IV. Ground Water Assessment

Ground water in Colorado is highly variable in quality and availability because of the diverse environmental and hydrogeologic conditions across the state. Ground water occurs in a wide variety of geologic deposits, including unconsolidated silt, sand, and gravel deposited by wind and streams or as talus along mountain slopes; consolidated sedimentary bedrock formations; and fractured igneous and metamorphic rocks of mountainous regions. Hydrologic conditions range from shallow unconfined alluvial aquifers along rivers to confined artesian aquifers within deep structural basins. Ground water quality in Colorado ranges from excellent, in mountain areas where snowfall is heavy, to poor, in certain alluvial aquifers of major rivers where surface and ground water are used and reused for multiple purposes. Climate, hydrogeologic conditions, naturally occurring soluble minerals, and man's activities are the primary factors affecting ground water quality in the state.

Ground water supplies 18 percent of water used in the state; approximately 96 percent of this is consumed by agriculture. The remainder is used for public and private water supplies. In some areas, ground water is the only source of water available.

A. Major Aquifers in Colorado

Colorado's complex geology is the result of multiple historic mountain-building episodes. Mountain uplifts in the central and western part of the state displaced overlying sedimentary formations, and subsequent erosion of these formations exposed the granite and crystalline metamorphic rock core. The uplifts also created deep basins filled with layered sedimentary formations. The High Plains, however, remained relatively undisturbed. Here the sedimentary Ogallala Formation, the only significant aquifer in the region, overlies the Pierre Shale. Episodes of massive vulcanism occurred in many parts of the state, including the San Juan Mountains, South Park, and San Luis Valley. Moving water, wind, and glacial activity have sculpted these geologic units into the landforms we see today: river valleys, terraces, sand dunes, and mountain chains.

Ground water occurs in three principal types of aquifers: unconsolidated alluvial deposits (sands and gravels deposited by rivers), consolidated sedimentary bedrock formations in deep basins and geologically undisturbed areas of the state, and fractured crystalline igneous and metamorphic rocks of the mountain core. Colorado's major aquifers are shown on Table 1: Major Aquifers in Colorado.

Shallow river alluvium or terrace aquifers occur along most of the important rivers and streams in the state, including the South Platte, Arkansas, and Colorado Rivers. Areas of older, high-level terrace gravels occur over much of the Eastern Plains. In areas where these gravels are fairly thick and permeable, they are extremely important sources of ground water. The Eastern Plains are also mantled with wind-blown sand, which sometimes contains usable quantities of water. These aquifers have large water-level fluctuations that often cause them to be only a seasonal source of water.

Table 1: Major Aquifers of Colorado

Watershed	*Structural Basin*	*Aquifer*	*Geologic Unit*	*Lithology*
All	Not applicable	Quaternary Aquifers	River alluvium, terrace gravels	Unconsolidated sand, silt, gravel
Arkansas/Rio Grande	Not applicable	Southeast	Dakota Group	Sandstone, shale
South Platte and Arkansas/Rio Grande	Denver-Julesburg	Denver Basin	Dawson Formation	Sandstone, shale, some conglomerate
			Denver Formation	Sandstone, siltstone, shale, clay
			Arapahoe Formation	Sandy shale, clay, beds of sandstone and gravel
			Laramie Formation	Silty shale, clay, beds of sandstone and gravel
			Fox Hills Sandstone	Massive sandstone
Lower Colorado	Paradox-San Juan	Paradox-San Juan Aquifer System	Mesa Verde Group	Sandstone, shale, siltstone, coal
			Dakota Formation	Sandstone, shale w/ interbedded siltstone, coal
			Morrison Formation	Sandstone, siltstone, limestone
			Entrada Formation	Sandstone
Upper Colorado and Lower Colorado	Piceance	Piceance Aquifer System	Uinta Formation	Sandstone, siltstone, shale
			Green River Formation	Interbedded siltstone, sandstone, limestone, shale
			Wasatch Formation	Clay, shale, sandstone, limestone
Arkansas/Rio Grande	San Luis Valley	San Luis Valley Aquifer System	Alamosa Formation	Unconsolidated valley fill sand, gravel, clay
			Santa Fe Formation	Sand, silt, gravel, clay

Table 1: Major Aquifers of Colorado (Continued)

Watershed	***Structural Basin***	***Aquifer***	***Geologic Unit***	***Lithology***
South Platte and Arkansas/Rio Grande	Not Applicable	High Plains	Ogallala Formation	Sand, gravel, silt, eolian sand
			White River Group	Clay, shale, sandstone, lime-stone
Upper Colorado and Lower Colorado	Not applicable	Paleozoic Aqui-fer System	Leadville Limestone	Limestone, dolomite, sand-stone, chert
			Minturn Formation Eagle Valley Evaporites	Sandstone, shale, limestone, gypsum

Many of the intermontaine basins and mountain valleys have accumulated thick alluvial deposits. The Alamosa Formation in the San Luis Valley, one of the major aquifers in the state, is one example. The valley fill in the high mountains is generally glacial, glacial-fluvial, or glacial-lacustrine in origin and classified as till. Tills can be very permeable and provide important local sources of ground water. In a few mountain areas, talus, landslide, or slump debris form aquifers.

Colorado is divided by the southern Rocky Mountains that extend north-south through the west-central part of the state. Sedimentary bedrock aquifers occur in geologic structural basins across the state, including the Denver-Julesburg Basin, Paradox-San Juan Basin, Piceance Basin, Raton Basin, and San Luis Valley. Minor bedrock aquifers are found in the intermontane basins; these include the Fountain and Lyons Formations near the Front Range, Raton Formation near Trinidad, Vermejo Formation near Walsenburg, and Troublesome and Browns Park Formations. Other sedimentary deposits in the state also serve as minor bedrock aquifers.

