Colorado Water Resources Research Institute
Special Report No. 16

Agricultural Chemicals & Groundwater Protection in Colorado 1990-2006

Colorado Department of Agriculture
Colorado State University Extension
Colorado Department of Public Health and Environment

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Design by Emmett Jordan / Illustrations by Dennis Anderson

Acronyms

AES	Agricultural Experiment Station (Colorado State University)
AMA	agricultural management area
AMP	agricultural management plan
ARS	Agricultural Research Service (United States Department of Agriculture)
BDL	below detection limit
BMP	best management practice
CCA	Certified Crop Advisor
CDA	Colorado Department of Agriculture
CDPHE	Colorado Department of Public Health and Environment
CSUE	Colorado State University Extension
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
LEPA	low-energy precision application
MCL	maximum contaminant level
MDL	minimum detection level
NASS	National Agricultural Statistics Service (United States Department of Agriculture)
NAWQA	National Water-Quality Assessment Program (United States Geologic Survey)
NRCS	Natural Resources Conservation Service (United States Department of Agriculture)
PAM	polyacrylamide
PVC	polyvinylchloride
PSNT	pre-sidedress nitrate testing
RUP	restricted use pesticide
SDWA	Safe Drinking Water Act
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WQCC	Water Quality Control Commission (Colorado Department of Public Health and Environment)
WQCD	Water Quality Control Division (Colorado Department of Public Health and Environment)

Agricultural Chemicals & Groundwater Protection in Colorado: 1990-2006

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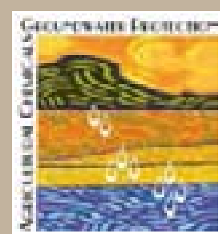

Colorado Department of Agriculture
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The authors of this publication want to acknowledge the dedicated efforts of several state and local advisory committees and workgroups. In particular, the members of the Groundwater Protection Program advisory committee have offered significant input and volunteered time and travel to guide the program staff toward relevant work in protecting water quality. The following individuals have served on this committee:

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- Colorado Department of Agriculture—Bradford Austin, Linda Coulter, Charlie Hagburg, Dan Hurlbut, Bob McClavey, Jim Miller and Mitch Yergert
- Colorado State University Extension—Jerry Alldredge, Luis Garcia, Jim Loftis and Lloyd Walker
- Rocky Mountain Agribusiness Association
- USDA Natural Resources Conservation Service—Jim Sharkoff, Travis James, Frank Riggle, Ron Schierer

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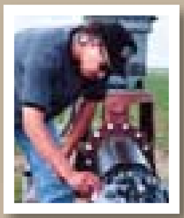
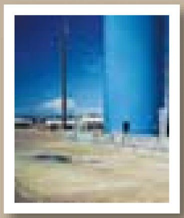
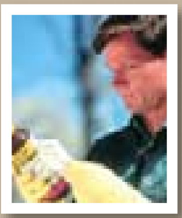
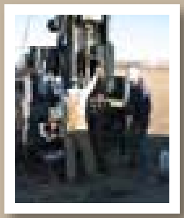
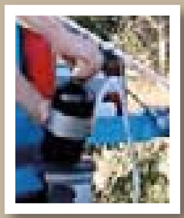
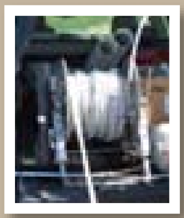












Executive Summary

The Agricultural Chemicals and Groundwater Protection Act took effect on July 1, 1990, and established the Groundwater Protection Program. Its purpose is to reduce agricultural chemicals' negative impacts on groundwater and the environment. Agricultural chemicals covered under this legislation include commercial fertilizers and all pesticides. The goal is to prevent groundwater contamination before it occurs by improving agricultural chemical management. This report summarizes the first 15 years of the Agricultural Chemicals and Groundwater Protection Act and provides an overview of activities and monitoring data.

The program employs three primary functions to protect groundwater in Colorado:

1. Program oversight and regulation;
2. Groundwater monitoring; and
3. Education and training.

Program Oversight and Regulation

The Colorado Department of Agriculture (CDA) is the program's lead agency. One of the CDA's responsibilities is to regulate agricultural chemical bulk storage and mixing/loading areas. Pesticide facility inspections began Sept. 30, 1997, and fertilizer facility inspections began Sept. 30, 1999. By December 2006, approximately 1,300 inspections were performed at 177 facilities around the state.

As part of program oversight, the CDA also manages a waste pesticide collection program. Initiated in 1995, the program has collected more than 100,000 pounds of waste pesticide from public and private sources.

Groundwater Monitoring

The monitoring program has prioritized its sampling in basins where agriculture predominates and rural homes utilize groundwater. These data form the backbone of the Groundwater Protection Program. They determine the need and priority for education and other program resources. The program completed sampling of groundwater systems in the largest agricultural and urban regions of Colorado. The aquifers sampled to date:

- South Platte alluvial aquifer;
- San Luis Valley unconfined aquifer;
- Lower Arkansas alluvial aquifer;
- Denver Basin aquifer system and alluvial deposits on the Front Range;
- High Plains/Ogallala aquifer;
- Colorado River and Uncompahgre River alluvial aquifers;
- North Platte alluvial and terrace formations in Jackson County;
- Gilpin County; and
- Wet Mountain Valley.

Monitoring data, vulnerability assessments, and chemical user survey data indicate there are areas in Colorado where water quality still is susceptible to contamination. Fortunately, the majority of wells sampled thus far are not contaminated at levels deemed unsafe for humans by the Environmental Protection Agency (EPA).

Groundwater monitoring has an integral role in protecting water resources.

Education and Training

The Agricultural Chemicals and Groundwater Protection Act specifies that Colorado State University Extension (CSUE) provide education and training on how to reduce groundwater contamination from agricultural chemicals. The CSUE has produced numerous publications on best management practices, or BMPs, and helped pilot the local BMP development process in four areas.

CSUE uses other avenues to provide information, such as applied research; field days; demonstration sites; continuing education through the Certified Crop Advisor program; a display booth; videos; and the Groundwater Protection Program Web site.

. . . land use changes may also affect Groundwater Protection Program activities and resources as the new rural residents also impact water resources through their land management activities

In order to assess the BMPs adopted by Colorado's agricultural producers, surveys were conducted in February 1997 and December 2001. Overall, results of the two surveys suggest producers accept many of the irrigation, pesticide, and nutrient management BMPs that help protect water quality and farm profitability. Nutrient and pesticide management BMP adoption is generally higher than irrigation management BMPs. Irrigation system improvements, or structural BMPs, are common in most regions, but adoption of irrigation management BMPs used to determine when and how much to water is not as common.

Future Direction

Predictions are that population growth and urbanization, coupled with increasing land and water values, will reduce the number of acres devoted to irrigated crop production in several river basins (SWSI, 2005). These trends may also change cropping patterns from large acreage, low value crops to smaller acres of higher value crops. Often, these crops require different levels of pesticide and fertilizer inputs.

Like much of the West, Colorado is experiencing an increase of small acreage 'ranchettes' as larger farms and ranches are subdivided. The result is that one landowner may be replaced by many more individuals on the same land area. These land use changes may also affect Groundwater Protection Program activities and resources as the new rural residents also impact water resources through their land management activities. Thus, changes in educational and monitoring efforts will be required to protect groundwater quality under these new land use environments.

Additionally, the increasing and changing population dynamics in Colorado may refocus the educational and monitoring programs from primarily agricultural to urban and exurban areas. Keeping partnerships with federal, state, and other agencies working in water resource protection will continue to be critical, but other partners also may need to be considered, such as municipalities, the green industry, and other entities that work more in the urban environment.

The Groundwater Protection Program has been working with agricultural producers, the agricultural chemical industry and several state and federal agencies to prevent contamination of Colorado's groundwater resources from point and non-point source pollution for more than a decade. This cooperation serves a good model for other programs working to protect Colorado's water for future generations. BMP adoption results and groundwater monitoring data indicate these efforts are working to protect groundwater quality in Colorado.

Agriculture and water are inseparable in a semiarid region such as Colorado. Adequate clean water supplies for drinking, agriculture, industry and recreation are critical for the lifestyle Coloradans enjoy.

Water resources are found in surface water and groundwater. Each is unevenly distributed across the state and quality varies considerably.

Surface water is the dominant water source in Colorado because of its availability and relative ease of diversion. The state's location in the heart of the Rocky Mountains results in large quantities of surface water from snow melt. Runoff provides drinking water supplies for most Coloradans. Only about 18 percent of Colorado's 4.5 million residents relies solely on groundwater (Dick Wolfe, Colorado Division of Water Resources, written communication, 2006).

However, groundwater is critical for residents where no other reliable water sources exist. Colorado's eastern plains, parts of the San Luis Valley, and sections of Adams, Arapahoe, and Douglas Counties are especially dependent. In these areas, the communities and rural residents depend on the resources' preservation. In addition, rapid population growth and land development in the rural foothills, mountains, and along the Front Range are increasing the number of people who rely on groundwater.

Groundwater occurs throughout Colorado, but usable supplies are generally found in aquifers, or porous geologic formations. Three types are predominant in Colorado:

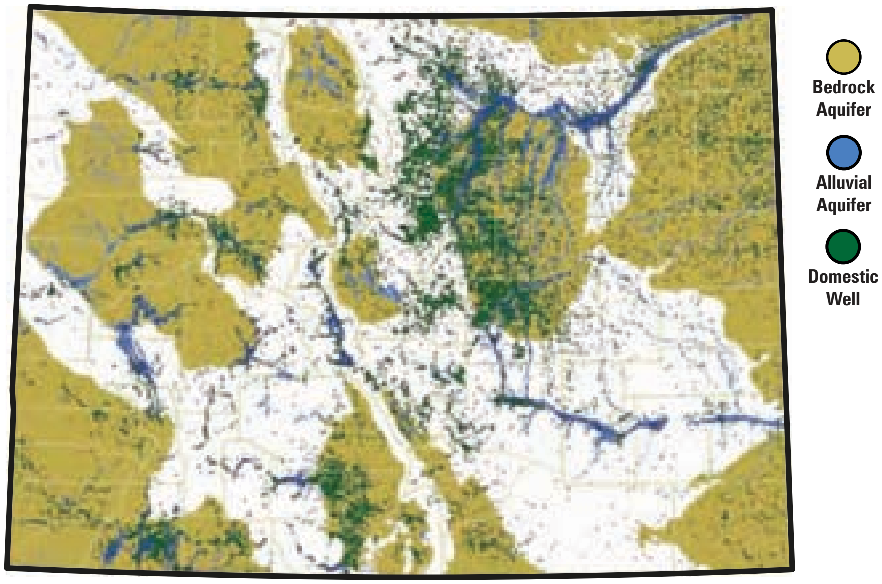
1. Alluvial aquifers—formed by materials laid in a stream/river channel or floodplain;
2. Sedimentary rock aquifers—formed by consolidated sedimentary formations; and
3. Mountainous region aquifers—formed in the fractures, joints, and faults in crystalline igneous and metamorphic rocks of the mountains (Topper and others, 2003).

Much of the groundwater is found and used in areas where intensive crop production occurs, such as the High Plains, San Luis Valley, and the South Platte River Valley. Agriculture withdraws an estimated 82-85 percent of Colorado's groundwater (Wolfe, 2006).

As of December 2005, the State Engineer reports approximately 234,000 permitted wells in Colorado, along with an estimated 5,000–10,000 wells without permits constructed before 1972. Of the total 234,000 permitted wells, more than 150,000 are residential and household wells; 2,400 are municipal (Wolfe, 2006).

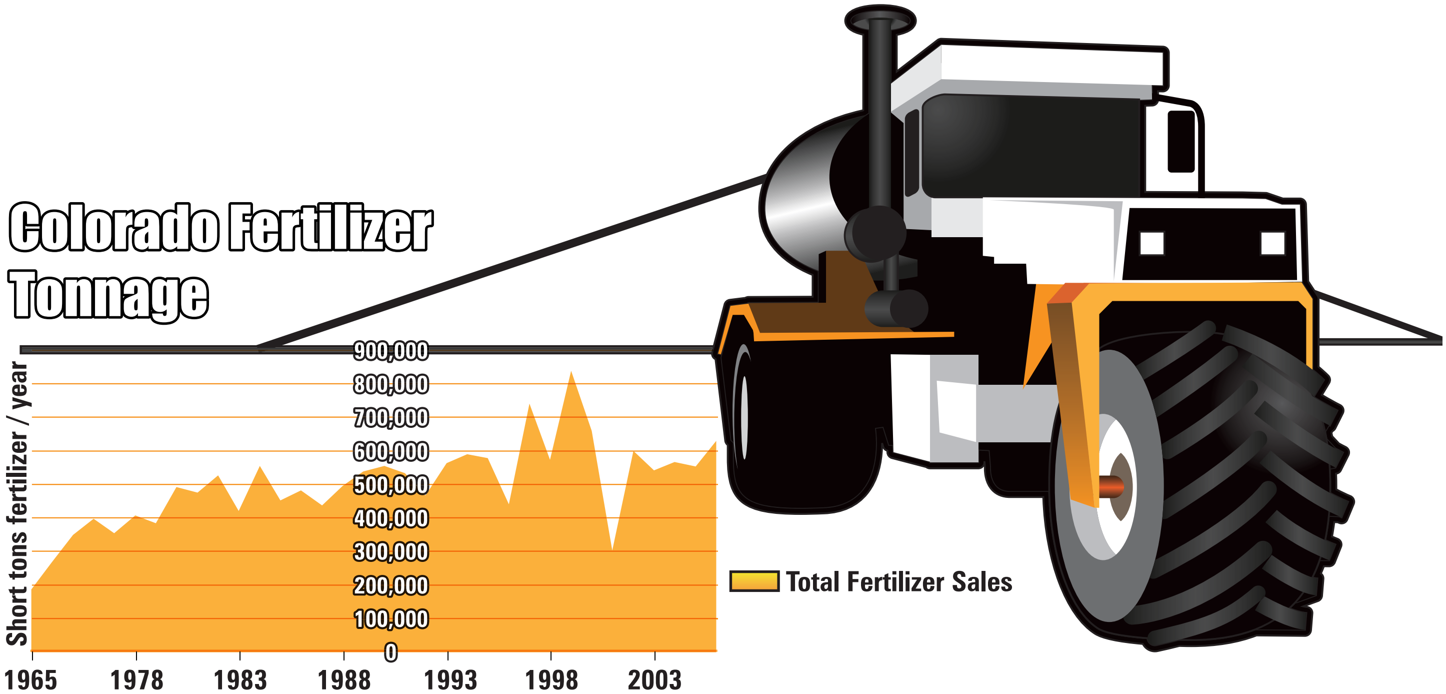
Total groundwater pumping in Colorado is approximately 3.1 million acre-feet of groundwater per year (one acre-foot = 325,900 gallons), which represents only 17 percent of the total 18 million acre-feet diverted annually in Colorado (Wolfe, 2006). Additional information on Colorado's aquifers and groundwater resources can be found in the Colorado Geological Survey's Ground Water Atlas of Colorado (Topper and others, 2003).

Colorado Domestic Use Wells



surface water: *water sources open to the atmosphere, such as rivers, lakes, and reservoirs.*

groundwater: *supply of fresh water found beneath the earth's surface, usually in aquifers, which is often used to supply wells and springs.*



point source pollution: *sources of pollution that originate from a single point, such as a discharge pipe or ditch.*

nonpoint source (NPS) pollution: *pollution sources which are diffuse and do not have a single point of origin, such as agriculture, forestry, and urban runoff.*

Although surface water is the dominant water resource in Colorado, groundwater is essential to the communities, businesses, farms, and residents who rely on it. Colorado's groundwater is a finite resource. If aquifers become contaminated, a valuable resource is lost. Therefore, the protection of the state's limited groundwater resources is an important function.

Regulatory Background

In the 1960's, studies linking the insecticide DDT—dichloro-diphenyl-trichloroethane—to declines in bald eagle populations created widespread public concern about pesticides' potential environmental impacts. In 1979, the discoveries of pesticide contamination from aldicarb in New York and from DBCP, or dibromochloropropane, in California led to the realization that groundwater was also susceptible to pollution from standard agricultural practices.

Beginning in the 1980s, public awareness began to emerge of the magnitude of water quality impacts from pollution sources other than discharge pipes, or point sources. As additional sources of pollution, or nonpoint sources, were studied, agriculture was identified as a significant contributor to surface water problems, especially due to soil erosion.

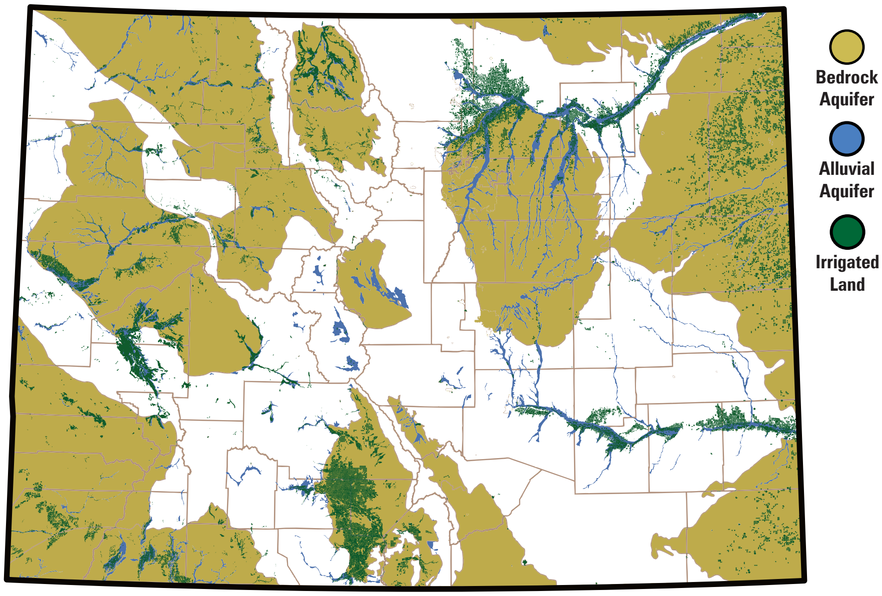
In Colorado in the 1980s, very little data existed to alleviate or confirm public concerns about pesticide and fertilizer's effects on water quality. In accordance with federal requirements, the Colorado General Assembly adopted the Colorado Water Pollution Act in 1966. Then, in 1973, legislators completely rewrote and renamed it the Colorado Water Quality Control Act to comply with new federal laws. A second total rewrite was adopted in 1981. The need to address water pollution from agricultural operations and other nonpoint sources was recognized both nationally and in Colorado by the mid to late 1980s.

The U.S. Department of Agriculture 2002 census data show Colorado's $4.5 billion agriculture industry encompasses approximately 31,000 farms and ranches that cover more than 31 million of the state's total 66 million acres. An estimated 3.2 million acres are irrigated and intensively farmed for a variety of crops and forages, utilizing inputs of pesticides and commercial fertilizers to achieve high yields (SWSI, 2005).

Pesticide and fertilizer use are an important component of agricultural practices. The 1997 CDA Pesticide Use Survey reported about 6 million pounds of pesticide active ingredients were applied by commercial applicators who responded (Colorado Department of Agriculture, 1997). Total – both commercially and privately applied—pesticide use is estimated at more than 11 million pounds of pesticide active ingredients. In 2005, there were 10,378 pesticide products registered for use in Colorado by 1,079 registrants, compared to 8,341 products by 880 registrants in 1990.

The 2002 USDA census reported combined annual production expenses for fertilizer, lime, soil conditioners, and chemicals exceed an estimated $180 million in Colorado (USDA, 2002). Fertilizer use in Colorado has increased from less than 200,000 tons in the mid-1960s to more

Colorado Irrigated Agriculture



than 800,000 in the late 1990's *(See facing page)*. High fertilizer prices, combined with drought caused a 50-plus percent drop in use in 2001. Since then, total use has averaged about 580,000 tons per year.

In 1990, the Rocky Mountain Plant Food and Agricultural Chemicals Association—now known as the Rocky Mountain Agribusiness Association—gathered support in the General Assembly for the passage of proactive legislation to address the potential for groundwater contamination from pesticides and fertilizers. Sen. Tom Norton (R-Greeley) sponsored Senate Bill 90-126, the Agricultural Chemicals and Groundwater Protection Act, to amend the Colorado Water Quality Control Act. The amendment established provisions to grant the Colorado Department of Agriculture new authority to protect groundwater. While the Water Quality Control Division of the Colorado Department of Public Health and Environment is the state's primary water quality agency, Colorado's agriculture department has a long history of regulating the pesticide and fertilizer industries. Its existing inspection programs, created under the Federal Insecticide, Rodenticide, and Fungicide Act and the Colorado Pesticide Act, allow the CDA to work with the pesticide and fertilizer industries to help administer the Agricultural Chemicals and Groundwater Protection Act.

The Agricultural Chemicals and Groundwater Protection Act

The Agricultural Chemicals and Groundwater Protection Act (C.R.S. 25-8-205.5) took effect on July 1, 1990, and established the Groundwater Protection Program. This act states, *"…the public policy of the state is to protect groundwater and the environment from impairment or degradation due to the improper use of agricultural chemicals while allowing for their proper and correct use…"* (Colorado Revised Statutes, 1990).

The implementation of this new law was originally funded by a 50-cent per ton tax on fertilizer sales and an annual $20 per product fee for pesticides registered in the state. The $20 pesticide registration fee increased to $30 in September 2005, after legislative changes were made to the statute. The fee setting authority was moved from the Colorado General Assembly to the Colorado Agricultural Commission.

The Groundwater Protection Program's work is defined by two classes of chemicals, commercial fertilizers and pesticides.

Commercial fertilizers are defined as, *"fertilizer, mixed fertilizer, or any other substance containing one or more essential available plant nutrients which is used for its plant nutrient content and which is designed for use and has value in promoting plant growth. It does not include untreated animal and untreated vegetable manures, untreated peat moss, and untreated peat humus, soil conditioners, plant amendments, agricultural liming materials, gypsum, and other products exempted by regulation of the commissioner"* (Colorado Revised Statutes, 1971).

Pesticides are defined as, *"any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant"* (Colorado Revised Statutes, 1990).

The goal of the Groundwater Protection Program is to reduce negative impacts to groundwater and the environment by improving the management of agricultural chemicals and to assure that groundwater remains safe for domestic and livestock consumption by preventing contamination. A voluntary approach is emphasized, using education and training to achieve the goal. The Agricultural Chemicals and Groundwater Protection Act gives the CDA au-

best management practice (BMP): *any voluntary activity, procedure, or practice. . . to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical.*

agricultural management area (AMA): *designated geographic area defined by the Colorado Commissioner of Agriculture where there is a significant risk of contamination or pollution of groundwater from agricultural activities.*

agricultural management plan (AMP): *any activity, procedure, or practice to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical adopted as a rule.*

> *The goal of the Groundwater Protection Program is to reduce negative impacts to groundwater and the environment by improving the management of agricultural chemicals.*

Best Management Practices for fertilizer application and irrigation are essential components to protect groundwater.

thority to develop best management practices, which are defined as *"any voluntary activity, procedure, or practice…to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical"* (Colorado Revised Statutes, 1990).

A three-tiered response is specified to address potential and actual groundwater pollution due to agricultural chemicals. The **first level of response** is preventive. These efforts include:

- Education and training in voluntary BMP implementation;
- Establishment of voluntary BMPs appropriate to local conditions and type of agriculture;
- Implementation of mandatory rules for agricultural chemical facilities with bulk storage and mixing/loading areas that exceed minimum thresholds; and
- Establishment of a statewide groundwater monitoring program and an aquifer vulnerability assessment analysis.

The **second level of response** is mandated management practices. If prevention efforts fail to remedy a groundwater pollution problem, the Commissioner of Agriculture has the authority to designate AMAs and/or require the use of AMPs. An AMA is a designated geographic area defined by the Commissioner where there is a significant risk of groundwater contamination or pollution from agricultural activities.

An AMP is any activity, procedure, or practice *adopted as rule,* rather than implemented on a voluntary basis, to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical. This procedure essentially replaces voluntary BMPs with mandated BMPs in these geographic areas.

