in response to accumulating evidence that unsafe levels of contaminants in public drinking water supplies, including ground water, were posing a threat to the public health. The amendments to the SDWA, which were passed in June 1986, established the first nationwide program to protect ground-water resources used for public water supplies from a wide range of potential threats. The goal of the SDWA, as its name implies, is to ensure the provision of a safe supply of drinking water to all Americans served by public water supply systems. Several major provisions to the SDWA relate specifically to ground-water quality. The SDWA provides protection to ground water through:

- The establishment of drinking water standards (40 CFR 141; Fed. Reg. Vol. 43[243])
- Sole-source aquifer designation (42 U.S.C. 300f, Sec. 1427)
- The establishment of the WHPP (42 U.S.C. 300f, Sec. 1428)
- The UIC Program (42 U.S.C. 300f, Sec. 1424; 40 CFR 144)

Drinking Water Quality Standards

Promulgation of drinking-water quality standards to apply to public water supply systems (those which supply water to 25 or more people or have more than 15 service connections) is required by Section 1412 of the SDWA. Standards known as National Primary Drinking Water Standards (NPDWSs) and National Secondary Drinking Water Standards (NSDWSs) were developed by the U.S. EPA to meet this requirement. The NPDWSs are legally enforceable health-related standards that set maximum contaminant levels (MCLs) for bacteria, turbidity, and a variety of inorganic and organic chemicals and radionuclides in public water supplies (Table 1.3) (U.S. EPA, 2003). This list, current as of June 2003, has expanded significantly since the standards were first issued as interim standards in June 1977. The NSDWSs are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water (Table 1.4) (U.S. EPA, 2003). The MCLs set under SDWA may also be used for enforcement purposes in ground-water monitoring programs conducted both at RCRA interim status and at RCRA permitted facilities and for establishing ground-water cleanup levels at RCRA or CERCLA site.

Sole-Source Aquifer Program

Another provision of the SDWA related to protection of ground water is the Sole-Source Aquifer Program, also known as the Gonzales Amendment. This program provides local, regional, or state agency with a legal mechanism to protect the recharge zones of specially designated aquifers. It establishes a procedure whereby the U.S. EPA, either on its own initiative or upon petition, may designate an aquifer as a sole or principal source of drinking water for an area. After such a designation, no Federal financial assistance may be granted to a project that EPA determines could contaminate the aquifer through its recharge zone so as to create a "significant hazard to public health." This is defined as

> Any level of contaminant which causes or may cause the aquifer to exceed any MCL set forth in any national drinking water standard at any point where the water may be used for drinking water purposes or which may otherwise adversely affect the health of persons or which may require a public water system to install additional treatment to prevent such adverse effects.

As of April 2004, the U.S. EPA had made 73 sole-source aquifer designations across the USA (Table 1.5). A limiting factor in the sole-source aquifer provision is that it protects aquifer recharge zones only from federally funded projects that might contaminate an aquifer — nonfederally funded projects are not regulated. Although there are no specific provisions for ground-water monitoring in the Sole-Source Aquifer Program, data from ground-water monitoring wells and systems are used extensively to support petitions for sole-source aquifer designation and would be used to detect contamination from existing contaminant sources located in recharge zones of these important aquifers.

Wellhead Protection Program

Part of U.S. EPA's goal of providing protection for ground-water resources was accomplished by the establishment of state WHPPs, which protect wellhead areas within their jurisdiction from contaminants that may have any adverse effect on the health of persons. One of the major elements of a WHPP is the determination of zones within which contaminant source assessment and management are addressed. These zones, designated as Wellhead Protection Areas (WHPAs), are defined in the SDWA as

> The surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield.

TABLE 1.3

National Primary Drinking Water Standards

	Contaminant	MCL or TT[a] (mg/l)[b]	Potential Health Effects from Exposure above the MCL	Common Sources of Contaminant in Drinking Water	Public Health Goal
OC	Acrylamide	TT[c]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage or wastewater treatment	0
OC	Alachlor	0.002	Eye, liver, kidney, or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	0
R	Alpha particles	15 pCi/l	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	0
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 01/23/06	Skin damage or problems with circulatory systems and may have increased risk of cancer	Erosion of natural deposits; runoff from orchards, glass and electronics production wastes	0
IOC	Asbestos (fibers >10 μm)	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increased blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	0
OC	Benzo(*a*)pyrene polycyclic aromatic hydrocarbons (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	0

(*Table continued*)

TABLE 1.3 *Continued*

	Contaminant	MCL or TT[a] (mg/l)[b]	Potential Health Effects from Exposure above the MCL	Common Sources of Contaminant in Drinking Water	Public Health Goal
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 mrem/yr	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	0
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	0
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	0
D	Chloramines (as Cl_2)	MRDL = 4.0[a]	Eye or nose irritation; stomach discomfort; anemia	Water additive used to control microbes	MRDLG = 4[a]
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	0
D	Chlorine (as Cl_2)	MRDL = 4.0[a]	Eye or nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG = 4[a]
D	Chlorine dioxide (as ClO_2)	MRDL = 0.8[a]	Anemia; nervous system effects in infants and young children	Water additive used to control microbes	MRDLG = 0.8[a]
DBP	Chlorite	1.0	Anemia; nervous system effects in infants and young children	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1

IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[d] action level = 1.3	Short-term exposure: gastrointestinal distress; long-term exposure: liver or kidney damage. People with Wilson's disease should consult their personal doctor if the amount of copper in water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[e]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	0
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel and metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane	0.0002	Reproductive difficulties; increased risk of cancer	Runoff and leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	0
OC	*o*-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	*p*-Dichlorobenzene	0.075	Anemia; liver kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	0
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	*cis*-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	*trans*-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1

(*Table continued*)

TABLE 1.3 *Continued*

	Contaminant	MCL or TT[a] (mg/l)[b]	Potential Health Effects from Exposure above the MCL	Common Sources of Contaminant in Drinking Water	Public Health Goal
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	0
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	0
OC	Di(2-ethylhexyl)-adipate	0.4	Weight loss; liver problems; possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl)-phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	0
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	0
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[c]	Increased cancer risk; over a period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	0
OC	Ethylbenzene	0.7	Liver or kidney problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	0
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); children may get mottled teeth	Water additive that promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0

M	*Giardia lamblia*	TT[e]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal wastes	0
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	N/A[f]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	0
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	0
M	Heterotrophic plate count (HPC)	TT[e]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is	HPC measures a range of bacteria that are naturally present in the environment	N/A
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	0
OC	Hexachlorocyclo-pentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[d] action level = 0.015	Infants and children: delays in physical or mental development; children could show slight defects in attention span and learning abilities; adults: kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	0
M	*Legionella*	TT[e]	Legionnaire's disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	0
OC	Lindane	0.0002	Liver or kidney problems	Runoff and leaching from insecticide used on cattle, lumber and gardens	0.0002

(*Table continued*)

TABLE 1.3 *Continued*

	Contaminant	MCL or TT[a] (mg/l)[b]	Potential Health Effects from Exposure above the MCL	Common Sources of Contaminant in Drinking Water	Public Health Goal
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff and leaching from insecticide used on fruits, vegetables, alfalfa, and livestock	0.04
IOC	Nitrate (as nitrogen)	10.0	Infants less than the age of 6 months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome	Runoff from fertilizer use; leaching from septic tanks and sewage; erosion of natural deposits	10.0
IOC	Nitrite (as nitrogen)	1.0	Infants less than the age of 6 months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome	Runoff from fertilizer use; leaching from septic tanks and sewage; erosion of natural deposits	1.0
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff and leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	0
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	0

R	Radium 226 and 228 (combined)	5 pCi/l	Increased risk of cancer	Erosion of natural deposits	0
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	0
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1.0	Nervous system; kidney or liver problems	Discharge from petroleum factories	1.0
M	Total coliforms (including fecal coliform and *Escherichia coli*)	5.0%[g]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[h]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste	0
DBP	Total trihalomethanes	0.08	Liver, kidney, or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	0
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff and leaching from insecticide used on cotton and cattle	0
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.2
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	0

(*Table continued*)

TABLE 1.3 *Continued*

	Contaminant	MCL or TT[a] (mg/l)[b]	Potential Health Effects from Exposure above the MCL	Common Sources of Contaminant in Drinking Water	Public Health Goal
M	Turbidity	TT[e]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-carrying organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites, and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches	Soil runoff	N/A
R	Uranium	30 μg/l	Increased risk of cancer; kidney toxicity	Erosion of natural deposits	0
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	0
M	Viruses (enteric)	TT[e]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal wastes	0
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

Note: D, disinfectant; DBP, disinfection byproduct; IOC, inorganic chemical; M, microorganism; OC, organic chemical; R, radionuclide; MFL, million fibers per liter.
[a]MCLG: the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals; MCL: the highest level of a contaminant allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards; MRDLG: the level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants; MRDL: the highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants; TT: a required process intended to reduce the level of a contaminant in drinking water.

[b] Units are in milligrams per liter (mg/l) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).
[c] Each water system must certify, in writing, to the state (using a third party or manufacturers' certification) that when it uses acrylamide or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified as follows: acrylamide = 0.05% dosed at 1 mg/l (or equivalent); epichlorohydrin = 0.01% dosed at 20 mg/l (or equivalent).
[d] Lead and copper are regulated by a TT that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/l; for lead, the action level is 0.015 mg/l.
[e] EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (a) disinfect their water and (b) filter their water or meet criteria for avoiding filtration, so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 01/01/02 for systems serving more than 10,000 and 01/04/05 for systems serving less than 10,000) 99% removal.
- *Giardia lambia*: 99.9% removal or inactivation.
- Viruses: 99.99% removal or inactivation.
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed or inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of 01/01/02 for systems serving more than 10,000 and 01/14/05 for systems serving less than 10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (effective date: 01/14/05): Surface water systems or GWUDI systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g., turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter backwash recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

[f] Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants: (a) Haloacetic acids: dichloroacetic acid (0), trichloroacetic acid (0.3 mg/l); (b) Trihalomethanes: bromodichloromethane (0); bromoform (0); dibromochloromethane (0.06 mg/l).
[g] No more than 5.0% samples can be total coliform-positive per month. (For water systems that collect fewer than 40 routine water samples per month, no more than one sample can be total coliform-positive per month.) [Every sample that has total coliform must be analyzed for either fecal coliform or *E. coli*. If two consecutive samples are TC-positive and one is also positive for *E. coli* fecal coliforms, this is defined as an acute MCL violation.]
[h] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.
Source: U.S. EPA Office of Water (4606M), EPA 816-F-03-016, June 2003 (www.epa.gov/safewater).

