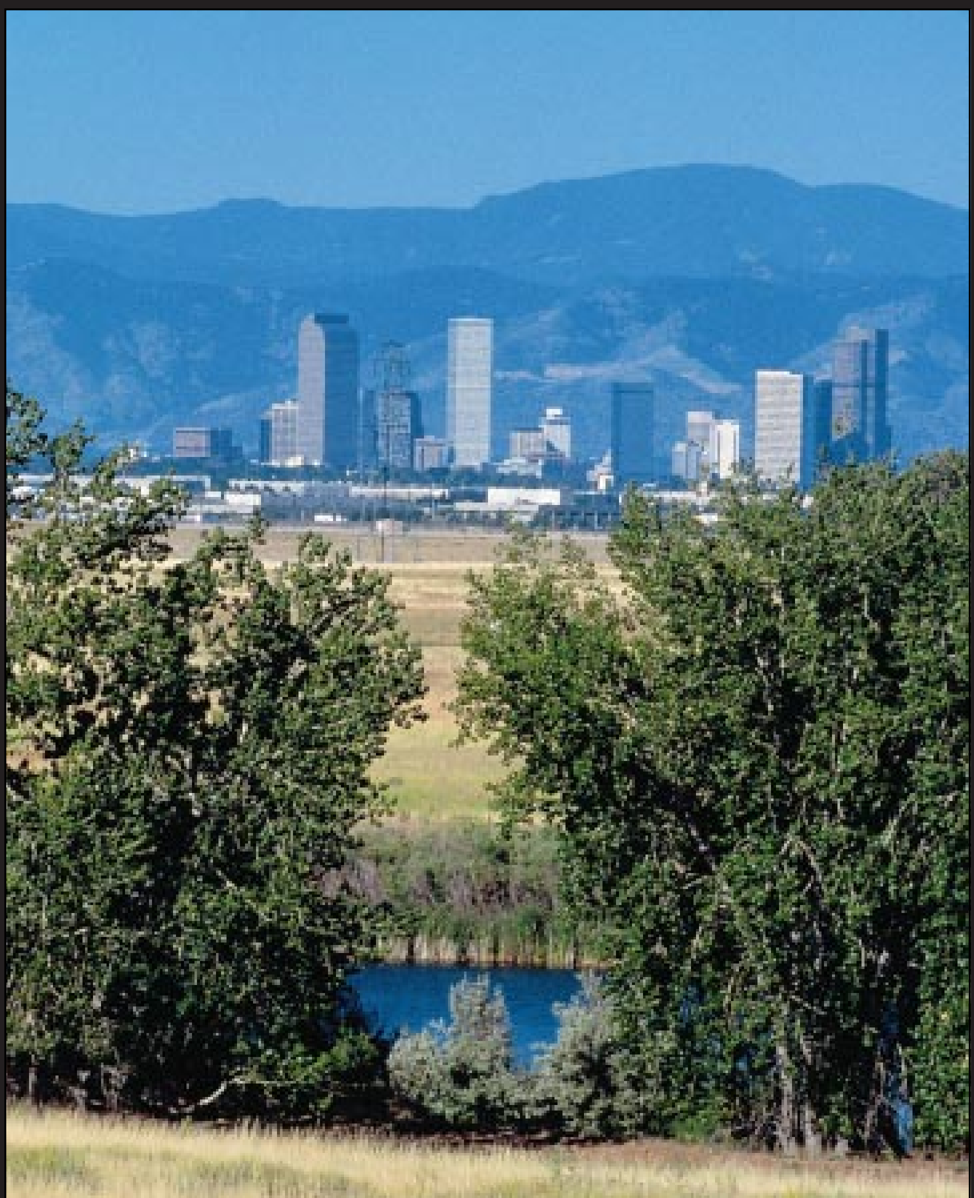
Water Quality in the South Platte River Basin

Colorado, Nebraska, and Wyoming, 1992–95



U.S. Department of the Interior
U.S. Geological Survey

Circular 1167

A COORDINATED EFFORT

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- •Central Colorado Water Conservancy District
- •Colorado Division of Water Resources
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- •Northern Colorado Water Conservancy District
- •National Park Service
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Front cover photograph: The Denver skyline looking west from the plains, *by* Michael Mauro©, (published with permission).
Back cover photograph: Siphon irrigation in a sugar beet field, *by* David W. Litke, U.S. Geological Survey.

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Information on the NAWQA Program is also available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resources Locator (URL):
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Water Quality in the South Platte River Basin, Colorado, Nebraska, and Wyoming, 1992–95

By Kevin F. Dennehy, David W. Litke, Cathy M. Tate, Sharon L. Qi, Peter B. McMahon, Breton W. Bruce, Robert A. Kimbrough, and Janet S. Heiny

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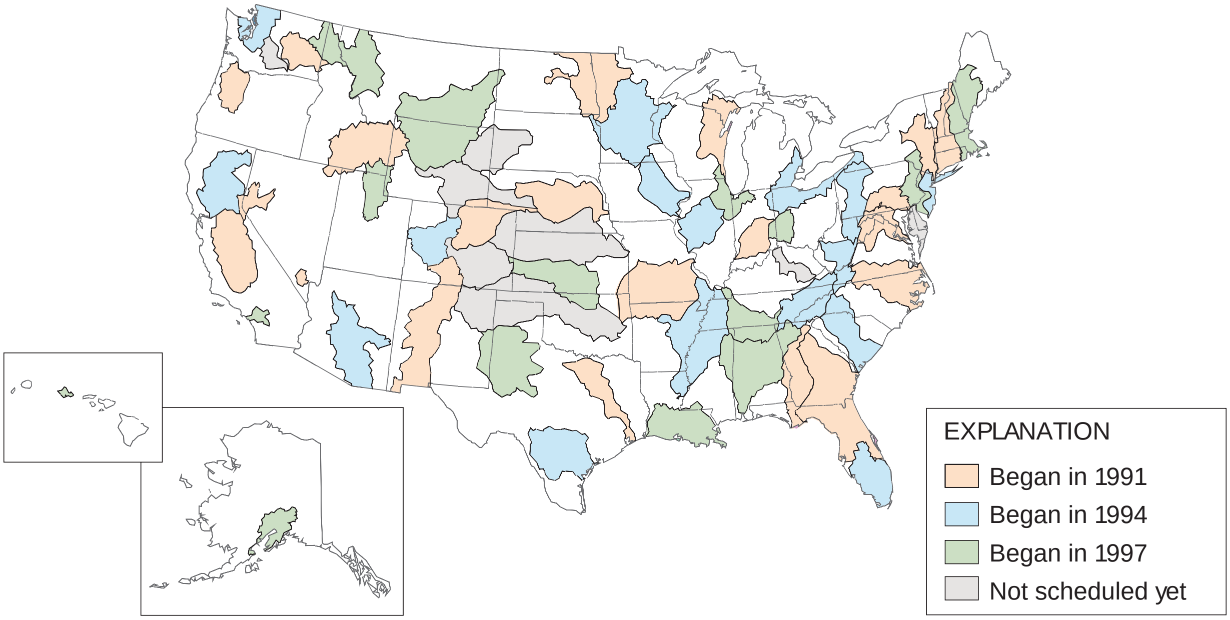


Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and because of the significant costs associated with decisions involving land and water management, conservation, and regulation. In 1991, the U.S. Congress appropriated funds for the U.S. Geological Survey (USGS) to begin the National Water-Quality Assessment (NAWQA) Program to help meet the continuing need for sound, scientific information on the areal extent of the water-quality problems, how these problems are changing with time, and an understanding of the effects of human actions and natural factors on water quality conditions.

The NAWQA Program is assessing the water-quality conditions of more than 50 of the Nation's largest river basins and aquifers, known as Study Units. Collectively, these Study Units cover about one-half of the United States and include sources of drinking water used by about 70 percent of the U.S. population. Comprehensive assessments of about one-third of the Study Units are ongoing at a given time. Each Study Unit is scheduled to be revisited every decade to evaluate changes in water-quality conditions. NAWQA assessments rely heavily on existing information collected by the USGS and many other agencies as well as the use of nationally consistent study designs and methods of sampling and analysis. Such consistency simultaneously provides information about the status and trends in water-quality conditions in a particular stream or aquifer and, more importantly, provides the basis to make comparisons among watersheds and improve our understanding of the factors that affect water-quality conditions regionally and nationally.

This report is intended to summarize major findings that emerged between 1992 and 1995 from the water-quality assessment of the South Platte River Basin Study Unit and to relate these findings to water-quality issues of regional and national concern. The information is primarily intended for those who are involved in water-resource management. Indeed, this report addresses many of the concerns raised by regulators, water-utility managers, industry representatives, and other scientists, engineers, public officials, and members of stakeholder groups who provided advice and input to the USGS during this NAWQA Study-Unit investigation. Yet, the information contained here may also interest those who simply wish to know more about the quality of water in the rivers and aquifers in the area where they live.

Robert M. Hirsch, Chief Hydrologist

How has water development affected water quality in the South Platte River Basin? **Page 8**

- Withdrawals of large volumes of water from streams in the basin for agricultural and urban use result in less water to dilute contaminants in streams.
- Alteration of the natural flow regime has degraded native aquatic habitat along streams.
- Ground water (subsurface irrigation return flow) is a major nonpoint source of nitrate, dissolved solids, and pesticides (atrazine and prometon) in the lower reaches of the South Platte River.
- Reuse of surface and ground water for irrigation has resulted in increased salinity in the lower South Platte River and surrounding alluvial aquifer. High salinity can be detrimental to irrigation and drinking-water supplies.
- Stream water having high concentrations of nitrate can be stored in agricultural reservoirs, where nitrate concentrations decrease during the summer; thus, reservoirs could be part of a nitrate management strategy.

Does land use contribute to contaminant inputs and affect habitat characteristics and biological communities in streams? **Page 10**

- Concentrations of contaminants, such as organochlorine pesticides and polychlorinated biphenyls (PCBs) in bed sediment and whole fish tissue were related to land use.
  - Lowest concentrations and fewest number of these compounds were measured in forested mountains or rangeland sites; highest concentrations and greatest number of compounds were measured in urban and mixed (urban/agriculture) areas.
- A habitat degradation index (HDI) and an index of biotic integrity (IBI), indicates that most sites were moderately degraded and that human activities and local site characteristics had a greater effect on habitat and fish communities than basin-scale characteristics such as land use.
- The relative abundance of families of fish were altered and the number of invertebrate taxa were lower in mining-affected sites and urban, agricultural and mixed land-use settings compared to minimally affected areas such as forest and rangeland.

What factors control the occurrence of uranium and radon, and are the reported concentrations a concern? **Page 12**

- High concentrations of uranium and radon in the South Platte River Basin are directly related to local geology.
- Median uranium concentrations were highest in shallow ground water from the alluvial aquifer in the plains, whereas, median radon concentrations were highest in ground water from the crystalline aquifer in the forested mountain areas.
- There currently are no Federal drinking-water standards for uranium or radon, although standards for both are under review by USEPA. Naturally occurring concentrations of both these elements were high compared to proposed and/or historical standards in most areas of the basin.

Have mining and residential development in the mountains affected water quality? **Page 13**

- Ground-water quality in the forested mountain areas generally was better than in other land-use areas. However, the potential for degraded ground-water quality is likely to increase as mountain communities grow.
- Surface-water quality generally was better in forested mountain areas than in other land uses. Development in mountain drainages correlated with elevated concentrations of dissolved solids, suspended sediment, and nutrients in surface water.
- Volatile organic compounds (VOCs) were detected in ground water in forested mountain areas. Ground water in crystalline bedrock is susceptible to contamination from surface sources.
- Bed sediments in forested mountain streams affected by mining or development had the highest concentrations of trace elements.
- Biological communities were less diverse and had fewer fish species in tributaries affected by mining or development compared to undeveloped mountain streams.

Does urban land use affect water quality? **Page 14**

- Pesticides were frequently detected in surface water and shallow ground water in the urban setting. However, pesticide concentrations were generally low, with only seven pesticides having median values above the method detection limit.
- VOCs, derived from gasoline and cleaning solvents, were detected in 86 percent of shallow urban ground-water samples.
- Nutrient concentrations in urban streams have many potential sources and generally were highest immediately downstream from wastewater treatment plants. Nutrient concentrations in streams did not exceed any existing USEPA drinking-water standards. However, three ground-water samples from the alluvial aquifer had nitrate concentrations that exceeded the drinking-water standard.
- Banned compounds, such as PCBs and chlordane, widely used historically in the urban setting, were detected in fish tissue. Stream-channel modifications for flood control and bank stabilization in the urban setting have altered the habitat available to biological communities.

Have agricultural chemicals affected water quality? **Page 16**

- Pesticides were detected in ground water, surface water, fish tissue, and bed sediment. Several pesticides were detected throughout the agricultural areas of the basin during the growing season. Although concentrations of individual pesticides generally were low compared to established criteria, the ecological and human-health effects of long-term exposure to pesticide mixtures are unknown.
- Nitrate concentrations in alluvial ground water were high in areas where agricultural fertilizers and manure were applied. These high nitrate concentrations have degraded the use of ground water as a rural drinking-water supply. Nitrate concentrations in surface water were smaller than in ground water because microbial activity in streambed sediments removes a substantial portion of the nitrate from the incoming ground-water return flows.

How do discharges from permitted municipal wastewater treatment plants affect nutrient levels in streams? **Page 18**

- Treated wastewater effluent can account for as much as 100 percent of streamflow downstream from Denver and is the primary source of nitrate, ammonia, and phosphorus to Front Range streams.
- Total nitrogen concentrations in streams along the Front Range urban corridor increased substantially downstream from wastewater treatment plants.
- Phosphorus concentrations in the South Platte River from Denver to Balzac, Colo., were higher than USEPA recommended limits for control of eutrophication.