A **third level of response** is specified if continued groundwater monitoring reveals that designated AMAs and/or AMPs are not preventing or mitigating the presence of agricultural chemicals. At this level, the Commissioner and the Water Quality Control Commission confer and determine the appropriate regulatory response. The Water Quality Control Commission has final authority over the content of any promulgated control regulation.

As of this report's publication, the declaration of an AMA or AMP has not been deemed necessary by any of the five Colorado Commissioners of Agriculture in office since the Groundwater Protection Program's inception in 1990. Nor has there been a recommendation for an AMA or AMP from Groundwater Protection Program staff, the Program's Advisory Committee, the Water Quality Control Commission, or the general public. In the early stages of the program, too little groundwater data was available to evaluate the need for these management tools. As groundwater data was collected and isolated areas of contamination identified, the program staff and Advisory Committee felt that voluntary BMP adoption had not been given sufficient time to diffuse within the agricultural community. Potential future use of these regulatory mechanisms will depend upon BMP adoption by agricultural chemical users and the results of the groundwater monitoring program.

There are three state agencies responsible for implementing the Agricultural Chemicals and Groundwater Protection Act:

- **Colorado Department of Agriculture** has overall responsibility

for the Groundwater Protection Program. The CDA enforces rules for bulk storage and mixing/loading of agricultural chemicals, monitors the quality of the state's groundwater, and designates AMAs and AMPs if necessary.
- **Colorado State University Extension** provides education and training in methods designed to reduce groundwater contamination from agricultural chemicals.
- **Colorado Department of Public Health and Environment** analyzes and interprets data, and writes reports.

These three agencies rely on a 13-member advisory committee to provide input from the agricultural community and the general public. Several groups with agricultural interests are represented, including pesticide applicators; agricultural chemical suppliers; agricultural producers; the green industry; the general public; and the Water Quality Control Commission. Committee members are approved by the Colorado Agricultural Commission and serve three-year terms.

The advisory committee meets one to two times per year and provides direction by helping to set educational and monitoring priorities; reviewing BMP feasibility; providing ideas on the most effective means of reaching intended audiences; and giving input on many other programmatic initiatives. This committee also helps draft policy and regulation when necessary. In 1991, a subcommittee was formed to draft the rules pertaining to bulk chemical storage and mixing/loading facilities. They were presented to the full committee before public hearings were conducted. In 2004, the committee helped introduce legislation regarding the Groundwater Protection Program's fee structure. The advisory committee's assistance and efforts were invaluable.

Cooperation with Other Agencies

The Agricultural Chemicals and Groundwater Protection Act is only one facet of the state's overall groundwater protection program. Statutory authority for protecting the waters of the state, both surface water and groundwater, is primarily vested in the CDPHE's Colorado Water Quality Control Commission and the Water Quality Control Division. However, there are a number of local, state, and federal agencies and other organizations in Colorado that have a mandate to protect water resources. The intent of the Agricultural Chemicals and Groundwater Protection Act and the implementing agencies is to fulfill one aspect of water quality management in the context of a much larger network. The Groundwater Protection Program has ongoing collaborations with many agencies and organizations in Colorado. The USDA Natural Resources Conservation Service (NRCS), the USDA Agricultural Research Service (ARS), and the Colorado Agricultural Experiment Stations (AES) are heavily involved in the development of BMPs, as are various conservation districts and water conservancy districts. The state nonpoint source program fostered coordinated education efforts and demonstration projects, many with a mission complementary to the Groundwater Protection Program.

Monitoring efforts have been augmented with cooperation from the Office of the State Engineer, the U.S. Geological Survey (USGS), and various groundwater management districts, water conservancy districts,

BMP cooperative demonstration site

Groundwater Protection Program Advisory Committee, approved by the Colorado Agricultural Commission, represents groups with ag-related interests and provides input to the program. (February 2008)

Fortunately, the majority of groundwater wells sampled thus far is not contaminated by pesticides or fertilizers at levels deemed unsafe for humans by the EPA.

and conservation districts throughout the state. Additionally, agricultural organizations such as Colorado Corn Growers, Colorado Livestock Association, Farm Bureau, Rocky Mountain Agribusiness Association and others cooperate with the Groundwater Protection Program to advance the goal of protecting Colorado's water resources.

Report Overview

This report summarizes the first 15 years of implementation of the Agricultural Chemicals and Groundwater Protection Act and is intended to provide an overview of activities and data. The monitoring program has prioritized its sampling in basins where agriculture predominates and rural homes utilize groundwater. These data form the backbone of the Groundwater Protection Program, as they determine the need and priority for education and other program resources. The program has completed sampling of groundwater systems in the largest agricultural regions of Colorado. These aquifers and the years they were sampled include:

- South Platte alluvial aquifer: 1992, 1993, and 1995 – 2005;
- San Luis Valley unconfined aquifer: 1993 and 2000;
- Lower Arkansas alluvial aquifer: 1994, 2004, and 2005;
- Denver Basin aquifer system and alluvial deposits on the Front Range: 1996 and 2005;
- High Plains/Ogallala aquifer: 1997;
- Colorado River and Uncompahgre River alluvial aquifers: 1998 and 2000;
- North Platte alluvial and terrace formations in Jackson County: 1999;
- Gilpin County: 2005;
- Wet Mountain Valley: 2002; and
- El Paso County: 2006.

Much work remains as the program continues to implement the Agricultural Chemicals and Groundwater Protection Act. Groundwater protection remains a state priority and agricultural chemical use is still prevalent. Monitoring data, assessing vulnerability, and surveying chemical user data indicate areas where water quality still is susceptible to contamination. Fortunately, the majority of groundwater wells sampled thus far is not contaminated by pesticides or fertilizers at levels deemed unsafe for humans by the EPA. Continued cooperation from crop producers, agricultural chemical applicators, and homeowners is critical to ensure adequate groundwater quality for generations to come.

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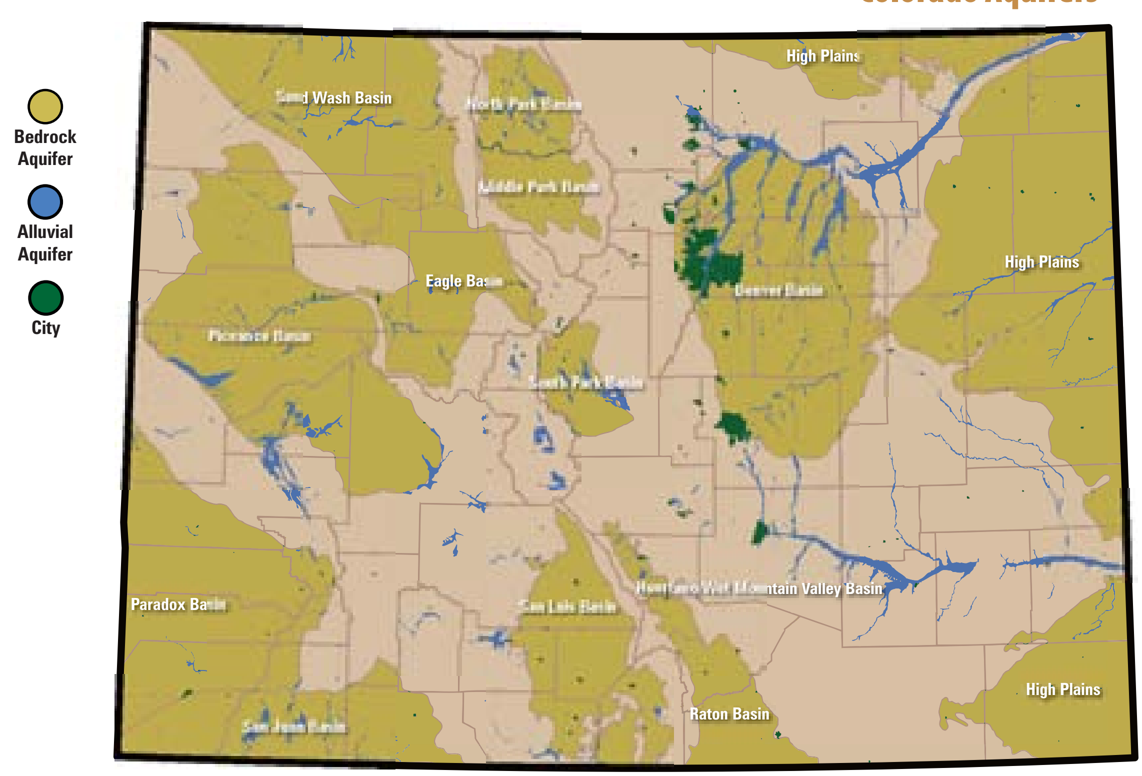
Colorado Aquifers



The Colorado Department of Agriculture serves as the lead agency for the Groundwater Protection Program.

Liquid fertilizer storage facility

The administration of this program is a multi-agency effort that involves the CDA partnering with Colorado State University Extension and the Colorado Department of Public Health and Environment. The CDA's responsibilities are to:

1. Coordinate efforts among the three agencies;
2. Regulate agricultural chemical bulk storage and mixing/loading;
3. Monitor the quality of Colorado's groundwater resources;
4. Perform analyses of groundwater samples at the CDA Standards Laboratory;
5. Assess the vulnerability of Colorado's groundwater to contamination from agricultural chemicals;
6. Negotiate yearly interagency agreements; and
7. Oversee the program's budget.

Regulation of Agricultural Chemical Bulk Storage and Mixing/Loading Facilities

The Commissioner promulgated rules for facilities where pesticides and/or fertilizers are stored and handled in quantities that exceed minimum thresholds. The purpose of the rules is to prevent spills and leaks that can potentially contaminate groundwater resources. The rules establish standards for the construction and operation of bulk liquid and dry storage facilities and mixing/loading areas.

The rules also require bulk storage and mixing/loading facility designs to be:

1. Signed and sealed by an engineer registered in the state of Colorado, or
2. From a Commissioner-approved source and available for public use.

To meet the latter, the CDA and CSUE produced a free set of design plans, "Agricultural Chemical Bulk Storage and Mix/Load Facility Plans for Small to Medium-Sized Facilities" (CSUE and CDA, 1995). Copies of the complete storage and mixing/loading rules (CDA, 1993) and a summary sheet with checklist to help determine if the rules apply to a particular operation (CDA, 1994) also are available from either agency.

The Commissioner is authorized to enforce these rules. Through various investigative powers, the Commissioner has the authority to issue cease and desist orders and impose civil penalties up to $1,000 per day, per violation.

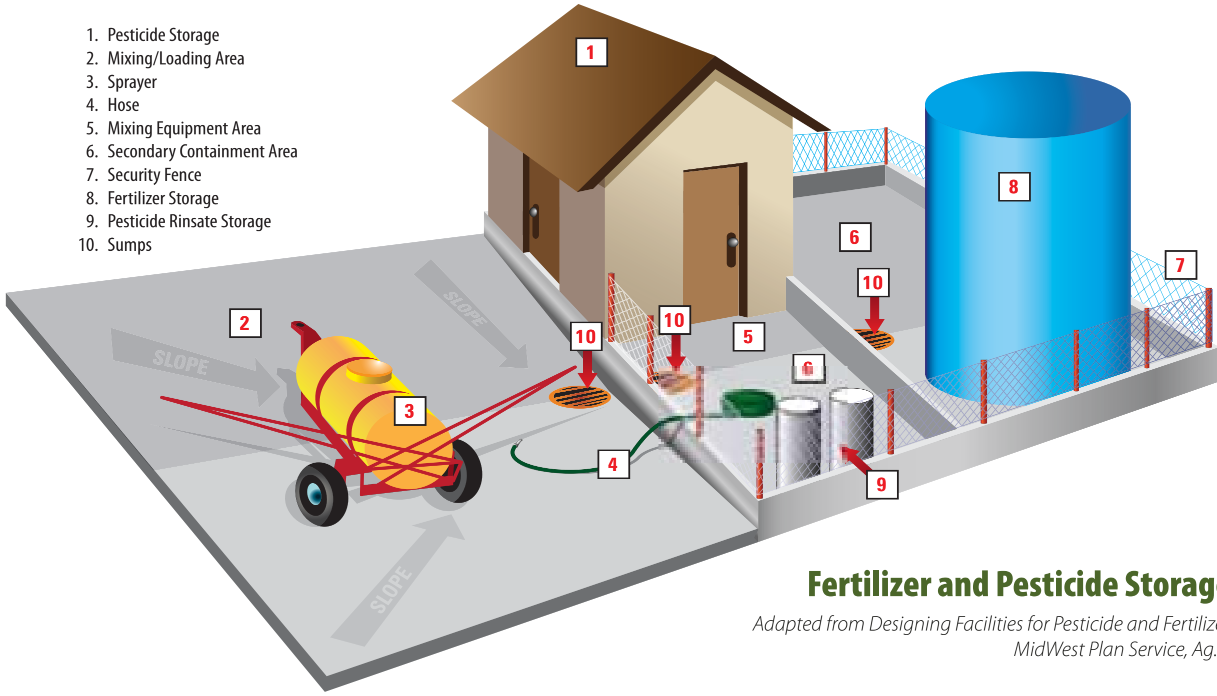
The CDA employs field inspectors throughout the state who, among other duties, enforce the bulk storage and mixing/loading rules. Facilities are also visited to provide information and answer specific questions regarding these rules. This educational process provides assistance to determine whether compliance with the rules is required, and what specifically must be accomplished to comply with the required rules.

Bulk pesticide storage facility inspections began Sept. 30, 1997, and bulk fertilizer storage facility inspections began Sept. 30, 1999. By December 2006, approximately 1,300 inspections were conducted at 177 facilities throughout the state. Although many had minor problems requiring correction, inspections resulted in a 97 percent compliance rate, based on the small number of cease and desist orders and violation notices issued. As this part of the Groundwater Protection Program moves forward, focus is shifting toward maintenance issues at existing facilities rather than construction of new facilities, which was common at the onset of the program.

Waste Pesticide Collection Program

In 1995, a pilot waste pesticide collection program debuted in Adams, Larimer, Boulder and Weld counties. Its purpose was to provide pesticide users the opportunity to dispose of banned, canceled or unwanted pesticides in an economically and environmentally sound manner. Part of the program funding was provided by an EPA Clean Water Act Section 319 grant. The program was a success with approximately 17,000 pounds of waste pesticides from 67 participants collected and safely disposed.

Based on the pilot program's success, CDA was asked to continue the program in other areas of the state. However, the CDA



Fertilizer and Pesticide Storage/Mixing Facility

Adapted from Designing Facilities for Pesticide and Fertilizer Containment, (MWPS-37) MidWest Plan Service, Ag. Eng., Iowa State Univ. 1991.

had no statutory authority or funding to operate such a program. Two alternatives were discussed to continue a waste pesticide collection program: the CDA could seek statutory authority and funding from the legislature to operate a state-run program; or the CDA could attempt to implement a private program operated by a hazardous waste handling company.

The CDA contacted hazardous waste contractors to determine their level of interest in creating a private waste pesticide collection and disposal program. One company, MSE Environmental, Inc., indicated interest and discussions began to explore the feasibility. The initial estimates for collection and disposal were between $2.25 and $2.65 per pound of waste. Based on this information, a private program was pursued, mainly because a state program required enabling legislation.

After numerous issues were addressed, MSE Environmental, Inc. targeted the San Luis Valley and six northeastern Colorado counties. Registration opened in early 1997 and scheduled collection began in March of that year. The program was very successful. MSE collected more than 10,500 pounds of waste pesticides from 33 participants for $2.65 per pound.

Based on the program's success, MSE conducted a statewide collection program in November 1997 and collected more than 23,000 pounds from 42 participants, again at $2.65 per pound. The summary results of all program years:

Year	lbs Collected	# Participants
1995	17,000	67
1997	33,500	75
1999	19,792	47
2001	13,486	34
2002	8,762	33
2003	2,254	7
2004	8,520	10
2005	5,023	11
Total	**108,337**	**317**

Waste Pesticide Collection Program

Colorado's Pesticide Management Plan and Groundwater Sensitivity/Vulnerability Mapping

In October 1991, the EPA released "Pesticides and Groundwater Strategy," which describes the policies, management programs, and regulatory approaches the EPA will use to protect the nation's groundwater resources from the risk of pesticide contamination. The strategy emphasizes prevention over remedial treatment. The centerpiece of the strategy was the development and implementation of state pesticide management plans (PMPs) for pesticides that pose a significant risk to groundwater resources (EPA, 1991).

The EPA published the proposed rule June 26, 1996 (EPA, 1996). Colorado submitted a complete draft of its generic PMP to the EPA for informal review in 1996. After multiple revisions based on comments received, Colorado submitted a final version with which the EPA concurred in March 2000 (Yergert and others, 2000). Six years later, the EPA eliminated the PMP rule, but still encourages states to produce generic PMPs and continue groundwater protection programs. Colorado plans to continue to use its PMP for program guidance.

One significant result for Colorado: The EPA required a sensitivity analysis and assessment map in Geographic Information System (GIS) format. The map was used to determine where to focus education and monitoring activities.

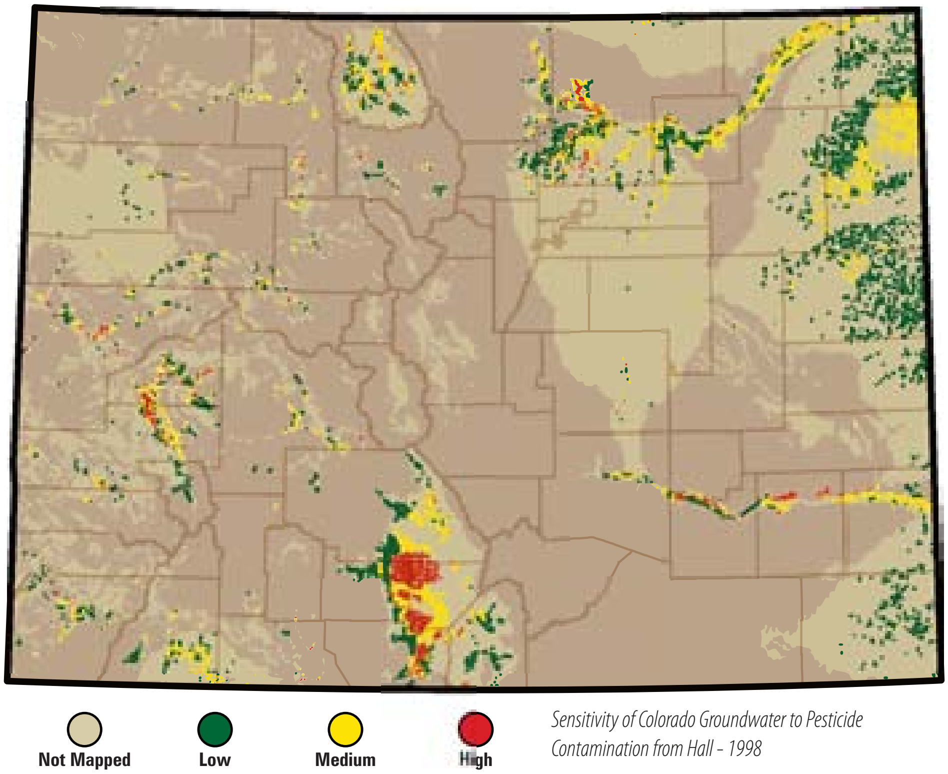
A small EPA grant paid for a sensitivity analysis pilot project in northeastern Colorado, which was completed and submitted in 1996. The EPA reacted favorably and provided money for a statewide sensitivity analysis, finished in 1998.

The Groundwater Protection Program used the information to publish an 8-page fact sheet, "Relative Sensitivity of Colorado Groundwater to Pesticide Impact." The publication assesses aquifer sensitivity based on conductivity of exposed aquifers; depth to water table; permeability of materials overlying aquifers; and availability of recharge for transport of contaminants. The factors incorporated the best statewide data available and the important aspects of Colorado's unique climate and geology (Hall, 1998).

In 1999, the Groundwater Protection Program received spending authority to begin an aquifer vulnerability project to complement and improve the existing aquifer sensitivity maps. One project was completed in 2001with the Colorado School of Mines (Schlosser and others, 2000; Murray and others, 2000). Another, "Probability of Detecting Atrazine/Desethyl-atrazine and Elevated Concentrations of Nitrate in Ground Water in Colorado," was done in conjunction with USGS, and completed in 2002 (Rupert, 2003).

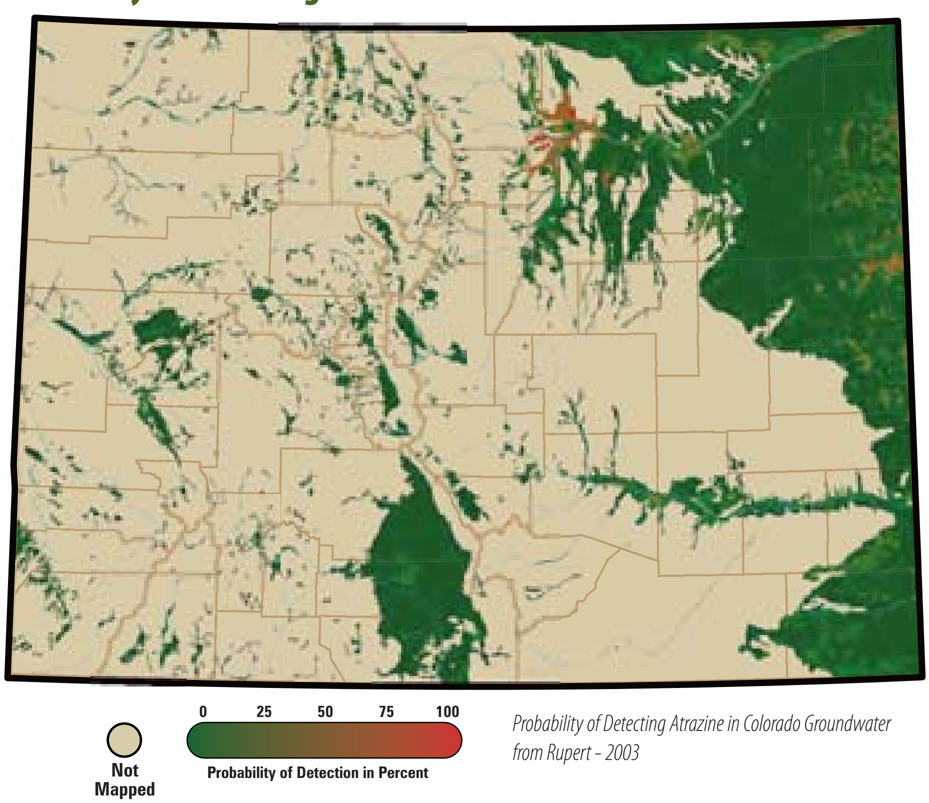
Using GIS resources and expertise gained by developing the maps, the Groundwater Protection Program created a statewide nitrate vulnerability map in 2001. A Colorado State University masters of science project produced the map and an accompanying field-scale nitrate leaching index (Ceplecha, 2001; Ceplecha and others 2004).