TABLE 1.4

National Secondary Drinking Water Standards[a]

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/l
Chloride	250 mg/l
Color	15 (color units)
Copper	1.0 mg/l
Corrosivity	Noncorrosive
Fluoride	2.0 mg/l
Foaming agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor number
pH	6.5 to 8.5
Silver	0.10 mg/l
Sulfate	250 mg/l
Total dissolved solids	500 mg/l
Zinc	5 mg/l

[a]NSDWSs are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Source: U.S. EPA Office of Water (4606M), EPA 816-F-03-016, June 2003 (www.epa.gov/safewater).

Hence, the law establishes the concept of protecting some of the recharge areas for these points of public drinking water withdrawal. Ground-water monitoring systems are not specifically required under the WHP, but there are few other reliable methods that can be used to generate the data required to support delineation of WHPAs. The states have been given flexibility in determining appropriate operational approaches to WHPA delineation.

The U.S. EPA published guidelines for delineation of WHPAs to assist the states in developing their programs (U.S. EPA, 1987b). The delineation guidelines assume that WHPA delineation and protection are targeted to three general threats. The first threat is the direct introduction of contaminants to the area immediately contiguous to the well through improper casing, road runoff, spills, and accidents. The second basic threat is from microbial contaminants such as bacteria and viruses. The third major threat is from the broad range of chemical contaminants including inorganic and naturally occurring or synthetically derived organic chemicals.

U.S. EPA's WHPA delineation policy is generally based on the analysis of criteria, criteria thresholds, and delineation methods. The criteria, or conceptual standards on which WHPA delineation may be based, include distance, drawdown, travel time, flow system boundaries, and the capacity of the aquifer to assimilate contaminants. Choice of the criteria to be applied in any particular program is based on both technical and nontechnical considerations. Criteria and criteria thresholds define the general technical basis of the WHPA. Selecting appropriate criteria thresholds is a key decision point, which must be done in conjunction with establishing the management elements of the WHPP. The WHPA delineation methods are used to translate or apply these criteria, and to develop on-the-ground or on-the-map WHPA boundaries. The specific methods to be used in delineating a WHPA range from simple radius-of-influence estimation techniques to

TABLE 1.5

Sole-Source Aquifer Designations made by the U.S. EPA as of April 2004

State	Sole-Source Aquifer Name	Federal Register Citation	Publication Date	GIS Map
U.S. EPA Region I				
CT	Pootatuck Aquifer	55 FR 11056	03/26/90	Yes
MA	Cape Cod Aquifer	47 FR 30282	07/13/82	Yes
MA	Nantucket Island Aquifer	49 FR 2952	01/24/84	Yes
MA	Martha's Vineyard Aquifer	53 FR 3451	02/05/88	Yes
MA	Head of Neponset Aquifer System	53 FR 49920	12/12/88	Yes
MA	Plymouth-Carver Aquifer	55 FR 32137	08/07/90	Yes
MA	Canoe River Aquifer	58 FR 28402	05/13/93	Yes
MA	Broad Brook Basin of the Barnes	60 FR 20989	04/28/95	Yes
ME	Monhegan Island	53 FR 24496	06/29/88	Yes
ME	Vinalhaven Island Aquifer System	54 FR 29779	07/14/89	Yes
ME	North Haven Island Aquifer System	54 FR 29934	07/17/89	Yes
ME	Isleboro Island Aquifer System	64 FR 186	09/27/99	No
RI	Block Island Aquifer	49 FR 2952	01/24/84	Yes
RI/CT	Pawcatuck Basin Aquifer System	53 FR 17108	05/13/88	Yes
RI	Hunt-Annaquatucket Pettaquamscutt	53 FR 19026	05/26/88	Yes
U.S. EPA Region II				
NJ	Buried Valley Aquifers, Central Basin, Essex, and Morris Counties	45 FR 30537	05/08/80	Yes
NJ	Upper Rockaway River Basin	49 FR 2946	01/24/84	Yes
NJ	Ridgewood Area Aquifers	49 FR 2943	01/24/84	Yes
NJ/NY	Highlands Aquifer System, Passaic, Morris, and Essex Counties — NJ Orange County — NY	52 FR 37213	10/05/87	Yes
NJ[a]/DE/PA	NJ Coastal Plain Aquifer System	53 FR 23791	06/24/88	Yes
NJ/NY	NJ Fifteen Basin Aquifers	53 FR 23685	06/23/88	Yes
NJ/NY	Ramapo River Basin Aquifer Systems	57 FR 39201	08/28/92	Yes
NY	Nassau/Suffolk Counties, Long Island	43 FR 26611	06/21/78	Yes
NY	Kings/Queens Counties	49 FR 2950	01/24/84	Yes
NY	Schenectady/Niskayuna	50 FR 2022	01/14/85	Yes
NY	Clinton Street-Ballpark Valley Aquifer System, Broome, and Tioga Counties	50 FR 2025	01/14/85	Yes
NY	Cattaraugus Creek Basin Aquifer, WY, and Allegany Counties	52 FR 36100	09/25/87	Yes
NY	Cortland-Homer-Preble Aquifer System	53 FR 22045	06/13/88	Yes