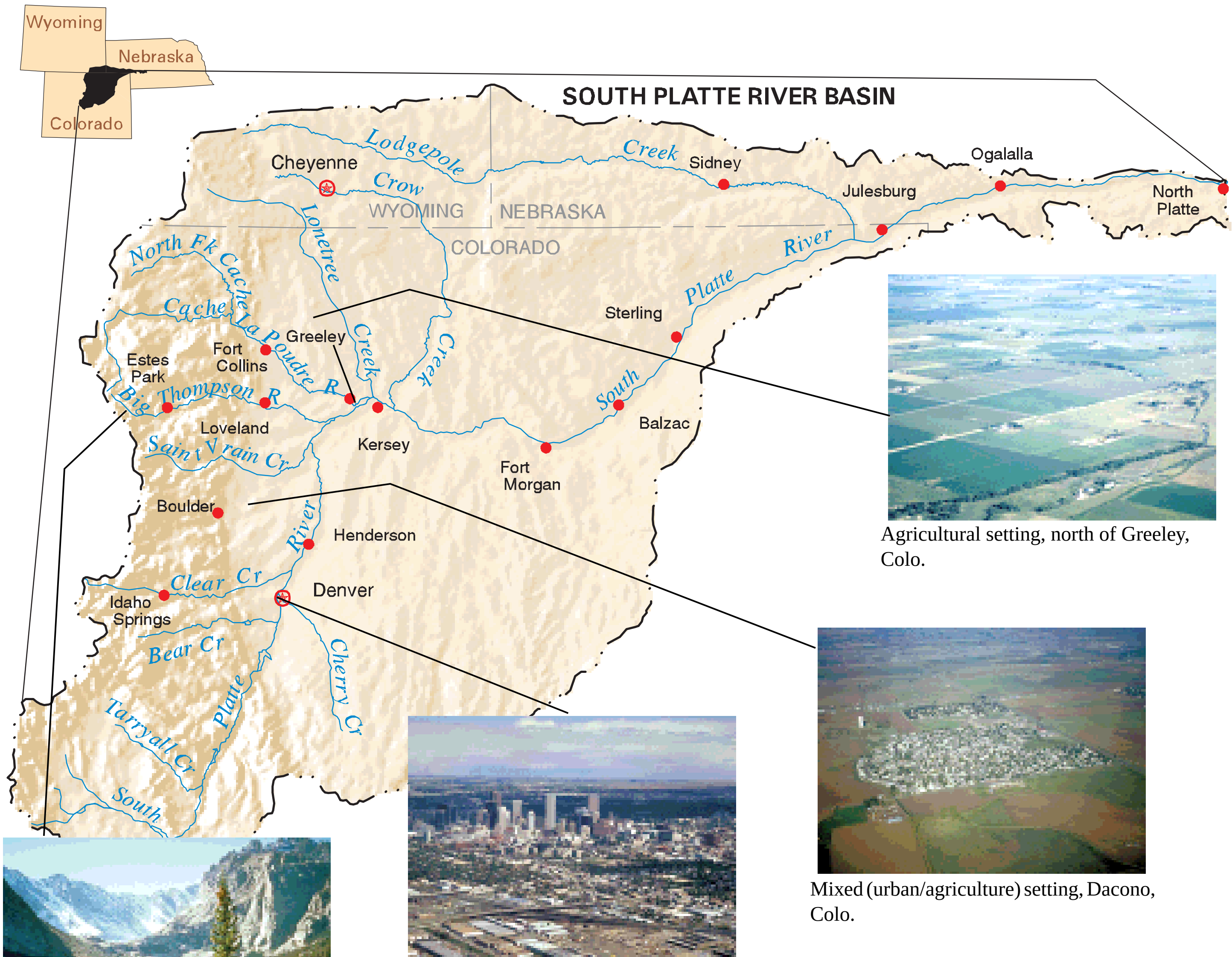
What are the cumulative effects of mixed (urban/agriculture) land use on water quality? **Page 19**

- The average number of pesticides detected in surface-water samples from the South Platte River were greater in mixed land-use areas than in land-use settings that were exclusively urban or agriculture.
- Federally banned compounds, DDT and dieldrin, were detected more often and at higher concentrations in bed sediment and fish tissue collected from mixed land-use sites than in urban or agricultural settings.
- Because of the cumulative effects of contaminants from point and nonpoint sources and habitat alteration, the number of aquatic invertebrate taxa generally was lower in mixed land-use areas than in either urban or agricultural land-use areas alone, and the IBI for fish indicated moderately to significantly degraded conditions.

What is the relative status of water quality by land use in the South Platte River Basin? **Page 20**

- Water quality in surface and ground water in the forested mountain region of the basin generally was of good quality and was relatively unaffected by humans.
- In contrast, water quality in the agricultural areas of the basin was the most degraded, primarily from nitrate and salinity in ground water and salinity and suspended sediment in surface water.
- Water quality in the ground water beneath urban areas and surface water within mixed land-use areas are degraded, as indicated by the highest relative ranking for VOCs and organochlorines and PCBs in fish within the basin, respectively.

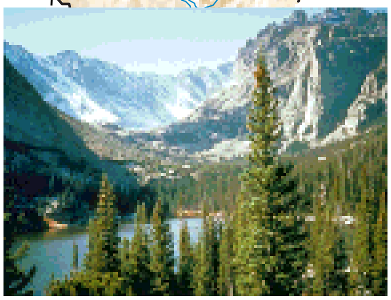
WELCOME TO THE SOUTH PLATTE RIVER BASIN



Agricultural setting, north of Greeley, Colo.

Mixed (urban/agriculture) setting, Dacono, Colo.

Urban setting, Denver, Colo.



Forested mountain setting, Loch Vale, Colo. (photograph by John Turk, U.S. Geological Survey).

This circular is intended for Federal, State, and local water professionals and anyone who has an interest in the water-quality conditions of the South Platte River Basin. All of us have a stake in our water resources, and perhaps more important, we have an interest in maintaining the resources for future residents of the basin.

The physical and cultural (land use) characteristics of the South Platte River Basin are quite diverse. The headwaters of the basin begin at an altitude of more than 14,000 feet along the Continental Divide. The population in the forested mountain areas lives primarily in single-family residences and small residential communities; however, rapid growth in these areas has occurred. This area exhibited a 22-percent increase in population during 1990-93 (Denver Regional Council of Governments, 1997). Between the mountains and the plains is a transition zone where the largest population centers of the basin are located, including Denver (2.2 million in 1997 in the Denver metropolitan area). The basin extends eastward across the Great Plains where agriculture is the predominant land use and water is used primarily for irrigation of crops. On the plains, the topography of the basin continues to slope gently to the mouth of the basin at North Platte, Nebr., at an altitude of 2,788 feet, thus resulting in an altitude change of slightly more than 11,000 vertical feet.

The physical and cultural diversity has a profound effect on water-quality conditions within the basin. The goal of data-collection activities and information from

Providing sufficient and safe drinking-water supplies is a goal of water managers within the basin.

studies presented in this report is to characterize, in a consistent manner, the broad scale geographic and seasonal distributions of water-quality conditions in relation to major contaminant sources and background conditions (Gilliom and others, 1995). These activities and studies also serve as the basis for the design of future assessments of long-term water-quality trends and changes in the basin.

Future demands on the water resources within the basin likely will be high; some of the issues include: (1) Allocating water between urban and agricultural demands; (2) managing growth without deterioration of water quality; (3) restoring degraded riparian habitat and fisheries in the plains; (4) developing future water supplies without affecting the environment; and (5) protecting existing drinking-water supplies. The pressures of growth present challenges that we need to be ready to address. By knowing the current water-quality conditions and identifying environmental factors that affect those conditions, we can meet the challenges of the future. Sufficient knowledge can help us (individually or collectively) make the right decisions. We can prepare now for the future if we can coordinate water-quality activities among agencies at all levels to create an integrated approach to problem resolution. Information exchange and coordination help ensure that the water-quality information produced is relevant to all interests.

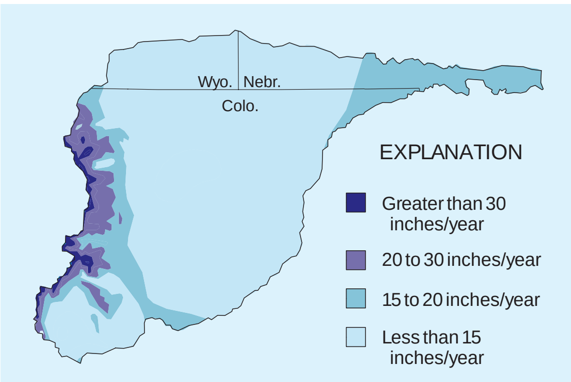
This circular summarizes the results of the occurrence and distribution assessment (high-intensity sampling phase) of the National Water-Quality Assessment (NAWQA) Program's South Platte River Basin Study Unit investigation. The circular presents: (1) Information on the

Recreational water use in mountain areas of the basin.

Irrigation in eastern plains.

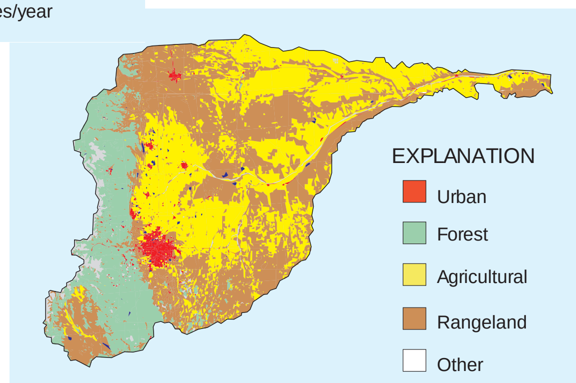
environmental setting and the hydrologic conditions during 1992-95; (2) a summary of major water-quality issues and findings; (3) a comparison of local water-quality results with national NAWQA findings; (4) a description of water-quality data-collection sites; and (5) tables summarizing the analysis and detections of compounds determined during the course of the study. The primary emphasis of NAWQA data collection is to provide information needed for an integrated assessment of water quality. Results presented in this circular and data available on the internet will provide information that can foster collaborative efforts within the water-resources community and continued evaluation and critical review of status and trends in water quality in the South Platte River Basin.

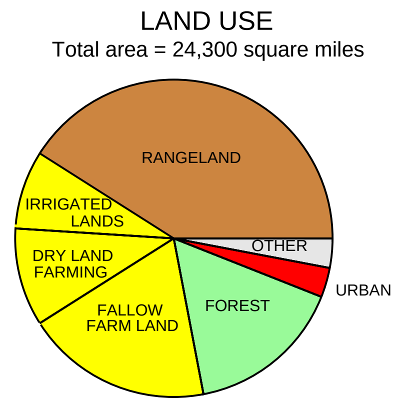
Water quality in the South Platte River Basin is a product of its environmental setting and hydrologic conditions. Environmental conditions that affect water quality include natural factors such as physiography, climate, geology, and soils and human factors such as water use, population, land use, and water-management practices. However, in the South Platte River Basin, the largest population center in the Rocky Mountain Region is in a predominantly semi-arid environment, so human factors have an especially large effect on water quality.



Mean-annual precipitation (1951-80) in the South Platte River Basin. Precipitation data are from the Colorado Climate Center (1984).

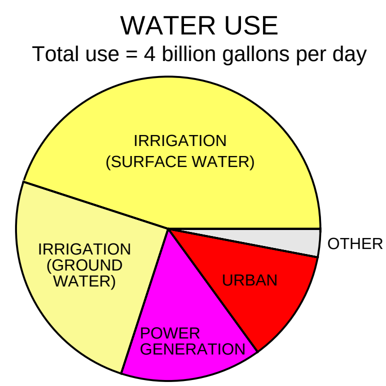
The South Platte River Basin is characterized by a continental-type climate having a wide temperature range (–30 to 100^{o}F) and irregular seasonal and annual precipitation. Precipitation patterns across the basin depend on altitude (mountains to plains). The greatest amount of precipitation (more than 30 inches annually) falls in the mountains as snow. In contrast, annual precipitation on the plains is less than 15 inches. Most of the precipitation on the plains occurs from April to September as thunderstorms.



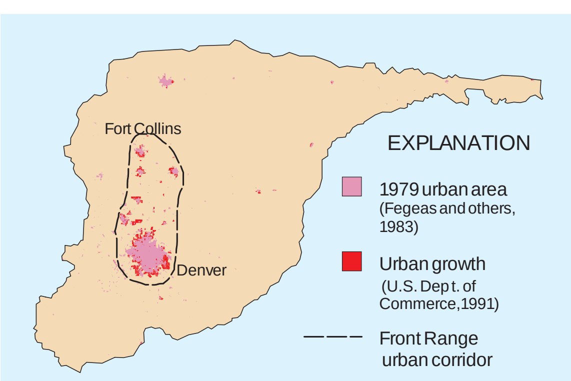


Major land uses, 1975-80, in the South Platte River Basin (modified from Fegeas and others, 1983).

Land use provides many of the chemical and sediment inputs that affect water quality. Forest and rangeland are sources of nutrients, suspended sediment, dissolved solids, and metals. However, urban and agricultural land uses are larger sources of these same constituents, as well as other chemicals such as pesticides and volatile organic compounds. In the South Platte River Basin, stream-water quality generally is dependent more on adjacent land use than on upstream land use because upstream water often is removed from the river by diversions. In terms of area, rangeland is the largest land use (41 percent), but has a relatively small effect on water quality because of the lack of water and minimal water use. Irrigated agriculture comprises only 8 percent of the basin but accounts for 71 percent of the water use. Urban lands comprise only 3 percent of the basin but account for 12 percent of the water use (or 27 percent if power generation is considered an urban water use).



Water use in the South Platte River Basin for 1990. Data are from the U.S. Geological Survey's National Water Information System (NWIS).

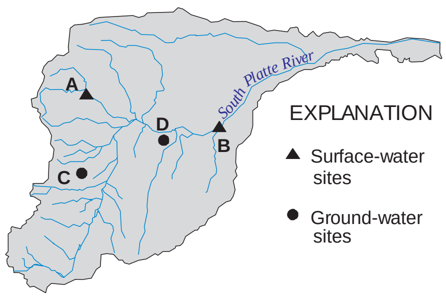


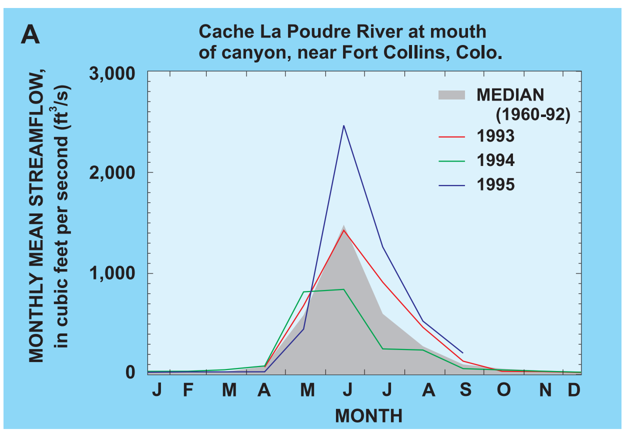
Population growth areas in the South Platte River Basin, during 1979-90.

Population density in the South Platte River Basin ranges from sparsely populated mountain areas in the headwaters region and rural agricultural areas downstream from Denver to the densely populated Denver metropolitan area and Front Range urban corridor in the central part of the basin.

Water quality is affected by hydrologic conditions such as the quantity of water in streams and aquifers and the source of that water. In the South Platte River Basin, the primary sources of water are snowmelt from the mountains and rainfall on the plains.

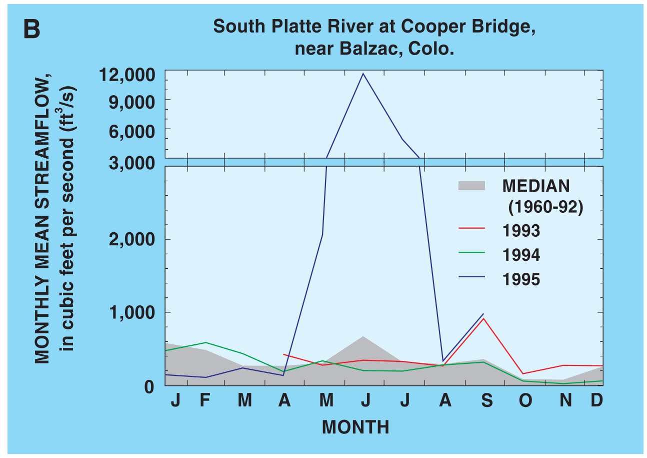
Streamflow in a typical mountain stream, the Cache La Poudre River, during the study period showed year-to-year variability. Snowfall, and the resulting streamflow, was about average during 1993. Mountain streamflow during 1993 helped to fill reservoirs, which had been at low levels during the prolonged dry spell of 1985-92. Mountain snowfall and streamflow were below average during 1994. The plains climate also was drier than normal during 1994, and the combined effect of dry mountains and dry plains made 1994 the driest year of the study period. This was followed during 1995 by a wet year in the mountains and the plains, which produced near-record high streamflows in some areas and localized flooding. The large flows during 1995 resulted in increased loads for many chemical constituents compared to the previous 2 years. Results from water-quality samples collected during 1995 would likely be atypical.