Pesticide Sensitivity



Sensitivity of Colorado Groundwater to Pesticide Contamination from Hall - 1998

Probability of Detecting Atrazine

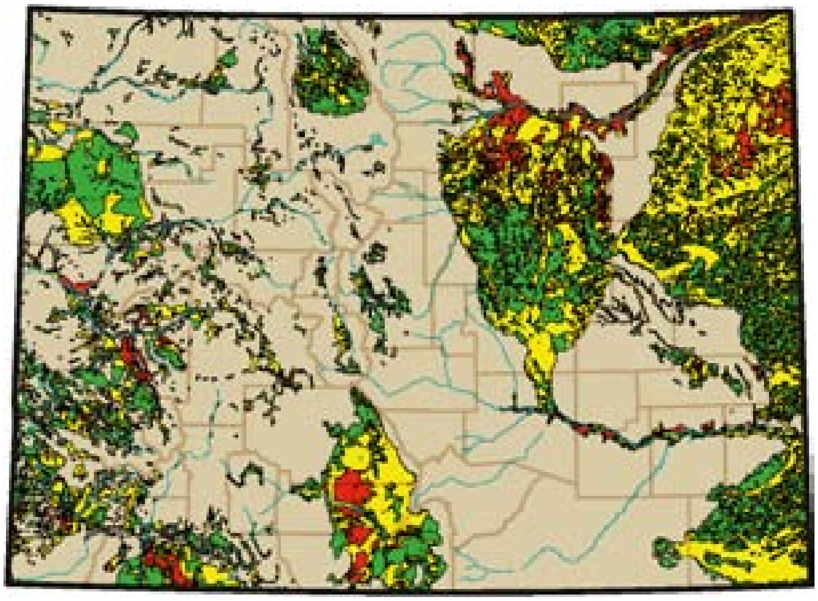


Probability of Detecting Atrazine in Colorado Groundwater from Rupert - 2003

aquifer sensitivity: *the relative ease with which a pesticide or nitrate can migrate to groundwater. It is largely a function of the physical characteristics of the overlying area and potential recharge (precipitation and irrigation).*

aquifer vulnerability: *combines aquifer sensitivity as well as land use, management and pesticide properties.*

Nitrate Vulnerability



Not Mapped   Low   Medium   High

Vulnerability of Colorado Groundwater to Nitrate Contamination from Ceplecha - 2001

These groundwater mapping projects improved the program's ability to focus resources on areas with the greatest potential for contamination. The program continues to refine and update the groundwater sensitivity and vulnerability maps as better data and resources become available.

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The groundwater monitoring program's purpose is to evaluate possible impacts to groundwater quality from current and past use of agricultural chemicals, and provide accurate data to:

- Determine if agricultural chemicals are present;
- Determine if trends in water quality exist;
- Provide monitoring data in an annual report to help the Commissioner of Agriculture to identify potential agricultural management areas;
- Evaluate the effectiveness of BMPs; and
- Assess groundwater vulnerability.

This monitoring program, which involves sample collection and lab analysis, is the first statewide effort to establish the potential impacts and magnitude of agricultural chemical contamination. Efforts focus primarily in Colorado's major agricultural regions, with some sampling in urban areas.

A map of the study areas and sample locations is provided on page 15. As of December 2006, the monitoring program has sampled 1,096 wells and analyzed 1,956 samples throughout Colorado.

Monitoring well sampling was conducted statewide to evaluate agricultural chemicals' effects on groundwater quality.

A technician prepares to sample a monitoring well.

Monitoring Approaches

The Groundwater Protection Program historically utilized different approaches to monitoring, depending on needs and objectives. In the early years, when little or no information existed, the focus was on acquiring baseline data from the state's major agricultural areas. The baseline investigations often covered broad areas with relatively light sampling densities.

As monitoring goals have evolved, the monitoring plan was modified to address specific needs, which varied according to location; amount of baseline data; agricultural practices; and program resource and budget constraints. Generally, the plan incorporates four approaches: reconnaissance surveys; regional monitoring; sub-regional monitoring; and dedicated monitoring networks.

Reconnaissance surveys produce a brief assessment of groundwater quality in an area of interest to decide whether additional investigation is warranted. Usually between 10 and 30 wells are selected for sampling. Typically, they are existing domestic, irrigation, or monitoring wells. When possible, locations are selected randomly, but access and owner consent dictate the final locations. In some instances, when a specific problem is suspected, the wells may be targeted to obtain the required information. When regional or sub-regional tests identify irregular or inconsistent results, a follow-up reconnaissance survey may be initiated.

Regional monitoring involves collecting groundwater quality samples from approximately 100 wells throughout a particular region. Exact numbers and sample density vary according to the hydrogeology, geography, agricultural practices and population density. Usually the region consists of a river drainage basin and its associated alluvial aquifers or a major regional aquifer.

Sub-regional monitoring covers a smaller area, typically a tributary basin or a political subdivision, such as a county or a special district. The sampling goal ranges from 30 to 50 exisiting wells. Sub-regional monitoring also may be used to confirm sampling results the year after regional monitoring.

Dedicated monitoring entails a network of wells specifically used and dedicated to long-term monitoring and represents one method to assess water quality trends. The Groundwater Protection Program uses dedicated monitoring well networks available through other agencies or organizations. In areas without existing wells, the program installs or has plans to install new wells to improve monitoring. Although this creates additional costs, the benefits include greater control over both the design and construction (Appendix I) of monitoring wells; reduced problems with access; and greater probability of repeatable long-term monitoring.

Study Area Selection

Factors considered in the choice of study areas for groundwater monitoring include:

1. Significant use of agricultural chemicals and the potential for chemical migration into groundwater supplies;
2. Groundwater in a major alluvial aquifer, or a significant portion of the groundwater is shallow;
3. Significant portion irrigated by either surface water diversions or groundwater pumping;
4. Soil types conducive to leaching, or soil that drains easily;
5. Alluvial and/or shallow bedrock aquifers used as domestic water supplies; and
6. Areas currently included in other water quality monitoring studies.

The monitoring program informs interested groups in the study area of the sampling program and closely coordinates with federal agencies, county extension agents, conservancy districts, and local health and water officials.

Well Selection

When existing wells are used, domestic wells are selected first, stock wells second and irrigation wells third. Other factors are:

- Low flow, shallow depth;
- Location in the target aquifer or connecting branch;
- Location down gradient of farming;
- Groundwater depth of no more than 150 feet and generally less than 50;
- Working pump in use or at least installed;
- Direction of groundwater flow;
- Wellhead and casing in good physical condition and documentation available;
- Wellhead area free of point sources of contamination; and
- Well owner cooperation.

Sample Collection and Analysis

Technicians typically sample wells between May and October. The samples are analyzed for basic water quality ions, selected pesticides, and in some areas, dissolved metals. Detailed information on sample collection protocol is in Appendix II.

The program has utilized laboratory services from all three participating agencies (CSU, CDPHE, CDA) since groundwater sampling began in 1992. The CSU Soil, Water and Plant Testing Lab has been used since 1992 to perform routine analysis for nitrate, basic inorganic compounds, and dissolved metals. The CDPHE Lab was used in 1992 and 1993 to perform analysis for pesticides. Since 1994, the CDA Standards Lab has been used to analyze samples for nitrate and pesticides. Additionally, USGS lab services were used in cooperative work efforts in the San Luis Valley in both 1992 and 2000.

Soil type, aquifers and irrigation are all factors in choosing study areas for groundwater sampling.

Crews drill a monitoring well in the Arkansas River Basin.

At the time of this publication, the CDA's lab analyzes for nitrate and a suite of 47 pesticides and pesticide breakdown. The lab performs these analyses using several methods, such as gas chromatography, mass spectrometry, and liquid chromatography (Appendix III). Since 1994, the Groundwater Protection Program leveraged USEPA funding to purchase the necessary instrumentation to accomplish this analytical work.

The program employs one full-time chemist. The addition of a dedicated chemist in 1994 has allowed the program to analyze for many more pesticide compounds than would have been economically possible using outside lab services. Additionally, employing a chemist has given the program flexibility to analyze for pesticides that have potential for groundwater contamination specific to Colorado conditions and fit use patterns.

A list of the analyzed substances, labo-

This sampling program was the first effort to monitor the entire South Platte aquifer to establish the possible effects and magnitude of agricultural chemical contamination.

ratory analysis methods, protocol, instrumentation, and minimum detection limits are in Appendix III.

The maximum level of nitrate in drinking water allowed by the EPA is 10 ppm nitrate-nitrogen (NO_3-N). Pesticide MCLs vary widely. For example, the drinking water standard for the herbicide atrazine is 3 ppb, but the standard for the insecticide lindane is 0.2 ppb. Most pesticides do not currently have established EPA drinking water standards (Environmental Protection Agency, 2006).

Monitoring Program Study Areas 1992-2006

The study areas sampled for water quality thus far can be organized into three types: major alluvial aquifers, non-alluvial sedimentary and bedrock rock aquifers, or unconsolidated region aquifers.

Major alluvial aquifer study areas are:

- South Platte River Basin, 1992-1993, 2001;
- South Platte River Basin, Weld County, sampled annually from 1995-present;
- Arkansas River Basin, 1994-1995, 2004-2005; and
- Colorado River Basin (Western Slope), 1998.

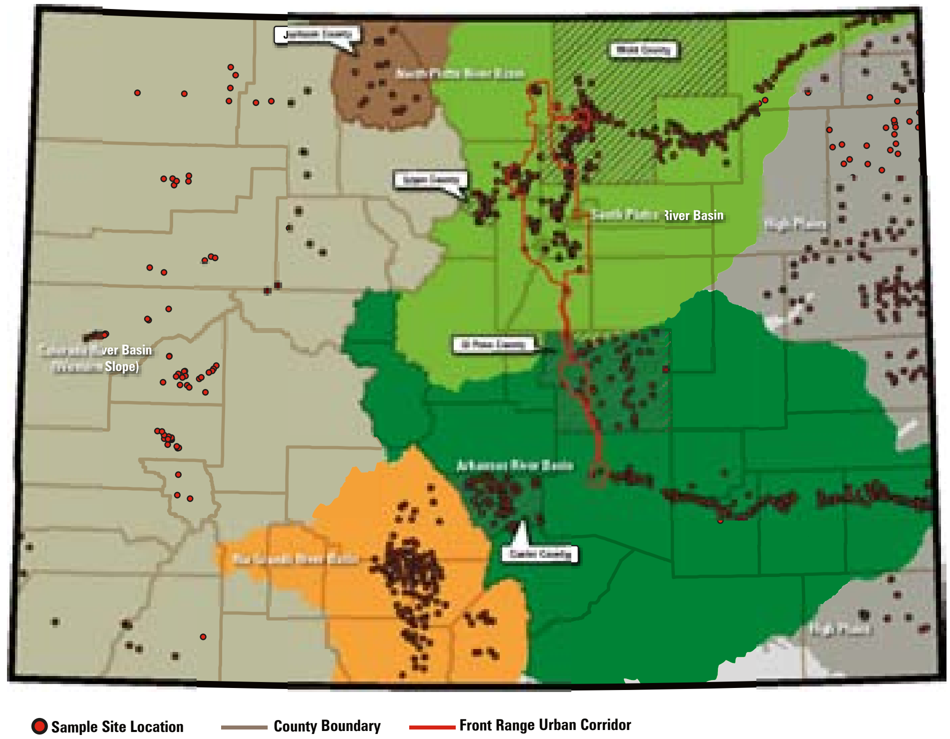
Sedimentary and bedrock rock aquifer study areas include:

- High Plains aquifer, 1997; and
- Gilpin County, 2005.

Unconsolidated regional aquifer study areas include:

- Rio Grande Basin, San Luis Valley, 1993 and 2000;
- North Park, Jackson County, 2000;
- Wet Mountain Valley, Custer County, 2002;
- Front Range Urban Corridor, 1996, 2005; and
- Fountain and Black Squirrel creeks, El Paso County, 2006.

Groundwater Monitoring Locations



In areas without existing wells, the Groundwater Protection Program installs or has plans to install new wells to improve monitoring.

Drinking Water Standards

Under the authority of the Safe Drinking Water Act (SDWA), the EPA sets standards for approximately 90 contaminants in drinking water. For each one, the EPA sets a legal limit, or maximum contaminant level (MCL). Water that meets these standards is considered safe to drink, although people with severely compromised immune systems and children may have special needs. Public water suppliers may not provide water that doesn't meet these standards. In most cases, EPA delegates responsibility for implementing drinking water standards to states and tribes. Private well owners are responsible for ensuring their well water is safe to drink (Environmental Protection Agency, 2008).

South Platte River, Kersey

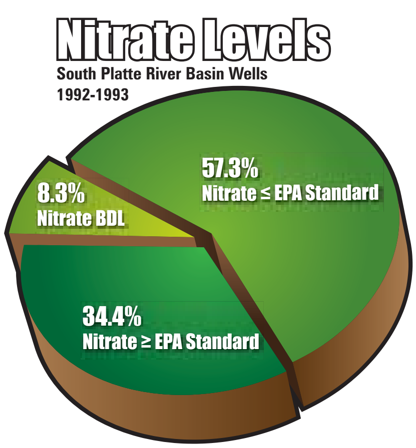
South Platte River Basin 1992-1993

The South Platte aquifer, which begins near Denver and follows the river valley to Julesburg, underlies one of Colorado's major agricultural regions. This extensive region of irrigated agriculture was the first program area chosen for groundwater sampling in 1992 and 1993. This sampling program was the first effort to monitor the entire South Platte River aquifer to establish the possible effects and magnitude of agricultural chemical contamination.

The sampling area stretched from northern Denver County, eastward to the Nebraska state line in Sedgwick County. Between June and August 1992, 96 domestic, stock, and irrigation wells were sampled.

South Platte River Basin 1992-1993 Nitrate

Laboratory test results indicated that nitrate affected portions of the study area. Of the 96 wells sampled, eight wells, or 8 percent, did not contain a measurable level of nitrate. Fifty five wells, or 57 percent, contained nitrate below the EPA drinking water standard and 33 wells, or roughly 34 percent, exceeded the standard.



A data analysis shows variations in nitrate levels as the river flows from Denver to Julesburg. Immediately downstream from Denver in Adams County, nitrate levels were well below the EPA drinking water standard. Just downstream from Brighton, the nitrate levels began to increase. An area from Brighton through Greeley had several wells above 20 ppm, with the average nitrate level consistently above the EPA drinking water standard. Around Wiggins in western Morgan County, a second area of elevated nitrate appears in the data. Nitrate levels then decrease through eastern Morgan and Logan counties, with the exception of two isolated wells at Sterling and Crook. Moving into Sedgwick County, nitrate levels once again began to increase with the overall average rising above the EPA drinking water standard.

In May 1993 a portion of the original study area was resampled. Analysis of the 1992 data identified three areas—the reach from Brighton to Greeley, an area in western Morgan County near Wiggins, and Sedgwick County—where nitrate levels exceeded the EPA drinking water standard.

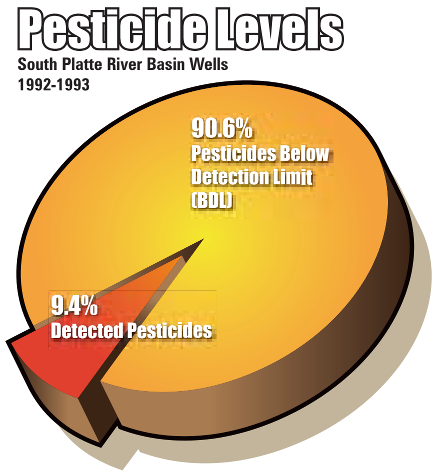
The Brighton to Greeley reach was not included in the resample because another agency sampled portions of it and the information would be in the final analysis. The 1993 results confirmed nitrate levels exceeded the EPA drinking water standard in Morgan and Sedgwick counties.

In Morgan County, 16 of the original 25 wells underwent resampling. Eighteen more were sampled for a total 34. Results showed 13, or 38 percent, exceeded the EPA drinking water standard. Only two wells, or 5 percent, contained no measurable nitrate.

In Sedgwick County, five wells were added to the eight sampled in 1992. Samples indicated little or no change from one year to the next. Five wells, or 38 percent, exceeded the EPA standard.

South Platte River Basin 1992-1993 Pesticides

Laboratory testing was conducted for 26 different pesticide compounds in 1992. Of the 96 wells sampled in 1992, 63 wells, or 65 percent, contained no measurable pesticide levels; seven wells, or 7 percent, contained measurable levels of atrazine; and one contained alachlor at 3 ppb, exceeding the EPA standard of 2 ppb.



South Platte River Basin, Weld County 1995-Present

A long-term monitoring effort was initiated in 1995 in the South Platte aquifer from Brighton to Greeley. Previous sampling detected widespread, elevated nitrate levels and a high percentage of wells with pesticides. The goal was to examine trends in groundwater quality and help forecast the future effects of best management practices implemented in the area.

Various other factors influenced the selection of Weld County for long-term monitoring. A suitable network of monitoring wells could be assembled from existing wells. The North Front Range Water Quality Planning Association (NFRWQPA) installed 20 monitoring wells in the

Sugar beets are harvested in Weld County, against a backdrop of Meeker and Long's peaks.

area in 1991 and began water quality testing in 1989 on a large set of the area's irrigation wells. Using the irrigation well data, CSU researchers' studies and models found the region had hydrogeology and surface activities vulnerable to nitrate and pesticide leaching. Finally, local water quality interests were willing to cooperate.

The network consists of three sets of distinct well types:

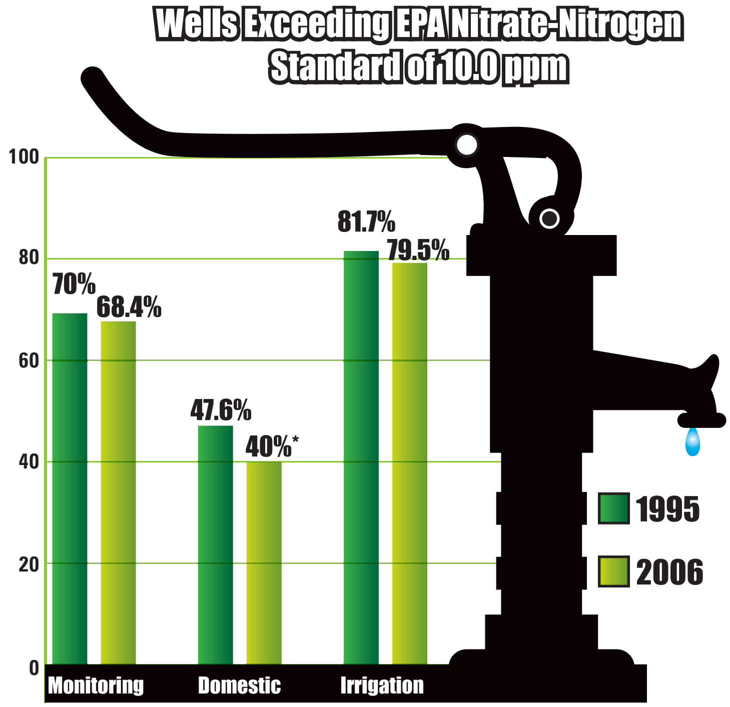
- Twenty NFRWQPA dedicated monitoring wells now operated by the Central Colorado Water Conservancy District (CCWCD), sampled each year since 1995;
- 60 irrigation wells sampled from 1989 through 1991 and each year since 1994; and,
- 21 domestic wells sampled in 1995, 18 wells sampled in 1998, 14 wells sampled in 2001, and 10 wells sampled in 2004.

The number of sampled wells varied due to well ownership changes and whether well owners granted access. The monitoring wells were sampled in cooperation with the CCWCD. Monitoring wells were typically sampled in June and irrigation and domestic wells in July and August.

The *monitoring wells* sample the top 10 feet of the aquifer, which represents the region usually affected first by contaminants. The *irrigation wells* sample the entire saturated zone and provide an average water quality for the entire aquifer. The *irrigation wells* record a narrower range in nitrate levels and a significantly less median value. The *domestic wells* record the lowest contaminant concentrations, because they are deeper and draw water from near the aquifer's bottom 20 feet. These differences are expected due to the different zones of the aquifer sampled by each type of well.

South Platte River Basin, Weld County 1995-Present Nitrate

The first year, 1995, results showed 69 percent of the monitoring wells, 48 percent of the domestic wells, and 82 percent of the irrigation wells exceeded the EPA's nitrate drinking water standard. In 2006, 68 percent of the monitoring wells and 79 percent of the irrigation wells exceeded the standard. Statistical analysis from 1995 through 2004 showed no discernable nitrate data trend.



South Platte River Basin, Weld County, 1995-Present

**Weld County Domestic Network is sampled once every three years —2006 most recent sampling event.*

South Platte River Basin, Weld County
1995-Present Pesticides

In 1995, groundwater testing was conducted for 33 pesticide compounds. Atrazine, metolachlor and prometon were detected in the monitoring wells. The same three, plus lindane, were detected in domestic well samples. In one domestic well sample, lindane measured 0.90 ppb, exceeding the EPA drinking water standard of 0.20 ppb. In the irrigation wells, atrazine, metolachlor, prometon and alachlor were detected.

Monitoring wells are still sampled annually. In 2005, researchers tested for 47 pesticide compounds. They found three compounds: atrazine and its breakdown product deethyl atrazine, metolachlor, and 2, 4-D.

Of the 18 monitoring wells sampled, five of them, or 28 percent, contained no measurable pesticides. The remaining 13 contained one or more pesticides, but were below EPA's standards.

An immunoassay screen for triazine herbicides was used for samples from the irrigation well network from 1995 to 2004. Unfortunately, its use was discontinued because of a manufacturer's change in the kit detection level. However, the program had obtained sufficient data to show a statistically significant (P<0.001) decline in pesticide concentration in the irrigation wells from 1995 to 2004. During that period the median concentration of triazine in the well network declined by 50 percent. Fourteen individual wells showed a statistically significant decrease in concentration, 19 wells had no trend, and none showed an increase.

South Platte River Basin; Weld, Logan, Morgan & Sedgwick Counties 2001

From July through August 2001, researchers sampled the South Platte River alluvial aquifer that underlays portions of Weld, Morgan, Logan, and Sedgwick counties. The area was sampled in 1992 as part of the overall South Platte alluvial aquifer study of privately owned wells. The 2001 sampling project used a network of 37 dedicated monitoring wells controlled by CCWCD, Lower South Platte Water Conservancy District and the CDPHE.

South Platte River Basin; Weld, Logan, Morgan, & Sedgwick Counties 2001 Nitrate

Nitrate levels tend to be most problematic in Weld and Morgan counties. The distribution appears to be associated with areas where commercial fertilizer and manure are both used. All of the study wells contained nitrate. Eighteen wells, or 49 percent, contained nitrate below the EPA standard while the other 19, or 51 percent, exceeded it.

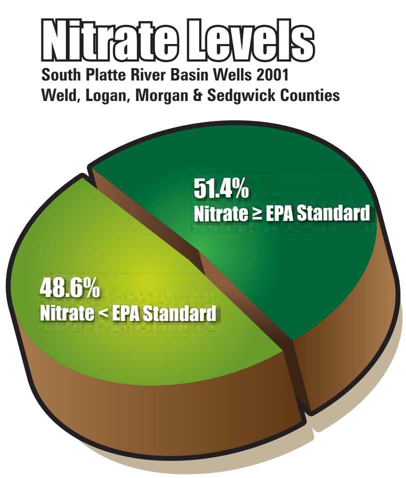
The U.S. Geological Survey National Water Quality Assessment (NAWQA) program used several of the monitoring wells in 1994. Although two sampling events separated by seven years are not suitable for analyzing water quality trends, a comparison found a 1994 mean nitrate-nitrogen value of 12.4 ppm vs. 16.0 ppm in 2001. Nitrate-nitrogen concentration increased in 14 wells and fell in seven others.

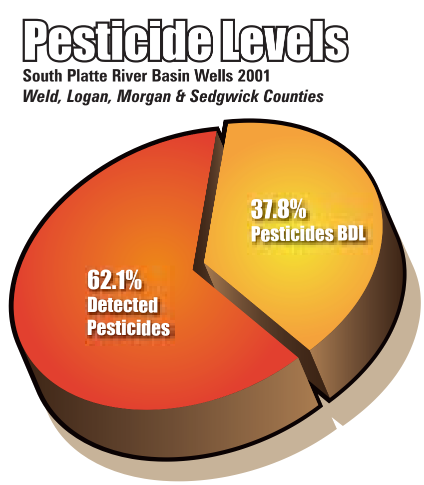
South Platte River Basin; Weld, Logan, Morgan, & Sedgwick Counties 2001 Pesticides

In 2001, 47 different pesticide compounds were analyzed, compared to 26 pesticide compounds in 1992. Improved technology during the most recent testing enabled the lab to detect lower concentrations than in 1992. The 2001 results showed eight pesticides and one breakdown product detected: acetochlor; atrazine and its breakdown product deethyl atrazine; dicamba; metalaxyl; metolachlor; prometon; velpar; and 2, 4-D.

Of the wells sampled, 14, or 38 percent, contained no measurable pesticide levels [Below Detection Level (BDL)] while 23 wells, or 62 percent, contained at least one pesticide. Eight contained more than one pesticide, but all wells were below EPA drinking water standards.