Ground water in the fractured igneous and metamorphic rocks of mountainous areas is limited to open fractures, and the amount of water available depends upon the size and interconnection of these fractures. These aquifers generally produce only small quantities of water to wells. They are important sources of water to individual private wells and small PWSs, as they may be the only source of water in the area. Fractured bedrock aquifers are very vulnerable to contamination from surface sources due to their high permeability and local recharge areas.

B. Ground Water Use

Ground water provides 18 percent of the water used in the state-96 percent of the ground water is used by agriculture; 2 percent by public water systems (PWS); 1 percent by rural domestic users; and 1 percent by livestock and industrial users (U.S. Geological Survey, 1985, p. 153. PWS relying wholly on ground water serve about 430,000 people, or about 10 percent of the State's 2000 population of 4,301,000 (U.S. Bureau of Census, 2000). Table 2 summarizes the types of

PWSs using ground water.

Table 2: Types of Public Water Systems Using Ground Water

Entity	*Number*	*Resident Population Served*
Municipalities	106	190,381
Special districts	89	175,544
Mobile home parks, trailer courts and subdivisions	138	19,115
Water companies	43	19,983
Associations, homeowners, and other water users	68	13,120
Institutions and resorts (schools, retreats, clubs)	41	1,469
Federal facilities	308	685
Water supplies/systems	14	5,070
Miscellaneous (campgrounds, pipelines, dispensers, etc.)	1	25

Source: CDPHE, WQCD, Drinking Water Unit, November, 2001

In rural areas, domestic water is supplied almost entirely from ground water sources. In most areas of the state, each farm has at least one water well. These wells are used for domestic supply, livestock watering and garden irrigation. Stock-watering wells are common where surface-water resources are unreliable or absent. Private, potable-water wells are common in many small towns and subdivisions where PWS have not been developed. Information regarding these wells is not usually reported to the state. Once a PWS is developed in an area, the use of private wells for domestic purposes is generally discontinued.

Crop irrigation constitutes the largest use of ground water in Colorado. Extensive irrigation networks of canals and ditches divert water from rivers, streams, and reservoirs. Ground water has been developed in recent years to supplement surface water irrigation and provide alternative source of water for crop areas overlying alluvial aquifers. In other areas, nontributary aquifers provide nonrenewable sources of ground water for irrigation, resulting in ground water mining situations. The use of spray irrigation systems is increasing and is now common in many agricultural areas of the state. These systems permit the efficient use of surface and ground water and allow automatic rate-application chemigation (application of agricultural chemicals during regular irrigation). The acreage irrigated by well water within the state has not been determined although each well must be permitted through the State Engineer's Office and a water right adjudicated for ground water use.

C. Plan for Assessing Colorado Aquifers

Historically, the WQCD has compiled water quality data reported by Colorado's public water systems (PWS) using ground water. These data indicate a difference in the ground water quality between shallow and deep aquifers in many parts of the state. The most common contaminants in the state are nitrate, fluoride, selenium, iron, manganese, alpha radiation, and uranium. Locally, nitrate, fluoride, selenium, gross alpha, and radium exceed standards in the aquifers of the eastern plains (from the eastern edge of the uplifted area eastward to the Colorado/Nebraska border). In some areas, total dissolved solids (TDS), hardness, sulfate, and sodium exceed recommended drinking water standards, but the water is still used as a potable source. Some constituents, such as fluoride, arsenic, iron, manganese, selenium, sulfate, sodium, radium, and uranium occur naturally in ground water.

Shallow unconfined aquifers in Colorado are very susceptible to contamination from surface activities. Agricultural activities have resulted in nitrate and salt contamination of many shallow aquifers. Deeper bedrock aquifers tend to have higher levels of natural constituents, such as metals, but lower levels of surface contaminants. This is especially true if the aquifers are under confined conditions.

Colorado's current aquifer assessment program meets both the requirements of Colorado Senate Bill 126 (SB 90-126) enacted in 1990 and EPA's 305(b) reporting requirements. This bill authorizes the Commissioner of Agriculture to take various measures, from education to regulation, in agricultural areas where agricultural chemicals are threatening ground water quality. The Colorado Department of Agriculture (CDA), WQCD, and the CSU Cooperative Extension Service are the agencies designated by the bill to monitor and control agricultural chemical use in the state. The WQCD is responsible for collecting ground water samples from the various river basins and evaluating the water quality results for impacts from agricultural chemicals. It then relays these findings to the Commissioner. The sampling is focused on evaluation of agricultural chemicals (selected pesticides and nitrate/nitrite as nitrogen) in vulnerable aquifers; however, each sample is also analyzed for basic water quality parameters (boron, bicarbonate, calcium, carbonate, chloride, magnesium, nitrate, pH, sodium, specific conductance, sulfate, potassium, total alkalinity, total dissolved solids (TDS), and hardness expressed as calcium carbonate) and selected metals. Table 3 shows the assessment cycle for the major aquifers being assessed under SB 90-126.

Since 1992, all of the major aquifers in agricultural areas of Colorado have been sampled. The sampling results have been evaluated for pesticide and nitrate contamination and in some cases, electrical conductivity (see Section E below). As funds become available, the Division intends to evaluate the other water quality data collected during this program and provide water users with a broader picture of ground water quality in Colorado. Under SB 90-126, the WQCD is now sampling "phase 2" aquifers in agricultural areas of Colorado. These aquifers are not considered major aquifers but are still important sources of water in agricultural areas. Once the phase 2 aquifers have been evaluated, the Division will determine the need to resample the major aquifers.