(*Table continued*)

TABLE 1.5 *Continued*

State	Sole-Source Aquifer Name	Federal Register Citation	Publication Date	GIS Map
U.S. EPA Region III				
DE/PA/NJ[b]	New Jersey Coastal Plain Aquifer	53 FR 23791	06/24/88	Yes
MD	Maryland Piedmont Aquifer, Montgomery, Howard, and Carroll Counties	45 FR 57165	08/27/80	Yes
MD	Poolesville Area Aquifer Extension of the Maryland Piedmont Aquifer	63 FR 3042	02/06/98	Yes
PA	Seven Valleys Aquifer, York County	50 FR 9126	03/06/85	Yes
VA	Prospect Hill Aquifer, Clark County	52 FR 21733	06/09/87	Yes
VA	Columbia and Yorktown, Eastover Multi-Aquifer System, Accomack, and North Hampton Counties	62 FR 17187	04/09/97	Yes
U.S. EPA Region IV				
FL	Biscayne Aquifer, Broward, Dade, Monroe, and Palm Beach Counties	44 FR 58797	10/11/79	No
FL	Volusia-Floridan Aquifer, Flagler, and Putnam Counties	52 FR 44221	11/18/87	No
LA[c]/MS	Southern Hills Regional Aquifer System	53 FR 25538	07/07/88	No
U.S. EPA Region V				
IN	St. Joseph Aquifer System	53 FR 23682	06/23/88	No
MN	Mille Lacs Aquifer	55 FR 43407	10/29/90	No
OH	Pleasant City Aquifer	52 FR 32342	08/27/87	Yes
OH	Bass Island Aquifer, Catawba Island Aquifer	52 FR 37009	10/02/87	Yes
OH	Miami Valley Buried Aquifer	53 FR 15876	05/04/88	Yes
OH	OKI Extension of the Miami, Buried Valley Aquifer	53 FR 25670	07/08/88	Yes
OH	Allan County Area Combined Aquifer System	57 FR 53111	11/06/92	Yes
U.S. EPA Region VI				
LA	Chicot Aquifer System	53 FR 20893	06/07/88	Yes
LA[d]/MS	Southern Hills Aquifer System	53 FR 25538	07/07/88	Yes
OK	Arbuckle-Simpson Aquifer, South Central Oklahoma	54 FR 39230	09/25/89	Yes
TX	Edwards Aquifer, San Antonio Area	40 FR 58344	12/16/75	Yes
TX	Edwards Aquifer, Austin Area	53 FR 20897	06/07/88	Yes
U.S. EPA Region VII				
There are no designated sole-source aquifers in Region VII as of April 2004				
U.S. EPA Region VIII				
MT	Missoula Valley Aquifer	53 FR 20895	06/07/88	No
UT	Castle Valley Aquifer System	66 FR 41027	08/06/01	No

UT	Western Uinta Arch Paleozoic Aquifer System at Oakley, UT	65 FR 232	12/01/00	No
UT	Glen Canyon Aquifer System	67 FR 736	01/07/02	No
WY[e]	Eastern Snake River Plain Aquifer Stream Flow Source Area	56 FR 50638	10/07/91	Yes
WY	Elk Mountain Aquifer	63 FR 38167	07/15/98	No
U.S. EPA Region IX				
AZ	Upper Santa Cruz and Avra Basin Aquifer	49 FR 2948	01/24/84	Yes
AZ	Bisbee-Naco Aquifer	53 FR 38337	09/30/88	Yes
CA	Fresno County Aquifer	44 FR 52751	09/10/79	Yes
CA	Santa Margarita Aquifer, Scotts Valley	50 FR 2023	01/14/85	Yes
CA	Campo/Cottonwood Creek Aquifer	58 FR 31024	05/28/93	Yes
CA	Ocotillo-Coyote Wells Aquifer	61 FR 47752	09/10/96	Yes
GU	Northern Guam Aquifer System	43 FR 17867	04/26/78	Yes
HI	Southern Oahu Basal Aquifer	52 FR 45496	11/30/87	Yes
HI	Molokai Aquifer	58 FR 23063	04/20/93	Yes
U.S. EPA Region X				
ID/WY[f]	Eastern Snake River Plain Aquifer	56 FR 50638	10/07/91	Yes
OR	North Florence-Dunal Aquifer	52 FR 37519	10/07/87	Yes
WA/ID	Spokane Valley Rathdrum Prairie Aquifer	42 FR 5566	02/09/78	Yes
WA	Camano Island Aquifer	47 FR 14779	04/06/82	Yes
WA	Whidbey Island Aquifer	47 FR 14779	04/06/82	Yes
WA	Cross Valley Aquifer	52 FR 18606	05/18/87	Yes
WA	Newberg Area Aquifer	52 FR 37215	10/05/87	Yes
WA	Cedar Valley (Renton Aquifer)	53 FR 38779	10/03/88	Yes
WA/ID	Lewiston Basin Aquifer	53 FR 49920	12/12/88	Yes
WA	Central Pierce County Aquifer System	59 FR 224	01/03/94	Yes
WA	Marrowstone Island Aquifer System	59 FR 28752	06/02/94	Yes
WA	Vashon-Maury Island Aquifer System	59 FR 34468	07/05/94	Yes
WA	Guemes Island Aquifer System	62 FR 5928-3	12/01/97	Yes