Because of its widespread use, atrazine detections were found throughout the study. Metolachlor, on the other hand, was mostly confined to Weld County, reflecting its more prevalent use in this area.





Arkansas River Basin
1994-1995

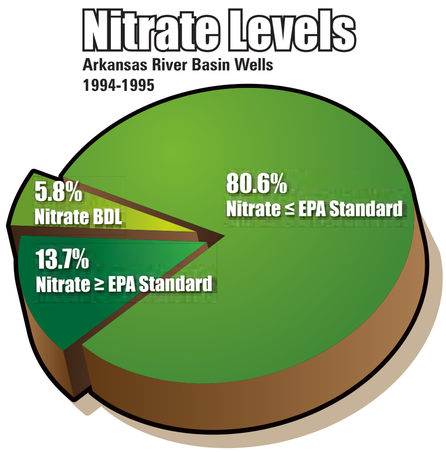
The Arkansas River Valley is characterized by intensely irrigated agriculture that encompasses both surface water diversions and large-capacity irrigation from the shallow unconfined aquifer below. Many irrigation wells were shut down in the late 1990s and early 2000s. This shallow aquifer is also a significant source for domestic water supplies throughout the valley. The sampling program was the first to monitor the entire shallow aquifer to determine possible impacts of agricultural chemical contamination.

Between July and December 1994, the program sampled 139 domestic, stock and irrigation wells from Pueblo to the Kansas state line in Prowers County.

Arkansas River Basin
1994-1995 Nitrate

According to the lab results, nitrate affected portions of the study area. Nineteen of the 139 wells sampled, or 14 percent, exceeded the EPA standard. The largest number, 112, or 81 percent, contained nitrate but were below the EPA drinking water standard. Eight wells, or 6 percent, did not contain measurable nitrate.

Locations above the standard appear to be concentrated in Pueblo County near Avondale, in Otero County between Fowler and La Junta, and in Prowers County near Lamar and Granada. Follow-up sampling of 32 wells in 1995 confirmed earlier results.



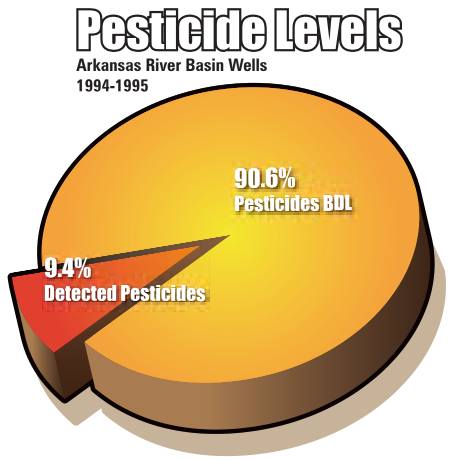
Arkansas River Valley as seen from the Fort Lyon Canal.

Arkansas River Basin
1994-1995 Pesticides

The laboratory tested for 27 different pesticide compounds. Three—atrazine, metolachlor and 2, 4-D—were detected. Of the 139 wells sampled, 126 wells, or 91 percent, did not contain measurable pesticide levels. The lab found 13 of the wells, or 9 percent, had one or more pesticides, but all were below the EPA standard.

In August 1995, researchers resampled 32 wells to confirm the 1994 pesticide detections and nitrate levels. The program was designed to determine if the contamination originally detected was representative of the groundwater quality at that site or a coincidence of timing. The only change in field or laboratory procedures from 1994 to 1995 was a decrease in the atrazine test detection level, from 0.5 to 0.1 ppb, a sensitivity change by a factor of five.

Little change in water quality was measured because nitrate levels were statistically the same. The laboratory again detected atrazine, but one well exceeded the EPA drinking water standard where none had in 1994. The well contained an atrazine concentration of 4.2 ppb. The EPA drinking water standard is 3 ppb.



Arkansas River Basin
2004-2005

The analysis of existing monitoring data, agricultural chemical use data, and aquifer sensitivity and vulnerability models developed by the monitoring program provided a means to prioritize areas for additional monitoring. The Arkansas River alluvial aquifer was lacking in monitoring well coverage and was selected to receive 20 monitoring wells in 2004 installed by the monitoring program with a grant from the EPA. The monitoring wells are located from just east of Pueblo through Otero, Bent, and Prowers counties near the Kansas state line. The criteria for selecting the specific sites of the new monitoring wells were similar to criteria used before: use of agricultural chemicals in significant quantities, depth to groundwater generally less than 50 feet, a representative array of soil types, and a mixture of irrigated and non-irrigated land use.

Nineteen of the 20 wells were sampled from August to September 2004. The well at the Holly airport was damaged and not sampled.

In 2005, the monitoring program collected another set of samples for nitrate and pesticides testing while collecting data on selenium for CPDHE. All 20 monitoring wells were sampled in September 2005.

Arkansas River Basin
2004-2005 Nitrate

Laboratory test results indicated the majority of the study area contained minor levels of nitrate contamination. Seventeen of the 19 wells sampled in 2004, or 90 percent, contained nitrate but were below the EPA drinking water standard. Of the two remaining, one didn't contain a measurable amount of nitrate and the other exceeded the EPA standard.

In 2005, groundwater test results again indicated the majority of the study area had minor levels of nitrate contamination. Of the 20 wells sampled in 2005, 16 of them, or 80 percent, contained nitrate but were below the EPA standard. Three wells, or 15 percent, didn't contain a measurable amount. Again, one exceeded the EPA standard.

Arkansas River Basin
2004-2005 Pesticides

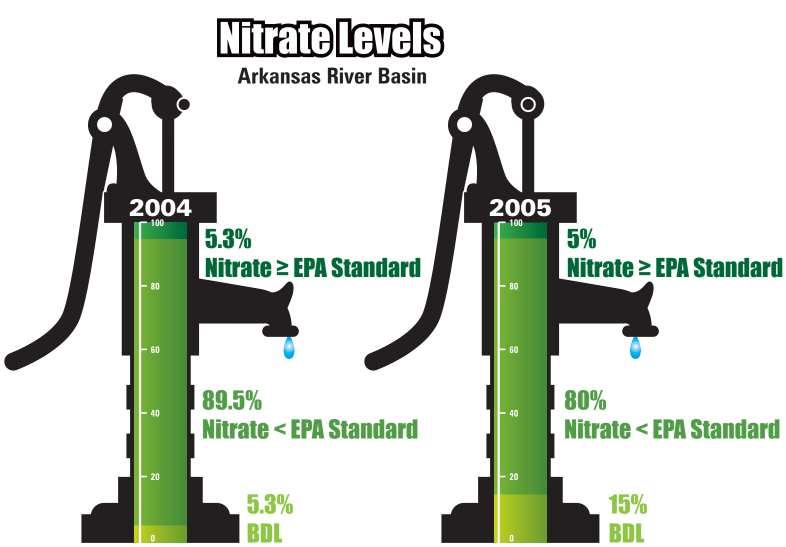
The lab tested for 47 different pesticide compounds. Results detected atrazine and its breakdown product deethyl atrazine; metolachlor; and 2, 4-D. In 2004, of the 19 wells sampled, 15, or 79 percent, contained no measurable pesticide levels. But, four others contained pesticides. One had both atrazine and deethyl atrazine. All were below EPA drinking water standards.

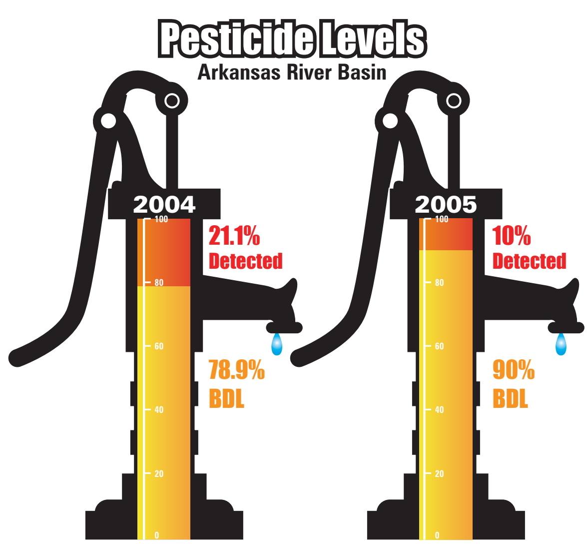
A year later, the tests were repeated. The results showed deethyl atrazine and metolachlor below EPA standards were found in one well. Measurable pesticide levels were absent in 18 wells sampled, or 90 percent, in 2005. Two wells each contained one pesticide, but were within the EPA standard.

Colorado River Basin (Western Slope)
1998

The Colorado River Basin (Western Slope) sampling program focused on groundwater quality on the Western Slope, which includes all of the state west of the Continental Divide. Samples of the Rocky Mountains in the center of the state were excluded because land use is predominantly national forest. The majority of groundwater sampled occurred along stream and river valleys in alluvial deposits, along with some local aquifers on the larger mesas. No single aquifer underlies this area, so sampling differed from past work. The region's agriculture is mainly rangeland or pasture with hay as the major crop.

From April through October 1998, technicians collected 81 samples from rural domestic wells. The initial samples were considered reconnaissance sampling.





Wheat harvest on the High Plains

Researchers chose wells based on shallow groundwater deposits and representative irrigated agriculture areas. Coverage was not uniformly distributed.

Colorado River Basin (Western Slope)
1998 Nitrate

Lab results indicated the majority of the study area has not been significantly affected by nitrate. One well sample exceeded the drinking water standard, which compares favorably to other areas of the state where 10 to 34 percent exceeded the standard.

Although nitrate was present in 51 of the samples, or 63 percent, the overall concentrations were low. Levels of measurable nitrate were not detected in 29 wells, or 36 percent of the samples. One well north of Craig, with 32 ppm nitrate-nitrogen, violated the drinking water standard. It was resampled in 1999. Nitrate-nitrogen had dropped to 14.8 ppm.

Colorado River Basin (Western Slope)
1998 Pesticides

Laboratory tests for 45 different pesticide compounds detected malathion in one well located west of Montrose at a level that did not exceed the EPA drinking water standard. This well was resampled in 1999 and tested negative for all pesticides.

High Plains Aquifer
1997

The High Plains of Colorado include all or part of 11 counties in a region bounded by the state line on the east, the South Platte River on the north, Big Sandy Creek on the west, and the Arkansas River on the south. Groundwater plays a major role in the High Plains' agricultural economy.

The Ogallala formation is the principal geologic unit in the region and is part of the largest aquifer in the United States. The Ogallala underlies about 12,000 square miles in parts of seven states and is the primary source of domestic and irrigation water for area residents. Precipitation solely recharges the Ogallala. In most cases, withdrawals exceed recharge making it essentially a nonrenewable resource.

Between July 1997 and May 1998, researchers sampled 129 wells. A majority of the wells were domestic. Well coverage, while not uniformly distributed, was representative of irrigated agriculture.

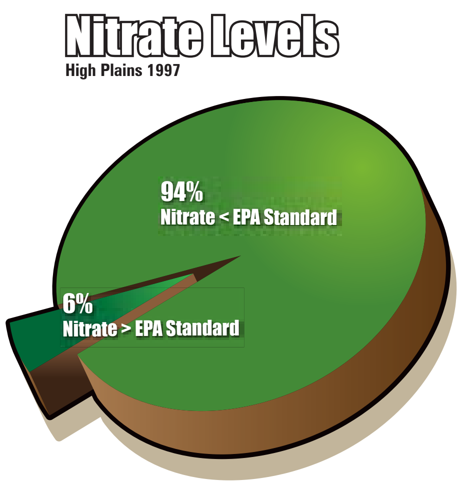
The groundwater management districts, in cooperation with the Office of the State Engineer and this program, concurrently collected samples. They concentrated monitoring in areas of the Ogallala overlain by dryland farming.

High Plains Aquifer
1997 Nitrate

Like the Western Slope, results indicated the majority of the area has not been significantly affected by nitrate. Approximately 6 percent of all the wells exceeded the drinking water standard, which compares to 10 to 34 percent elsewhere in Colorado. While overall levels were low, nitrate was detected in every well tested.

Of the wells sampled, 121 of 129, or 94 percent, contained nitrate below the EPA standard. In half of them, the nitrate-nitrogen concentration was less than 2.5 ppm. Overall, 80 percent were at less than 5 ppm.

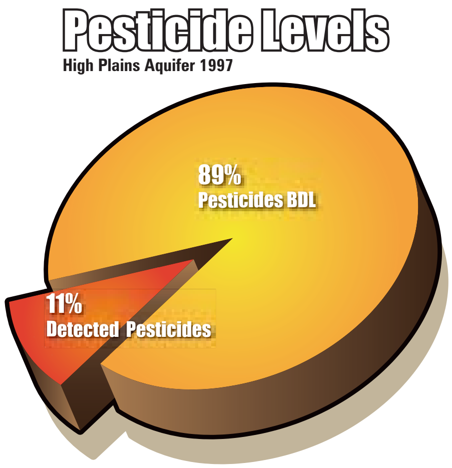
Eight wells, or 6 percent, exceeded the EPA drinking water standard. Of them, five ranged from 13 to 15 ppm. Three tested above 20 ppm.



High Plains Aquifer
1997 Pesticides

Laboratory testing was conducted for 45 different pesticide compounds. Researchers found three of them, plus a breakdown product—prometon, bromacil, and atrazine along with its breakdown product deethyl atrazine.

Of the sample wells, 115, or 89 percent, contained no measurable pesticide levels. The remaining 14 wells, or 11 percent, contained



one or more pesticides. Five wells were near Springfield. Only one exceeded EPA standards, but was no longer used as a drinking water supply.

Gilpin County
2005

Gilpin County is located in the Rocky Mountains' Front Range. Besides Black Hawk and Central City, mountain subdivisions make up all development. A Gilpin County CSU Extension agent contacted the monitoring program in 2004. More than two dozen residents were concerned about weed spraying and development's effect on water quality. The monitoring program was able to accommodate the 27 well owners.

Gilpin County
2005 Nitrate

Researchers found the majority of the area had very minor levels of nitrate contamination. One-third of the wells sampled contained no measurable nitrate levels.

Eighteen wells contained nitrate below the EPA standard. Fifteen of them were below 5 ppm nitrate-nitrogen. None exceeded the drinking water standard.

Gilpin County
2005 Pesticides

No pesticides were detected in the area.

Rio Grande Basin, San Luis Valley
1993

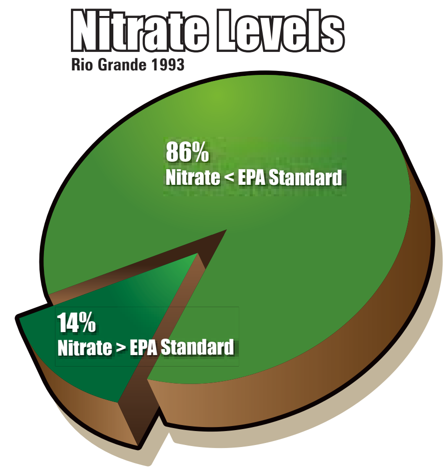
Colorado's portion of the Rio Grande Basin is in south-central Colorado. The Rio Grande and Conejos rivers originate in the eastern San Juan Mountains and are the basin's dominant watersheds. The San Luis Valley is an intermontane valley bounded steeply on the east by the Sangre de Cristo Range and on the west by the San Juan Mountains. The valley includes the eastern half of Saguache, Rio Grande and Conejos counties, plus all of Alamosa and Costilla counties.

During the last 40 years, irrigation increased substantially. Groundwater supplied the rise of center-pivot irrigation systems. To date, more than 1,600 center pivots operate in the valley. The San Luis Valley is of interest to the monitoring program because of the intensively irrigated agriculture overlaying a large, shallow aquifer.

Ninety-three domestic wells were sampled in 1993 in an effort to monitor the entire unconfined aquifer and establish the possible impacts and magnitude of agricultural chemical contamination.

Rio Grande Basin, San Luis Valley
1993 Nitrate

Laboratory test results indicated nitrate affected portions of the area. Of the 93 wells sampled, 80, or 86 percent, contained nitrate



but were below the EPA drinking water standard. The remaining 13, or 14 percent, exceeded the EPA drinking water standard.

Elevated nitrate levels above the EPA drinking water standard appeared east and southeast of Center and in the southwest corner of Alamosa County and southeast corner of Rio Grande County.

Rio Grande Basin, San Luis Valley
1993 Pesticides

The laboratory tested for 27 pesticides. Three—hexazinone; 2, 4-D; and 3 lindane—were detected. Ninety of the wells sampled, or 97 percent, had no measurable pesticide levels. The remaining 3 percent contained a pesticide. Only one well contained lindane at 0.29 ppb, exceeding the EPA drinking water standard of 0.20 ppb.

Center pivot irrigation, Rio Grande Basin, San Luis Valley

Rio Grande Basin, San Luis Valley
2000

The Groundwater Protection Program and USGS conducted a joint project in 2000 to sample 35 dedicated monitoring wells. Originally installed in 1993 by the USGS' National Water-Quality Assessment Program (NAWQA), the wells were part of the state program's Rio Grande Basin groundwater quality study.

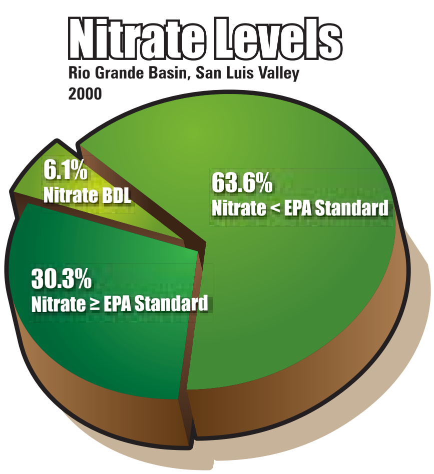
The project's purpose was to obtain more recent groundwater quality information and determine changes from the 1993 NAWQA sampling; derive the age of groundwater samples through special techniques to learn more about the valley's groundwater recharge system; and acquire a high quality data set to use in an aquifer vulnerability modeling project with the USGS.

Of NAWQA's original 35 wells, 33 were sampled. One was dry and another unavailable. NAWQA sampled the wells using an ultra-clean sampling technique and the USGS National Water Quality Laboratory performed the analysis.

Rio Grande Basin, San Luis Valley
2000 Nitrate

A comparison of nitrate results between 1993 and 2000 suggests little change in nitrate contamination. The mean nitrate-nitrogen concentration dropped slightly, from 8.95 ppm in 1993 to 8.77 ppm in 2000. The median value slightly increased from 3 ppm in 1993 to 3.10 ppm in 2000, with 15 wells increasing in concentration and 16 decreasing. Twenty-one of the wells sampled, or 64 percent, had nitrate, but were below the EPA standard. In fact, 17 of these wells tested below 5 ppm.

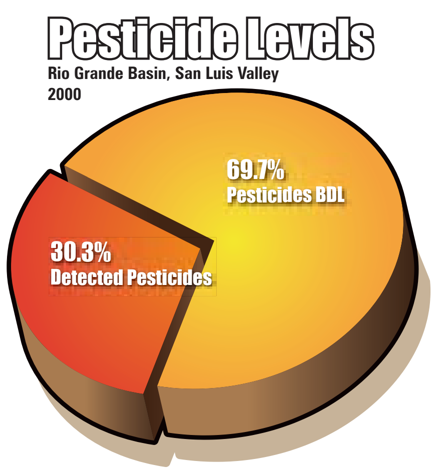
Ten wells, or 30 percent, exceeded the EPA drinking water standard and two contained no measurable nitrate.



Rio Grande Basin, San Luis Valley
2000 Pesticides

Two pesticides, metolachlor and metribuzin, were detected. Twenty-three of the wells, or 67 percent, did not contain measurable levels of any tested pesticides. The remaining 10 contained pesticides, but all were below established standards.

In the 1993 NAWQA sampling, metribuzin was detected in six wells and metolachlor in four wells. No pesticides above an EPA drinking water standard were detected in the 1993.



North Park, Jackson County
2000

In 2000, a groundwater quality study began in Jackson County's North Park, a distinct drainage basin in north-central Colorado's intermontane region. National forest borders the park's east, south, and west sides. Cattle ranching and irrigated hay production dominate land use.

North Park, Jackson County
2000 Nitrate

The study area, according to laboratory tests, showed no significant nitrate impact. Results ranged from no nitrate detection to a high of 9 ppm nitrate-nitrogen (NO_3-N). No well exceeded the EPA drinking water standard.

Ten of the 21 domestic wells sampled, or 48 percent, did not contain a measurable level of nitrate. The 11 others, or 52 percent, contained nitrate below the EPA drinking water standard.

North Park, Jackson County
2000 Pesticides

None of the wells had measurable levels of any tested pesticides.

Wet Mountain Valley

Wet Mountain Valley, Custer County
2002

In 2002, a regional groundwater quality study was conducted in the portion of the Wet Mountain Valley in Custer County. The valley, an intermontane basin approximately 50 miles west of Pueblo, is bounded by the Sangre de Cristo Mountains on the southwest and the Wet Mountains on the northeast. The region's principal aquifer is in the central portion of the valley. Secondary aquifers occur throughout the adjacent Wet Mountains.

Groundwater depth ranges from less than 10 feet over broad areas of the valley floor to more than 100 feet near the valley margins. A total of 58 privately owned domestic wells were sampled in this study area. The well network assembled for this project was a joint effort with the USGS Pueblo subdistrict and Custer County. While USGS utilized the wells in a water supply study for Custer County, coverage was not uniformly distributed. Efforts were concentrated in areas representative of recent development. All geographic and hydrogeologic areas were represented in the study.

Wet Mountain Valley, Custer County
2002 Nitrate

Of the 58 wells sampled, the majority had minor levels of nitrate contamination. For instance, 47 wells, or 81 percent, contained nitrate within the EPA drinking water standard. All but seven of the wells tested below 2.5 ppm.

Ten wells, or 17 percent, did not contain a measurable level of nitrate and only one slightly exceeded the standard, with 11.6 ppm.

Wet Mountain Valley, Custer County
2002 Pesticides

One well was positive for picloram at a level within the EPA drinking water standard.

Front Range Urban Corridor
1996

The 1996 Front Range urban corridor sampling was the Groundwater Protection Program's first attempt to determine how urban use of agricultural chemicals affects groundwater. Fertilizers and pesticides are applied to residential, commercial, and public landscapes, including parks and golf courses.

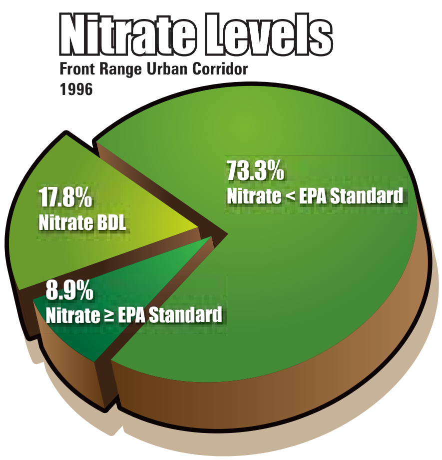
Finding sampling sites in urban areas presented new challenges. The majority of the study area had few known existing wells. The ones still in operation were mainly on the fringe of areas annexed by cities after primary development. Well coverage was not uniformly distributed or representative of most of this study area. The sample number was correspondingly lower in comparison to the rural sites.

In all, technicians sampled 90 wells, most privately owned and permitted for domestic use.

Front Range Urban Corridor
1996 Nitrate

Almost three-quarters of the samples—66 of the 90, or 73 percent, contained nitrate below the EPA drinking water standard—below the nitrate levels found in some irrigated agricultural areas.

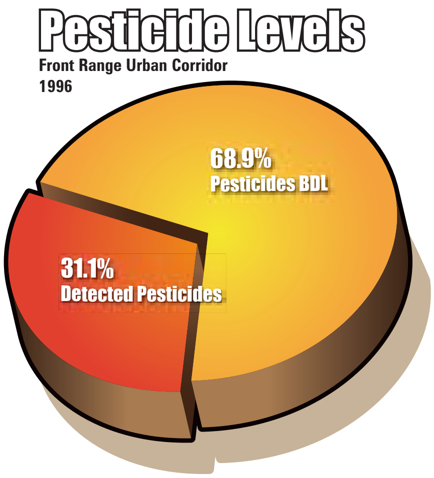
Nearly a fifth—16 wells—did not contain a measurable nitrate level. And eight wells, or 9 percent, exceeded the EPA drinking water standards.