Table 3: Assessment Cycle for Major Colorado Aquifers (Continued)			
Aquifer	***Location***	***Last Evalua-tion***	***Next Evaluation***
South Platte River Alluvium	South Platte River Basin including North Park	2000-2001	Ongoing resampling of Brighton-Greeley wells, beginning in 1995
San Luis Valley Alluvium	San Luis Valley (Rio Grande River Basin)	2000	Not planned
Lower Arkansas River Alluvium	Arkansas River Basin	1994	Not planned
Ogallala Aquifer	High Plains (Republican and Arkansas River Basins)	1997	Not planned
Western Slope Alluvium	Green, Colorado, and San Juan River Basins	1998, 2000	Not planned

Samples of ground water from the deeper, less vulnerable Colorado aquifers have been, and continue to be, collected by multiple state agencies under various programs. The Division is working with these agencies to compile this available information and use it to evaluate the quality of these deeper ground water resources.

D. Ground Water Contaminants/Contamination Sources

The most common ground water contaminants in the state are nitrate, fluoride, selenium, iron, manganese, alpha radiation, and uranium. Nitrate, fluoride, selenium, gross alpha, and radium often exceed EPA's maximum contaminant levels for drinking water (MCLs) in eastern plains aquifers. In some areas, total dissolved solids, hardness, sulfate, and sodium exceed EPA's secondary primary drinking water standards, but the water is still used as a potable source. Fluoride, arsenic, selenium, radium, and uranium occur naturally in Colorado's ground water. The SB 90-126 agricultural chemical sampling discussed above did not identify any major areas of pesticide contamination, although widespread nitrate contamination was identified. The major sources of contamination and contaminants in Colorado's ground water are shown on Table 4.

Table 4: Major Sources of Ground Water Contamination

Contaminant Sources	*Ten Highest-Priority Sources (√)*	*Factors Considered in Selecting a Contaminant Source*	*Contaminants*
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots	√	D, E, A, C	E, J, L
Drainage wells			
Fertilizer applications			
Irrigation practices			
Pesticide applications			
On-farm agricultural mixing and loading procedures			
Land application of manure (unregulated)			
Storage and Treatment Activities			
Land application (regulated or permitted)			
Material stockpiles			
Storage tanks (above-ground)			
Storage tanks (underground)	√	A, D, C, E	C, D, M (MTBE)
Surface impoundments	√	A, D, C, E	D, E, G, J, L, I, M
Waste piles			
Waste tailings			
Disposal Activities			
Deep injection wells			
Landfills	√	A, C, D, E, H	B, C, G, H, J, L, M
Septic Systems	√	D, C, E, A	E, J, L
Shallow injection wells			

Table 4: Major Sources of Ground Water Contamination

Contaminant Sources	*Ten Highest-Priority Sources (√)*	*Factors Considered in Selecting a Contaminant Source*	*Contaminants*
Other			
Hazardous waste generators			
Hazardous waste sites	√	A, B, C, E	A. B. C, I M
Large industrial facilities	√	A, B, C, D, E	C, D, H, I
Material transfer operations			
Mining and mine drainage	√	A, C, D, E, H	H, M (cyanide, pH)
Pipelines and sewer lines			
Salt storage and road salting			
Salt water intrusion			
Spills	√	A, B, C, E	A, B, C, D, I, M
Transportation of materials			
Urban runoff			
Small-scale manufacturing and repair shops	√	D, A, C, E, H	C, D, H, M
Other sources (please specify)			

Key to Table 4. Major Sources of Ground Water Contamination

Contaminant Sources

A Human health and/or environmental risk
B. Size and population at risk
C. Location of sources relative to drinking water sources
D. Number and/or size of contaminant sources
E. Hydrogeologic sensitivity
F. State findings, other findings
G. Documented from mandatory reporting
H. Geographic distribution/occurrence
I. Other criteria (described in narrative)

Contaminants

A. Inorganic pesticides
B. Organic pesticides
C. Halogenated solvents
D. Petroleum compounds
E. Nitrate
F. Fluoride
G. Salinity/brine
H. Metals
I. Radionuclides
J. Bacteria
K. Protozoa
L. Viruses
M. Other (described in narrative)

E. Ground Water Protection Programs

Ground water protection in Colorado is a shared responsibility of many agencies at all levels of government. Under the Colorado Water Quality Control Act, the Water Quality Control Commission is charged with the most comprehensive responsibilities for all state water quality, including ground water. Recent amendments to the Act direct multiple state agencies to enter into a partnership to protect ground water quality. Table 5, Summary of State Ground Water Protection Programs, lists the ground water protection programs in Colorado.

1. The Basic Standard for Ground Water, Regulation No. 41

The development of ground water protection programs in Colorado is ongoing. "The Basic Standards for Ground Water", Regulation No. 41 (5 CCR 1002-41), provides the framework under which ground waters are classified and protective standards are set. The Basic Standards were originally adopted in 1987 and have been amended several times since then; the most recent amendments became effective in November 2001. The Basic Standards establish a long list of

Table 5: Summary of State Ground Water Protection Programs

Programs of Activities	***Applicable Programs (√)***	***Implementation Status***	***Responsible State Agency***
Active SARA Title III Program	√	Fully established	CDPHE, HMWMD
Ambient ground water monitoring system	√	Under development	CDPHE, WQCD
Aquifer vulnerability assessment	√	Continuing effort	CDPHE, WQCD
Aquifer mapping	√	Continuing effort	CDWR/CSEO*
Aquifer characterization	√	Continuing effort	CDPHE, WQCD
Comprehensive data management system	√	Under development	CDPHE, WQCD
Colorado Ground Water Quality Protection Council	√	Continuing effort	CDPHE, WQCD
Ground water discharge permits	√	Fully established	CDPHE, WQCD
Ground water Best Management Practices	√	Continuing effort	CDA
Ground water legislation	√	Continuing effort	CDPHE, WQCD
Ground water classification	√	Continuing effort	CDPHE, WQCC
Ground water quality standards	√	Fully established	CDPHE, WQCC
Interagency coordination for ground water protection initiatives	√	Continuing effort	CDPHE, WQCD

Table 5: Summary of State Ground Water Protection Programs (Continued)