[a] The New Jersey Coastal Plains Aquifer is jointly managed with Region III. While listed in both regions, it is counted only once in the national total of 73.
[b] The New Jersey Coastal Plains Aquifer is jointly managed with Region II. While listed in both regions, it is counted only once in the national total of 73.
[c] The Southern Hills Regional Aquifer system is jointly managed with Region VI. While listed in both regions, it is counted only once in the national total of 73.
[d] The Southern Hills Regional Aquifer System is jointly managed with Region IV. While listed in both regions, it is counted only once in the national total of 73.
[e] The Eastern Snake River Plan Aquifer is jointly managed with Region X. While listed in both regions, it is counted only once in the national total of 73.
[f] The Eastern Snake River Plan Aquifer is jointly managed with Region VIII. While listed in both regions, it is counted only once in the national total of 73.
Source: U.S. EPA Office of Ground Water and Drinking Water, April 2004 (www.epa.gov/safewater/ssanp.html).

highly complex and comprehensive numerical modeling techniques. Regardless of the method used, data from existing or yet to be installed ground-water monitoring systems are critical to proper delineation of WHPAs.

Underground Injection Control Program

The UIC Program was developed under SDWA to protect current and future sources of drinking water (defined as all ground water with a total dissolved solids content of less than 10,000 mg/l), from endangerment by underground injection of fluids. The basic concept of the UIC Program is to prevent contamination of fresh-water aquifers by ensuring that injected fluids are confined within the injection wells and the intended injection zone. The need for such a program was compelling when it was first conceived, as the EPA estimated that in 1980, there were more than 600,000 wells injecting more than 850 billion gallons of fluid per year beneath the surface (U.S. EPA, 2002). Considering the types of fluids injected (ranging from storm water runoff to hazardous wastes), the number of facilities in operation, and the complexity and diversity of geology in areas where underground injection is practiced, the task of regulating this industry is quite complex.

To ensure effective regulation of injection wells, standards have been set for each of five types or classes of injection wells, which are described in Table 1.6. The UIC regulations establish minimum standards for injection well design, construction, operation, monitoring, and decommissioning procedures, and state program requirements. Wells in Classes I to III come under rigid permitting requirements; Class IV wells are forbidden; and Class V wells are permitted or forbidden on a case-by-case basis. The U.S. EPA Regional Administrator may require ground-water monitoring at an underground injection point to evaluate whether an underground source of drinking water may be endangered by injection of fluids into Class II enhanced recovery wells, Class IV wells, and some Class V wells. In addition, the owner or operator of a Class I, II, or III well can be required

> To install and use monitoring wells within the area of review if required by the Director (of the U.S. EPA), to monitor any migration of fluids into and pressure in the underground sources of drinking water.
>
> (40 CFR 144.28)

The type, number, and location of the wells; the parameters to be measured; and the frequency of monitoring must be approved by the EPA.

Under the UIC Program, aquifers that do not currently serve as a source of drinking water or could not in the future are exempted from protection, because they are (1) mineral, hydrocarbon, or geothermal-energy producing; (2) situated at a depth or location that makes recovery of the water for drinking economically or technologically impractical; or (3) so contaminated that it would be infeasible to render the water fit for human consumption. Moreover, in keeping with SDWA policy, only ground water that supplies or could supply in the future any public water supply system is protected. Consequently, the UIC Program does not apply to either ground water used for purposes other than drinking or ground-water supplying nonpublic water systems.

Surface Mining Control and Reclamation Act

The SMCRA of 1977, under the administration of the U.S. Department of the Interior (specifically the OSM), provides authority for various levels of government to control environmental impacts resulting from all mining activities, even though the title of the Act refers only to surface mining. Among the purposes of the Act are to:

- Establish a nationwide program to protect society and the environment from the adverse effects of mining operations
- Ensure that mining operations are conducted so as to protect the environment