Front Range Urban Corridor
1996 Pesticides

The lab tested for 46 pesticides. Three—atrazine, prometon and bromacil—were detected. The breakdown product of atrazine, deethyl atrazine, was present in several samples.

Sixty-two wells, or 69 percent, contained no measurable pesticide.



The remaining 28, or 31 percent, contained one or more pesticides. All but two contained prometon and every well was within EPA drinking water standards.

The Front Range's population density creates special monitoring challenges.

Front Range Urban Corridor
2005

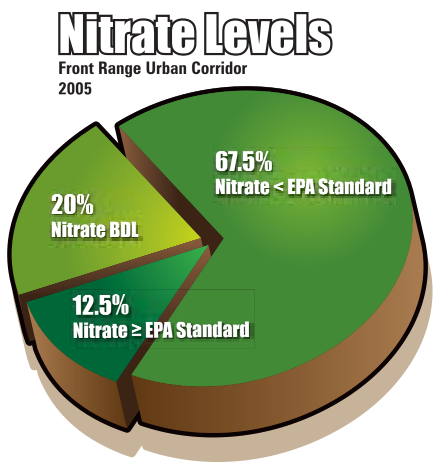
Continued monitoring of the Front Range urban corridor is a priority for the Groundwater Protection Program. Although urban areas do not generally have large tracts used for farming, they do use pesticides and fertilizers for residential and public landscaping, as well as household insect control.

The Front Range corridor's development density creates special considerations and monitoring challenges. The Denver metro area has hundreds of dedicated monitoring wells. The majority was installed for site investigations of leaking underground storage tanks and is unusable for monitoring agricultural chemicals.

To avoid the expense of installing new wells, the monitoring program contacted numerous well owners to enlist their cooperation. Enough of them responded and a Denver area sampling program was launched in 2005. Technicians sampled 40 existing monitoring wells, including four in Greeley, one in Windsor, and the rest in the metro area. The effort will be expanded in the future to include Fort Collins, Colorado Springs and Pueblo.

Front Range Urban Corridor
2005 Nitrate

Laboratory test results indicated most of the study area has minor levels of nitrate contamination. Twenty-seven of the 40 wells sampled, or 68 percent, contained nitrate but were below the EPA drinking water standard. Eight wells, or 20 percent, contained no measurable nitrate and the remaining five, or 12 percent, exceeded the standard.



Front Range Urban Corridor
2005 Pesticides

One pesticide—mecoprop (MCPP)—similar compound to 2,4-D, was detected in three wells, or 8 percent, along the west side of the South Platte River. The pesticide was below the EPA standard.

El Paso County
2006

El Paso County contains a diversity of landforms ranging from Palmer Divide and Black Forest in the north, foothills and Pikes Peak on the west and grass steppe covering most of the county east of Colorado Springs. This reconnaissance survey collected groundwater samples from the shallow bedrock aquifers of the Denver Basin and alluvial aquifers along the many streams in the county.

El Paso County agriculture mostly consists of irrigated alfalfa hay, some cash crops, a few turf production operations and grazing of rangeland. Urbanization is the other major land use. The expansion of the city's edge, plus an increasing density of sub-divisions evolving in neighboring rural areas, is creating the likelihood of an even more complex array of nitrate and/or pesticide pathways that may affect groundwater quality. Consequently, monitoring the groundwater in El Paso County for agricultural chemicals is appropriate.

Various well types—domestic, stock, municipal—were sampled in this survey. Priority was given to shallow wells in the alluvial aquifers of various streams, including Bracket, Squirrel and Fountain creeks. The monitoring program sampled 49 wells, a majority of them domestic.

El Paso County
2006 Nitrate

The laboratory analysis for nitrate concentrations demonstrated that contamination was not a pressing concern in El Paso County. Wells in alluvial aquifers influenced by agricultural activities contained nitrate at higher amounts than other areas in the county. Forty-two of the wells tested, or 86 percent, contained nitrate but were below the EPA drinking water standard. Six, or 12 percent, contained no measurable level of nitrate, and only one well exceeded the drinking water standard.

El Paso County
2006 Pesticides

No detectable concentrations were found.

Monitoring Summary

The Groundwater Protection Program has learned much about Colorado's groundwater quality during 15 years of monitoring. In fact, this data is the largest set of Colorado groundwater quality information with respect to pesticides and nitrate that exists today. In addition, water quality data on many inorganic constituents was collected. While not reported in this publication, it can be found on the Groundwater Protection Program's online database. The Web address is provided in the references.

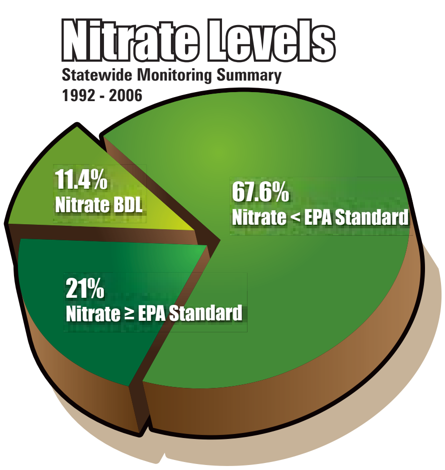
Monitoring Summary Nitrate

Several areas of the state have been identified as having significant nitrate contamination at levels that exceed the drinking water standard. Included are portions of the South Platte alluvial aquifer, the San Luis Valley unconfined aquifer and smaller sections along the Arkansas River. Because of the findings, the program will focus attention on more intensive monitoring and educational efforts to prevent additional contamination and improve management.

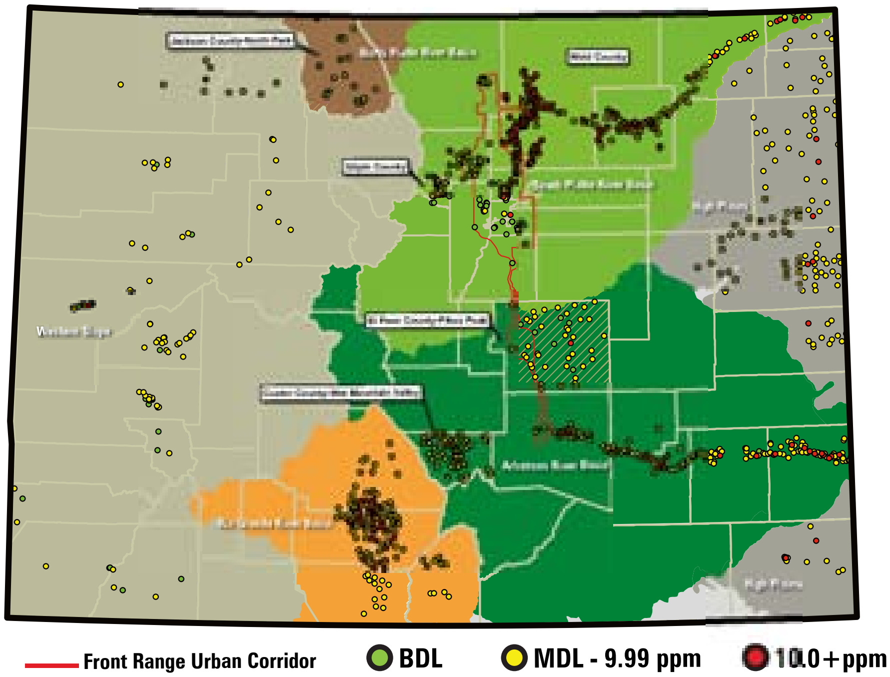
Statewide nitrate monitoring data shows that nearly a third—741 wells or 68 percent—contained nitrate, but were below the EPA drinking water standard.

Slightly more than a fifth—230 wells or 21 percent—exceeded the drinking water standard.

And, 125 wells, or 11 percent, contained no measurable level of nitrate.



Statewide Summary, Nitrate-Nitrogen, 1992-2006

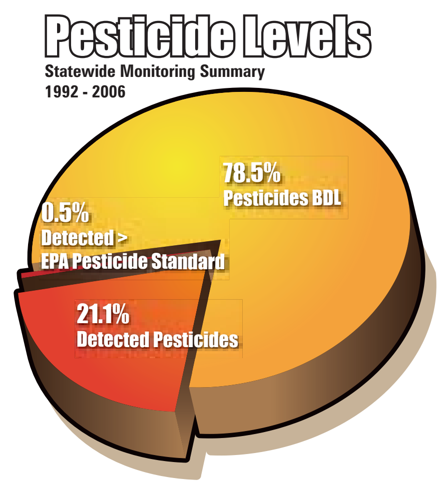


Monitoring Summary Pesticides

In comparison to nitrate contamination, pesticide detections are relatively rare and occur at very low concentrations. More than 80 percent of pesticide detections are herbicides, or weed killers. The top three are the compounds atrazine and its breakdown products, metolachlor, and prometone. Pesticide detections above a drinking water standard are extremely rare. Statewide pesticide monitoring to date shows 856 wells—78 percent—contain no measurable pesticide levels.

Roughly one-fifth, 230 wells, had one or more pesticides, but all were within EPA drinking water standards. Most of these pesticide detections are less than one ppb. Less than half a percent, six wells, exceeded a EPA drinking water standard.

The Groundwater Protection Program online database mentioned above was launched in 2007. It is designed to provide the general public and government entities quick and efficient access to Colorado groundwater quality information. The database will be updated as this program conducts future monitoring in similar and new environments. Hopefully, the database will increase the program's exposure and spur interaction with other agencies and entities previously unaware of this information.

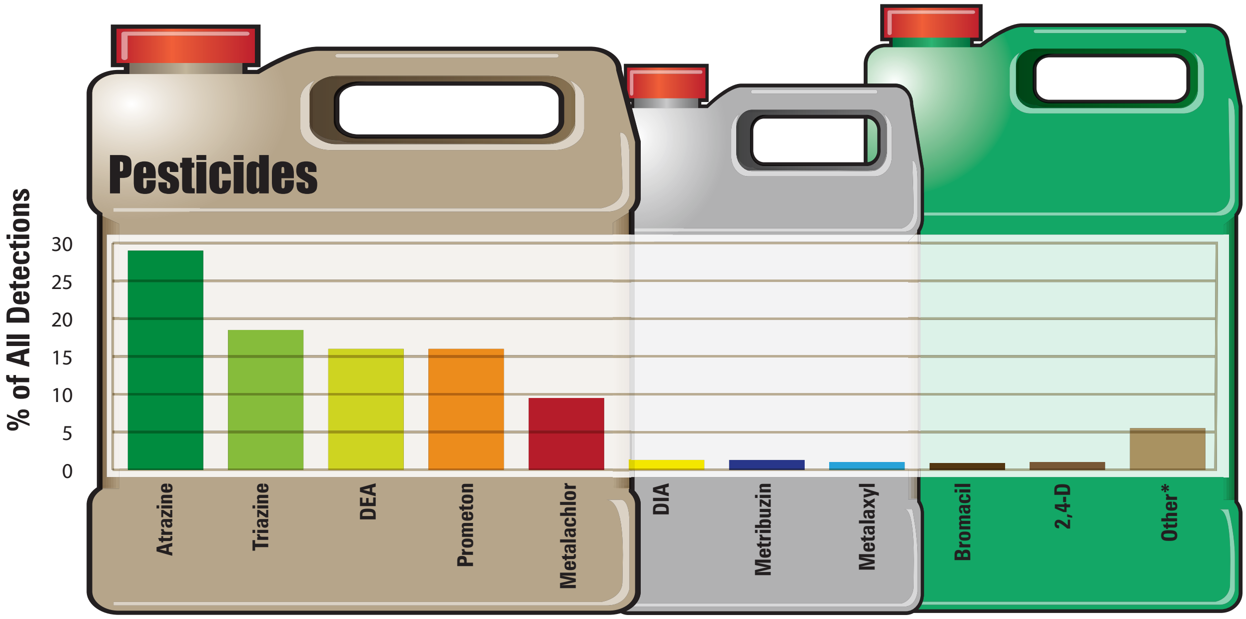


References

The Agricultural Chemicals and Groundwater Protection Database System: http://ids-nile.engr.colostate.edu/webkit/Groundwater/index.html

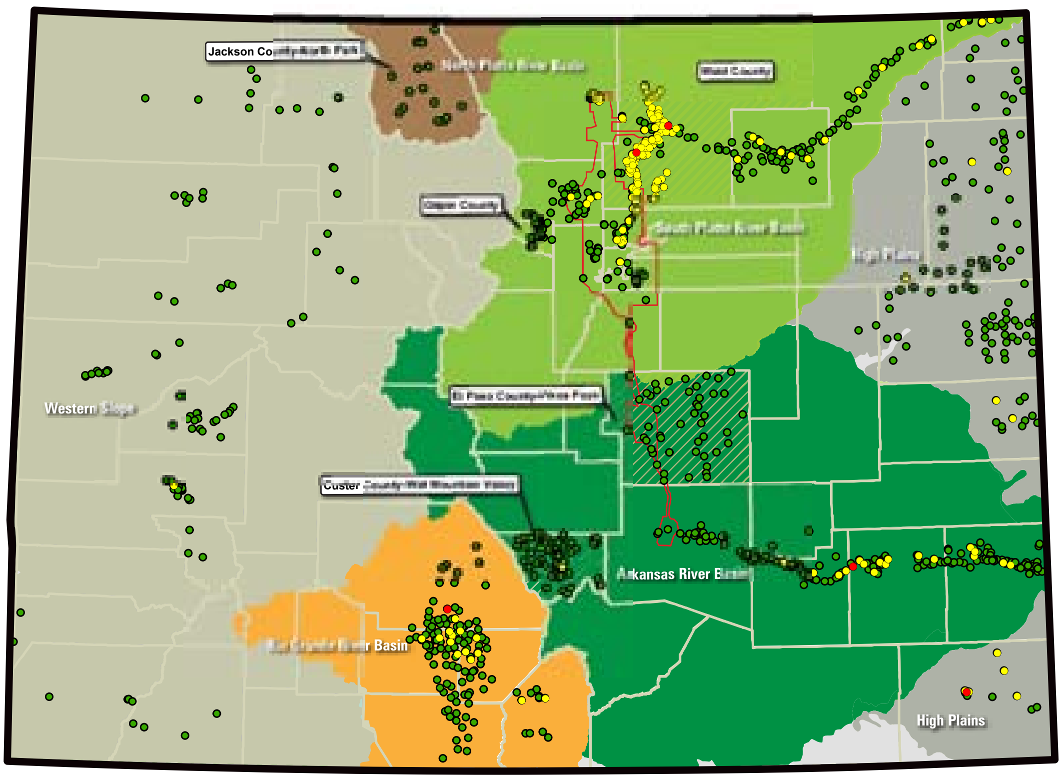
US Environmental Protection Agency, 2008. Groundwater & Drinking Water. http://www.epa.gov/safewater/standard/setting.html

Summary of Statewide Pesticide Detections



From 1992-2006, researchers detected one or more pesticides in 220 of 1096 (20.97 percent) wells sampled. The most commonly detected compounds, as seen above, are Atrazine, Triazines (includes Atrazine), DEA (Atrazine breakdown product), Prometon and Metolachlor. All other pesticides mentioned were detected six times or less. Other is a summation of detections (23) of the following pesticides with no one having greater than four detections total: Hexazinone, Dicamba, MCPP, Alachlor, Clopyralid, Malathion, Lindane, Acetochlor, Picloram, Simazine, and DCPA. In 15 years, 18 herbicides, two insecticides and one fungicide were detected in areas monitored by the Program.*

Statewide Summary, Pesticides, 1992-2006



Front Range Urban Corridor | BDL | Detected | MCL Exceeded

Development of Best Management Practice Publications

The Agricultural Chemicals and Groundwater Protection Act (C.R.S. 25-8-205.5) specifies that Colorado State University Extension must provide education and training on how to reduce groundwater contamination from agricultural chemicals.

Numerous BMP guides assist Colorado growers, chemical applicators, landowners, and homeowners in better protecting Colorado's groundwater resources.

CSUE is required to work with the Colorado Department of Agriculture to develop best management practices for Colorado farmers, landowners, and commercial agricultural chemical applicators. The Colorado Water Quality Control Act defines BMPs in this context as "any voluntary activity, procedure, or practice…to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical" (Colorado Revised Statutes, 1990).

Because of the site-specific nature of groundwater protection, chemical users must ultimately select the BMPs appropriate for their situations. The local perspective is necessary to evaluate the practices' feasibility and economic impact. For these reasons, the Groundwater Protection Program Advisory Committee recommends a significant level of local input be solicited before the BMPs are accepted. The Advisory Committee and a technical review team's input and review are also important components.

BMP documents published early in the program include the following fact sheets:

- "BMPs for Water Quality" (1993);
- "BMPs for Turfgrass Production" (1993); and
- "BMPs for Agricultural Chemical Handling, Mixing, and Storage (1994).

In 1995, CSUE published "Best Management Practices for Colorado Agriculture," which included broad BMPs addressing nutrient, pest and water management. This publication, created in notebook form, included chapters about:

- Nitrogen fertilization;
- Phosphorus fertilization;
- Manure utilization;
- Irrigation management;
- Crop pests;
- Agricultural pesticide use;
- Pesticide storage and handling; and
- Private well protection.

The document provides a template for local BMP development committees. Information is updated as needed. For example, the chapters on manure management and private well protection were revised in 1999 and 2005, respectively.

CSUE also piloted a local BMP development process in the Front Range area of the South Platte Basin; San Luis Valley; Lower Gunnison Basin; and the lower South Platte Basin.

Beginning in 1993 in the Front Range/South Platte Basin and San Luis Valley, local working committees—consisting of small groups of producers, consultants, and chemical applicators -- began work on BMP development. Localized BMPs for the Front Range/South Platte Basin were published in "Best Management Practices for Irrigated Agriculture."

San Luis Valley publications included:

- "Best Management Practices for Nutrient and Irrigation Management in the San Luis Valley;"
- "Best Management Practices for Integrated Pest Management in the

San Luis Valley—Potato;" and
- "Best Management Practices for Integrated Pest Management in the San Luis Valley—Small Grains."

In 1995, the Shavano Conservation District began working with local CSU extension agents and producers to develop "Best Management Practices for the Lower Gunnison Basin" appropriate for the West Slope. During 1996, the Lower South Platte Basin local BMP work group was initiated and their findings were published in "Best Management Practices for the Lower South Platte River Basin." Although most of these work groups have been inactive since finishing their local publications, the guides are still distributed at the local and state levels.

Building on these efforts, the first crop-specific BMP publication, "Barley Practices for Colorado—A Guide for Irrigated Production," was published in 1997 with co-

From the beginning of the Groundwater Protection Program, the producers' cost to implement BMPs has been a legitimate concern. In 1996, an economic analysis was performed to determine the cost of implementing BMPs that required purchasing a service or product to adopt the practice.

operation and funding from Coors Brewing Company. In 2003, "Best Management Practices for Colorado Corn" was published with support from the Colorado Corn Growers and through a grant from the EPA Nonpoint Source Pollution Program.

More than 2,500 copies reached corn producers through distribution to Colorado Corn Growers' members, county extension offices, the NRCS and the Groundwater Protection Program.

The greenhouse industry was specifically addressed in "Pollution Prevention in Colorado Greenhouses" in 1998.

From the beginning of the Groundwater Protection Program, the producers' cost to implement BMPs has been a legitimate concern. In 1996, an economic analysis was performed to determine the cost of implementing BMPs that required purchasing a service or product to adopt the practice. This information was condensed into two fact sheets:

- "Economic Considerations of Nutrient Management BMPs," and
- "Economic Considerations of Pest Management BMPs."

In 1999, two fact sheets were produced to summarize the results of a 1997 BMP survey:

- "Water Quality Best Management Practices: What Are Colorado Producers Doing?" and
- "Irrigation Best Management Practices: What Are Colorado Producers Using?"

The survey results are detailed in the BMP assessment section below.

With cooperation from the Extension Colorado Environmental and Pesticide Education Program, CSUE developed and published the pocket-sized "Pesticide Record Book for Private Applicators" for growers to record restricted use pesticide (RUP) applications according to federal law. The booklet also contains water quality and pesticide safety BMPs, sprayer calibration guidelines, and numerous equations and conversions to help private applicators correctly apply pesticides. The record book is typically revised and reprinted at least every two years. CSUE

Pocket-sized record books help producers track restricted pesticide use and irrigation management.

Homeowner's Guides were developed to encourage pesticide and fertilizer BMPs in urban settings.

has distributed approximately 1,500 booklets each year since 1997.

CSUE also developed the pocket-sized "Irrigated Field Record Book" to help growers improve irrigation water management. Records of water application timing and amount are essential to good crop management. Along with record keeping tables and guidance, the booklet contains equations for determining flow, application depth, soil moisture tables, and crop water use information. CSUE cooperated with the NRCS in 2004 to print more than 2,500 copies.

Increasing development in previously rural areas created a new water quality audience—the rural small acreage landowner. While not major users of agricultural chemicals in terms of total product used, new rural residents have the potential to affect water quality. They rely on groundwater for their primary drinking water source and utilize septic systems for wastewater treatment. Thus, there is a need for education to explain how to prevent drinking water supply contamination. In response, "Best Management Practices for Private Well Protection" was revised in 2005 to a more comprehensive publication, "Protecting Your Private Well."

Urban use of pesticides and commercial fertilizers can also have an impact on groundwater resources. In 1996, BMP fact sheets on urban pesticide and fertilizer use were developed and distributed in cooperation with Colorado Springs. Four BMP fact sheets were developed as part of a response to the detection of the insecticide diazinon in Colorado Springs storm water:

- "Homeowner's Guide to Protecting Water Quality and the Environment;"
- "Homeowner's Guide to Pesticide Use Around the Home and Garden;"
- "Homeowner's Guide to Alternative Pest Management for the Lawn and Garden;" and
- "Homeowner's Guide to Fertilizing Your Lawn and Garden."

The series was revised and reprinted in 2002.

Other Educational Efforts

CSUE also uses other avenues to provide information to affected individuals and organizations, as well as the general public. A display booth is used at conferences and trade shows to provide local groundwater quality monitoring results, publications and regulatory information. Throughout the state, extension agents present information on radio shows, in mass media, through news releases and at meetings.

For example, local agents and the Colorado Water Well Contractors Association collaborated to host numerous educational meetings around the state for real estate agents and small rural acreage landowners. CSUE also offers technical assistance to water conservancy districts, groundwater management districts and other local entities interested in helping rural residents.

Two videos, "Protecting Colorado's Groundwater" and "Best Management Practices for Colorado Agriculture," were produced to inform the general public about groundwater quality, agricultural chemicals and the Agricultural Chemicals and Groundwater Protection Act. In the videos, Colorado farmers discuss why voluntary BMP adoption is preferable to a regulatory approach and the need for their continued diligence.

The initiation of the National Certified Crop Advisor (CCA) program in Colorado in 1995 provided another mechanism for training and education. More than 345 individuals have passed the national and state exams and gained sufficient experience to become certified crop advisors in Colorado. More than 190 are currently active registered advisors (Troy Bauder, CSUE, written communication, 2007). They must obtain continuing education credits to maintain their certification. Continuing education affords an ideal opportunity to provide information on chemical use and groundwater protection to advisors and consultants who make recommendations to farmers.

The Internet allows access to information previously unimaginable to former generations. Its increased use by all segments of society, including farmers, provides new ways to reach audiences. Beginning in 1998, a Groundwater Protection Program Web site, www.colorado.gov/ag/csd opened. It offers many program publications and links to other reliable sources. Publications are also available online at CSUE Web sites:

- www.ext.colostate.edu
- www.csuwater.info

Demonstration Sites and Field Days

Field demonstrations are an integral part of illustrating BMPs' effectiveness and practicality. When feasible, the cooperating producer conducts much of the fieldwork and demonstration setup, which increases the BMP's creditability with farmers and their neighbors. Field demonstrations have been conducted with cooperation from organizations such as the Colorado Corn Growers Association, water and soil conservancy districts, the NRCS and agricultural businesses. Specific practices demonstrated include:

- Nitrogen credits in irrigation water and manure;
- Nutrient management planning;
- Irrigation scheduling and system adjustments;
- Surge irrigation;
- Water measurement;
- Soil testing laboratory comparisons;
- Polyacrylamide (PAM) use;
- Pest scouting;
- Pre-sidedress soil nitrate testing (PSNT); and
- Alternative herbicides.