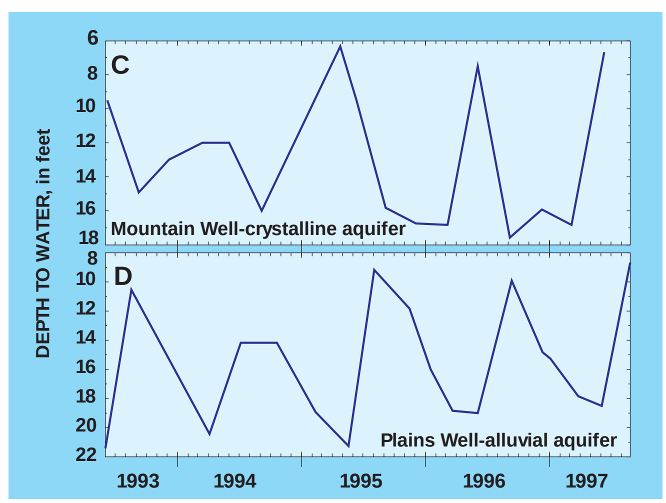
The snowmelt peak at mountain sites was about twice as large during 1995 as during the previous 2 years.

The hydrograph for the Cache La Poudre River showed a consistent seasonal pattern of streamflow. Streamflow was high only during the annual snowmelt-runoff peak, which occurred during April through August. In contrast, the hydrograph at a plains site, such as the South Platte River at Cooper Bridge, near Balzac, Colo., showed more monthly variability. This variability was caused by two factors: precipitation and water use. The high-flow peak during May-August 1995 at the Balzac site was caused by unusually large rainfall amounts in the foothills and the plains that coincided with the annual snowmelt peak. The remaining monthly variability at the Balzac site primarily was due to the effects of irrigation water diversions along the river.



Streamflow at plains sites was about 10 times larger during 1995 than during the previous 2 years.

Ground-water levels in the mountains and plains during the study period showed seasonal patterns. Ground-water levels in the mountains fluctuated in response to snowmelt and the subsequent infiltration of water, which resulted in the highest water levels occurring between March and June. The crystalline-bedrock aquifer in the forested mountains primarily is used to supply small quantities of water to individual households, so water use usually does not drawdown water levels except during extreme dry periods. Ground-water levels in the alluvial aquifer in the plains fluctuated in response to the application of irrigation water to fields, which resulted in the highest water levels occurring between July and September. The South Platte alluvial aquifer in the plains primarily is used for irrigation but also is used as a drinking-water supply.



Ground-water-level fluctuations occur in response to different factors depending if wells are located in mountains (snowmelt) or in the plains (irrigation).

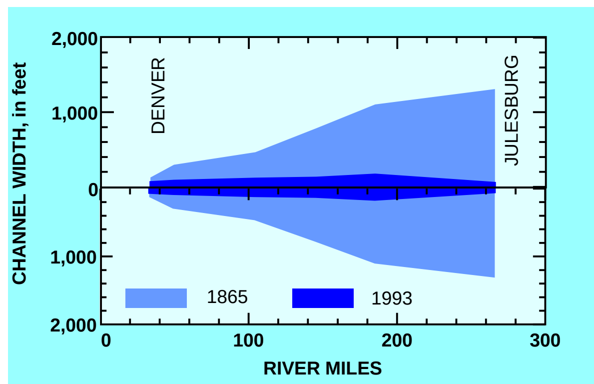
Water development in the South Platte River Basin began in 1870 when the first irrigation ditches were dug in the vicinity of Greeley, Colo. Today, hundreds of structures withdraw more than 3 million acre-feet of water from streams each year, dozens of water storage reservoirs store more than 2 million acre-feet of water each year, 12 transmountain diversions import 400,000 acre-feet of water into the basin each year, and several thousand wells pump an estimated 1 million acre-feet of water each year (Dennehy and others, 1993).

These alterations of the natural hydrologic system have affected the quantity and quality of water in the South Platte River. For example, at several locations along the river, there exist "dry points"—locations where water diversions remove all the water from the river. Withdrawals of water for urban and agricultural use have resulted in less water available to dilute contaminants in the river. The existence of dry points (lack of streamflow) upstream from wastewater-treatment plant discharges has led to nutrient concentrations in the South Platte River that are substantially higher than elsewhere in the Nation (Litke, 1996).

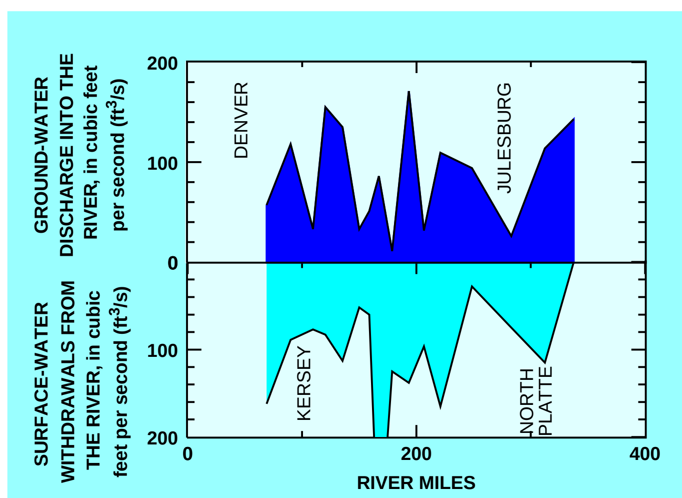
Alterations of the natural hydrologic system also have resulted in less water in the river during spring snowmelt runoff and more water in the river during fall and winter. Historically, the South Platte River ran dry in the plains when the supply of mountain snowmelt was exhausted. Now, seepage of irrigation water from ditches and fields replenishes the alluvial aquifer during spring and summer, and the aquifer slowly drains during fall and winter by discharging ground water to the South Platte River. This altered flow regime has changed native aquatic habitat along the river. For example, because scouring high flows are less common, vegetation along the channel has increased (Knopf, 1991), and the active channel is narrower than in the past.

Ground water contributes substantially to streamflow in the South Platte River in the plains (Litke, 1996). As a result, nitrate, dissolved solids, and the pesticides atrazine and prometon, which can be mobilized in irrigation water as it infiltrates from agricultural fields into ground water, are subsequently transported into streams (Litke, 1996; Bruce and McMahon, 1998; Kimbrough and Litke, in press). Improvements in water quality, therefore, depend on management of agricultural nonpoint sources, which are a long-term concern because ground water and its associated dissolved chemical constituents can take as long as 25 years to migrate from beneath fields to the river (McMahon, 1995).

The Burlington Canal can remove all the flow from the South Platte River near Denver, Colo.



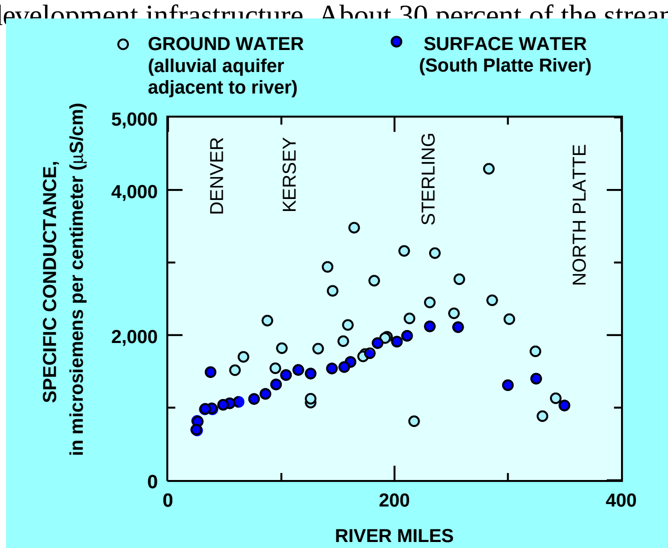
Alteration of natural streamflow for development has resulted in a substantial decrease in channel width along the South Platte River from 1865 to the present. Most of the change occurred prior to 1938.



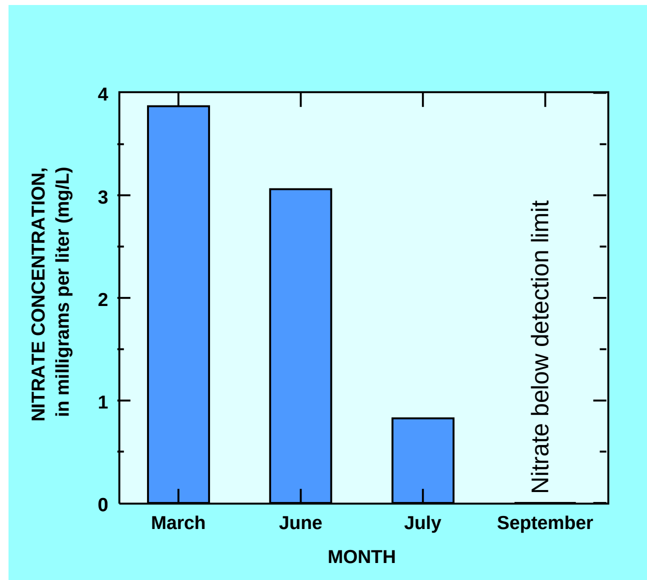
The importance of ground-water discharge to the South Platte River is shown in the river water balance during April 1994. Large amounts of water withdrawn from the river for irrigation are replaced by large amounts of ground-water discharge into the river.

Because surface water was withdrawn all along the river and was replaced by ground water, there was a recycling effect on the water as it moved downstream. This reuse resulted in increasing salinity in a downstream direction in shallow alluvial ground water (Bruce and McMahon, 1998) and in surface water (Litke and Kimbrough, 1998). Salinity increases are related to water reuse and are caused by evaporation, dissolving soil minerals, and the concentration of salts in the soil zone as plants utilize soil water. Deterioration of the quality of the water resource from increased salinity can affect its suitability for irrigation and as a drinking-water supply.

Offstream reservoirs are an important part of the water development infrastructure. About 30 percent of the streamflow in the South Platte River at Kersey, Colo., is stored in offstream reservoirs during fall and winter for use the following irrigation season. Total nitrogen concentrations, more specifically nitrate, decreased in reservoir water during summer (R. Kimbrough, U.S. Geological Survey, written commun., 1997), most likely due to biological uptake. The practice of storing streamflows in agricultural reservoirs could reduce nitrate concentrations before flows are released for irrigation in summer. Expanded use of this management strategy could reduce nitrate levels throughout the basin.



Specific conductance (a measure of salinity) in ground water from the alluvial aquifer adjacent to the South Platte River and in surface water from the South Platte River indicates that salinity increases from Denver to Sterling, Colo., as water is reused. Salinity then decreases near the mouth of the basin, probably due to dilution by discharge of higher quality ground water from the Ogallala aquifer.



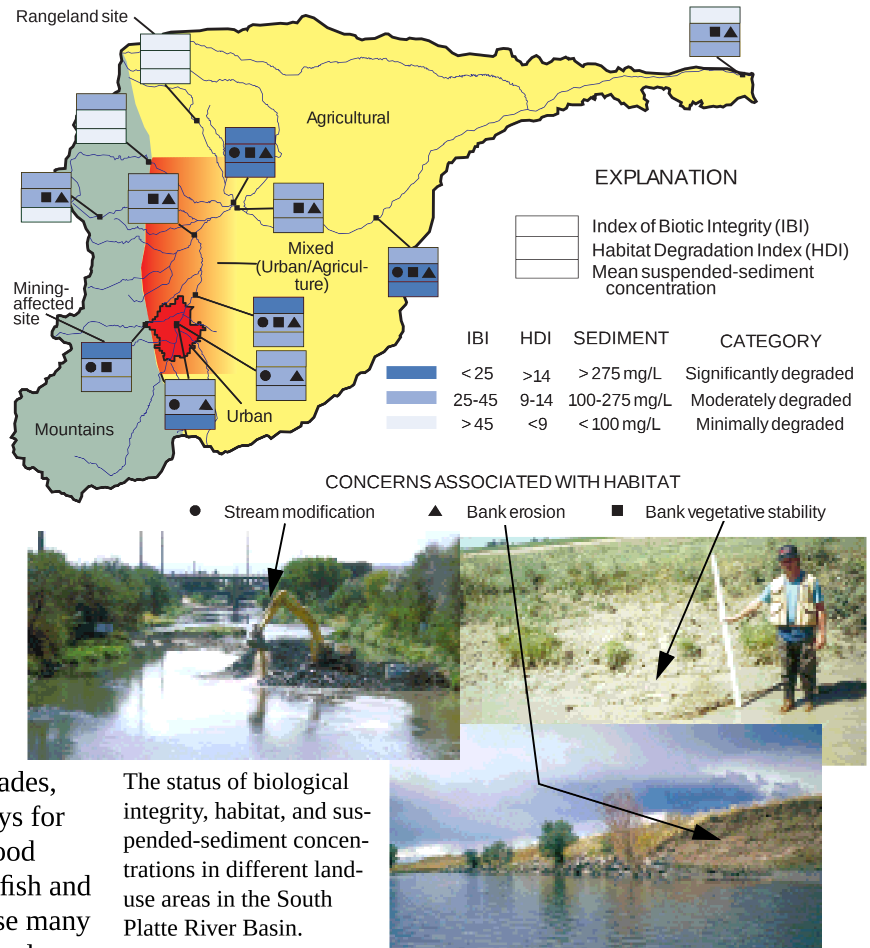
Nitrate concentrations in water from an agricultural reservoir during monthly sampling in 1994 decreased steadily during the summer, most likely due to biological uptake.

Recreational land developed along an agricultural reservoir in Loveland, Colo., shows that use of water resources can be shared.

Water development has led to the extensive use and reuse of water in the South Platte River Basin, and urban and agricultural water development have contributed to some degradation of water quality. However, the existence of the water-development infrastructure allows for the possibility of improvement of water quality by careful management.

MAJOR ISSUES AND FINDINGS: Does Land Use Contribute to Contaminant Inputs and Affect Habitat Characteristics and Biological Communities in Streams?

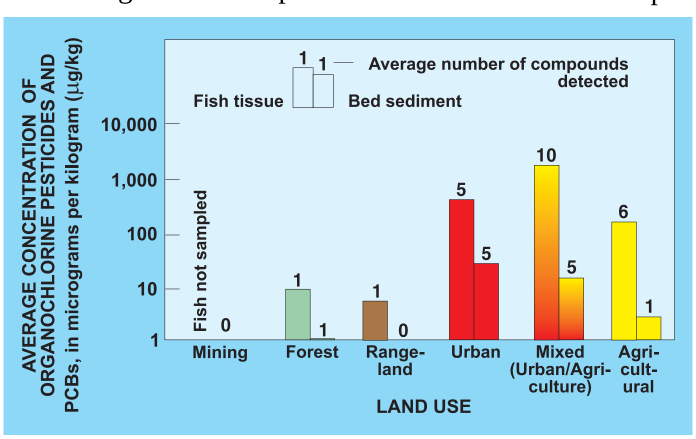
Biological communities vary naturally with elevation (mountains compared to plains) and corresponding changes in the physical habitat. Land use can affect biological communities directly by introduction of contaminants and indirectly by altering the physical habitat. Humans also can alter biological communities by stocking nonnative fish. Evaluation of invertebrate and fish communities provides the opportunity to assess responses to changes in environmental conditions using organisms with different life spans. Collection of these data can provide some of the multiple lines of evidence needed to assess water-quality conditions.