Nonpoint source controls	√	Continuing effort	CDPHE, WQCD
Programs of Activities	***Applicable Programs (√)***	***Implementation Status***	***Responsible State Agency***
Pesticide State Management Plan	√	Fully established	CDA
Pollution Prevention Program	√	Continuing effort	CDPHE
Resource Conservation and Recovery Act (RCRA) primacy	√	Fully established	CDPHE, HMWMD
Source Water Assessment Program	√	Fully established	CDPHE, WQCD
State Superfund	√	Fully established	CDPHE, HMWMD
State RCRA Program incorporating more stringent requirements than RCRA primacy	√	Fully established	CDPHE, HMWMD
State septic system regulations	√	Fully established	CDPHE, WQCD
Programs of Activities	***Applicable Programs (√)***	***Implementation Status***	***Responsible State Agency***
Underground storage tank (UST) installation requirements	√	Fully established	CDL&E,OIS
UST Remediation Fund	√	Fully established	CDL&E,OIS
UST Permit Program	√	Fully established	CDL&E,OIS
Underground Injection Control Program	√	Class II, fully est.	COGCC
Vulnerability assessment for drinking water/wellhead protection	√	Continuing effort	CDPHE, WQCD
Well abandonment regulations	√	Fully established	CDWR/CSEO*
Wellhead Protection Program (EPA-approved)	√	Continuing effort	CDPHE, WQCD
Well installation regulations	√	Fully established	CDWR/CSEO*
Other programs or activities (please specify)			
Voluntary Cleanup Program	√	Fully established	CDPHE, HMWMD
Mined Land Reclamation	√	Fully established	CDMG
Mine operating permits	√	Fully established	CDMG

Table 5: Summary of State Ground Water Protection Programs (Continued)

Chemigation	√	Fully established	CDA

CDA: Colorado Dept. of Agriculture
CDPHE: Colorado Dept. of Public Health and Environment
CDMG: Colorado Dept. of Minerals and Geology
CDWR: Colorado Dept. of Water Resources
COGCC: Colorado Oil and Gas Conservation Commission
CSEO: Colorado State Engineers Office
HMWMD: Hazardous Materials and Waste Management Div., CDPHE
WQCD: Water Quality Control Division, CDPHE

maximum concentration levels (MCLs) for organic and inorganic chemicals, and radioactive pollutants, and a system for assigning use classifications and standards to protect those uses. In the last triennial review hearing, November 2001, 39 new organic chemical standards were added to regulation No. 41 and 25 existing chemical standards were modified.

Regulation No. 41 also includes the interim narrative standard for most ground waters in the state. The interim narrative standards require that ground water be maintained at current ambient quality where past activities have elevated concentrations of pollutants to levels above "table values" (MCLs in most cases). Water quality must be maintained at "table values" where the water is relatively uncontaminated. The combination of statewide numeric standards to protect public health from organic chemical pollution, an interim narrative standard to maintain ambient or MCL-level quality for inorganic and metal parameters, and site specific use classifications and standards provides a very comprehensive enforceable standards program.

2. Classification and Water Quality Standards for Ground Water, Regulation No. 42

"Classification and Water Quality Standards for Ground Water" Reg. No. 42 (5 CCR 1002-42), is a compilation of the actions taken by the Commission to date in classifying site specific areas of the state. This regulation has also been amended several times, most recently in September 2000. The scope of the amendments implemented during this reporting period was discussed in Part II. Background. 39 site-specific areas have been classified for "Domestic Use Quality" and "Agricultural Use Quality." 26 additional site-specific areas with deep aquifers (3,000 to 8,000 feet below ground surface) have been classified for "Limited Use Quality" to allow injection of oil field produced water through the Class II Underground Injection Program.

3. State Discharge Permit System

The primary source control program in the Division is the point source discharge permitting program authorized under the "Regulations for State Discharge Permit System", Reg. No. 61 (5 CCR 1002-61). Under this regulation, the Division is authorized to issue permits for discharges to ground water from wastewater treatment impoundments and land application systems. The program has been implemented and will be the primary mechanism for protecting ground water from degradation by wastewater.

4. Nonpoint Source Program

The Nonpoint Source Program, developed under Section 319 of the Clean Water Act, has funded a number of demonstration and education projects aimed at ground water protection through control of nonpoint pollution sources.

5. Voluntary Programs

The voluntary Nonpoint Source Program (NPS) established by Section 319 of the Clean Water Act has performed a number of important educational and demonstration projects directed toward ground water protection. To two primary areas of focus are improved irrigation efficiency and Best Management Practices for agriculture.

The voluntary Wellhead Protection Program (WHP) is also an important program for protecting ground water. The WHP program has developed a guidance document outlining the necessary components of a plan to protect PWS wellhead areas from contamination by possible sources. The Division offers technical assistance to communities and PWS districts that wish to establish Wellhead Protection Areas and WHP plans. The Division also provides information to private well owners that wish to ensure that their wellheads are protected from surface contaminants. The Division has developed a database that contains all ground water data gathered from reputable sources. This data is entered in a standardized format and is available for use by all ground-water protection programs, both internal and external.

6. Other State Programs

Senate Bill 181 adopted in 1989 (SB 89-181) recognized state agencies other than the WQCC as important players in ground water protection and authorized them to participate in ground-water protection activities. The "implementing agencies" are the Colorado Division of Minerals and Geology (CDMG), the Colorado Oil and Gas Conservation Commission (COGCC), the State Engineer's Office (Division of Water Resources), the Department of Labor and Employment (Division of Oil and Public Safety), and the CDPHE (Hazardous Materials and Waste Management Division). Each of the implementing agencies has developed regulations to protect ground water within its area of authority and each reports annually on its progress to the WQCC- the agency with final authority for protecting the resource. Although progress is somewhat uneven among these partner agencies, each agency has made ground water protection part of the mission, and they have fully implemented ground water quality protection programs.