Demonstration sites help to show the effectiveness and practicality of BMPs in real field settings.

Newsletters, news releases, brochures and online communications carry stories of demonstration results. The BMPs' economic value is often highlighted.

Applied Research

Applied research is problem-driven and seeks to develop a product or process that solves the problem. The Groundwater Protection Program has conducted or sponsored applied research intended to develop, test or verify BMP effectiveness and practicality. The work is completed with internal resources as well as external grants. Most were conducted with the collaboration of CSU faculty, USDA/ARS researchers and others. Noteworthy field research projects include:

- Reducing nitrate leaching through in-season nitrate and leaf chlorophyll testing;
- Refining nitrogen credit recommendations for irrigation water nitrate;
- Effectiveness of linear polyacrylamide to prevent sediment and nutrient loss;
- BMP development for corn production;
- Evaluation of atmometers to predict reference evaporation;
- Volatilization of ammonia from sprinkler-applied swine effluent;
- Evaluation of runoff water quality from mountain hay meadows;
- Validation of alternative manure

management systems for confined feeding operations;
- Evaluation of the phosphorus index for predicting phosphorus runoff from irrigated crop fields;
- Impact of surface water quality from high altitude golf courses; and
- Limited irrigation cropping systems.

An atmometer estimates crop water use to help better schedule irrigation.

CSU Extension integrates applied research with demonstration sites and educational field days. The intent is to interest producers in techniques or management practices that protect water quality while maintaining or improving profitability.

Assessing BMP Adoption

Significant resources have been used to develop, encourage, and extend BMPs to producers for irrigated crop production. At the Groundwater Protection Program's inception in 1990, little quantified information existed about the number of Colorado producers using BMPs and where they were. Work began in 1996 to obtain quantifiable information about specific BMPs in use and producers who maintained productivity while protecting the environment. The information is necessary to conduct relevant education programs, research, and training in the areas and topics most needed. The data also helps to document the producers' progress in protecting water quality and to identify where more effort is needed.

Surveys were mailed in February 1997 and December 2001 to obtain information on BMP adoption. The purposes of the second survey were to assess whether growers had changed management practices in the five years since the first one; to gain more detailed information than the first survey; and to explain questions that arose in the first survey.

For both surveys, the USDA National Agricultural Statistics Service determined representative samples of all irrigators in the state from their crop production database. The surveys were mailed to producers who had at least 40 acres of cropland and irrigated at least one crop. A total of 3,281 surveys were mailed in 1997 and 3,240 surveys were mailed in 2001.

Using approximately 50 questions, both confidential surveys asked producers about irrigation, nutrient and pest BMPs on their farms. The surveys asked about practices used anywhere on the respondents' farms, and about a particular "representative field" with field-specific questions.

The results were grouped into six geographic regions: South Platte; Eastern Plains; Arkansas Valley; San Luis Valley; mountains; and Western Slope. Survey authors defined the regions based on known differences in water sources and cropping opportunities.

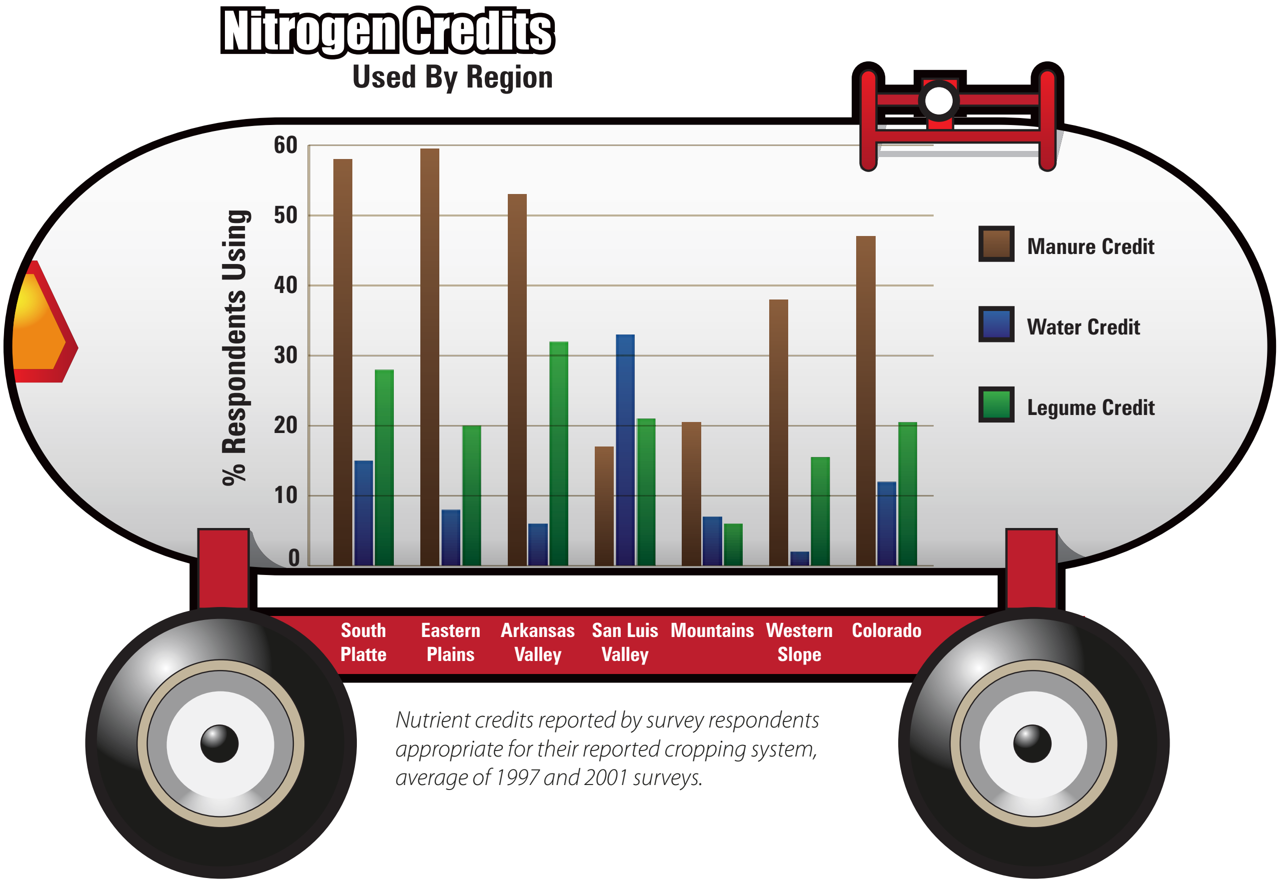
A full description of the 1997 survey methodology and results is published in "Irrigation Management in Colorado: Survey Data and Findings" (Frasier and others, 1999). The 2001 survey methodology and results are published in "Survey of Irrigation, Nutrient, and Pesticide Management in Colorado" (Bauder and Waskom, 2005).

Nutrient Management BMP Adoption

The results show Colorado farmers use key fertilizer and nutrient management BMPs at a reasonable level for their situations.

Statewide, more than half the respondents selected soil test analysis as the most common practice. Less than half, though, said they keep written fertility records. Regional differences among BMP adoption rates reflected cropping diversity, fertilization practices and respondent characteristics.

For example, plant tissue analysis was more commonly reported in areas such as the San Luis Valley where fertigation, or injecting chemicals through an irrigation system, is most prevalent. On the Eastern Plains, producers said they relied on consultants for nutrient management guidance,



Nutrient credits reported by survey respondents appropriate for their reported cropping system, average of 1997 and 2001 surveys.

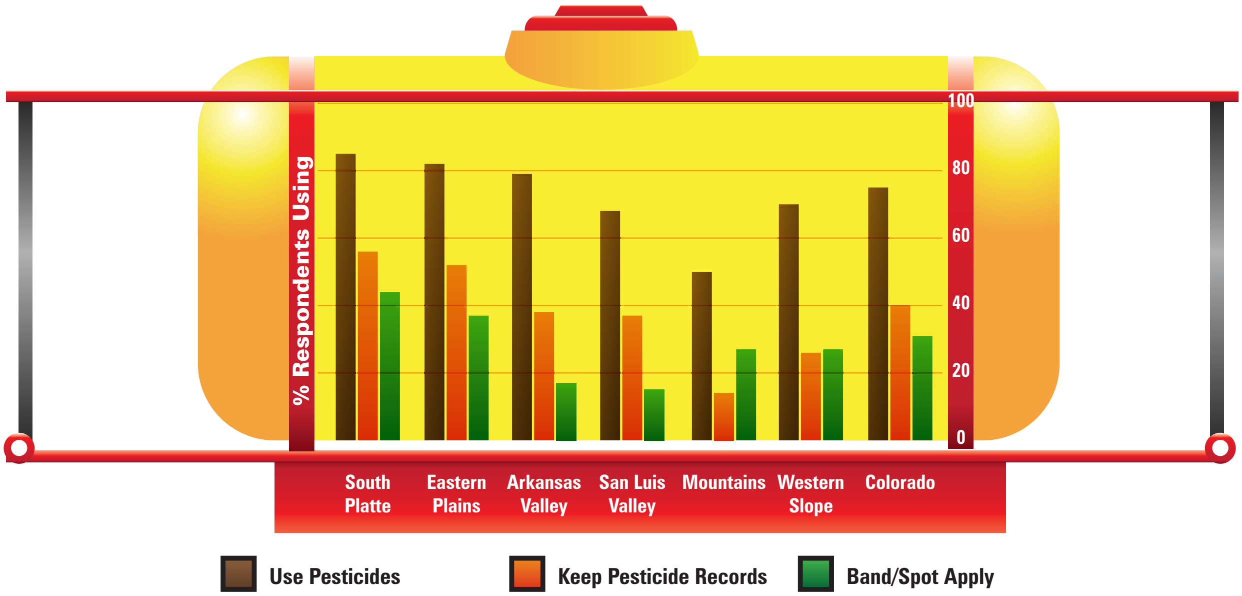
and were more likely to test soil.

Sound nutrient management also requires considering nutrients from other sources in addition to chemical fertilizers. In many areas of Colorado, manure, irrigation water and legume crops can significantly reduce nitrogen requirements. Considerable outreach efforts were focused on helping producers understand the economic and water quality benefits of properly accounting for these nutrient sources, or "nitrogen credits." As shown above, the practice of calculating nutrient credits varied extensively according to the characteristics of the area. For instance, approximately a third of San Luis Valley respondents reported crediting nitrogen received with their irrigation water when calculating their total nitrogen fertilizer needs. The adoption rate is similar to the percent of irrigation wells with nitrate in this area.

Adoption of nutrient management BMPs averaged across 1997 and 2001 surveys.

	Region						
Nutrient BMP	S. Platte	E. Plains	Ark. Valley	San Luis Valley	Mtns.	W. Slope	Colorado
	Percent Respondents Reporting Use						
Soil Test Analysis	73	84	52	55	34	42	57
% Acreage Sampled	49	77	26	50	18	27	45
Plant Tissue Analysis	8	11	4	20	2	6	8
Establish Yield Goals	60	64	52	45	29	36	47
Keep Written Records*	48	50	33	40	27	40	41
Use Crop Consultants	32	42	20	29	8	15	25
None Used**	7	6	12	24	37	15	11

*Question only asked on 2001 survey **No BMPs listed on questionnaire reported



Selected pesticide BMPs reported by survey respondents. Results are an average of the 1997 and 2001 surveys.

Pest Management BMP Adoption

Controlling crop pests—such as weeds, insects and diseases—represents a significant percentage of crop costs. Pesticides, including herbicides, fungicides and insecticides, are frequently used for pest control. However, a wide variety of other practices can be employed, some in combination with pesticides, to manage pests. Many of these practices are included in the concept of Integrated Pest Management (IPM) that is widely promoted over an approach that relies solely on chemicals.

Adoption of pesticide management BMPs averaged across 1997 and 2001 surveys.

	Region						
	S. Platte	E. Plains	Ark. Valley	San Luis Valley	Mtns.	W. Slope	Colorado
Pesticide BMP	Percent Respondents Reporting Use						
Field Scouting	70	78	64	62	28	46	58
Use Crop Consultants	39	58	27	40	7	13	30
Economic Thresholds	48	59	47	37	7	20	37
Resistant Varieties	37	46	49	29	9	29	33
Crop Rotation	64	68	76	60	5	39	56
Biological Controls	8	13	8	7	6	14	11
Pest Forecasting	14	19	11	20	0	6	12

Field scouting, or the practice of monitoring crops for pest populations, was reported in use by more than 50 percent of the respondents statewide and by more than 75 percent in some areas. In many places, crop consultants perform the field scouting and provide pest control advice to growers. Ensuring the advice is agronomically and environmentally sound is a focus of the Groundwater Protection Program through program educational efforts and involvement of the certified crop advisors.

Record keeping is another IPM practice and recommended BMP that helps growers track outbreaks, reduce pesticide resistance by rotating chemical families, prevent crop damage from carry-over, and reduce liability from misapplied pesticides. Pesticide record keeping is also required by law for restricted use pesticides. However, only 40 percent of pesticide users statewide reported keeping these records. As previously described, the pocket-sized “Pesticide Record Book for Private Applicators” was developed to help growers improve their record keeping.

Irrigation Management BMP Adoption

Irrigation BMPs include both *structural* and *management* improvements. Structural improvements generally include upgrades to existing irrigation systems or changes to a different system. Many are intended to increase the irrigation uniformity and/or efficiency of a particular system. Frequently, installation costs are shared with the NRCS. Producers chose to implement some of the recommended structural BMPs, while other recommended BMPs are less popular. For example, the adoption of surge valve use is not expanding in many areas of the state, even though several entities promote it, particularly in the South Platte Basin. Among center pivot irrigators, drop nozzles and low pressure systems are popular, but low-energy precision application (LEPA) is not.

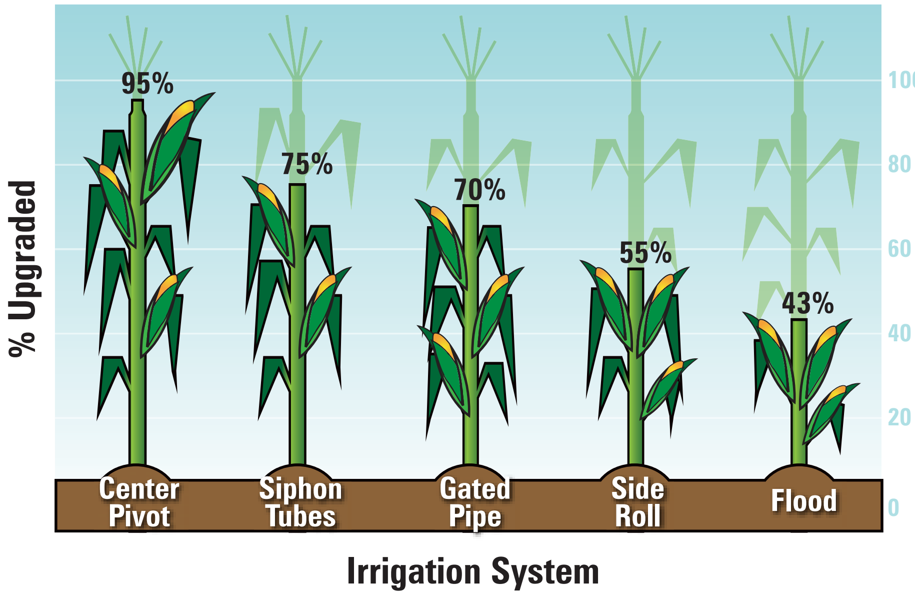
Two key irrigation BMPs are determining when to water and how much to water at each irrigation. The management BMPs help prevent under- and overwatering. The percentage of growers reporting the use of irrigation management BMPs was lower than structural BMPs, suggesting this area requires more attention. While careful use of nutrient or pesticide inputs generally offers a cost savings to producers, the same is not always true for water. This dilemma was reflected in the methods respondents reported using to determine when to water. More precise scheduling methods, such as monitoring soil moisture and evapotranspiration (ET), had lower use than less precise scheduling methods like crop appearance and the producer's experience.

Irrigation BMPs have more physical and policy barriers than nutrient or pesticide BMPs. Lack of control over when and how water is delivered can significantly affect irrigation scheduling. This is reflected by groundwater users, who have more control over their water supply than surface water users, reporting higher use of more precise irrigation timing methods, such as soil moisture and ET, or crop water demand.

Irrigation scheduling methods reported being used by respondents in 2001-2002 survey. Percentages do not sum to 100, because respondents selected more than one method.

Methods Used to Schedule Irrigation	Respondent's Water Source		
	All Surface Water	All Ground Water	Mixed Water
	% Using Method		
Experience	48	43	60
Crop Appearance	37	30	51
Ditch Schedule	28	2	33
Fixed Number of Days	22	9	19
Crop Consultant	1	30	10
Soil Moisture Methods*	8	42	18
ET Methods**	2	9	12
Other	23	28	12

*Sum of soil probe, tensiometers, gypsum blocks
**Sum of atmometers, weather station, and computer program



Irrigation system upgrades reported from 1997 survey.
Options given in survey for selecting irrigation system upgrades:

LEPA	Corner catcher	Surge valves
Drop nozzles	Flow meters	None apply
Low pressure sprinklers	Lined ditches	Other
Computer controller	Field leveling	

Center pivot irrigation

Overall BMP Adoption

For almost every BMP category, the region, farm size and income level, cropping system, irrigation water source, and other factors influence the choices producers make. BMP adoption rates are typically higher among growers who use commercial fertilizers and pesticides, which indicates a key audience is being reached. Implementation of more specialized BMPs, such as biological controls, pest forecasting, and nutrient crediting is lower. This may indicate a greater level of knowledge required to use some BMPs and a limited applicability to many cropping systems.

Overall, the two surveys suggest producers accept many of the irrigation, pesticide, and nutrient management BMPs that help protect water quality and farm profitability. Adoption of nutrient and pesticide management BMPs is generally higher than irrigation management BMPs. Irrigation system improvements, or structural BMPs, are common in most regions. But adoption of irrigation management BMPs used to determine when and how much to water is not as common.

Practices that have an obvious economic benefit, such as soil sampling and pest scouting, seem to be used more often than those where the economic return is less obvious. For example, record keeping for pest, nutrient and irrigation water is not widely practiced, as growers likely do not believe they will benefit from the time invested. However, there were considerable differences in adoption rates between region, crop mix, water source and irrigation system. Water source, either groundwater or surface water, appeared to have the largest impact on irrigation management. The majority of growers did not report making a management change on their representative fields in the last five years, illustrating the difficulty of making such changes in irrigated agriculture.

Conclusion

Colorado growers have come a long way towards adopting many effective BMPs, but may never achieve full adoption of all defined BMPs. However, full adoption may not be required or necessary to meet water quality goals in many situations. Additionally, new technologies, farming methods, crops and other circumstances continue to redefine BMPs and the ease with which they can be adopted. The recent advances in precision agriculture and sub-surface drip irrigation illustrate how technology pushes and enables BMP adoption. All sectors of the agricultural community must continue working to improve and implement the practices that protect Colorado's water resources. The Groundwater Protection Program's educational program will be a key to helping the agricultural community meet this challenge.

References

Bauder, T.A. and R.M. Waskom. 2005. Survey of irrigation, nutrient, and pesticide management in Colorado: Colorado State University, Agricultural Experiment Station Technical Report, TR05-07, 51 p.

Frasier, W.M., Waskom, R.M., Hoag, D.L. and T.A. Bauder. 1999. Irrigation management in Colorado: survey data and findings: Colorado State University, Agricultural Experiment Station Report Technical Report, TR99-05, 100 p.

Colorado Revised Statutes, 1990. Pollution from agricultural chemicals: 25-8-205.5. C.R.S. (1).

Appendix I

Monitoring Well Installation Procedures

Well Installation and Sampling

A hollow-stem continuous flight auger drill rig was used to drill monitoring wells. During drilling, the cuttings were logged at 5-foot minimum intervals or whenever a change in lithology was detected. A 2-foot core sample was taken at each 5-foot interval from the surface to the water table. Borehole samples/cuttings were described and a borehole lithologic log was prepared. Data gathered for each drilled well included:

- Lithologic description and remarks;
- Soil type, color, moisture, and consistency;
- Depth;
- Penetration resistance (blow counts);
- Groundwater depth;
- Perched water zones;
- Borehole diameter;
- Date drilled;
- Method of sample collection and ID number;
- Project identification and location; and
- Well identification and completion data.

All measurements and activities were documented in a field logbook. Well casings were constructed of 2-inch schedule 40 ASTM-approved polyvinylchloride (PVC). Pipe sections were flush threaded to prevent the introduction of contaminants such as glue or solvents into the well. All installed well casing and screens were cleaned prior to emplacement to ensure all oils, greases, and waxes had been removed. After each monitoring well installation, all down-hole drilling equipment was decontaminated with drilling with steam cleaning, Liquinox, and water rinse.

Drilling a monitoring well (above) and the completed well (below).

Well Construction and Completion

In the alluvial materials, the shallower portions of the borehole would typically fail to stand open when the auger was retracted prior to the construction of the monitoring well. Therefore, all monitoring wells were constructed through the hollow axis of the auger column. When the auger column was used as a temporary casing during well construction, the hollow axis facilitated the installation of the monitoring well casing, screen, filter pack, and annular seal. All screened intervals used 10 slot (0.010 inch) schedule 40 PVC screen. All filter packs were constructed using 10-20 (mesh) sand. Screened intervals varied based on saturated thickness, but were nominally 20 feet.

The filter pack extended from the bottom of the well screen to approximately two feet above the top of the well screen. The annular seal was constructed by placing sodium bentonite pellets above the filter pack, in the annular space between the well casing and the borehole wall. Potable water was added to the bentonite to complete the seal for all locations above the water table. The annular seal extended from the top of the filter pack to the bottom of the surface seal. A bentonite-cement mixture surface seal was placed from the top of the annular seal to the base of the concrete apron. The concrete apron was used for the remaining annular space to provide for an adequate surface seal and positive drainage.

At completion of the well, a locking surface casing was installed to prevent tampering or the entrance of foreign material. Typical well construction is illustrated on the following page.

Well Development

Following the construction of the monitoring wells, natural hydraulic conductivity of the formation was restored and all foreign sediment removed to ensure turbidity-free ground water samples. Well development was completed two weeks after completion of drilling. All well development equipment was decontaminated with Liquinox prior to use, rinsed twice—first with tap water, then with a final dionized water rinse.

Before initiating the well surging, the well was bailed to ensure water flowed into it. A mechanical method of development, a surge block, was used to force water to flow into and out of the screened interval. Development began above the screened interval and moved progressively downward to prevent the tool from becoming sand locked. Surging and cleaning was continued until little or no sediment could be pulled into the well.