TABLE 1.6

U.S. EPA Injection Well Classifications Under the UIC Program of the SDWA

Class of well	Description
Class I	Wells used by generators of hazardous wastes or owners or operators of hazardous waste management facilities to inject hazardous waste. In addition, industrial and municipal disposal wells used to inject fluids beneath the lowermost formation containing, within 0.25 mi of the well, an underground source of drinking water
Class II	Wells that inject fluids, which are brought to the surface in connection with conventional oil and natural gas production, those used for enhanced recovery of oil or natural gas, and those used for storage of liquid hydrocarbons
Class III	Wells that inject for the purpose of extracting minerals or energy, including solution mining wells, wells used for *in situ* combustion of fossil fuel, wells used for recovery of geothermal energy, and wells used in the mining of sulfur by the Frasch process
Class IV	Wells used by generators of hazardous wastes or radioactive wastes, by owners and operators of hazardous waste management facilities, or by owners and operators of radioactive waste disposal sites to dispose of hazardous wastes or radioactive wastes into or above a formation that, within 0.25 miles of the well, contains an underground source of drinking water
Class V	Any injection well not included in the Classes I to IV, including: 1. Air-conditioning return-flow wells used to return to the supply aquifer, the water used for heating or cooling in a heat pump 2. Cesspools or other devices that receive wastes, which have an open bottom and sometimes have perforated sides. The UIC requirements do not apply to single family residential cesspools 3. Cooling-water return-flow wells used to inject water previously used for cooling 4. Drainage wells used to drain surface fluid, primarily storm water runoff into a subsurface formation 5. Dry wells used for the injection of wastes into a subsurface formation 6. Recharge wells used to replenish the water in an aquifer 7. Saltwater intrusion barrier wells used to inject water into a freshwater aquifer to prevent the intrusion of saltwater into the freshwater 8. Sand backfill wells used to inject a mixture of water and sand, mill tailings, or other solids into mined out portions of subsurface mines 9. Septic system wells used: • To inject the waste or effluent from a multiple dwelling, business establishment, community, or regional business establishment septic tank • For a multiple dwelling, community, or regional cesspool. The UIC requirements do not apply to single family residential waste disposal systems 10. Subsidence control wells (not used for the purpose of oil or natural gas production) used to inject fluids into a nonoil or gas-producing zone to reduce or eliminate subsidence associated with the overdraft of freshwater 11. Wells used for the storage of hydrocarbons which are gases at standard temperature and pressure 12. Geothermal wells used in heating and aquaculture 13. Nuclear disposal wells

Source: U.S. EPA Underground Injection Control Program regulations as outlined in the Federal Register, Vol. 45(123), June 24, 1980.

- Ensure that adequate procedures are followed to reclaim surface areas as contemporaneously as possible with surface mining operations
- Promote the reclamation of mined areas left without adequate reclamation prior to enactment of this Act and which continue, in their un-reclaimed condition, to substantially degrade the quality of the environment, prevent or damage the beneficial use of land or water resources, or endanger the health or safety of the public

Several sections of SMCRA deal specifically with ground water. For new mines, permit applications described under Section 507 must include the determination of the probable hydrologic consequences of the mining and the reclamation proposed. Of particular concern is the determination of the impact of mining and reclamation on the quantity and quality of water in both surface-water and ground-water systems. All permit applications must be accompanied by geologic maps and cross-sections of the land to be affected showing, among others, the locations of aquifers and estimated water levels (Lehr et al., 1984).

Reclamation plan requirements outlined in Section 508 compel mine operators to provide a detailed description of the measures to be taken during the mining and reclamation process to ensure the protection of the quality of surface water and ground water from the adverse effects of the mining and reclamation process. In addition, the operator must recognize the rights of the present users to this water and must ensure the protection of the quantity of surface water and ground water from the mining and reclamation operation or provide alternate sources of water where such protection cannot be assured.

Section 515 of SMCRA outlines general environmental protection performance standards applicable to mining and reclamation operations that require the operation to

> Minimize the disturbances to the prevailing hydrologic balance at the mine site and to the quality and quantity of water in surface-water and ground-water systems both during and after mining operations and during reclamation.

Water quality is to be preserved by avoiding acid or other toxic mine drainage through such means as preventing or removing water from contact with toxic deposits, treating drainage to reduce its toxic content, or burying or otherwise disposing of acid-forming or toxic materials in a manner to prevent contamination of both surface water and ground water. Mine operators are required to maintain the hydrologic balance of the area by restoring the recharge capacity of the mined area to approximate premining conditions.

Under Section 517, the OSM may require mine operators to install, use, and maintain ground-water monitoring systems. The preparation of a ground-water monitoring plan is required under 30 CFR 780, which deals with the application for a surface mining permit. For those mining and reclamation operations that disturb aquifers, the OSM has the power to specify monitoring sites to record the level, amount, and quality of ground water in aquifers affected or potentially affected by the mining operation. The OSM has set forth standards and procedures for the collection and analysis of data generated by ground-water monitoring programs required under SMCRA. As part of the minimum requirements for the required Reclamation and Operations Plan, hydrogeologic information must be supplied concerning the quality of the surface water and ground water in the permitted area and adjacent areas.

Brownfields

In 1995, the U.S. EPA addressed the problem associated with former industrial and urban sites with minor contamination by creating the Brownfields Initiative. This was a new approach to management of contaminated property which, unlike the RCRA and CERCLA regulations, was based on a partnership model. Prior to the initiative, marginally contaminated sites were largely ignored by developers because the magnitude of contamination often was unknown and the liability for this contamination was not something developers wanted to assume. Under this initiative, the U.S. EPA has established the Brownfields National Partnership and provides local communities with seed money to encourage local governments to develop these properties and manage any contamination associated with them. The local governments, in turn, create 2 year pilot programs that are used to build local capabilities, with technical guidance provided at the Federal level.

Brownfields sites fall into one of the following several categories:

- Brownfields Assessment Pilots provide funding for environmental assessments and community outreach.
- Brownfields Cleanup Revolving Loan Fund Pilots provide funding to capitalize loans that are used to clean up brownfields.
- Brownfields Job Training and Development Demonstration Pilots provide environmental training for residents of brownfields communities.
- RCRA and Brownfields Prevention Pilots utilize the inherent flexibility in RCRA regulations to prevent brownfields from being developed on RCRA properties.
- Clean Air/Brownfields Partnership Pilots help to determine the potential air quality and other environmental and economic benefits of redeveloping urban brownfields.
- Brownfields Showcase Communities serve as national models for successful brownfields assessment, cleanup, and redevelopment.
- Targeted Brownfields Assessments provide funding or technical assistance for environmental assessments at selected brownfields sites not targeted by EPA Assessment Pilots.