Senate Bill 126 (SB 90-126), adopted in 1990, authorizes the Commissioner of Agriculture to take measures to alter or curtail agricultural practices that have been shown to damage ground water. Under this bill, WQCD plans sampling programs, collects ground water samples, and evaluates the analytical results to identify any areas where agricultural chemicals are contaminating ground water. These results are relayed to the Commissioner. WQCD's plan for assessing all aquifers in agricultural areas was discussed previously. The results of the sampling events are discussed in Part IV. F. Water Quality Summary.

7. Local Programs

At the local level of government, counties and local health departments assist in the job of ground water protection by exercising good judgment in zoning and siting decisions, establishing ordinances restricting the improper disposal of possible hazardous materials, and closely regulating the location and design of individual sewage disposal systems (ISDS systems). As mentioned earlier, establishing wellhead protection areas administered by a municipality or county promises to be an important additional means of controlling those activities that might threaten community water supply wells.

8. Federal/State Partnerships

The federal government also plays an important role in protecting ground water in Colorado. EPA has worked diligently with the state to pursue cleanup of contaminated sites through the CERCLA (Superfund) program and the deep well underground injection control (UIC) program. The agencies under the U.S. Department of Agriculture have taken their responsibility to protect ground water very seriously and have educated producers about proper chemical and fuel usage. The land management agencies, primarily the Forest Service and Bureau of Land Management, are increasing their participation in the Nonpoint Source Program by instituting Best Management Practices that directly protect ground water and surface water.

Coordination of Colorado's ground water quality protection program has been a concern for some time. To address this issue, WQCD developed and implemented the Colorado Ground Water Quality Protection Council in early 2000. The Council is presently composed of state agencies with direct ground water quality protection responsibilities. As the Council evolves, other state, federal, and local agencies may be added.

The Council's purpose is to provide a statewide, long-term, body that works together to provide a comprehensive and integrated ground water quality protection program. It is hoped that this Council will address the full range of ground water quality issues: coordination of existing programs, sharing of information and data, establishing priorities, identifying gaps in ground water protection, and providing a forum for all interested parties concerned with ground water protection.

Table 5, Summary of State Ground Water Protection Programs, represents a summary of Colorado's ground water protection programs. Several of the programs are unique to the state: the Voluntary Cleanup Program and the Chemigation Program. The Voluntary Cleanup Program provides for the limited cleanup of a site so that it can be developed for limited uses under a cleanup/use plan. The owner must file a new cleanup/use plan if he wishes to change the approved use. The Chemigation Program, administered by the Colorado Department of Agriculture, requires back-flow prevention valves for certain types of irrigation systems.

F. Ground Water Quality Summary

Since 1991, SB 90-126 has provided funding for assessment of the effects of agricultural chemicals on ground water. The Division devised a systematic plan to sample all of the vulnerable aquifers in the major agricultural areas of Colorado. Aquifers were selected for the SB 90-126 study if they met the following criteria:

* Aquifer is shallow and / or unconfined.
* It is located in an area where agricultural chemicals are used.
* Sampling density is increased if the area is irrigated by surface or ground water.
* The alluvial or shallow bedrock aquifers are used for domestic water supply.

When pesticides or high nitrate levels were found in several wells or a specific area, additional sampling was conducted in these areas in subsequent years. To date, the major aquifers in all of the primary river basins have been sampled and evaluated for agricultural chemicals. Samples for basic water quality parameters were also collected from each well. These results have been entered into the state's database, although the Division has not yet completely evaluated the ambient water quality of the aquifers using these results. The ambient water quality evaluations will be conducted over the next five years. Results of the SB 90-126 sampling program are discussed in the sections below.

There are numerous other programs being conducted across the state that generate ground water quality data. The Division is working to obtain these data and from the various sources and enter it into its database. Once entered, these data will provide a more complete picture of the state.

1. South Platte Alluvial Aquifer

The South Platte alluvial aquifer was studied both in agricultural areas and along the urban corridor from the Fort Collins/Greeley area south through Aurora and into Douglas County. Study of Agricultural Areas: This study was the first conducted under SB 90-126. Ninety-six wells from Denver to Julesburg were sampled in June through August 1992. The wells selected for sampling were all used for domestic or household purposes and were located in the valley fill of the South Platte River or one of its major tributaries. Wells were only sampled if the well owner agreed.

The results of the sampling showed that nitrate was a pervasive contaminant in the South Platte alluvial aquifer. Thirty-three wells (35%) had nitrate above EPA's primary drinking water standard of 10 mg/L, 55 wells (57%) had detected nitrate, but below 10 mg/L, and eight wells (8%) had no detected nitrate. Three hot spots of elevated nitrate were identified from the study: Brighton to Greeley, western Morgan County around Wiggins, and Sedgwick County.

Seven pesticides (Alachlor, Atrazine, Benefin, DCPA, Diazinon, EPTC, Hexazinone) were found in the ground water; however, only one well contained a pesticide exceeding its EPA MCL Alachor was detected at 3.09 µg/L; its MCL is 2.0 µg/L. Nineteen wells had detectable levels of Atrazine, but only seven had measurable concentrations. Atrazine is a common herbicide used extensively on corn in Colorado and the contamination appears to result from nonpoint sources.

Follow-up sampling of 47 wells was conducted in May 1993, to confirm the three nitrate hot spots. The majority of the original wells in Morgan and Sedgwick Counties, as well as the wells in the Brighton to Greeley corridor were resampled. The results of this sampling confirmed that nitrate levels exceeded the drinking water standard in both counties. In Morgan County, 13 of the 34 wells resampled (38%) had nitrate levels above 10 mg/L and only two (5%) had no detectable nitrate. The area of elevated nitrate around Wiggins had expanded and elevated levels also were identified in western Morgan County. In Sedgwick County, 5of the 13 wells (38%) resampled had nitrate above 10 mg/L and all of the wells contained detectable nitrate. There was little or no change in the nitrate levels in the wells sampled both years. The study also confirmed elevated nitrate levels in ground water near Ovid.