The status of biological integrity, habitat, and suspended-sediment concentrations in different land-use areas in the South Platte River Basin.

An indicator of how land use can contribute contaminants to streams is the measurement of organochlorine pesticides and PCBs in bed sediment, and fish tissue at a site offers a clearer picture of the persistence of these compounds in the environment and their relation to land-use settings (Tate and Heiny, 1996). Although most of these compounds have been banned since the 1970's, they can persist in the environment for decades, which is important because of the multiple pathways for these contaminants to become part of the natural food chain. Assessing the effects of organochlorines on fish and wildlife is becoming increasingly important because many organochlorine pesticides and PCBs have been linked to hormone disruption and reproductive problems in aquatic invertebrates, fish, birds, and mammals (Colborn and others, 1993; Goodbred and others, 1997).

Organochlorine pesticides and PCBs in bed sediment and fish tissue were related to land use. Few organochlorine pesticides and PCBs were detected, and concentrations were low in bed sediment or fish tissue in forested or rangeland areas. Concentrations of organochlorine pesticides and PCBs in whole fish tissue did not exceed U.S. Food and Drug Administration (U.S. Food and Drug Administration, 1989) standards for human consumption of fish fillets. However, concentrations of several organochlorine pesticides and PCBs in whole fish exceeded National Academy of Sciences (NAS) and National Academy of Engineering (NAE) (1973) guidelines for the protection of aquatic life and wildlife. Concentrations of PCBs and chlordane exceeded guidelines primarily in urban areas, whereas total DDT exceeded guidelines in mixed and agricultural land-use areas (Tate and Heiny, 1996).

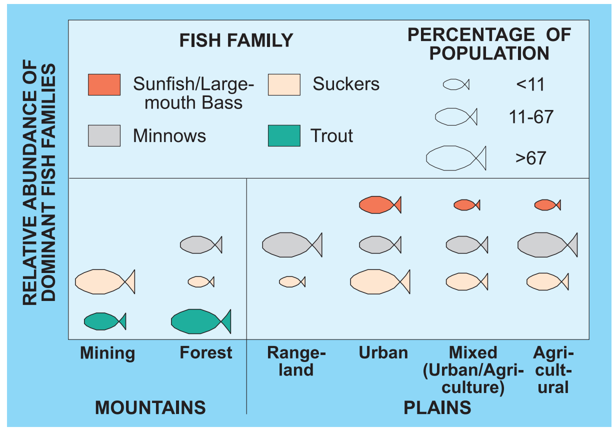


The highest number of compounds and highest concentrations were detected in the urban and mixed (urban/agriculture) land-use areas.

The number and diversity of aquatic biological communities are directly related to the available stream habitat and concentrations of suspended sediment. A habitat degradation index (HDI) was developed by the NAWQA Program to indicate habitat conditions at a site (Gilliom and others, in press). An HDI score for a site was calculated by summing the ranks of three parameters; the amount of stream modification, bank erosion, and bank vegetative stability. Site scores were then grouped into three degradation classes; significantly degraded, moderately degraded, and minimally degraded. HDI scores varied throughout the basin and showed the effect of human activities on a site-by-site basis. Most forested sites in the mountain area had HDI scores indicating moderately degraded conditions with the exception of one site which was minimally degraded. Forested mountain sites had suspended-sediment concentrations indicating minimally degraded conditions, whereas, the mining-affected site had concentrations indicating moderately degraded conditions. Most plains sites had HDI scores and suspended-sediment concentrations indicating moderately degraded conditions; however, the rangeland site had HDI scores and suspended-sediment concentrations indicating minimally degraded conditions. Two sites in the agricultural area had HDI scores and suspended-sediment concentrations indicating significantly degraded conditions and only one urban site had suspended-sediment concentrations indicating significantly degraded conditions. These results indicate that human activities local to a site has a greater affect on habitat characteristics and suspended-sediment concentrations than basin-scale characteristics such as land use.

An index of biotic integrity (IBI) developed for fish in the South Platte River Basin (Schrader, 1989) can be used as a biological indicator of habitat and water-quality conditions. An IBI for a site was calculated by summing the ranks of three categories of fish-community characteristics; the number and types of fish, fish feeding habits, and fish abundance and health. The ranks were determined by comparing a fish-community characteristic at a site to those expected under natural conditions. The site scores were then grouped into three classes; significantly degraded, moderately degraded, and minimally degraded. IBI scores varied throughout the basin and showed the effect of human activities on a site-by-site basis. Forested sites in the mountain areas had IBI scores indicating moderately degraded conditions, whereas a mining site in the mountains had an IBI indicating a significantly degraded condition. Most plains sites had IBI scores indicating moderately degraded conditions; however, two sites in the plains were significantly degraded: one immediately downstream from Denver and one farther downstream in an agricultural area. Only two sites in the plains had IBI scores indicating minimally degraded conditions: the rangeland site and one agricultural site. These results indicate that local site characteristics had a greater effect on fish communities than basin-scale characteristics such as land use.

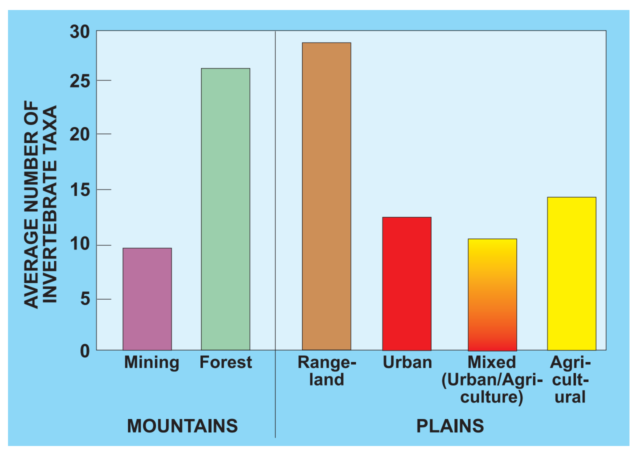
The relative abundance of dominant families of fish was affected by natural environmental factors (elevation) and human activities (land use). Trout were present only in mountain streams; however, the relative abundance of trout was lower in areas affected by mining than in minimally affected forest settings. Suckers, which are tolerant of



Minnows are the dominant fish family present at the rangeland site and a majority of the agricultural sites in the plains areas of the basin.

contaminants, were dominant in urban environments. Mixed (urban/agriculture) land-use settings had a similar composition of fish families to urban and agricultural settings but had smaller relative abundance for each family.

Invertebrate taxa also vary naturally with elevation and in response to human activities (land use). The decreased numbers of invertebrate taxa in mining, agricultural, urban, and mixed land-use areas compared to minimally affected areas (forest and rangeland) in the mountains and plains, showed the effect of human activity on the invertebrate communities. The decline in the number of taxa was not a result of natural variability (Tate and Heiny, 1995).



The highest number of invertebrate taxa are present in the minimally degraded land-use (forest and rangeland) area.

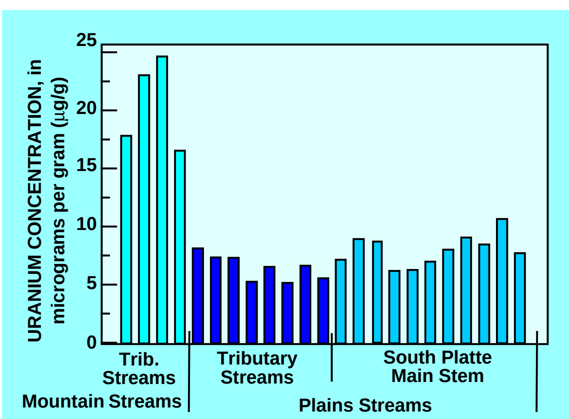
The composition and health of biological communities are the integrated result of the physical and chemical environment at a site. Human activities associated with land use directly (introduction of chemicals) and indirectly (alteration of physical habitat) affect local invertebrate and fish communities.

MAJOR ISSUES AND FINDINGS: What Factors Control the Occurrence of Uranium and Radon, and Are the Reported Concentrations a Concern?

Uranium is a naturally occurring radioactive element that is present in rocks throughout the South Platte River Basin. Radon gas is a product of the radioactive decay of uranium. Both of these constituents could be a health concern in the South Platte River Basin because of the radiotoxicity effects in humans. Uranium also is a heavy metal, which can cause liver damage. Radon may be a concern in drinking water, and radon also can enter indoor air from household water use, leading to exposure through inhalation. Uranium was detected in a majority of ground-water and bed-sediment samples and in some surface-water samples during the NAWQA study (Bruce and McMahon, 1998; Heiny and Tate, 1997). Radon also was detected in all ground-water samples (Bruce and McMahon, 1998).

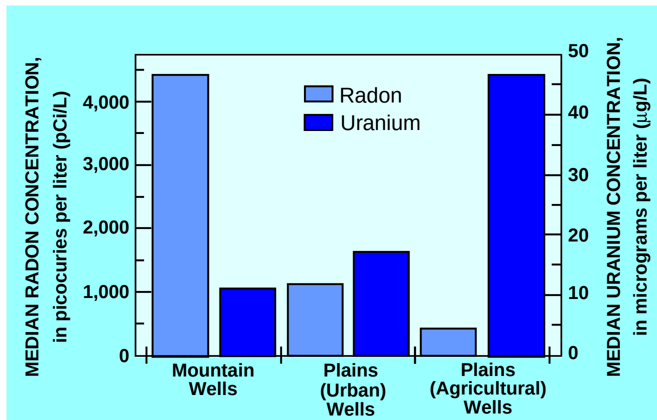
High concentrations of uranium and radon in the South Platte River Basin are directly related to the local geology. The local bedrock, particularly the crystalline rocks (primarily granitic) in the mountains and marine shales and coal deposits in the plains, are naturally high in uranium. Sediments derived from crystalline rocks in the mountains are transported by the streams eastward onto the plains. Uranium concentrations in bed sediments were higher in the mountain streams than in the plains streams. There was no relation between mining impacts to the streams and uranium concentration in bed sediment. The highest uranium concentration in bed sediment (25 µg/g) was detected in the North St. Vrain Creek (naturally occurring), a mountain drainage that is relatively unaffected by humans.

Median uranium concentrations in shallow ground water were higher in the plains than in the mountains, indicating a secondary source of dissolved uranium in the eastern part of the basin other than the mountain-derived alluvial sediments. Preliminary evidence points to the presence of natural uranium in coal deposits and shale bedrock of marine origin that are in contact with alluvial ground water. Samples from at least 10 wells exceeded the proposed USEPA maximum contaminant level (MCL) of 20 µg/L (equal to parts per billion) in each of the three study areas.



Uranium concentrations in streambed sediments are highest in mountain streams.

Uranium occurs naturally in the South Platte River Basin as a result of weathering of crystalline and some sedimentary rocks.



The source of the elevated radon and uranium concentrations is linked to the local geology.

Median radon concentrations in shallow ground water in the forested mountains were higher than in the plains. Currently (1998), there is no standard for radon in drinking water. USEPA withdrew the previous standard of 300 pCi/L pending further review. Median radon concentrations in ground water of the basin exceeded the previous USEPA standard. Once new standards for uranium and radon are finalized (expected by the year 2001), ground water in the South Platte River Basin may require special treatment before it can be used for human consumption. Analysis of fish liver tissue from numerous points in the basin indicated that uranium does not bioaccumulate (Heiny and Tate, 1997).

Uranium and radon levels in ground-water resources of the South Platte River Basin were high compared to proposed and historical USEPA drinking-water standards. Revised standards for both constituents are pending.

As population has increased in the Denver metropolitan area, many mountain tributary basins have changed from forested areas with little or no development to high-volume traffic corridors with suburban and recreational development.

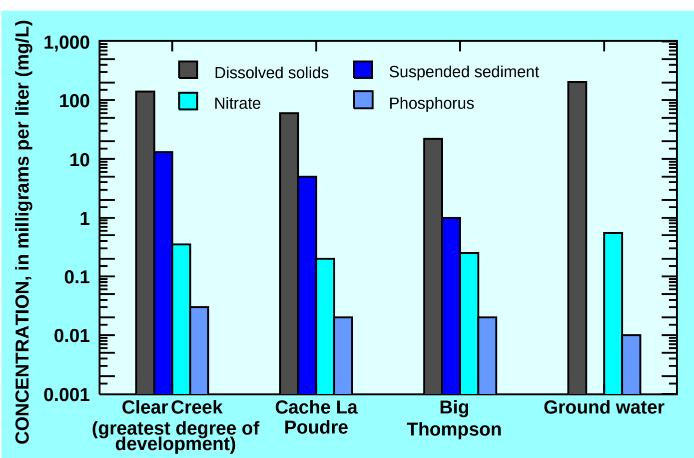
Throughout the mountains, alteration of land use for the ever-increasing numbers of new homes may increase the probability of contaminants being introduced to the ground-water system. Wells are the primary drinking-water source for most mountain communities. Data from wells and stream sites indicated that ground- and surface-water quality in the mountains generally was representative of natural background conditions. Most chemical concentrations were lower in the forested mountains than in urban, agricultural, and rangeland areas. For example, pesticide compounds were not detected in ground water from the forested mountain areas, but often were detected in other land-use areas (Bruce and McMahon, 1998).

Among the mountain tributaries sampled, concentrations of dissolved solids, suspended sediment, nitrate, and phosphorus correlated with the degree of development in the basin. There were higher concentrations of these constituents in Clear Creek (a more developed area) and lower concentrations in the Cache La Poudre and Big Thompson Rivers (less developed areas) (Litke and Kimbrough, 1998). In ground water, only 1 of 27 mountain wells had a nitrate concentration above the drinking-water standard of 10 mg/L as nitrogen, and 5 of those 27 wells had nitrate concentrations that might be affected by septic systems (more than 2 mg/L) (Mueller and Helsel, 1996).

Volatile organic compounds (VOCs) are manufactured chemicals such as organic solvents, by-products of chlorinated disinfectants, and many petroleum-based derivatives that are components of gasoline, fuel oil, and lubricants. VOCs were detected in 8 of 27 ground-water wells sampled, but none of the concentrations exceeded drinking-water standards (Bruce and McMahon, 1998). The occurrence of VOCs in the mountain wells indicates that ground water is susceptible to contamination from development and human activity.

Undeveloped mountain drainage and residential development in mountain areas.

Median concentrations of selected constituents in forested mountain areas of the South Platte River Basin.



Geology and proximity to the source rocks are important factors affecting the concentration of trace elements in bed sediments. Higher concentrations of most elements were present in bed sediment in the mountains, and concentrations generally exceeded basin background levels (Heiny and Tate, 1997). Elevated concentrations of some elements in Clear Creek bed sediments were attributed to the effects of mining or development.

The numbers of invertebrate and fish taxa at forested mountain sites were related to past mining activity and the level of urban development. Clear Creek (mining/development-affected) had fewer invertebrate taxa (10) and lower invertebrate density (1,980 individuals per square meter) than the Cache La Poudre River above Fort Collins, Colo. (less developed; 19 taxa and 3,300 individuals per square meter) (Tate and Heiny, 1995). Clear Creek also had fewer fish species, more unstable banks, more channelization, and less available habitat than the Cache La Poudre or Big Thompson Rivers.