While ground-water monitoring is not specifically required under the Brownfields Initiative, some level of monitoring (typically short-term monitoring) is generally necessary to determine the presence or absence and types and levels of contaminants in ground water at each site.

Federal Ground-Water Protection Strategy

When the U.S. EPA established a Ground-Water Protection Strategy in August 1984 (U.S. EPA, 1984), it concluded that state governments have the primary responsibility for ground-water protection policies and implementation, yet it set national goals and management strategies for implementing existing federal laws.

The strategy sets a policy framework to guide U.S. EPA's programs affecting ground water. This framework involves developing a system for classification of the nation's ground water. The agency uses this classification system to evaluate the siting of RCRA facilities and will continue to use the immediacy of a threat to ground water as a factor in selecting sites for Superfund cleanup.

Specifically the policy calls for EPA to:

- Provide financial support to states for ground-water protection program development and institution building

- Assess the problems that may exist from sources of ground-water contamination, which were previously not addressed
- Study the need for further regulation of land disposal facilities including surface impoundments and landfills
- Issue guidelines for agency decisions affecting ground-water protection and cleanup
- Establish an Office of Ground-Water Protection within EPA to coordinate agency policies (Bird, 1985)

The classification of ground water is the backbone of the policy, which helps to provide consistency in agency decisions.

Ground-Water Classification

The Environmental Protection Agency released a draft document of guidelines for ground-water classification as part of its Ground-Water Protection Strategy. The document established three classifications for ground water. Class I, special ground water, is ecologically vital or irreplaceable as a source of drinking water. Ecologically vital ground water is defined as that "which supports habitats for species listed or proposed for listing under the Endangered Species Act or which provides the base flow for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat." Class I water is considered to be highly vulnerable to contamination because of the hydrologic characteristics of the area in which the ground water occurs. With its authority under RCRA, EPA will ban the siting of new disposal facilities and require very stringent cleanup levels (involving cleanup to background or drinking water levels) to be applied to existing facilities above Class I ground water. EPA also has considered developing special permit conditions under the UIC Program to protect these waters.

Class II ground water includes current or potential sources of drinking water and water having other beneficial uses. Class III ground water includes water not considered to be a potential source of drinking water and water that may be contaminated naturally (e.g., highly saline ground water, with total dissolved solids levels over 10,000 mg/l) or by human activity, beyond levels that allow cleanup using methods reasonably employed in public water system treatment.

Essentially, Class I ground water would receive the highest level of protection, Class II ground water would receive less protection, and Class III ground water would receive the least protection under this ground-water classification system. There is a provision for variances to lower the protection levels.

Discussion of Ground-Water Quality Standards

Ground-water monitoring only becomes meaningful when the results of the analyses for water quality are compared to some useful reference point. In many cases, ground-water quality standards are applied to water used for consumptive purposes as it leaves the tap. In other cases, standards are applied to ground water after it has been cleaned up or as it discharges to a surface water body or in terms of the risk posed by a specified exposure. Further complicating the issue is the fact that many states have different or more restrictive standards than the Federal government.

To achieve a better understanding of the standards that can be applied, a definition of some of the basic terms is appropriate. The SDWA states:

> The term "Primary Drinking Water Regulation" means a regulation which (1) applies to public water systems, (2) specifies contaminants which may have an adverse effect on the health of persons, (3) specifies for each contaminant either a maximum contaminant level or a reduced level based on treatment, and (4) contains criteria and procedures to assure a supply of drinking water that will comply with the maximum contaminant levels (MCLs) and the requirements for the minimum quality of water that can be taken into the system.

The Secondary Drinking Water Regulations, also defined in the SDWA, are described as follows:

> The term "Secondary Drinking Water Regulation" means a regulation which applies to public water systems and which specifies the maximum contaminant levels which are requisite to protect the public welfare. This applies to any contaminant in drinking water which may adversely affect the odor or appearance of the water so that a significant number of users discontinue its use.

The term MCL refers to the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. These are enforceable standards that are set as close to maximum contaminant level goals (MCLGs) as feasible. These standards are often applied to ground water that is used for drinking water purposes, regardless of whether it is supplied by a public system or a private well. These standards also consider the best technology that is available, treatment technologies that can be applied, and associated costs.

The MCLG, previously called a recommended maximum contaminant level, is the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, which allows for an adequate margin of safety. These are non-enforceable health goals (40 CFR 141.2, July 1987).

The CWA also has established water-quality criteria that are not limited to ground water, known as the 304(a)(1) criteria. They are not rules and are not enforceable. Rather, these criteria present specific data and guidance on the environmental effects of pollutants, which can be useful in deriving regulatory requirements based on considerations of water-quality impacts. They are, therefore, comparable to the MCLGs, as they are not based on technology or cost, but are on health goals. These standards can be used when protection of a drinking water source is not the sole objective, and they can be applied to water-quality-based effluent limitations and toxic pollutant effluent standards (Federal Register, 1980). Although these standards were derived for surface water, they have application to ground water, particularly where other standards for certain chemicals have not yet been set.