After reviewing the results of the 1992-1993 sampling, the Division began a long-term monitoring program of the wells in the Brighton to Greeley corridor in 1995. The long-term monitoring network consists of 20 monitoring wells operated by the Central Colorado Water Conservancy District; 60 irrigation wells sampled in 1989, 1990, 1991, and 1994 by previous investigators; and 18 domestic wells first sampled in 1992 by the 126 Program.

The Brighton to Greeley corridor (Weld County long term monitoring project) was sampled during the summers of 2000 and 2001 (both years of this reporting period). In 2000, 73 wells in the long-term network were sampled and the samples analyzed for nitrate-nitrite as nitrogen. Samples from 19 of the monitoring wells were analyzed for 45 pesticides. Samples from the irrigation wells were tested for triazine herbicides using an immuno assay. The nitrogen analysis indicated that 79% of the monitoring wells, and 69% of the irrigation wells exceeded the nitrate drinking water standard of 10 mg/L.

Four pesticides and the breakdown products of Atrazine were present in the monitoring well samples. Of the four detected pesticides, Atrazine was present in 37% of the wells; Metolachlor in 26%, Prometone in 11%, and Hexazinone in 11%. The breakdown product Deethyl Atrazine was detected in 47% of the wells. The triazine herbicide screen used on the irrigation well samples detects any pesticide in this family. In 2000, triazine herbicides were detected in 78% of the irrigation wells, with concentrations ranging from 0.10 to 0.64 µg/L.

In 2001, 84 wells in the long-term network were sampled. All samples were analyzed for nitrate-nitrite as nitrogen; the 18 monitoring wells and 14 domestic wells were analyzed for a suite of 45 pesticides. Fifty-two irrigation wells were screen for triazine herbicides by immuno assay. The nitrogen analysis indicated that 67% of the monitoring wells, 50% of the domestic wells, and 71% of the irrigation wells exceeded the nitrate drinking water standard of 10 mg/L. The 2001 summary statistics for nitrate are shown below.

Six pesticides were identified in the 2001 monitoring well samples: Acetochlor, Atrazine, Dicamba, Hexazinone, Metolachlor, and 2,4_D. Atrazine in some form was present in 38% of the wells, Metolachlor in 56%, Dicamba in 17%, and Hexazinone in 11%. The other two pesticides were only detected in one well each. Atrazine was detected at a level exceeding the applicable standard (3.0 ug/l) in one well at a level of 5.47 ug/l. Triazine herbicides were detected in 72% of the irrigation wells (compared to 92% in 1999), with the highest concentration identified at 0.58 µg/L.

Urban Corridor Study: This study, conducted in 1996, monitored ground water in the shallow alluvial aquifer along the urbanized Front Range corridor where there was no production agriculture. This was the first time that the SB 90-126 program was used to determine possible impacts to ground water from urban uses of agricultural chemicals. These urban uses include commercial and homeowner application of agricultural chemicals to yards and gardens, as well as municipal and private applications to parks and golf courses. Seventy-seven wells were sampled for basic water quality constituents, nitrate, and 46 pesticides. Location of wells suitable for sampling was difficult-most of the wells used were privately owned and permitted as domestic wells.

The analytical results of the ground water samples indicated that seven wells (9%) had nitrate levels above EPA's drinking water standard of 10 mg/L. Fifty-three wells (69%) had nitrate concentrations above the analytical detection limit and 17 wells had nitrate concentrations below this level. Three pesticides were detected in the ground water samples, although none of the detections exceeded an applicable water quality standard. Nine of the 77 (12%) wells contained the herbicide Atrazine, which is commonly used for weed control. Atrazine is commonly found in the ground water of agricultural areas. Prometone, a nonselective herbicide used on highway and railroad right-of-ways and industrial areas for complete vegetation control, was detected in 24 (31%) of the wells. Bromacil was detected in one well.

2. San Luis Valley Unconfined Aquifer

The sampling of the San Luis Valley unconfined aquifer was the second study conducted under SB 90-126. It was the first sampling program to screen the entire shallow aquifer to establish possible impacts and the magnitude of agricultural chemical contamination. The San Luis Valley is intensely irrigated using surface water and large-capacity irrigation wells. The unconfined aquifer is a major source of domestic water supply throughout valley. The wells selected for sampling were all used for domestic or household purposes and were located in the valley fill.

Wells were only sampled if the well owner agreed.

Ninety-three domestic wells sampled in May through August 1993. Nitrate was found in 13 of the domestic wells (14%) at levels above EPA's primary drinking water criterion of 10 mg/L. Three pesticides were detected (2,4-D; Hexazinone; and Lindane), but only one pesticide was detected in each well. Only Lindane (0.29 µg/L) was detected above EPA's MCL of 0.2 µg/L.

In 2000, a joint monitoring program with the U S Geological Survey to sample thirty-five dedicated monitoring wells in the San Luis Valley was completed. The wells were originally installed in 1993 by the USGS NAWQA program as part of the Rio Grande Basin regional water quality study. The purpose of the sampling project is to acquire a high quality data set to use in an aquifer vulnerability modeling project began in 2001 with the USGS.

Thirty-three monitoring wells were sampled utilizing the NAWQA program ultra clean sampling technique. The samples will be analyzed for basic ions, nutrients, dissolved metals, and pesticides. The analysis will be performed by the USGS laboratory utilizing detection levels down to 50 parts per trillion.

A GIS based statistical approach will then be used to map the San Luis Valley unconfined aquifer for pesticide vulnerability utilizing the data gathered in 2000. The final report on this work should be available in early 2003.