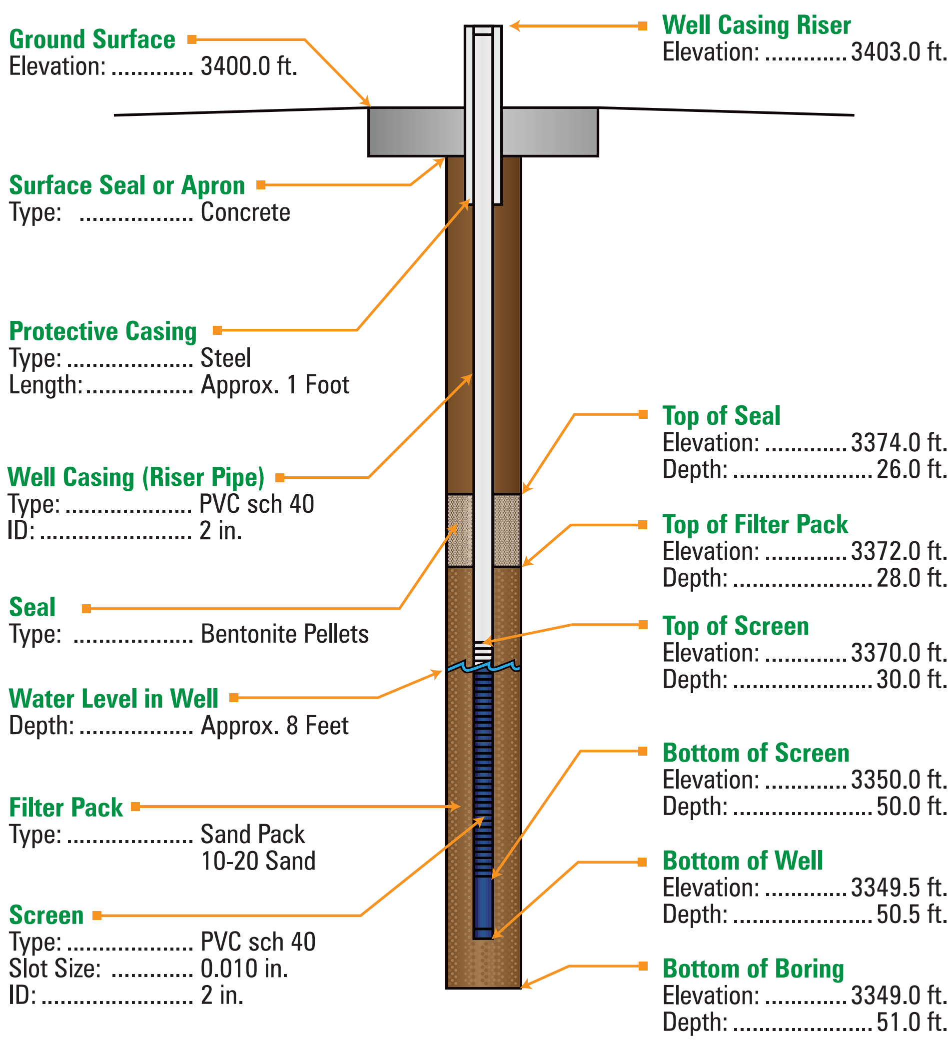
Appendix I

Monitoring Well Installation Procedures

CDA - Ag. Chems & GW Protection Program		**Well Number: MW-01**
DATE DRILLED: 03/04/2004	Location Coordinates	**PROJECT:** Ark River MW Network
INSPECTED BY:		
COMMENTS: Site Details		**JOB NO:**
		INSTALLED BY: Drilling Company

Monitoring Well Construction Diagram

Not To Scale



DATE COMPLETED: 3/4/04
CASING (RISER) ID: .... 2 IN.
SCREEN LENGTH .... 20.0 FT.
SCREEN SLOT SIZE: .... 0.010 IN.

ALL ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

Appendix II

Well Sampling Procedures

Sampling of all well types—domestic, livestock, irrigation and monitoring—includes protocols for wellhead inspection, well purging, sample collection and storage, quality assurance and quality control (QA/QC) and equipment decontamination. This section provides a general description of protocol used by the Groundwater Protection Program during well sampling. A more detailed protocol is available by contacting Groundwater Protection Program staff.

Wellhead Inspection

Proper well construction and maintenance are required to prevent contamination from the ground surface. Thus, each sampling event begins with a thorough inspection of the wellhead and surrounding area.

For monitoring wells this includes checking the protective casing for damage or signs of tampering like a broken lock or well cap, and inspecting the concrete apron poured around the protective casing for cracks or other damage. In the case of flush mount wells it is important to note whether standing water is present under the well cap and the status of the riser cap. When a j-plug type cap is used on the riser and it is not properly installed then standing water under the well cap may enter the well.

If a well's integrity has been compromised and an inspection determines a potential for interference with sample collection or analysis, the well is either removed from the network, repaired, or, in the case of monitoring wells, re-installed.

The condition of domestic and irrigation well casing and seals also are inspected before sampling and potential problems noted in the sampling log. Nearby potential contamination sources—such as chemical storage or containers, chemigation equipment, livestock corrals, or septic systems—are recorded as necessary. With all wells, the general land use surrounding the well is recorded. Locations are found using a global positioning system and coordinates recorded.

Well Purging

Purging a well ensures no stagnant water or plumbing surfaces will interfere with the collection of formation quality water. Generally, for an irrigation well, the ideal time to sample is while a well is running for irrigation. Often the well must be turned on and run for a period of time. Most wells require five to 15 minutes for pH, temperature and specific conductance to stabilize. Water samples are collected when three consecutive test readings stabilized to within 5 percent, which created a reasonable assumption that the well casing and piping were purged and fresh formation water arrived at the sampling point.

Monitoring well and domestic well purging involves the use of a flow-cell and multi-parameter probe which measures dissolved oxygen, pH, temperature, oxidation-reduction potential, and specific conductivity. Purging of a well with this equipment is complete after three consecutive readings are in agreement with the criteria in Table A-1. The measurement interval of the observer is dependent on the flow rate of the pump and the amount of time needed for at least 500 mL of water to flow through the 500 mL flow-cell. When the parameters are stable, the well is ready for sampling.

Sample Collection and Storage

Bottles for the collection of pesticide samples are prepared at the CDA Biochemistry Lab. When a preservative is used, the bottle is not rinsed and is not over-filled so that preservative concentration is preserved.

Samples for nitrate-nitrogen are collected in a translucent Nalgene bottle without preservative. Head space on any samples collected is minimized to prevent volatilization losses and the introduction of air to the samples. Care is taken to not excessively agitate the water and to prevent introduction of foreign matter such as air or air-borne contaminants. To minimize degassing, the sampling port is operated at a low volume. In addition, samples for volatile constituents are collected first, nitrate and inorganic samples collected next, and dissolved metals samples collected last. Dissolved metals samples are filtered in the field with a 0.45 micron filter.

All samples are handled and preserved in accordance with the lab requirements

Table A-1. A flow-cell and multi-parameter probe are used to determine target stabilization criteria parameters for adequate purging of a well. When three consecutive readings are within the desired range for all four parameters, the well is purged. The reading interval is variable and is dependent on the pump flow rate. The accuracy and range for probes associated with the YSI 556-MPS are shown.

		YSI 556-MPS	
Parameter	Desired	Accuracy	Range
pH	± 0.2	± 0.2	0 – 14
sEC	± 5%	± 0.5% of reading or ± 0.001 mS/cm, whichever is greater	0 - 200 mS/cm
ORP	± 20 mV	± 20 mV	
DO	± 10%	0-20 mg/L: ± 2% of reading or 0.2 mg/L, whichever is greater	0 - 200 %
		20-50 mg/L: ± 6% of reading	200 - 500 %

Appendix II

for each particular analysis. Upon collection of the samples, all bottles are placed or wrapped in a cushioning bubble wrap. Samples are promptly placed in a cooler with ice in order to maintain sample temperature at 10°C or less. Samples are protected from undue exposure to light during handling, storage, and transport. Transport of the samples to the laboratory is completed within holding times—two days for nitrate and seven for pesticide samples, since time of collection.

Irrigation well samples are collected at a discharge point that has not been compromised by chemigation equipment or surface contamination. Domestic well samples are collected from hydrants, outside faucets, or other means available prior to any type of treatment such as a water softener.

All samples are handled in accordance with standard laboratory chain of custody procedures after collection and identification. A completed chain of custody record accompanies the samples and is signed by both the sampler and the laboratory employee receiving the samples.

Equipment Decontamination

Any equipment used to collect a groundwater sample from more than one location is thoroughly decontaminated. Such equipment could include a pump, associated tubing, or glass collection jugs (used when collecting irrigation well samples) depending on well type and situation. In general, all potentially contaminated surfaces are triple rinsed with each of the following: Liquinox soap in tap water, laboratory grade deionized water, and 50/50 (v/v) reagent grade methanol in deionized water. After decontamination, care is taken to prevent dust or foreign liquids, such as rain or snow, from coming in contact with sampling equipment.

Quality Assurance and Quality Control (QA/QC)

The sampling team collects quality assurance/quality control (QA/QC) samples of rinsate blanks, duplicate samples, split samples, and spiked samples. Field blanks are utilized for field QA/QC and subjected to the same conditions as all other collected samples. Duplicate, split, and spiked samples are prepared for lab calibration checks. A brief description of the four QA/QC sample types:

Rinsate Blank

A blank, or pure, water sample is periodically tested in field sampling equipment to check the effectiveness of field decontamination procedures. Deionized water in decontaminated sampling equipment is tested, and would produce no contaminant results if effective field decontamination procedures are followed.

Duplicate Samples

Duplicate groundwater samples, or multiple identical samples, are randomly and periodically collected and tested at the same lab, which produces nearly identical results if effective field collection and lab analysis procedures are followed.

Split Samples

Duplicate samples are periodically split between two labs for independent analysis, which produces nearly identical results if effective field collection and lab analysis procedures are followed.

Spiked Samples

Spiked samples are samples with a known concentration of pesticide added to them, and are submitted for lab analysis to assess laboratory performance. Spiked samples are prepared in duplicate in accordance with instructions provided by the spiking kit manufacturer.

Appendix III

Analytes, Laboratory Methods and Minimum Detection Limits

Pesticide Common Name	Pesticide Trade Name	Pesticide Use	Chemical Type	*EPA Method	**MDL Low (ppb)	**MDL High (ppb)
1-Naphthol	BP[1]	insecticide	carbamate	531.1	0.67	2.125
2,4-D	Weed B-Gone	herbicide	phenoxyAcid	515.2	0.1	0.2
2,4,5-T	Weedone	herbicide	phenoxyAcid	515.2	0.1	0.1
2,4,5-TP	Silvex	herbicide	phenoxyAcid	515.2	0.0303	0.3
2,6 Diethylaniline	BP[1]	herbicide	organoCL	USGS	0.003	0.003
3-Hydroxycarbofuran	BP[1]	insecticide	carbamate	531.1	0.28	2
Acetochlor	Harness	herbicide	acetoalinide	525.1	0.082	0.104
Alachlor	Lasso	herbicide	organoCL	525.1	0.076	2
Aldicarb	Temik	insecticide	carbamate	531.1	0.38	1
Aldicarb sulfone	BP[1]	insecticide	carbamate	531.1	0.27	2
Aldicarb sulfoxide	BP[1]	insecticide	carbamate	531.1	0.33	2
Aldrin	Aldrex	insecticide	cyclodiene	508	0.75	0.75
Alpha BHC	Alpha-Lindane	insecticide	organoCL	USGS[2]	0.002	0.002
Atrazine	AAtrex	herbicide	triazine	525.1	0.063	0.5
Azinphos methyl	Azimil	insecticide	organoPH	USGS	0.001	2.5
Benfluralin	Balan	herbicide	organoFL	525.1	0.056	0.3
Bromacil	Hyvar X	herbicide	uracil	525.1	0.028	0.46
Butylate	Sutan +	herbicide	thiocarbamate	USGS	0.002	0.002
Captan	Captanex	fungicide	carboximide	525.1	0.165	2.8
Carbaryl	Sevin	insecticide	carbamate	531.1	0.23	2
Carbofuran	Furadan	insecticide	carbamate	531.1	0.36	1.5
Chlorothalonil	chlorothalonil	fungicide	nitrile	525.1	0.1	0.25
Chlorpyrifos	Lorsban	insecticide	organoPH	525.1	0.1	1.2
Clopyralid	Stinger	herbicide	picolinicAcid	515.2	0.071	0.235
Cyanazine	Bladex	herbicide	triazine	525.1	0.178	2.5
DCPA	Dacthal	herbicide	phthalic acid	525.1	0.067	0.3
DDD	BP[1]	insecticide	organoCL	508	0.1	0.1
DDE	BP[1]	insecticide	organoCL	508	0.1	0.1
DDT	DDT	insecticide	organoCL	525.1	0.077	0.4
Deethyl atrazine	BP[1]	herbicide	triazine	525.1	0.056	0.2
Deisopropyl atrazine	BP[1]	herbicide	triazine	525.1	0.185	1.34
Diazinon	Dazzel	insecticide	organoPH	525.1	0.098	2
Dicamba	Banvel	herbicide	benzoicAcid	515.2	0.058	0.437
Dichlobenil	Barrier	herbicide	nitrile	525.1	0.022	0.1
Dieldrin	Dieldrix	insecticide	organoCL	508	0.1	0.1
Dimethoate	Cygon	insecticide	organoPH	525.1	0.104	0.5
Disulfoton	Disyston	insecticide	organoPH	USGS	0.017	0.017
Endosul I	Endosulfan	insecticide	organoCL	508	0.1	0.1
Endosul II	Endosulfan	insecticide	organoCL	508	0.1	0.1
Endrin	Endrix	insecticide	organoCL	525.1	0.1	0.68
EPTC	Eptam	herbicide	carbamate	507	0.5	0.68
Ethalfluralin	Sonalan	herbicide	organoFL	508	0.3	0.3
Ethoprop	Jolt/Menap	insect/nemat[3]	organoPH	USGS	0.003	0.003
Fonofos	Dyfonate	insecticide	organoPH	USGS	0.003	0.003

Appendix III

Analytes, Laboratory Methods and Minimum Detection Limits

Pesticide Common Name	Pesticide Trade Name	Pesticide Use	Chemical Type	*EPA Method	**MDL Low (ppb)	**MDL High (ppb)
Heptachlor	Heptagran	insecticide	organoCL	525.1	0.05	0.6
Heptachlor epoxide	BP[1]	insecticide	organoCL	525.1	0.05	0.8
Hexazinone	Velpar	herbicide	triazine	525.1	0.06	1.5
Lindane	Gamma-mean	insecticide	organoCL	525.1	0.05	0.433
Linuron	ANSI	herbicide	urea	USGS	0.002	0.002
Malathion	Malathion	insecticide	organoPH	525.1	0.072	0.483
MCPA	Agritox	herbicide	phenoxyAcid	515.2	0.014	2
MCPP	Kilprop	herbicide	phenoxyAcid	515.2	0.018	2
Metalaxyl	Ridomil	fungicide	acylalanine	525.1	0.068	0.2
Methiocarb	Mesurol	insecticide	carbamate	531.1	0.6	4
Methomyl	Lannate	insecticide	carbamate	531.1	0.32	1
Methoxychlor	Marlate	insecticide	organoCL	525.1	0.02	0.9
Methyl parathion	Penn/Meta[4]	insect/nemat	organoPH	USGS	0.006	0.006
Metolachlor	Dual	herbicide	acetamide	525.1	0.029	0.1
Metribuzin	Sencor	herbicide	triazine	525.1	0.063	0.977
Molinate	Ordram	herbicide	thiocarbamate	USGS	0.004	0.004
Napropamide	Devrinol	herbicide	amide	USGS	0.003	0.003
Oxamyl	DPX	insecticide	carbamate	531.1	0.34	2
Parathion[5]	Chem. Methyl	insecticide	organoPH	8140	0.5	0.5
Pebulate	Tillam	herbicide	thiocarbamate	USGS	0.004	0.004
Pendimethalin	Prowl	herbicide	dinitroaniline	525.1	0.033	1.2
Permethrin	Permethrin	insecticide	organoCL	508	0.154	2.5
Phorate[6]	Thimet	Tri-use	organoPH	USGS	0.002	0.002
Picloram	Tordon	herbicide	picolinicAcid	515.2	0.171	0.35
Prometon	Primatol	herbicide	triazine	525.1	0.096	2.803
Pronamide	Kerb	herbicide	amide	USGS	0.003	0.003
Propachlor	Ramrod	herbicide	Chloroacetanilide	USGS	0.007	0.007
Propanil	Erban/Rogue	herbicide	anilide	USGS	0.004	0.004
Propargite	Comite	insect/acari[7]	organosulfite	USGS	0.013	0.013
Propoxur	Baygon	insecticide	carbamate	531.1	0.35	1
Simazine	Princep	herbicide	triazine	525.1	0.09	0.2
Tebuthiuron	Spike	herbicide	urea	USGS	0.01	0.01
Terbacil	Sinbar	herbicide	uracil	USGS	0.007	0.007
Terbufos	Counter	insect/nemat	organoPH	USGS	0.013	0.013
Thiobencarb	Bolero	herbicide	thiocarbamate	USGS	0.002	0.002
Triallate	Avadex/Fargo	herbicide	thiocarbamate	USGS	0.001	0.001
Triazines	Triazines	herbicide	Triazine	I.A.[8]	0.05	0.05
Triclopyr	Turflon	herbicide	picolinicAcid	515.2	0.015	0.08
Trifluralin	Treflan	herbicide	organoFL	525.1	0.038	2.5

**EPA Method—EPA is responsible for evaluating analytical methods for drinking water and approving methods that it determines to meet agency requirements. An analytical method is a procedure used to analyze a sample in order to determine the identity and concentration of a specific sample component. Analytical methods generally include information on the collection, transport, and storage of samples; define procedures to concentrate, separate, identify, and quantify components contained in samples; specify quality control criteria the analytical data must meet; and, designate how to report the results of the analyses. Additional information can be found on the EPA Web site at http://www.epa.gov/safewater/methods/methods.html (EPA, 2006).*

***MDL—minimum detection limit; the lowest concentration of a substance that can be measured. Low/high equals lowest and highest MDL obtainable by laboratory in history of monitoring program.*

[1] BP: breakdown product of another pesticide
[2] USGS: analyte follows USGS Schedule 2001/2010 testing procedures
[3] insect/nemat: analyte is both an insecticide and a nematicide
[4] Penn/Meta: full trade names are Penncap M and Metacide
[5] Parathion: full trade name is Cheminova Methyl
[6] Phorate: analyte has three uses: Acaricide, Insecticide, Nematicide
[7] insect/acari: analyte is both an insecticide and an acaricide
[8] I.A.: immuno assay method used for triazine screening

Appendix III

Analytes, Laboratory Methods and Minimum Detection Limits

Non-Pesticide Analyte	Chemical Type	Lab Method	MDL (ppm)
Alkalinity	inorganic	titration	1.0
Aluminum	dissolved metal	EPA 200.0	0.1
Barium	dissolved metal	EPA 200.0	0.1
Bicarbonate	inorganic	ALPHA 2320B	0.1
Boron	inorganic	EPA 200.0	0.01
Bromide	inorganic	not available	0.01
Cadmium	dissolved metal	EPA 200.0	0.01
Calcium	inorganic	EPA 200.0	0.1
Carbon	inorganic	not available	not available
Carbonate	inorganic	ALPHA 2320B	0.1
Chloride	inorganic	EPA 300.0	0.1
Chromium	dissolved metal	EPA 200.0	0.01
Conductivity	inorganic	EPA 120.1	1 [umhos/cm]
Copper	dissolved metal	EPA 200.0	0.01
Fluoride	inorganic	not available	0.1
Hardness	inorganic	calculation	1.0
Iron	dissolved metal	EPA 200.0	0.01
Lead	dissolved metal	EPA 200.0	0.05
Magnesium	inorganic	EPA 200.0	0.1
Manganese	dissolved metal	EPA 200.0	0.01
Molybdenum	dissolved metal	EPA 200.0	0.01
Nickel	dissolved metal	EPA 200.0	0.01
Nitrate-nitrogen	inorganic	technicon	0.5 (1992-1994)
Nitrate-nitrogen	inorganic	EPA 300	0.5 (1994-2000)
Nitrate-nitrogen	inorganic	EPA 300	0.1 (2001-2005)
pH	inorganic	EPA 150.1	0.1
Phosphorus	dissolved metal	EPA 200.0	0.1
Potassium	Inorganic	EPA 200.0	0.1
Sodium	Inorganic	EPA 200.0	0.1
Sulfate	Inorganic	EPA 300.0	0.1
Total dissolved solids	Inorganic	gravimetric	10
Zinc	dissolved metal	EPA 200.0	0.01

Instrument List: CDA Biochemistry and Groundwater Laboratory (2007)

GC/MS Pesticides

- Hewlett-Packard 5890 Gas Chromatograph
- Hewlett-Packard 5972 Mass Spectrometer
- Hewlett-Packard 7673 Autosampler

GC Organophosphate Pesticides

- Hewlett-Packard 6890 Gas Chromatograph
- OI Analytical 5380 Pulsed Flame Photometric Detector
- Hewlett-Packard 7683 Autosampler

LCMS Pesticides (Carbamates, Phenoxy Acids)

- Thermo Finnigan Surveyor Autosampler
- Thermo Finnigan Surveyor Mass Spec LC Pump
- Thermo Finnigan LCQ Duo Mass Spectrometer

IC Anions (Nitrate, Nitrite)

- Dionex Autosampler
- Dionex GP40 Pump
- Dionex CD20 Conductivity Detector
- Dionex LC20 Chromatography Module

Appendix IV

Publications Associated with the Groundwater Protection Program

Annual Reports (1992 – 2006)

"Status of Implementation of Senate Bill 90-126, The Agricultural Chemicals and Groundwater Protection Act," Colorado Department of Agriculture, Colorado State University Cooperative Extension, and Colorado Department of Public Health and the Environment. Authors includedBradford Austin, Troy Bauder, Karl Mauch, Greg Naugle, Reagan Waskom, Robert Wawrzynski, and Mitch Yergert.

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"Agricultural Chemicals and Groundwater Protection Brochure," Brad Austin, Reagan Waskom, Robert Wawrzynski, Mitch Yergert. 1993. Revised biennially.

"Colorado Chemsweep: Colorado Pesticide Waste Collection Program," 1995 – 2007.

"Pesticides and Fertilizers: Does your operation require secondary containment and/or a mixing and loading pad?" 2005. Agricultural Chemicals and Groundwater Protection. Robert Wawrzynski.

Best Management Practices – Bulletin Form

"Best Management Practices for Colorado Agriculture: An Overview," 1994. Colorado State University Cooperative Extension Bulletin XCM-171. Reagan Waskom.

"Best Management Practices for Nitrogen Fertilization." 1994. CSU Cooperative Extension Bulletin XCM-172. Reagan Waskom.

"Best Management Practices for Irrigation Management." 1994. CSU Cooperative Extension Bulletin XCM-173. Reagan Waskom.

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"Best Management Practices for Irrigated Agriculture: A Guide for Colorado Producers." 1994. Colorado Water Resources Research Institute Completion Report No. 184. Reagan Waskom, Grant Cardon, and Mark Crookston.

"Best Management Practices for Nutrient and Irrigation Management in the San Luis Valley." 1994. Reagan Waskom and Steve Carcaterra.

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"Water Quality and Best Management Practices in the Lower South Platte River Basin." 1998. CSU Cooperative Extension Bulletin XCM-210. Mahdi Al-Kaisi in cooperation with the Local BMP Committee of the Lower South Platte River Basin.

"Best Management Practices for Manure Utilization—Revised." 1999. CSU Cooperative Extension Bulletin No.568A. Reagan Waskom and Jessica Davis.

"Best Management Practices for Agriculture in the Uncompahgre Valley—Making Vital Decisions." 1996. Shavano Soil Conservation District and CSU Cooperative Extension.

"Barley Management Practices for Colorado: A Guide for Irrigated Production." 1997. CSU Department of Soil and Crop Sciences. Grant Cardon, Reagan Waskom, Ali Ali, and Jerry Alldredge.

"Pollution Prevention in Colorado Commercial Greenhouses." 1998. CSU Cooperative Extension Bulletin XCM-206. Karen Panter, Steve Newman and Reagan Waskom.

"Best Management Practices for Colorado Corn." 2003. CSU Cooperative Extension Bulletin XCM574A. Troy Bauder and Reagan Waskom.

"Protecting your private well." 2005. CSU Cooperative Extension Bulletin XCM-179. Reagan Waskom and Troy Bauder.

"High Plains Irrigation Guide." 2004. Rachel Barta, Israel Broner, Joel Schneekloth and Reagan Waskom. 2004. Colorado Water Resources Research Institute, Special Publication 14.

Fact Sheets

"Nitrates in Drinking Water." 1992. CSU Cooperative Extension SIA No. 0.517. J.R. Self and Reagan Waskom.