Lists of various national and state standards and criteria are available from the U.S. EPA and various state regulatory agencies. Extreme caution should be exercised in applying these criteria and standards to specific site conditions. These criteria, for the most part, do not take into account some other important factors that should be considered when applying standards to ground water used for consumptive purposes. These considerations include the population that will be using the water, the exposure from other sources that could contribute to the risk, and some of the other risks of exposure other than carcinogenic effects. Clearly, the application of water-quality standards and criteria is neither simple nor straightforward and requires expertise in other fields, particularly toxicology.

Mechanisms for a Workable Federal Ground-Water Program

Even the best-laid plans have elements that make implementation more difficult than it first appears — environmental regulations are no exception. Now that major Federal waste-management regulations have been in place for more than two decades, there are functional goals that must be kept in mind if the mandated protection of ground water is going to succeed.

The first element is communication. The regulations will do no good if the regulated community will not follow them, even under the threat of civil or criminal penalty. Enforcement bodies have limited resources for informing the regulated community of their obligations under the law. As a result, most cases of noncompliance are the result of ignorance rather than malice or the profit motive. It is essential for the regulations to be communicated to those parties that they directly affect. Industrial facilities must be made aware of the limitations placed on their practices, such as management of waste, discharge of process wastewater, standards that treatment works must meet, and the permits that must be obtained. Even individual homeowners must be made aware that they are responsible for protecting their small portion of the ground-water resource. Federal, state, and local regulations generally can be easily accessed on the Internet or by calling the appropriate regulatory agency. Every effort must be made to disseminate this information to the people who need it.

The second element is the establishment of standardized evaluation and protection practices and the application of the same basic standards to similar situations. It is well known that ground water is a dynamic resource and the hydrogeologic settings in which it occurs very widely. However, there are sound scientific and engineering practices that can be applied to the evaluation of ground water to ensure that suitable and appropriate conclusions and recommendations concerning its potential use or abuse can be drawn. Similarly, the standards that are applied to the protection and cleanup of an aquifer should be made clear and not left to the whimsy of an individual regulator. There is a broad spectrum of standards and policies, ranging from nondegradation to inaction, routinely being applied by regulators who lack direction. Standards that are health- or risk-based, technology-sensitive, and use-directed are in the process of being developed and will do much to bring this element into focus. However, a standard baseline for protection and cleanup would do much to minimize the uncertainty currently associated with site evaluation.

Finally, there should be a mechanism at all levels for changing and amending the regulations as conditions change. This is found to some degree at Federal and state levels with the owner's ability to request a waiver to a portion of a regulation or to apply alternate standards in particular cases. This ability should be expanded and streamlined as much as possible to address the changing nature of the resource. If new practices pose new health risks, or if the chemical or physical nature of an aquifer changes substantially over time, the mechanisms must be in place to revise regulations and applicable standards.

Comprehensive State Ground-Water Protection Programs

Comprehensive State Ground-Water Protection Programs (CSGWPPs) are partnerships between states and the U.S. EPA and Tribal Nations to implement EPA's ground-water protection goals and principles. The purpose is to achieve a more efficient, coherent, and comprehensive approach to protecting and managing the nation's ground-water resources. This program will be used to prevent contamination and to consider use, value, and vulnerability in setting priorities for both protection and remediation.

This program is used to establish goals and set priorities based on local needs and to clarify the roles and responsibilities for ground-water management across federal, state, and local jurisdictions. CSGWPPs can be used as a template to plan and implement ground-water protection and remediation strategies.

Ground Water and Terrorism

Owing to the terrorist attacks of September and October 2001, which included the use of commercial airliners as weapons and using the U.S. Postal Service to deliver pathogens through the mail, federal, regional, state, and local governments all are taking a closer look at the safety of our water supply. Surface-water sources would seem to be the most vulnerable target, due to easier access and faster dispersion of contaminants in that medium. Ground water, by its very nature, is protected, both by its slow flow rate and by the natural cleansing action of the porous media through which it passes. In fact, ground water could prove to be a "safe haven" for the storage and retrieval of uncontaminated drinking water. Comprehensive emergency preparedness plans should include guidelines and procedures for monitoring and maintaining the quality of the nation's ground-water supply. Additional security at the well head should be undertaken for water systems supplying large populations.

Ground Water and Development

One of the most stressful impacts on natural resources in the late 20th and early 21st centuries has been the exploitation of ground water. Anxiety about this limited resource is especially pronounced in the Western U.S., where water can be scarce, heavily laden with salts, or deep and expensive to retrieve. Land-use decisions are beginning to take water resource availability into account. A law that took effect in the state of California in January 2002 may have far-reaching impacts on development. In essence, this law states that all developers are required to provide detailed proof that an ample water supply exists and can be tapped for at least 20 years for every housing development involving over 500 homes. If this cannot be demonstrated, the developers are not allowed to break ground (Anonymous, 2001). This law may serve as a model for other states seeking to protect potable ground-water resources. It may also be used to avoid the battles that sometimes ensue over water used for domestic supply, agricultural use, ranching and that needed to sustain and protect endangered species.

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