3. Lower Arkansas River Valley Aquifer

The Lower Arkansas River alluvial aquifer was sampled July through December in 1994. This was the first sampling program to screen the entire shallow aquifer to establish possible impacts and the magnitude of agricultural chemical contamination. The Arkansas River Valley is intensely irrigated using surface water and large-capacity irrigation wells and alluvial aquifer is a major source of domestic water supply throughout valley. The wells selected for sampling were all used for domestic or household purposes, located in the unconfined valley fill aquifer and had no known construction deficiencies. Wells were only sampled if the well owner agreed. One hundred thirty-nine domestic, stock, and irrigations wells in the shallow alluvial aquifer along Arkansas River were sampled.

The results of the sampling showed that 19 of the 139 wells (14%) contained nitrate above 10 mg/L (EPA's drinking water standard) and 111 (80%) contained detectable nitrate below 10 mg/L. Twelve wells (9%) contained the herbicide Atrazine; one contained Metolachlor; and one contained 2,4-D. All were below applicable drinking water standards. In 1994, confirmation sampling was conducted on those wells with nitrate concentrations above 10 mg/L or a pesticide detection. Nitrate levels were statistically unchanged and Atrazine was the only pesticide detected. This one detection of Atrazine was above the MCL of 3.0 µg/L.

Salinity: The Lower Arkansas River in Colorado is the most saline stream of its size in the United States. The average salinity levels increase from 300 parts per million (ppm) TDS east of Pueblo to over 4,000 ppm near the Kansas state line. The shallow alluvial ground water along the River has similar salinity. Water containing greater than 2,000 TDS is usually considered unsuitable for irrigation. Using this high salinity ground water for irrigation is a concern of agricultural producers in Valley. Salinity can also be measured by electrical conductivity (EC). Water above 1,500 micro mhos per centimeter (µmmhos/cm) electrical conductivity may have adverse effects on many corps and requires careful management practices. Water with EC above 3,000 µmmhos/cm can be used on salt-tolerant crops in permeable soils with careful management practices.

4. High Plains (Ogallala) Aquifer (Republican and Arkansas River Basins)

The High Plains Ogallala Aquifer was monitored in 1997. The High Plains includes most of Colorado east of the foothills of the Rocky Mountains, excluding the South Platte and most of the Arkansas River Valleys. The Ogallala Aquifer is the largest aquifer system in the United States and underlies 12,000 square miles of eastern Colorado. It is the sole source of water for that region. Agriculture is the economic base of the High Plains and the majority of the region is either cropland or pasture.

One hundred twenty-nine wells were sampled over an eight-month period. All samples were analyzed for nitrate, basic water quality parameters and 46 pesticides. Most of the wells were privately owned and used for domestic purposes.

The results of the nitrate analyses indicated that all wells sampled in the Ogallala Aquifer contained detectable nitrate concentrations. Approximately 6% of the wells exceeded the nitrate drinking water standard of 10 mg/L. Three pesticides (Atrazine, Prometon, and Bromacil) were detected in the wells. The Atrazine concentration in one well (3.0 µg/L, located near Springfield) exceeded the MCL and was taken out of service. Atrazine was detected in nine wells (7%); Prometon was detected in three wells (2%). The area with the most pesticide detections was Springfield, where five wells contained more than one pesticide.

Due to the vast size of the study area, this survey did not fully establish a baseline for agricultural chemical in ground water in the area. The local Ground Water Management Districts, in cooperation with the Colorado State Engineer's Office, also conducted a study during 1997. This study focused on areas of the Ogallala Aquifer overlain by dry land farming. This study, and monitoring studies being conducted by others, will eventually be incorporated into the Division's evaluation of the Ogallala Aquifer.

5. Western Slope Alluvial Aquifers (Green, Colorado, and San Juan River Basins)

During 1998 and 2000, the SB 90-126 program conducted a regional ground water quality baseline study of the Western Slope of Colorado (all of Colorado west of the Continental Divide). The ground water sampled occurs along stream and river valleys in alluvial aquifers or as local aquifers on the larger mesas. The central core of the Rocky Mountains, where the land use is predominantly National Forest, was excluded. No single aquifer underlies this area and the aquifers sampled are located in the Green, Colorado, and San Juan River Basins. The agriculture in this region is dominated by ranching and hay production, although dry-land wheat is grown in Moffat County, corn is grown in some areas, dry beans are grown in Montezuma County, and fruit and wine grapes are grown in Mesa County. Ninety wells were sampled during 1998 and ten more were added in 2000. All wells in this study were existing, privately owned and permitted domestic wells. The samples were analyzed for nitrate and 45 pesticides.

The results of the study showed that ground water in most of the Western Slope shallow aquifers has not been adversely impacted by current agricultural practices. Only one well, located in Moffat County near Craig (32 mg/L), contained a nitrate concentration above the MCL of 10 mg/L. Sixty-three percent (63%) of the wells, however, contained nitrate below 10 mg/L. Likewise, only one well contained a pesticide. This well, located in Montrose County west of Montrose, contained Malathion at 0.23 µg/L.

Follow-up sampling of these two wells was conducted in 1999. The second sample of the well near Craig contained nitrate at 14.8 mg/L, still above the MCL but only half of concentration found in 1998. No pesticides, including Malathion, were detected in the Montrose County well in the follow-up.

6. Other Water Quality Contaminants

Organic Contaminants: Volatile organic chemical contaminants are known to occur in ground water in industrialized areas of the state, especially in the South Platte alluvium in south Adams County and near the Rocky Mountain Arsenal (a Superfund site). The U.S. Army and Shell Oil Company, the primary responsible parties at the Rocky Mountain Arsenal have made significant progress toward containing and cleaning up contaminants at the site.

Petroleum product spills are the cause of ground water contamination in alluvium at some locations, such as the Conoco Refinery in Commerce City, the former Stapleton International Airport, and the Gary Refining Company in Grand Junction. In all three cases, hydrocarbons are leaking to nearby streams via ground water transport. Stapleton is currently closed and undergoing intensive cleanup to meet ground water protection levels established by the WQCD Hazardous Materials and Waste Management Division and the Oil Inspection Section of the Colorado Department of Labor and Employment. As areas of Stapleton are remediated, they will be developed as residential, commercial, and industrial properties.