Water quality in the forested mountain setting generally represents background conditions; however, surface water, ground water, bed sediment, and fish communities have been minimally affected by mining activities and residential development. Because continued development is anticipated in mountain communities, long-term monitoring of water quality is important.

Land-use practices in the Denver metropolitan area can affect the quality of streams and shallow ground water in various ways. For example, fertilizers and pesticides applied to lawns, parks, and roadways can wash into streams. Sediment from construction sites also can wash into streams. Fuels and solvents used throughout the urban area can migrate into shallow aquifers.

List of pesticides that comprise eighty percent of all pesticides detected in surface and ground water within the urban setting. [<, less than indicated value]

Pesticide	Percent detection		Maximum concentration (µg/L)	
	Surface water	Ground water	Surface water	Ground water
Carbaryl	97	0	5.2	< 0.003
Atrazine	86	43	0.2	0.2
Prometon	86	63	0.16	1.4
Diazinon	69	0	0.24	< 0.002
Simazine	64	30	0.048	0.068
DCPA	61	0	0.029	< 0.002
Tebuthiuron	53	17	0.17	0.79
Chlorpyrifos	31	0	0.11	< 0.004
Malathion	25	0	0.089	< 0.005

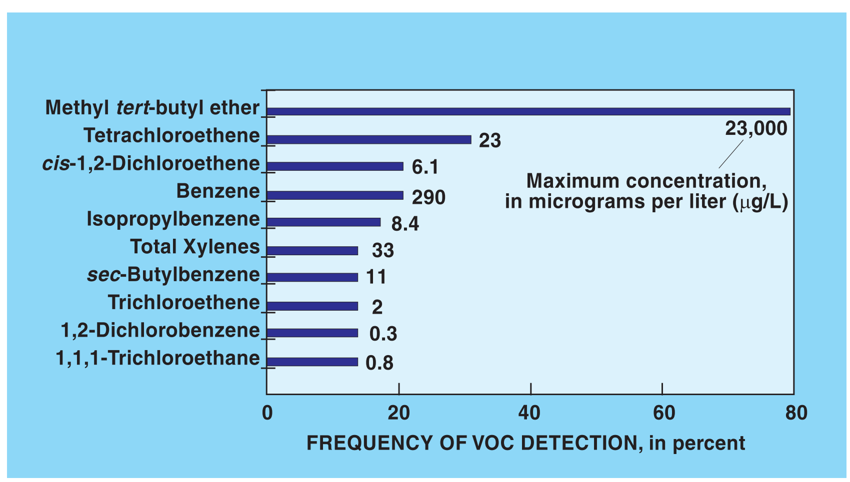
Color indicates type of pesticide: Herbicide and Insecticide.

All 36 of the surface water samples collected at two urban sites in the Denver metropolitan area contained at least one pesticide (Kimbrough and Litke, in press), and water from 90 percent of the wells (27 of 30 wells) sampled in the urban alluvial aquifer contained at least one pesticide (Bruce and McMahon, 1996, 1998). Twenty-eight different pesticides were detected in surface water, but only 9 pesticides were detected in ground water. Atrazine, prometon, and simazine were frequently detected in both surface water and ground water.

Pesticide concentrations were generally low, with only seven pesticides having median values above the method detection limit. However, the health advisory limit was exceeded for diazinon for one surface-water sample, and aquatic-life criteria were commonly exceeded for carbaryl, diazinon, and chlorpyrifos. No ground-water sample had a pesticide concentration in excess of a regulatory criteria. The frequent detection of pesticides, however, indicates that pesticide use in Denver does affect water quality.

Surface water and shallow ground water in Denver, Colo., are susceptible to contamination by urban activities.

Volatile organic compounds derived from substances commonly used in urban areas, such as gasoline and cleaning solvents, were detected in 86 percent of the wells sampled from the alluvial aquifer in Denver (Bruce and McMahon, 1996; McMahon and Bruce, 1997). Sixty-two percent of the samples had more than one VOC present. The most frequently detected VOC was methyl *tert*-butyl ether (MTBE), a gasoline additive used to reduce carbon monoxide emissions from vehicles during winter. The second most frequently detected VOC was tetrachloroethene (PCE), a common cleaning



Thirty-one (ten most frequently detected VOCs shown) of 59 VOCs were detected in shallow urban ground water.

solvent. Benzene and PCE were the only VOCs whose concentrations exceeded drinking-water standards (*see* Summary of Compound Detections and Concentrations section, p. 28-34 for range of concentrations). These findings indicate that gasoline and solvents used in the urban area affect water quality.

Nutrients such as ammonia, nitrate, and phosphorus have many potential sources in the Denver metropolitan area, including fertilizers applied to lawn areas and discharges from wastewater treatment plants. However, nutrient concentrations in urban streams did not exceed any existing USEPA drinking-water standard (Litke, 1996). Three of 30 samples of shallow alluvial ground water had nitrate concentrations that exceeded the 10-mg/L drinking-water standard (Bruce and McMahon, 1996). Nutrient concentrations in urban streams generally were highest immediately downstream from wastewater treatment plants. The effect of wastewater discharges on water quality are discussed on page 18 of this report.

Urban sources of surface water and alluvial ground water are not currently (1998) used for drinking water in the Denver metropolitan area. However, it is possible that these supplies could become drinking-water sources as demand for water increases.

Fish and stream habitat in the urban environment have been affected by land-use activities. For example, tissue from common carp and white sucker from urban streams contained the banned compounds, PCBs and chlordane, both of which were widely used historically in the urban environment (Tate and Heiny, 1996). Fish communities also were dominated by suckers, a family of fish that is tolerant of degraded water-quality conditions. Channel modifications for flood control and bank stabilization in Cherry Creek and the South Platte River have resulted in high suspended-sediment concentrations and degraded habitat for biotic communities. Despite these negative effects of urban land use on fish communities and habitat, an IBI developed for fish communities in the South Platte River Basin as a tool to assess the ecological health of streams across the basin indicated water-quality conditions were only moderately degraded.

Development of areas along the South Platte River is ongoing.

Channel modification has a direct effect on stream habitat and biological communities in the South Platte River.

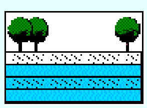
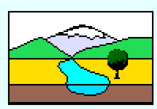
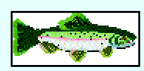
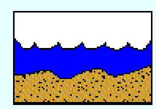
The NAWQA study determined that streams and shallow ground water in the urban area are susceptible to contamination from pesticides and VOCs, indicating that better management of potentially toxic substances may be needed to protect water resources for possible future use as drinking-water supplies.

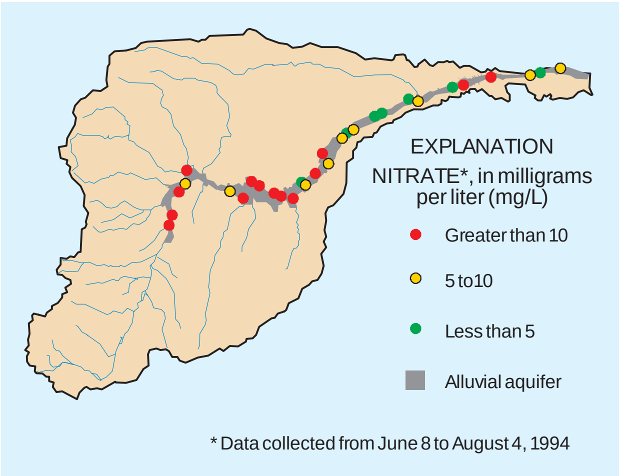
Irrigated fields south of Greeley, Colo. Corn, hay, dry beans, and other small grains are the principal irrigated crops in the basin.

Agriculture accounts for about 37 percent of the land use in the South Platte River Basin, and agricultural chemicals (fertilizers and pesticides) are used to enhance production. It is estimated that more than 2 million pounds of active pesticide ingredients are applied in the basin each year. Eleven chemicals account for about 90 percent of the pesticide usage: eight herbicides, which are applied predominantly on corn during spring planting; and three insecticides, which are applied as needed throughout the growing season (Dennehy and others, 1995). Fertilizer use is predominantly nitrogen and phosphorus compounds applied in the form of chemical fertilizer or manure. It is estimated that about 40,000 tons of phosphorus and 200,000 tons of nitrogen are applied in the basin each year (Litke, 1996). Residual chemicals migrate into the hydrologic system by ground- and surface-water irrigation return flows or storm runoff.

Pesticides were detected in surface-water (Kimbrough and Litke, in press), ground-water (Bruce and McMahon, 1998), bed-sediment, and fish-tissue (Tate and Heiny, 1996) samples collected as part of NAWQA studies during 1992-95. Generally, the most commonly detected pesticides were those that were most commonly used. DDT, which was banned in 1972, was detected in bed sediment and fish tissue;

Feedlot near Fort Lupton, Colo. Feedlots generate substantial quantities of manure, which are applied to nearby fields as supplemental fertilizer.

PESTICIDE OCCURRENCE AT AGRICULTURAL SITES	 **Ground Water**	 **Surface Water**	 **Fish Tissue**	 **Bed Sediment**
What pesticides were detected?	Fifteen pesticides were detected. Atrazine and prometon were most frequently detected. A greater variety of pesticides was detected in agricultural wells than in urban wells.	Twenty-five pesticides were detected. Atrazine, prometon, DCPA, metolachlor, cyanazine, and EPTC were detected in at least one-half of the samples collected.	DDT or DDT metabolites were detected in all samples. Dieldrin and dacthal also were commonly detected.	DDT was detected in about one-half of the samples.
Where do pesticides occur?	Pesticides were detected in 29 of the 30 wells sampled between Fort Lupton, Colo., and North Platte, Nebr.	Atrazine and prometon were detected at all 10 sites sampled between Kersey, Colo., and North Platte, Nebr. All sites had at least five pesticides detected.	DDT was detected at all sites from Henderson, Colo., to North Platte, Nebr. Dieldrin and dachthal occurred primarily between Henderson and Fort Morgan, Colo.	DDT was detected primarily from Henderson to Fort Morgan, Colo.
When were pesticides detected?	Wells were sampled once (summer of 1994).	Pesticide detections were more frequent in June than in May or August 1994. Atrazine and prometon persisted throughout the growing season.	Fish samples were collected once, during 1992 or 1993.	Bed sediment samples were collected once, during 1992 or 1993.

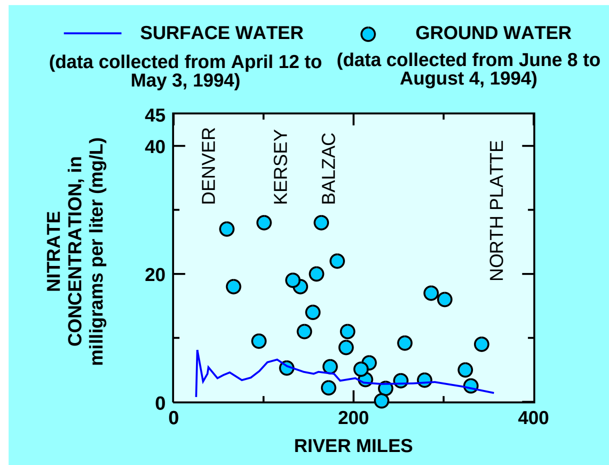


Nitrate concentrations exceeded the U.S. Environmental Protection Agency drinking-water standard of 10 milligrams per liter in about one-half of the wells sampled. Locations of exceedances are scattered and depend on fertilizer application rates and soil leaching potential.

and dieldrin, which also was banned in the 1970's, was detected in all four media. The common occurrence of some pesticides, and the persistence of others, can be an ecological and human health concern. Although individual pesticide concentrations were small, generally less than MCLs, the effects of long-term exposure to pesticide mixtures are unknown.

Nitrate was the predominant form of nitrogen in ground and surface water within the basin. Nitrate concentrations in alluvial ground water were high in some areas where agricultural fertilizers and manure were applied to the land. Previous work has shown that the location of nitrate "hot spots" is related to soil texture and to the locations of combined organic/inorganic fertilizer applications (Wylie and others, 1993). At nitrate hot spots, nitrate concentrations exceeded the drinking-water standard (10 mg/L), and have resulted in the restricted use of ground water as a rural drinking-water supply. Nitrate-contaminated ground water generally cannot be avoided by drilling deeper wells because nitrate concentrations typically are similar throughout the depth of the alluvial aquifer, most likely due to mixing of water in the aquifer caused by irrigation pumpage. Mixing was documented by age-dating of the ground water, which showed small age differences between the top and bottom of the aquifer (McMahon and Böhlke, 1996).

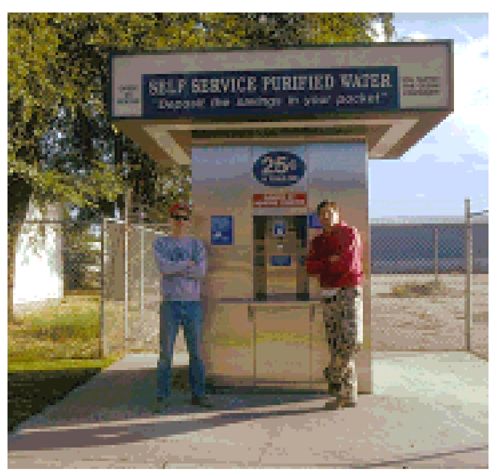
Ground water contributes substantially to the flow of the South Platte River in the agricultural part of the basin, but nitrate concentrations in surface water were much smaller than in ground water and did not exceed the USEPA drinking-water standard. Studies have shown that microbial activity in streambed sediments removes a substantial portion of the nitrate in the incoming ground water (McMahon and Böhlke, 1996), and that as much as 90 percent of the nitrate can be removed from surface water over short distances (Sjodin, and others, 1997). This natural removal process does much to improve nitrate concentrations in the South Platte River, but concentrations are still large enough that, when excessive phosphorus concentrations also are present, increased growth of nuisance algae and other aquatic plants can occur in streams and reservoirs.



Nitrate concentrations in surface water are substantially lower than concentrations in wells adjacent to the South Platte River. Microbial action removes some nitrate from ground water as it moves from the aquifer to the river.

Agricultural pesticides were detected at low concentrations throughout the agricultural land-use area, but the effects of long-term exposure to pesticide mixtures are unknown.

The use of agricultural fertilizers and manure has affected the use of ground water as a drinking-water supply in some areas.



Drinking water for sale near Greeley, Colo., in an area where the ground-water supply is contaminated by high nitrate concentrations.

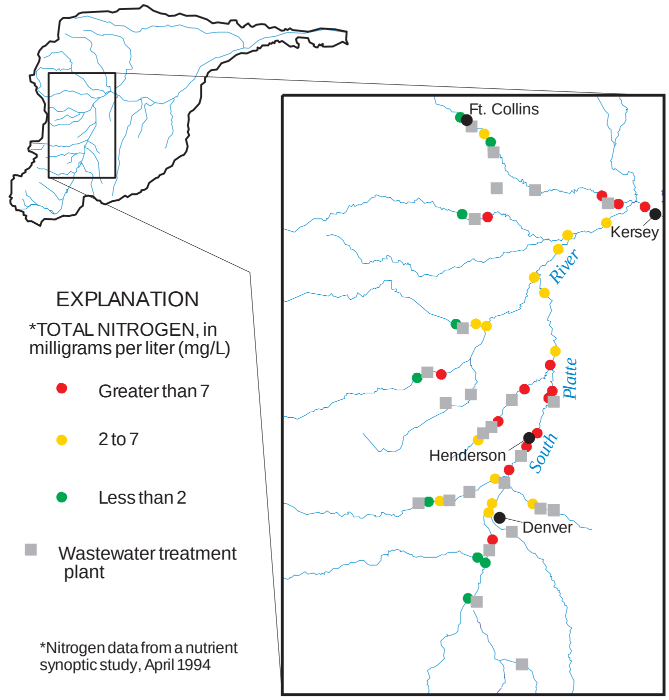
Wastewater-treatment plant effluent can contribute almost all of the flow in the South Platte River downstream from Denver.