"Regulations Drafted for Bulk Storage and Mixing/Loading Areas." 1992. Ag. Chemicals and Groundwater Protection Fact Sheet. Reagan Waskom and Mitch Yergert,

"Best Management Practices for Water Quality." 1993. Ag. Chemicals and Groundwater Protection Fact Sheet. Reagan Waskom and Mitch Yergert,

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"Best Management Practices for Agricultural Chemical Handling, Mixing, and Storage." 1994. Ag. Chemicals and Groundwater Protection Fact Sheet No.7. Reagan Waskom and Mitch Yergert.

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"Groundwater Monitoring in the San Luis Valley." 1995. Ag. Chemicals and Groundwater Protection Fact Sheet No.9. Brad Austin, Reagan Waskom and Mitch Yergert.

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"Irrigation Best Management Practices: What Are Colorado Producers Doing?" 1999. Ag. Chemicals and Groundwater Protection Fact Sheet No.19. Troy Bauder, Reagan Waskom, Marshall Frasier and Dana Hoag.

"Homeowner's Guide to Pesticide Use Around the Home and Garden." 2002. CSU Cooperative Extension Bulletin. XCM-220. Reagan Waskom and Troy Bauder.

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"Selecting an Analytical Laboratory." Colorado State University Coop. Extension Fact Sheet No.0.520. Revised 2007. Reagan Waskom, Troy Bauder, Jessica Davis and James Self.

Groundwater Monitoring Reports

"Report to the Commissioner of Agriculture, Groundwater Monitoring Activities: South Platte River Alluvial Aquifer—1992-1993; San Luis Valley Unconfined Aquifer—1993; Arkansas River Valley Alluvial Aquifer—1994-1995; Front Range Urban Corridor —1996; West Slope of Colorado—1998; High Plains Ogallala Aquifer—1997-1998." Agricultural Chemicals and Groundwater Protection Program. Brad Austin.

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"Pre-sidedress Nitrate Test (PSNT) Demonstration: Colorado Corn/CSU Demonstration Site Results." 1999. Colorado Corn News, Colorado Corn Growers. Troy Bauder

"Use Nitrogen Credits to Reduce Fertilizer Costs: Colorado Corn/CSU Demonstration Site Results." 2000. Colorado Corn News, Colorado Corn Growers. Troy Bauder

"Alternative Herbicides: Colorado Corn/CSU Demonstration Site Results." 2000. Colorado Corn News, Colorado Corn Growers. Troy Bauder

"Irrigating Corn under Tight Nitrogen Budgets: Colorado Corn/CSU Demonstration Site Results." 2000. Colorado Corn News, Colorado Corn Growers. Troy Bauder

Appendix IV

Publications Associated with the Groundwater Protection Program

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"Pesticide Record Book for Private Applicators." 1997. Colorado State University Cooperative Extension Publication XCM-202. Troy Bauder, Sandra McDonald and Reagan Waskom. Revised and reprinted in 1999, 2001 – 2002, 2003, 2005.

"Irrigated Field Record Book." 2004. Colorado State University Cooperative Extension Publication XCM-228. Troy Bauder and Joel Schneekloth. Revised and reprinted 2005 and 2007.

"Pesticide Record Book for Private Applicators—Microsoft Excel Version." 2005. Mary Jay Vestal and Troy Bauder.

"Pesticide Record Book for Private Greenhouse Applicators." 2005. Colo. Colorado Environmental Pesticide Program. Sandra McDonald and Troy Bauder.

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"Pre-sidedress nitrate soil testing to manage nitrogen fertility in irrigated corn in a semi-arid environment." 1996. Communications in Soil and Plant Analysis 27:561-574. Spellman, D.E., A. Ronaghi, D.G. Westfall, R.M. Waskom and P.N. Soltanpour.

"Sensitivity of ground water resources to agricultural contamination in the San Luis Valley, Colo." 2000. GSA Abstracts Vol. 32, No. 5:A-34. Kyle Murray, John McCray, Reagan Waskom and Bradford Austin.

"The effect of variations in hydrogeologic and physicochemical transport properties on the model-predicted vulnerability of Colorado groundwater to pesticides." 2000. GSA Abstracts Vol. 32, No. 5:A-37. S. A. Schlosser, J.E. McCray, and R.M. Waskom.

"Regional nitrate leaching variability: What makes a difference in northeast Colorado." 2001. Journal of the American Water Resources Association. Vol. 37, No 1:139-144. Hall, M.D., M.J. Shaffer, R.M. Waskom and J.A. Delgado.

"Irrigated mountain meadow fertilizer application timing effects on overland flow water quality." 2003. Journal of Environmental Quality: 32-1802-1808. S.K. White, J. E. Brummer, W.C. Leinenger, G.W. Frasier, R.M. Waskom and T.A. Bauder.

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"Vulnerability assessments of Colorado ground water to nitrate contamination." 2004. Water, Air, and Soil Pollution 159 (1): 373-394. Zac Ceplecha, Reagan Waskom, Troy Bauder, Jim Sharkoff and Raj Khosla.

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"Agricultural Chemical Bulk Storage and Mix/Load Facility Plans for Small to Medium-Sized Facilities." 1995. CSU Cooperative Extension and Colorado Department of Agriculture. Lloyd Walker. Revised in 2002 by Robert Wawrzynski.

"Irrigation Management in Colorado - Survey Data and Findings." 1999. Colorado Agricultural Experiment Station Technical Report TR 99-05. Marshall Frasier, Reagan Waskom, Dana Hoag and Troy Bauder.

"Generic Groundwater Pesticide Management Plan for the State of Colorado." 2000. Colorado Department of Agriculture. Mitch Yergert, Robert Wawrzynski, Reagan Waskom, Troy Bauder and Brad Austin.

"Estimating Cost of Adoption for Irrigation, Pest, and Nutrient Management Best Management Practices in Colorado." 2001. CWRRI Technical Report for the Colorado Department of Public Health and Environment. William M. Frasier, Reagan Waskom, Troy Bauder, and Brett Jordan.

"Colorado Phosphorus Index Risk Assessment Version 2.0." 2002. USDA-NRCS Agronomy Technical Note No. 95. Jim Sharkoff, Reagan Waskom and Jessica Davis.

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"Center Pivot Irrigation in Colorado as Mapped by Landsat Imagery." 2004. Colorado State University Agricultural Experiment Station Bulletin TB04-04. Troy Bauder, Jan Cipra, Reagan Waskom and Michael Gossenauer.

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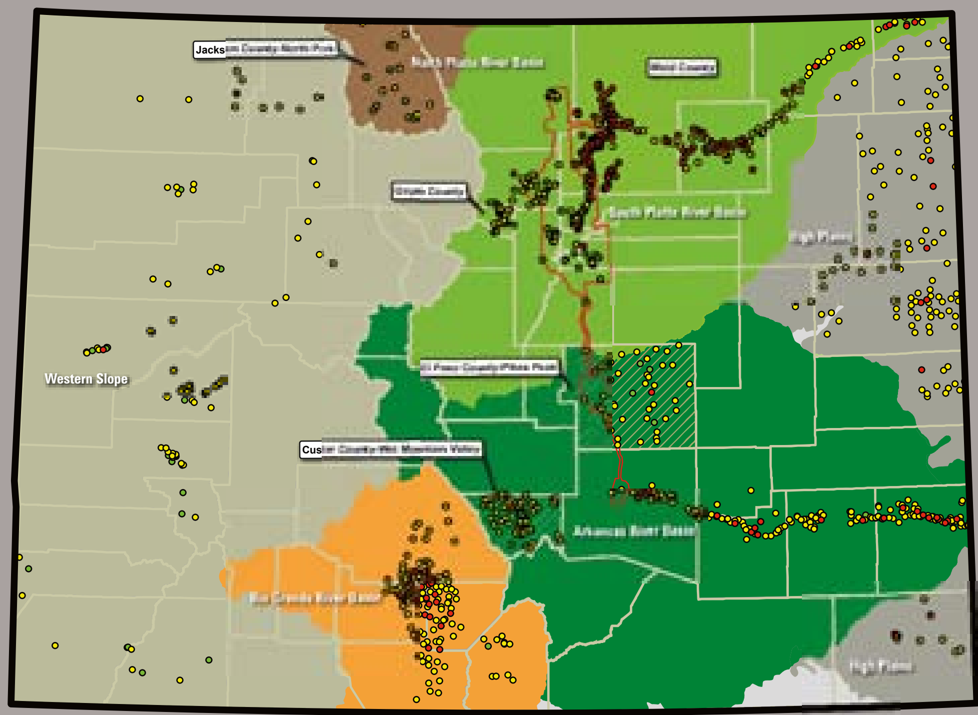
"Protecting Colorado Groundwater." 1993. CSU Public and Media Relations Department. Reagan Waskom.

"Colorado Wetlands—Immeasurable Wealth." 1995. CSU Public and Media Relations Department. Reagan Waskom.

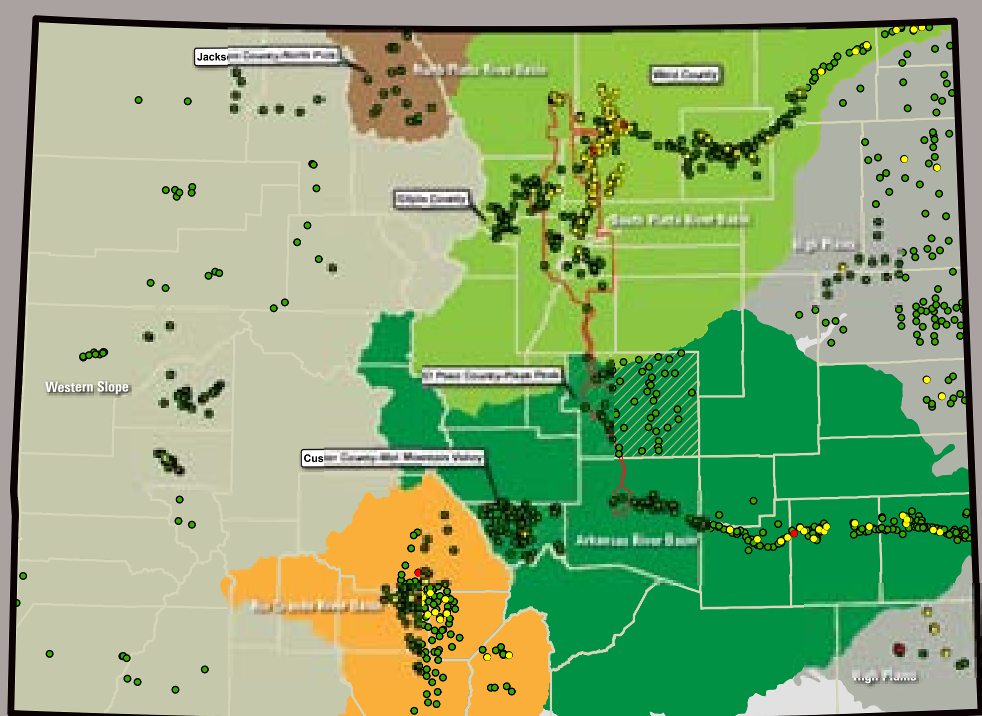
"Best Management Practices for Colorado Agriculture." 1996. CSU Public and Media Relations Department. Reagan Waskom.

Statewide Summary, Nitrate-Nitrogen, 1992-2006



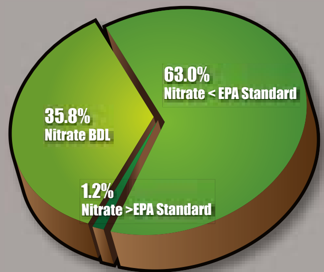
Front Range Urban Corridor   BDL   MDL - 9.99 ppm   10.0+ppm

Statewide Summary, Pesticides, 1992-2006

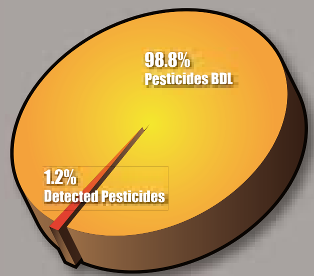


Front Range Urban Corridor   BDL   Detected   MCL Exceeded

Colorado River Basin 1998
(Western Slope)



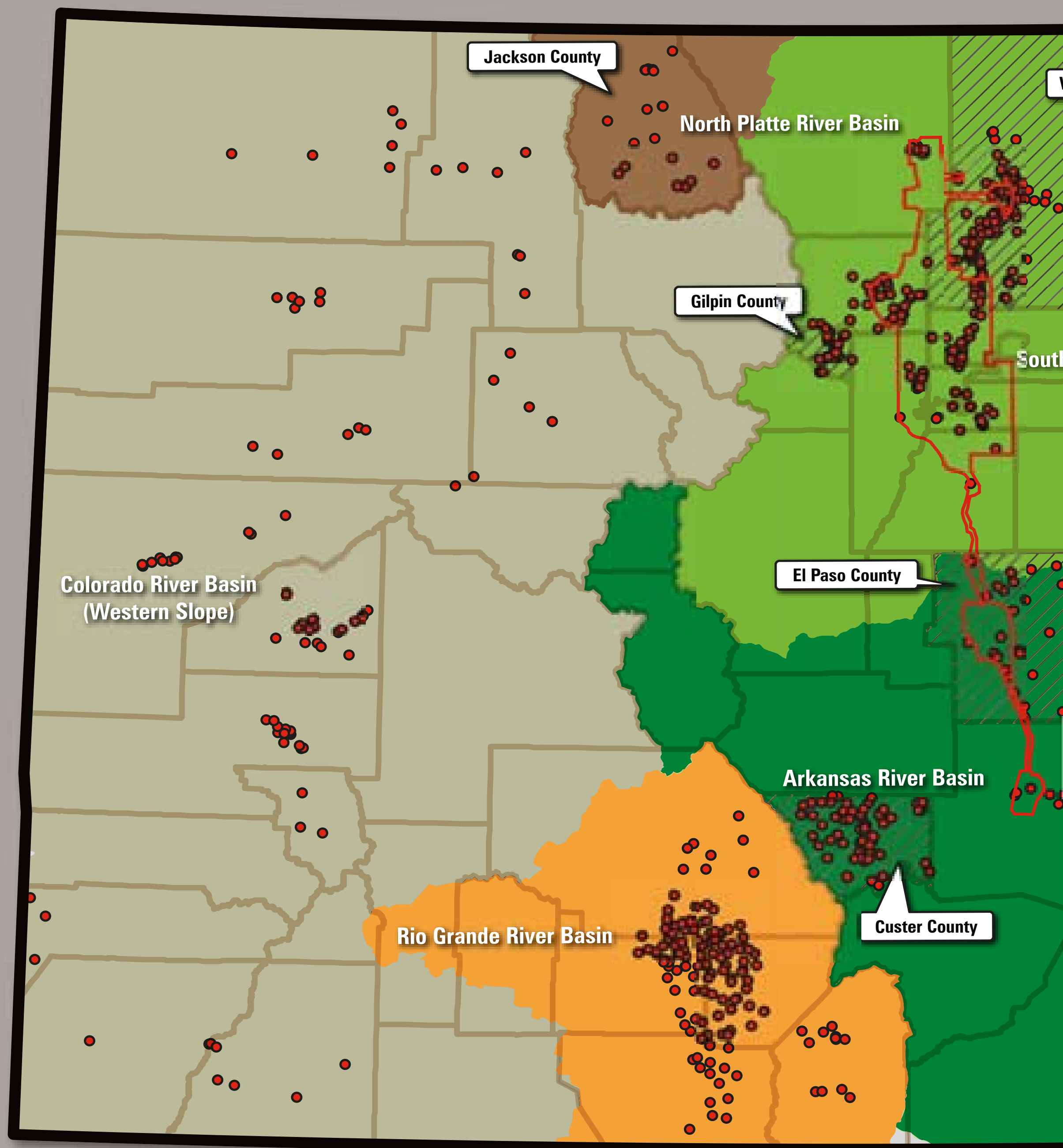
Nitrate Levels



Pesticide Levels

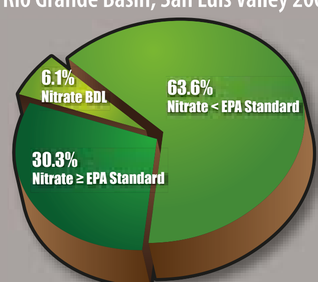
Statewide Summary

Legend
Sample Site Location
County Boundary
Front Range Urban Corridor



BDL below detection limit

Rio Grande Basin, San Luis Valley 2000



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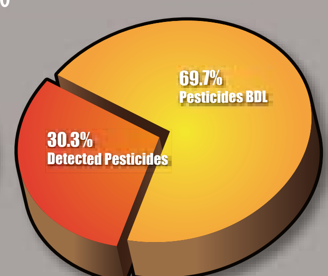
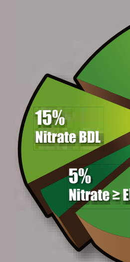
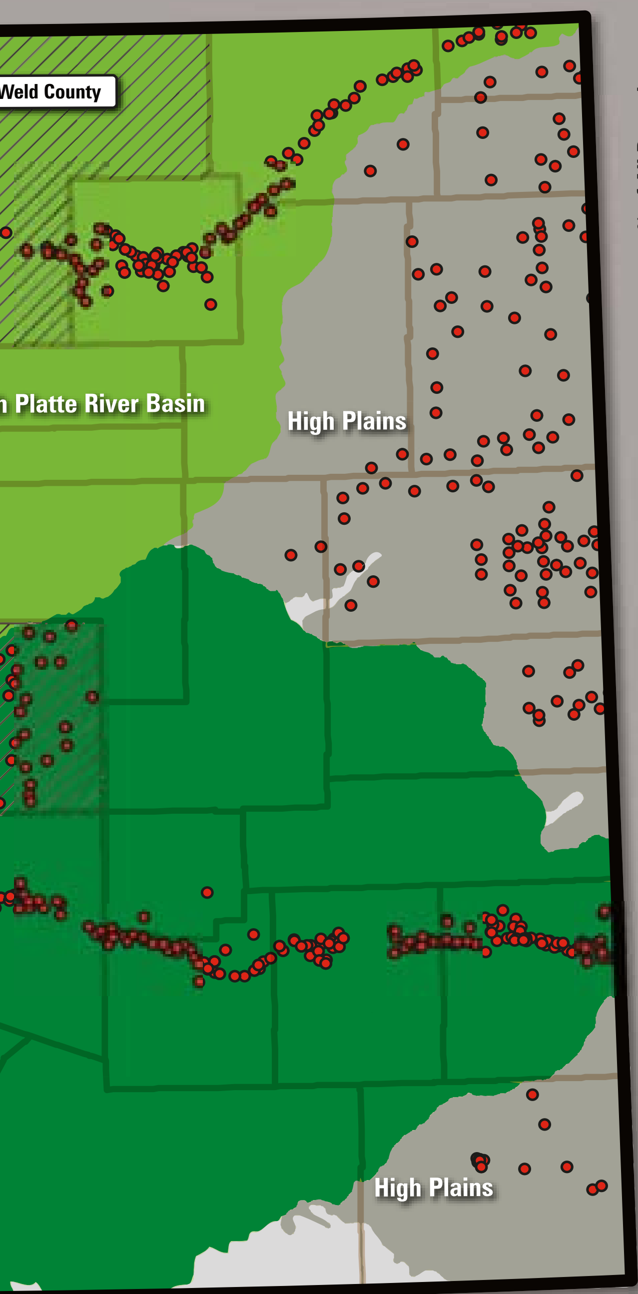


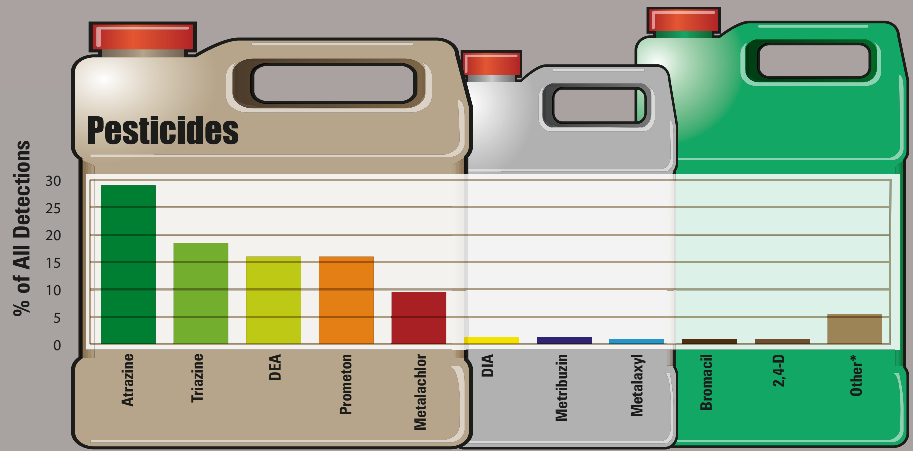
Pesticide Levels

Arkansas River

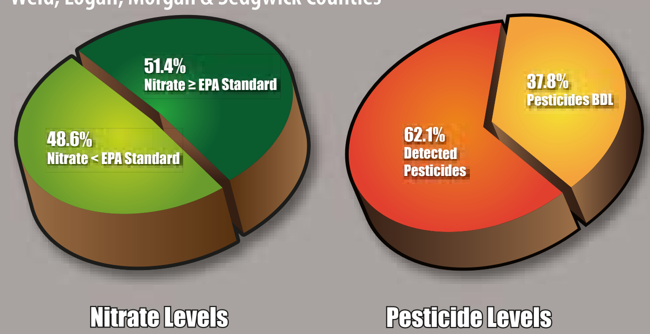




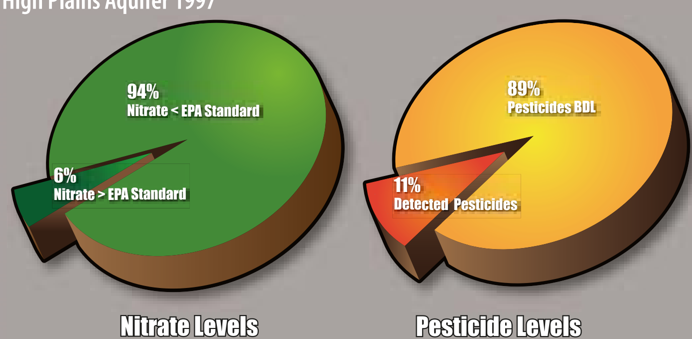
Summary of Statewide Pesticide Detections



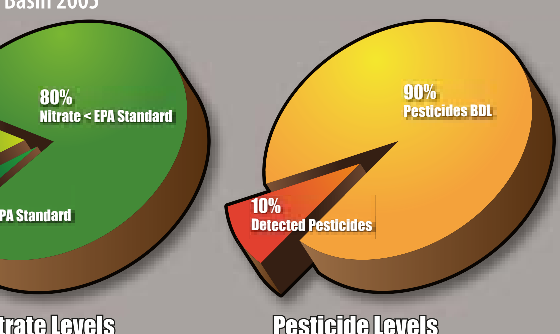
South Platte River Basin Wells 2001
Weld, Logan, Morgan & Sedgwick Counties



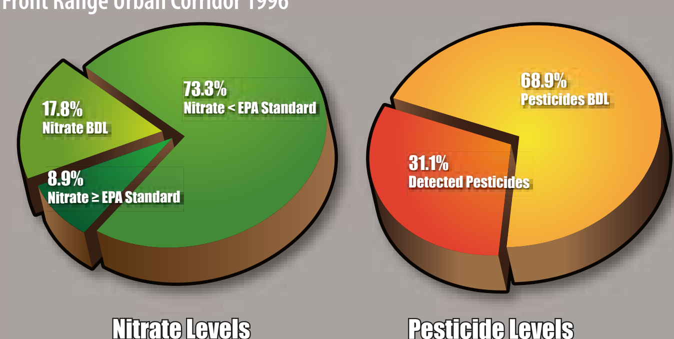
High Plains Aquifer 1997



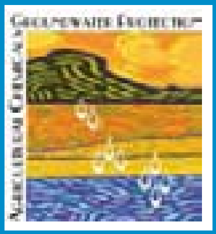
Basin 2005



Front Range Urban Corridor 1996



Agricultural Chemicals & Groundwater Protection in Colorado 1990-2006



Troy Bauder

Reagan Waskom

RobWawrzynski

Karl Mauch

Greg Naugle

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