At Hudson and Platteville in Weld County, methane contamination in ground water has resulted in accumulations of gas in buildings, and at least one explosion. The source of the methane is attributed either to abandoned oil and gas wells or to coal mines in the areas. Methane contamination in La Plata County has become a very serious concern and solutions to problem are under development. The COGCC, oil and gas production companies and citizens groups have been involved in investigating the sources of methane contamination. Coal bed methane development areas are being monitored by COGCC for ground water methane contamination. Other areas of the state are subject to similar problems and concerns resulting from coal bed methane exploration and development. The COGCC is also monitoring the ground water and sampling ambient ground water quality in these areas.

About 8,000 underground storage tanks throughout Colorado have the potential to leak and impact shallow ground water with hydrocarbon products, although that threat is being reduced significantly by the UST program implemented in the Department of Labor, Oil Inspection Section. Some hydrocarbon leakage problems are beyond the purview of the UST program and alternative programs for their remediation have been established through the CDPHE's Hazardous Materials Waste Management Division, Solid Waste Program. Hydrocarbon leaks in oil fields have been reported to the Division and may be a potential source of contamination in ground water. The COGCC has revised its Exploration and Production Rules to provide additional controls on the discharge of oil field wastes to ground water.

Inorganic Contaminants: Contamination of ground water from coal mines (mainly sulfate and acidic water) may be occurring in several areas of the state, including Trinidad, Colorado Springs, and Lakewood, where old mines were abandoned and the areas have now become urbanized; Weld and Larimer Counties; Hayden; Oak Creek; Craig; Paonia; Carbondale and Durango. Ore milling or concentration sites are numerous in Colorado, especially near Denver, Pueblo, Leadville, Minturn, Canon City, Grand Junction, Durango, and Gunnison. Often, contaminant plumes have developed in local shallow aquifers near these operations; contaminants associated with these sites include acidic water and high concentrations of zinc, copper, iron, manganese, cadmium, and sometimes molybdenum. The contamination does not usually extend more than a mile downgradient of these sites. At uranium mills, uranium, radium, thorium and strontium may be present in addition to the metals listed previously. Occasionally the processing chemicals used at these sites-cyanide, mercury and copper-are ground water contaminants. Heap-leach gold mining operations using cyanide are a serious concern in Colorado, after a heap leach pad liner was compromised at the Summitville Mine in Rio Grande County, discharging a large quantity of zinc, copper, cadmium, iron, and low pH-contaminated water into the Alamosa River. The Summitville Mine was declared a Superfund site and both the EPA and Colorado have spent approximately $130 million remediate the mining operation and environmental damage to the river and riparian areas.

7. Aquifer Vulnerability Study

In addition to requiring sampling of all shallow aquifers for agricultural chemicals, SB 90-126 also required the implementing agencies to determine the likelihood that an agricultural chemical would enter ground water. This determination is based on the chemical's properties, the behavior of the chemical in the soil types of the region under study, the depth to ground water, the farming practices in use, and other site-specific factors. This determination is described as a vulnerability analysis.

To efficiently use the state's available resources, the CDPHE, CDA, and Colorado State University (CSU) studied various types of vulnerability analyses. In 1996, CDPHE, CDA, and CSU conducted a limited test of an aquifer sensitivity method in the northeastern part of the state. After review of this pilot project by parties involved and EPA, the sensitivity method was approved for use across the state. The statewide aquifer sensitivity assessment was completed during this reporting period (June 1998). In 1999, the Colorado legislature approved additional funding to expand this vulnerability study to include additional factors. This project, which will take two years for development and two more for full evaluation, will develop a method for determining aquifer vulnerability to both pesticides and nitrate statewide. Separate aquifer vulnerability maps will be produced for nitrate and pesticides, based on the unique properties that influence their movement in ground water. The project will develop vulnerability matrices to account for local factors influencing nitrate and pesticide movement, such as irrigation practices, aquifers that are most vulnerable to nitrate and pesticide contamination.

G. Continuing Issues of Concern

As discussed above, many of the threats to ground water quality are being addressed by a variety of programs at all levels of government. The remaining issues of concerns are discussed below.

* A comprehensive ground water quality database for Colorado does not exist at present; however, the Division is working with other federal, state, and local agencies to collect their ground water quality information and enter it into the Division's database. In the near future, the data will be entered into the EPA STORET database to make is accessible by the general public.

* Responsibility for ground water quality protection is divided among a number of state and local agencies. The Division has begun formation of the Ground Water Quality Protection Council to address this problem. The council is meeting regularly to provide a long term coordination body for the agencies.

* Although ground water quality data is available for the most of the major aquifers in the state, this information is not stored in one place (the Division database) and the Division has not had the resources to summarize and interpret it.

* Near urbanized areas, land-use protection measures for sensitive aquifers and ground water supplies are needed. Currently only a few counties, such as Boulder County, have adopted planning and land-use zoning restrictions that consider ground water protection.

* The state must accelerate implementation of the PWS wellhead protection program. Much of the program’s concerns are being addressed through the SWAP program.

* Nitrate contamination from agricultural areas or animal feedlots is common and current aquifer protection strategies should be closely monitored for effectiveness.

* Naturally occurring impurities in ground water, such as arsenic, selenium, fluoride, sulfate, sodium, iron, manganese, total dissolved solids (TDS), hardness, or high radiation levels have created problems for PWSs. An unknown number of private water supplies also may be affected by these contaminants. Colorado needs to develop a means of informing the public about the hazards of using these contaminated waters.

* Coal bed methane development is occurring in a number of areas in the state, and ground water quality may be affected by this activity.