There are more than 100 permitted municipal wastewater treatment plants (WWTPs) in the South Platte River Basin. Twenty-five plants located along the Front Range urban corridor discharge about 275 million gallons of effluent per day or about 95 percent of the total daily effluent discharge in the basin. Most plants discharge into streams, and in some locations, effluent can make up a substantial part of the streamflow. For example, Metro Wastewater Reclamation District annually contributes about 69 percent of the streamflow and at times 100 percent of the streamflow in the South Platte River downstream from Denver, Colo. (Dennehy and others, 1995). About 7,000 tons of nitrogen and 1,200 tons of phosphorus enter the South Platte River Basin every year from WWTPs (Litke, 1996).

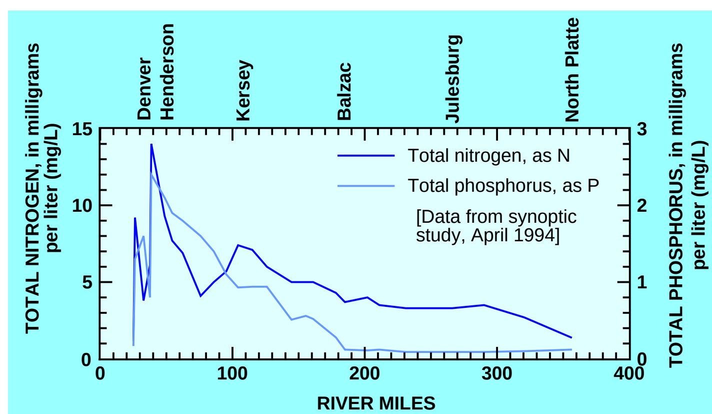
Nitrate and ammonia were the primary forms of nitrogen present in WWTP effluent in the basin (Litke, 1996). Elevated levels of these constituents can lead to excessive growth of algae and other aquatic plants. Also, high nitrate levels can be a health concern to infants, and high levels of ammonia in its un-ionized form can be toxic to fish. Data collected from synoptic sites indicated that for most streams along the Front Range urban corridor, total nitrogen concentrations were substantially higher downstream from WWTPs.

Phosphorus is the nutrient that often is the controlling factor in causing eutrophication in reservoirs and aquatic plant growth in streams, and the USEPA has recommended a limit of 0.1 mg/L for total phosphorus in streams (U.S. Environmental Protection Agency, 1986). NAWQA synoptic data showed that total phosphorus concentrations in the main stem South Platte River generally exceeded this limit in the 150-mile reach of the river from Denver to Balzac, Colo. On the main stem, total nitrogen and total phosphorus concentrations were largest just downstream from Denver and generally decreased in a downstream direction.

Elevated nutrient concentrations in streams have the potential to affect oxygen and food supplies for aquatic communities through eutrophication. Among the five main-stem sites monitored for IBI, the South Platte River at Henderson, Colo., had an IBI score of 24, which was the lowest for all sites considered and indicated significantly degraded conditions. Elevated nutrient concentrations in the South Platte River at Henderson, primarily caused by effluent from Denver's WWTPs, contribute to degraded conditions at this site.



Total nitrogen concentrations in streams along the Front Range were substantially larger downstream from WWTPs.



Total nitrogen and total phosphorus concentrations in the South Platte River were largest just downstream from Denver and then generally decreased in a downstream direction.

Nutrient concentrations were elevated downstream from WWTPs. Phosphorus concentrations were consistently in excess of USEPA recommended limits.

Mixed (urban/agriculture) land use has developed along the Front Range urban corridor starting just north of Denver, Colo., and extending to the Fort Collins, Colo., area. Water quality in this mixed land-use setting is the product of combined urban and agricultural land-use practices. For example, nitrate in surface water can be attributed in part to the large number of permitted discharges of WWTP effluent (point sources) in the urban area. However, ground-water irrigation return flows (nonpoint sources) from agricultural lands also contribute to the nitrate load in the river (McMahon and Böhlke, 1996).

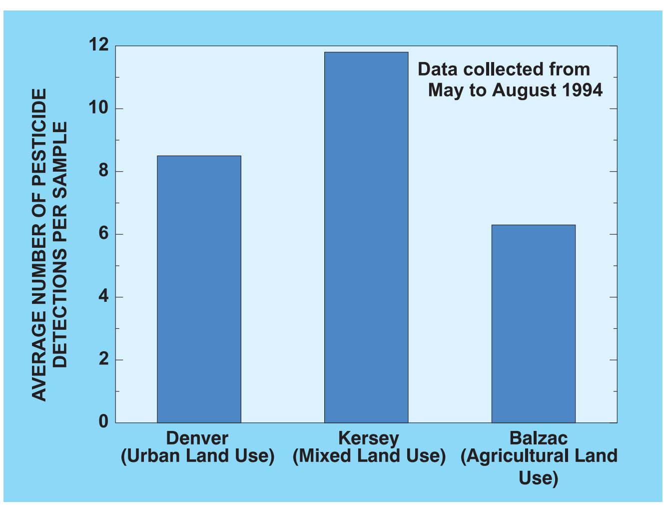
An example of a mixed (urban/agriculture) land-use setting, Dacono, Colo.

The average number of pesticides detected in surface-water samples at main-stem synoptic sites was greater in mixed land-use areas than in land-use settings that were exclusively urban or agricultural. The types of pesticides detected were a combination of the types of pesticides generally associated with urban settings (prometon, simazine, carbaryl, and diazinon) and those used commonly in agricultural areas (atrazine, metolachlor, cyanazine, and EPTC) (Kimbrough and Litke, in press). Pesticide concentrations measured at mixed land-use sites did exceed aquatic life criteria for three pesticides (Gilliom and others, in press); however, no drinking-water criteria were exceeded. Although no pesticides exceeded MCLs, the ecological or human health effects of long-term exposure to low concentrations of multiple pesticides is unknown.

The organochlorine compounds DDT, chlordane, dacthal, dieldrin, and PCB in bed sediment and fish tissue were detected in the greatest number and at the highest concentrations in streams affected by urban and mixed land use (*see* Summary of Compound Detections and Concentrations section, p. 28-34 for range of concentrations). This result represents a cumulative effect of multiple land uses (urban/agriculture) (Tate and Heiny, 1996). Furthermore, the highest mean concentrations of federally banned compounds (DDT and its metabolites, dieldrin, and total PCBs) in bed sediment and fish tissue throughout the basin occurred in the mixed land-use setting. Although these compounds have been restricted or banned for 20 to 25 years, they still are present in the environment and in a few samples persist at concentrations above levels of concern for the protection of fish-eating wildlife (Tate and Heiny, 1996).

Streams in the mixed land-use setting are slow moving with meandering to straight channels composed of runs and point bars. Channel bottoms are composed of gravel, the canopy is open with some overhanging vegetation, and streambanks are eroding or lined with rip-rap. Bank erosion and vegetation instability, which result in increased suspended sediment and less favorable habitat conditions for biological communities, are common in mixed land-use streams. The cumulative effect of contaminants from point and nonpoint sources and habitat alterations generally decreased the number of insect (invertebrate) species (Tate and Heiny, 1995) and also resulted in fish populations representative of moderately to significantly affected water-quality conditions based on an IBI.

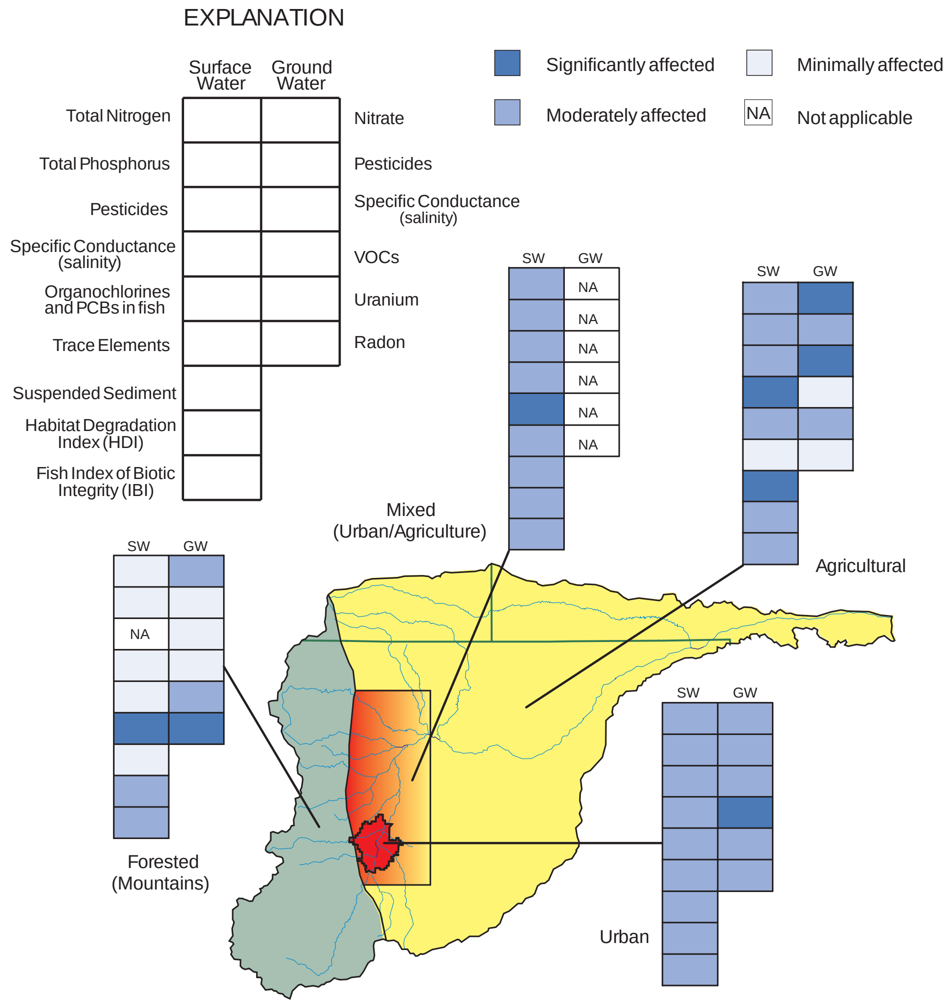
More pesticides were detected in surface-water samples from mixed (urban/agriculture) land-use areas.



The cumulative effects on water quality from urban and agricultural land uses in the mixed land-use setting were greater for selected constituents than in either land use alone.

MAJOR ISSUES AND FINDINGS: What Is the Relative Status of Water Quality by Land Use in the South Platte River Basin?

Previous sections of this report have examined the effects of different land uses on water quality using a combination of physical, chemical, and biological information from streams and aquifers. In this section, the status of water quality for each of four land uses will be compared and contrasted, and the role of land use as the primary factor in determining water quality will be discussed. A determination of the relative status of water quality will be accomplished by aggregating NAWQA data by land use and then summarizing the results in a single graphical display. Median values are used to characterize each land use, which places a greater emphasis on average characteristics for a land use rather than on extreme values that might occur at individual sites. The graphical display consists of nine measures of water quality for surface water and six measures of water quality for ground water. The surface-water measures include information on water, but also include information about stream habitat, fish communities, and suspended sediment. Each measure is ranked as to whether it is significantly affected, moderately affected, or minimally affected by land use. Details on how the 15 measures were classified and ranked are shown in the chart on the following page.



Relative ranking of water-quality indicators by land use in surface and ground water of the South Platte River Basin.

In the forested mountains, most measures rank as minimally affected by land use, but there are six measures that rank as more than minimally affected. Of these, four are affected by factors other than the dominant land use: trace elements in surface water are affected by mining, radon in ground water is affected by bedrock geology, and nitrate and VOCs in ground water are affected by low-density residential development. These exceptions indicate that other factors (such as geology) and minor land uses can have a larger effect on water quality than the dominant land use.

In the forested mountains, the habitat index (HDI) and fish index (IBI) also are ranked as moderately affected by land use. However, these two measures are ranked as moderately affected in all of the land uses. This situation arises because in each land use, there are sites that rank as minimally affected and sites that rank as more significantly affected; that is, there is as much variability among sites within the same land use as there is variability in sites between land uses. Habitat HDI and fish IBI can be affected by localized channel conditions as well as the land use in the immediate vicinity of the site.

The urban and mixed (urban/agriculture) land uses are very similar in overall water quality, with almost all measures ranked as moderately affected. There is considerable site-to-site variability in surface-water quality within urban land use, depending primarily on the magnitude of WWTP discharges near a site (Litke and Kimbrough, 1998). There is less variability in surface-water quality within the mixed (urban/agriculture) land use because sites in this land use integrate land-use effects. This integration was particularly evident for pesticides: concentrations of organochlorine pesticides and PCBs in fish were higher in mixed land use than elsewhere; and the largest variety of pesticides detected at a site occurred at a mixed (urban/agriculture) site. The significantly affected rankings for trace elements in surface water and radon in ground water within the forested land use do not carry through to the urban or mixed (urban/agricultural) land use. Much of the surface water from mountain streams is removed before it reaches the plains, and the crystalline mountain aquifers and plains alluvial aquifers are not hydrologically connected.

Agricultural land use has the most significant relative effect on water quality because it is a source for three constituents: nitrate in ground water, specific conductance (salinity) in surface water and ground water, and suspended sediment in surface water. Ground water in the agricultural land use is derived almost entirely from irrigation return flows, which infiltrate into the aquifer. Therefore, ground water is very representative of agricultural land use: it is highly affected by nitrate and salinity, but minimally affected by VOCs and radon. Surface water in the agricultural area, however, has three primary sources: upstream urban water, surface return flows from agricultural lands (irrigation return flows and occasional storm runoff), and ground-water recharge from the aquifer. When upstream urban water predominates, urban contaminants are carried to the agricultural users. When irrigation return flows predominate, water quality is related primarily to agricultural land use. But the mix of sources leads to considerable geographic and temporal variability in agricultural water quality.

An integrated assessment of water-quality conditions using multiple lines of evidence is a valuable tool for examining the physical, chemical, and biological factors affecting surface- and ground-water resources in the basin. Results from the NAWQA study demonstrate that natural and human factors can affect the quality of ground water and surface water and the biological communities at a given site. Moreover, water quality can vary depending on the physical features (mountains compared to plains), hydrologic conditions, land use in the immediate vicinity of the site, water-management practices, and the land use upstream/upgradient from the site.

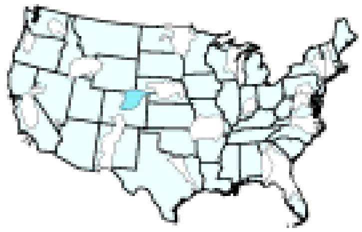
CLASSIFICATION RANKINGS

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than; >, greater than]

Water-quality indicators	Minimally affected	Moderately affected	Significantly affected
SURFACE WATER			
Total nitrogen[1]	< 1.6 mg/L	1.6 - 7.3 mg/L	> 7.3 mg/L
Total phosphorus[1]	< 0.1 mg/L	0.1 - 0.87 mg/L	> 0.87 mg/L
Pesticides[1]	< 6 detections	6 - 10 detections	> 10 detections
Specific conductance (salinity)[1]	< 397 µS/cm	397 - 1,350 µS/cm	> 1,350 µS/cm
Organochlorines and PCBs in fish[1]	< 2 detections	2 - 7 detections	> 7 detections
Trace elements[1]	< 3 exceedances	3 - 12 exceedances	> 12 exceedances
Suspended sediment[2]	< 14 mg/L	14 - 131 mg/L	> 131 mg/L
Habitat degradation index (HDI)[1]	< 9 = minimally degraded	9 - 14 = moderately degraded	> 14 = significantly degraded
Fish index of biotic integrity (IBI)[3]	> 45 = minimally degraded	25 - 45 = moderately degraded	< 25 = significantly degraded
GROUND WATER			
Nitrate[1]	< 0.4 mg/L	0.4 - 9.0 mg/L	> 9.0 mg/L
Pesticides[1]	No detections	1 - 3 detections	> 3 detections
Specific conductance (salinity)[1]	< 590 µS/cm	590 - 1,918 µS/cm	> 1,918 µS/cm
VOCs[1]	No detections	1 detection	> 1 detection
Uranium[1]	< 10 µg/L	10 - 49 µg/L	> 49 µg/L
Radon[1]	< 450 pCi/L	450 - 2,500 pCi/L	> 2,500 pCi/L

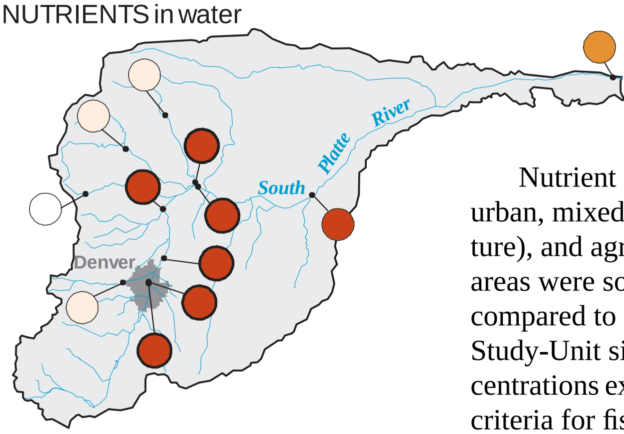
[1] Classification breakpoints are 25^{th} and 75^{th} percentiles of data sets. For trace elements, exceedances are above background levels determined by Heiny and Tate, 1997.
[2] Classification breakpoints were selected to bracket mean land-use concentrations.
[3] Classification breakpoints modified from Schrader, 1989.

WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT: Comparison of Stream Quality in the South Platte River Basin Study Unit with Nationwide NAWQA Findings.



Seven major water-quality characteristics were evaluated for stream sites in each NAWQA Study Unit. Summary scores for each characteristic were computed for all sites that had adequate data. Scores for each site in the South Platte River Basin Study Unit were compared with scores for all sites in the 20 NAWQA Study Units sampled during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water and semivolatile organic compounds, organochlorine pesticides and PCBs in sediment. (Methods used to compute rankings and evaluate aquatic-life criteria are described by Gilliom and others, in press).

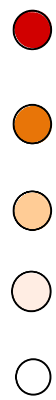
NUTRIENTS in water



Nutrient concentrations in urban, mixed (urban/agriculture), and agricultural land-use areas were some of the highest compared to other NAWQA Study-Unit sites. Ammonia concentrations exceeded aquatic-life criteria for fish (salmonids) toxicity at most sites in these land uses. In contrast, nutrient levels in mountain and rangeland sites were among the lowest nationally.

EXPLANATION

Ranking of stream quality relative to all NAWQA stream sites — Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more aquatic-life criteria were exceeded.



Greater than the 75th percentile (among the highest 25 percent of NAWQA stream sites)

Between the median and the 75th percentile

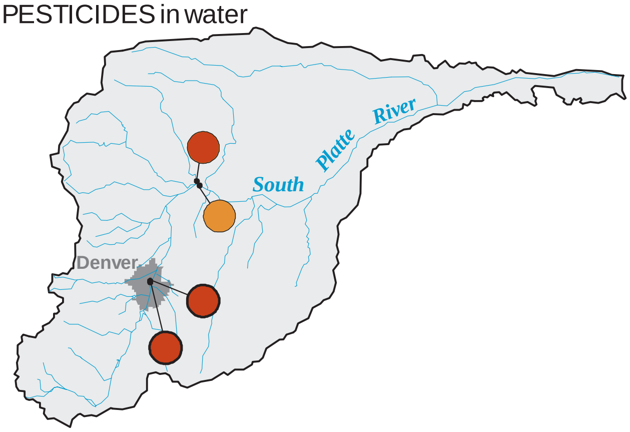
Between the 25th percentile and the median

Less than the 25th percentile (among the lowest 25 percent of NAWQA stream sites)

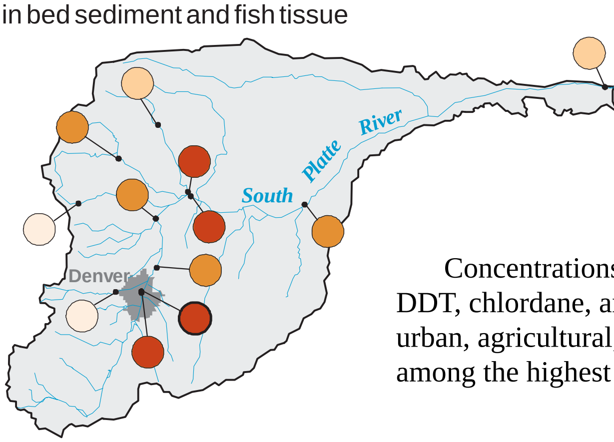
Insufficient data for analysis

Pesticide concentrations in the Denver urban area and in an agricultural area near Greeley, Colo., are among the highest of all NAWQA Study-Unit sites. Both urban sites exceeded the aquatic-life criteria for three compounds during the summer.

PESTICIDES in water

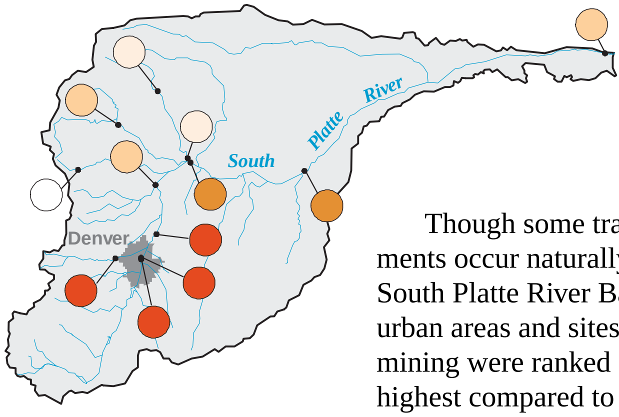


ORGANOCHLORINE PESTICIDES AND PCBs in bed sediment and fish tissue



Concentrations of organochlorine pesticides and PCBs including DDT, chlordane, and dieldrin in the South Platte River Basin in urban, agricultural, and mixed (urban/agriculture) land uses rank among the highest of all sites sampled in NAWQA Study Units.

TRACE ELEMENTS in bed sediment

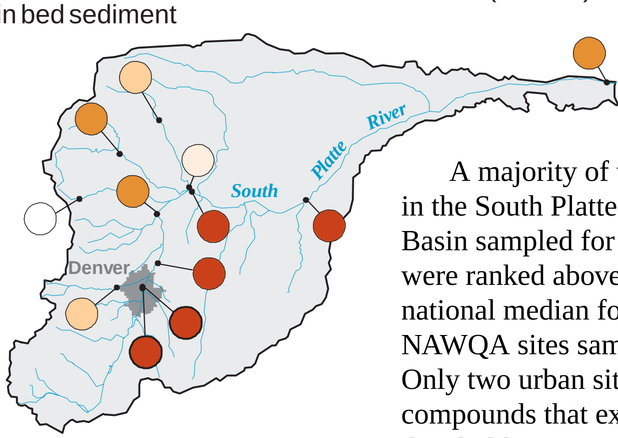


Though some trace elements occur naturally in soils, South Platte River Basin sites in urban areas and sites affected by mining were ranked among the highest compared to sites in other NAWQA Study Units.

CONCLUSIONS

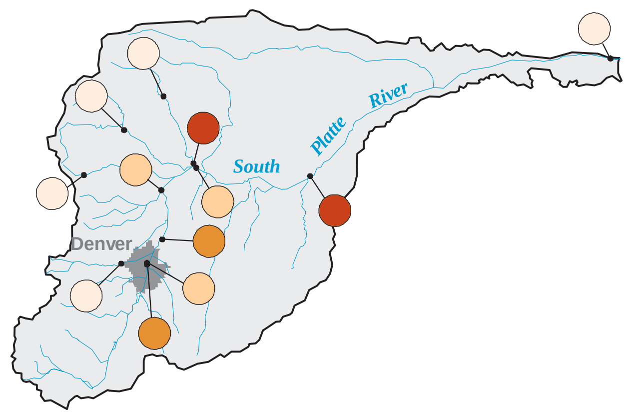
Physical, chemical, and biological measures indicate that urban, mixed (urban/agriculture), and agricultural land-use areas generally have poorer water quality not only within the South Platte River Basin but also compared to all sites sampled for the NAWQA program. In contrast, sites in forested mountain and rangeland areas have good water quality both within the basin and in comparison to all Study Units.

SEMIVOLATILE ORGANIC COMPOUNDS (SVOCs) in bed sediment



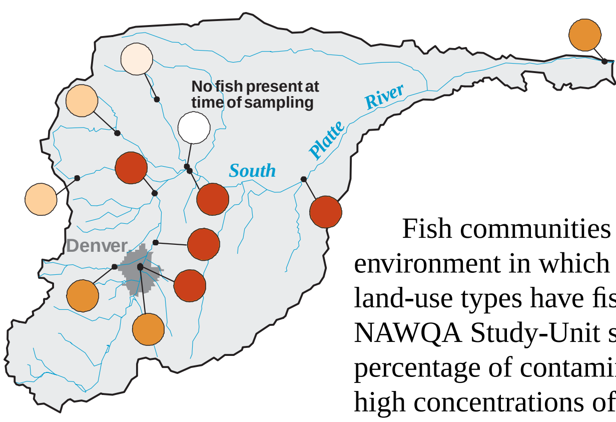
A majority of the sites in the South Platte River Basin sampled for SVOCs were ranked above the national median for all NAWQA sites sampled. Only two urban sites had compounds that exceeded threshold concentrations known to have adverse effects on aquatic life.

STREAM HABITAT DEGRADATION



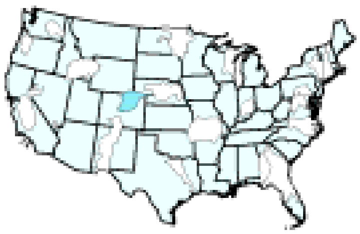
Physical characteristics of stream channels (natural compared to modified) and streambanks (vegetation cover, bank erosion) strongly affect water quality and the ability of streams to support biological communities. In the South Platte River Basin, the physical condition of most stream habitat assessed was lower than the national median; the exceptions occurred at sites located in agricultural and urban areas, which also had degraded fish communities.

FISH COMMUNITY DEGRADATION



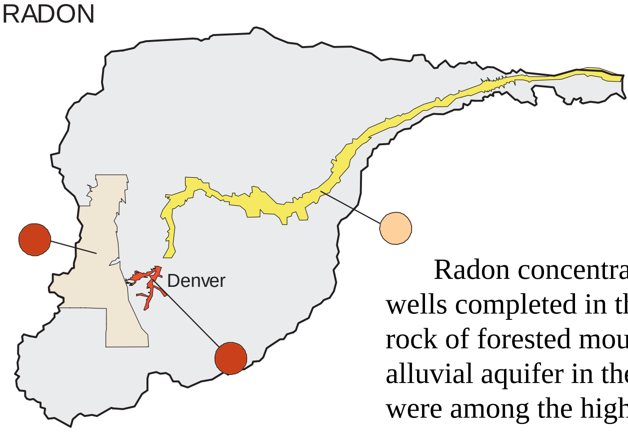
Fish communities are directly related to the habitat available and the chemistry of the environment in which they live. Sites in urban, agricultural, and mixed (urban/agriculture) land-use types have fish communities that are among the most severely degraded of all NAWQA Study-Unit sites. These degraded fish communities are characterized by a large percentage of contaminant-tolerant species and correlated to stream habitat degradation and high concentrations of chemicals in water, sediment, and fish. In contrast, fish communities in forested mountain and rangeland sites were ranked lower than the national median; the exception occurs at a mountain site having high concentrations of trace elements in sediment as a result of upstream mining.

WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT: Comparison of Ground-Water Quality in the South Platte River Basin Study Unit with Nationwide NAWQA Findings.



Five major water-quality characteristics were evaluated for ground-water studies in each NAWQA Study Unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that had adequate data. Scores for each aquifer and shallow ground-water area in the South Platte River Basin Study Unit were compared with scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer also are compared to established drinking-water standards and criteria for protection of human health. (Methods used to compute rankings and evaluate standards and criteria are described by Gilliom and others, in press).

RADON



Radon concentrations measured in wells completed in the crystalline bedrock of forested mountain areas and the alluvial aquifer in the Denver urban area were among the highest of all NAWQA ground-water sites nationwide. Wells completed in agricultural areas (alluvium) had comparatively low concentrations and were ranked below the national median (50th percentile).

EXPLANATION

Drinking-water aquifers

Forested mountain area

Shallow ground-water areas

Agricultural area (irrigated cropland)

Urban area

Ranking of ground-water quality relative to all NAWQA ground-water studies — Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more standards or criteria were exceeded.

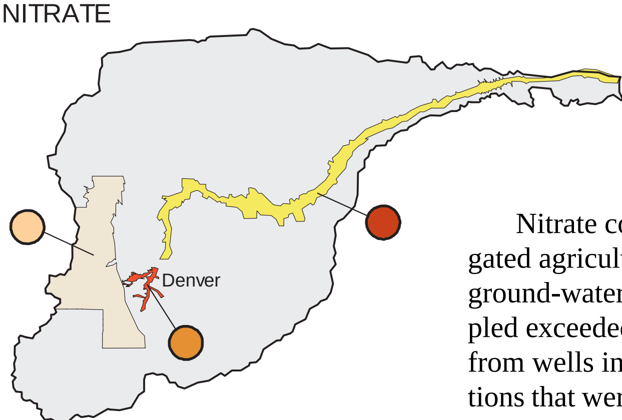
Greater than the 75th percentile (among the highest 25 percent of NAWQA ground-water sites)

Between the median and the 75th percentile

Between the 25th percentile and the median

Less than the 25th percentile (among the lowest 25 percent of NAWQA ground-water sites)

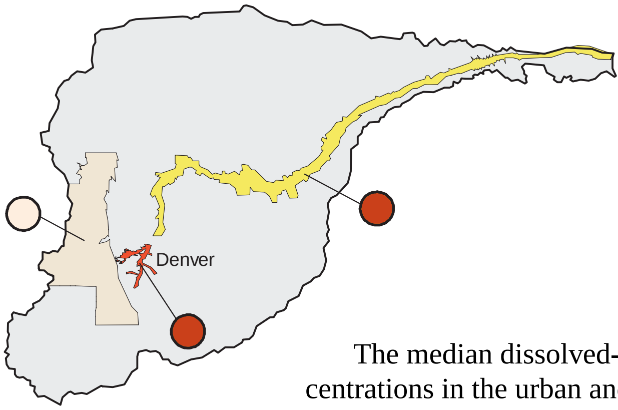
NITRATE



Nitrate concentrations in shallow ground water underlying irrigated agricultural lands were among the highest of all NAWQA ground-water sites, and water from about one-half the wells sampled exceeded drinking-water standards. Ground water sampled from wells in the forested mountain areas had nitrate concentrations that were below the national median. Only one well exceeded drinking-water standards in the mountain area. Ten percent of the samples collected from the shallow alluvial ground water in the urban area exceeded the USEPA drinking-water standard.

WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT: Comparison of Ground-Water Quality in the South Platte River Basin Study Unit with Nationwide NAWQA Findings.

DISSOLVED SOLIDS



The median dissolved-solids concentrations in the urban and agricultural areas of the basin ranked in the top 25 percent of all NAWQA ground-water sites; no drinking-water wells were sampled in these areas. Although dissolved-solids concentrations in the mountain area were among the lowest for NAWQA sites, they exceeded drinking-water standards in 2 of the 27 household wells sampled.

CONCLUSIONS

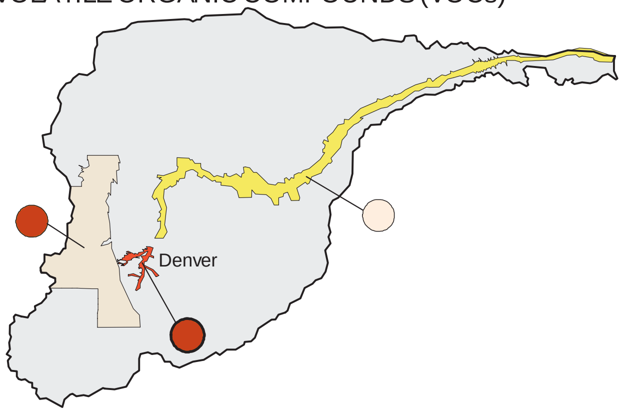
In the South Platte River Basin, compared to other NAWQA Study Units:

Radon and VOCs in the urban land-use setting and developed areas in the forested mountain setting were among the top 25 percent.

Dissolved solids and pesticides in the urban and agricultural land-use settings were among the top 25 percent.

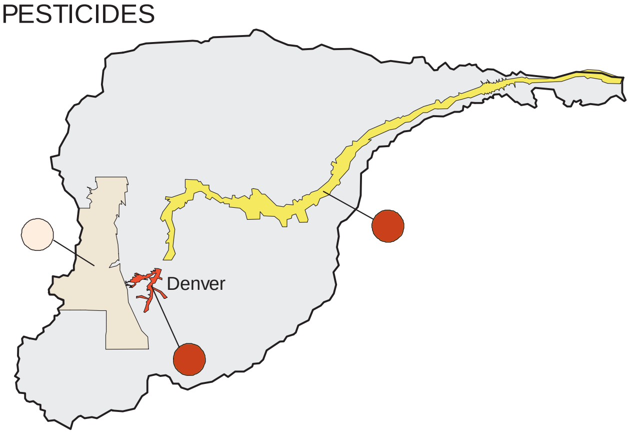
Nitrate concentrations in the urban and agricultural land-use settings were higher than the national median (50th percentile).

VOLATILE ORGANIC COMPOUNDS (VOCs)



No VOCs were detected in ground water underlying agricultural areas. In contrast, more than 86 percent of urban wells sampled contained VOCs, placing it in the top 25 percent of all NAWQA ground-water sites nationwide. Only 30 percent of mountain wells sampled contained VOCs, but national NAWQA rankings were such that VOC detections in drinking-water wells sampled in the mountain areas of the basin were also among the highest for all NAWQA ground-water sites nationwide.

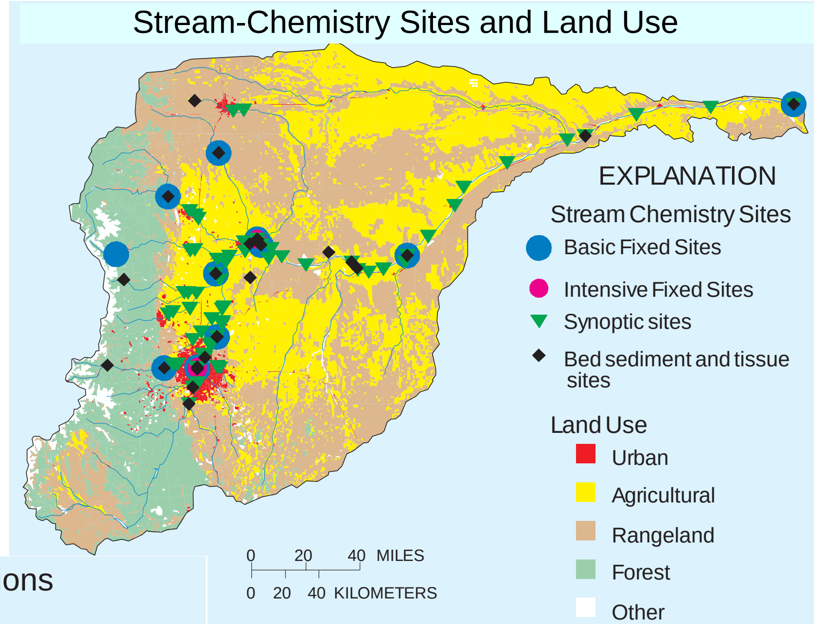
PESTICIDES

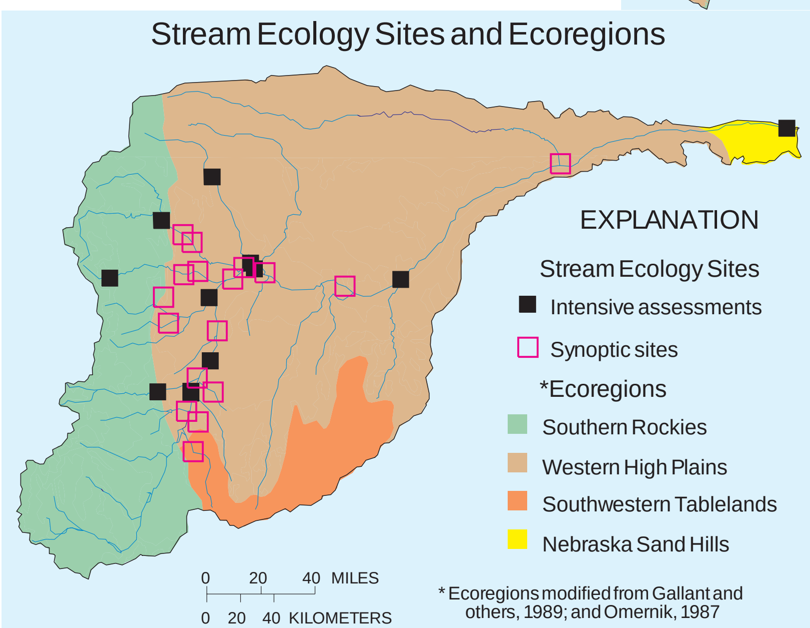


Pesticides were detected in greater than 90 percent of the wells sampled in urban and agricultural areas. Pesticides were detected in 27 of 30 wells sampled in the urban area and 29 of 30 wells sampled in the agricultural area, which ranks these areas among the highest of all NAWQA ground-water sites nationwide. No pesticides were detected in the mountain area.

STUDY DESIGN AND DATA COLLECTION

The goal of the data collection for this study was to characterize, in a nationally consistent manner, the broad-scale geographic and seasonal distribution of water-quality conditions in relation to major contaminant sources and background conditions (Gilliom and others, 1995). The study design was multidisciplinary in nature, examining the stream chemistry, stream ecology, and ground-water chemistry across the basin. To the extent possible, sampling sites represent homogeneous combinations of land use, ecoregions, and hydrogeology that generally are relevant to surface- and ground-water quality. An environmental framework of the basin was developed and a stratification process followed in

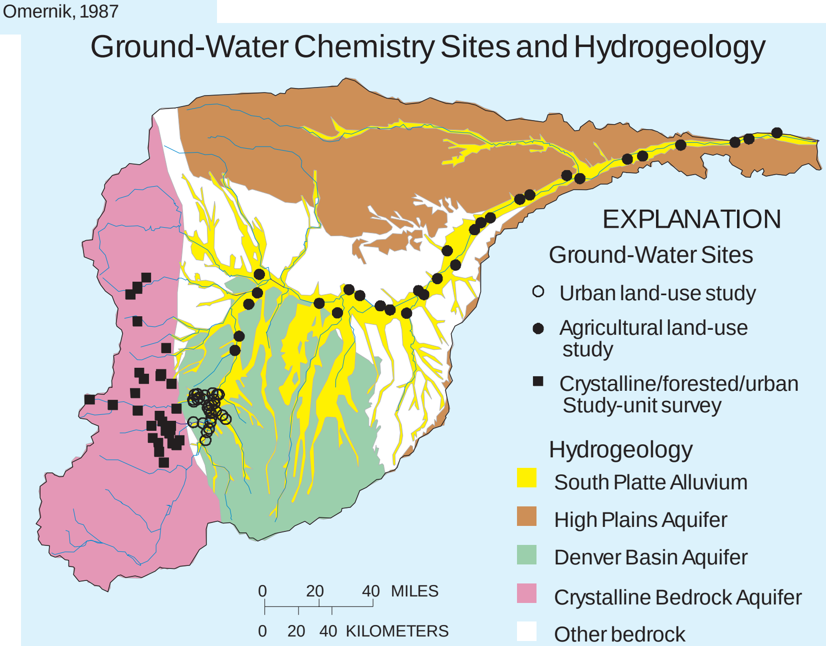




which sampling sites were selected that address the most important water-quality issues and concerns within the basin. Physiographic province, ecoregion, geology, and land use were the strata used in the site selection process.

One of the advantages of the NAWQA design is the use of multiple lines of evidence to describe water-quality conditions (Gilliom and others, 1995). The multiyear (April 1993-September 1995), intensive data collection phase of the South Platte River Basin study provided information on stream chemistry, chemistry of bed sediment and fish tissue, stream ecology, and ground-water chemistry. The sampling sites associated with the various study components are plotted on the appropriate maps, and the designs of the individual study components are described in the table on the following page.

Finally, study design and data collection activities during the intensive multiyear sampling effort yielded 104 surface-water sites on 24 streams, 35 sampling locations in 5 reservoirs, and 159 wells throughout the basin.



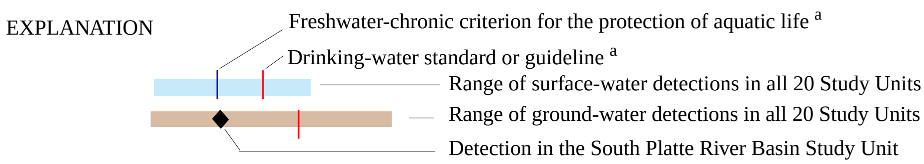
SUMMARY OF DATA COLLECTION IN THE SOUTH PLATTE RIVER BASIN STUDY UNIT, 1992-95

Study component	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream Chemistry				
Basic Fixed Sites — water column	Continuous streamflow, major ions, nutrients, organic carbon, suspended sediment, and physical parameters: Describe concentration, seasonal variability, and loads.	Streams draining predominant land-use types across basin: forest, urban, mixed, agricultural, and rangeland.	12	Monthly plus storms; April 1993-Sept. 1995
Intensive Fixed Sites — water column	In addition to the above constituents, 83 dissolved pesticides were analyzed to determine concentration and timing of occurrence.	A subset of basic sites draining agricultural and urban land-use areas.	3	Minimum monthly plus storms and more often during high use period; ~20 per year, 1993-94
Synoptic sites — water column	Streamflow, nutrients or pesticides, and physical parameters were determined during high or low flow conditions to describe short-term presence and distribution of constituents over broad scale in basin.	Streams draining a variety of land-use types; 5 synoptics for nutrients and 3 synoptics for pesticides.	20-64 16-20	April, May, June, Aug., 1994, Jan., 1995 May, June, Aug., 1994
Contaminants — bed sediments	Trace elements and hydrophobic pesticides and other organic compounds were analyzed in streambed sediments to determine occurrence and spatial distribution.	Depositional zones for all basic and intensive sites and several synoptic sites.	23	Summer 1992 (17) and 1993(6)
Contaminants — fish tissue	Trace elements in fish livers and organic compounds in composites of whole fish were sampled and analyzed to determine occurrence and spatial distribution.	All basic and intensive sites and some synoptic sites. Samples were taken from fish species common to and across Study Unit.	23; only 19 had fish	Summer 1992 (17) and 1993 (7); one site sampled twice
Stream Ecology				
Intensive assessments	Fish, macroinvertebrates, algae, and aquatic and riparian habitat were sampled and described to assess biological communities in different land uses.	Stream reaches were co-located with basic sites. Sites represent the variety of land uses within the basin.	11 1	Once in 1993-95; 3 reaches sampled at each of 4 sites in 1994 Once in 1995
Synoptic sites	Macroinvertebrates, algae, nutrients, and aquatic and riparian habitat were sampled to assess spatial distribution of biological communities in predominant land uses.	Stream reaches were co-located with basic sites and a sub-set of synoptic stream chemistry sites. Sites represent urban, agricultural, and mixed land uses.	26	Once in summer 1993 (Aug.-Sept.)
Ground-Water Chemistry				
Land-use effects — alluvial/urban	Major ions, nutrients, pesticides, VOCs, radon, trace elements, and DOC were sampled and analyzed to determine effects of Denver metro area on the quality of recently recharged ground water in the alluvial aquifer.	Existing non-drinking water wells screened near the water table in the urban area were located using a statistically random selection process.	30	Once in 1993 (July-Sept.)
Land-use effects — alluvial/agricultural	Major ions, nutrients, pesticides, VOCs, radon, trace elements, tritium, DOC, and isotopes of nitrogen and uranium were sampled and analyzed to determine effects of irrigated agriculture on the quality of recently recharged ground water in the alluvial aquifer.	Newly installed monitoring wells completed at water table were located using a statistically random selection process. Predominant crops: Corn, wheat and grains >20 percent.	30	Once in 1994 (June-Aug.)
Aquifer Study-unit survey — crystalline/forest/urban	Major ions, nutrients, pesticides, VOCs, radon, trace elements, tritium, and DOC were sampled and analyzed to assess condition of ground-water quality in forested urbanized crystalline bedrock aquifer.	Existing domestic wells completed in bedrock (<400 ft deep) located using a statistically random selection process.	27	Once in 1995 (July-Sept.)
Special Studies				
Reservoir sites — water column (Five agricultural reservoirs downstream from Kersey, Colo.)	Nutrients and physical parameters were determined from vertical profiles in agricultural reservoirs during one reservoir irrigation season. Nutrient budgets computed to determine if reservoirs are a source/sink of nutrients to irrigation supply water. Sampled for algae and chlorophyll.	Five reservoirs (Riverside, Jackson, Jumbo, Prewitt, and Sterling) were selected in agricultural land-use areas.	35 (7 sites per reservoir)	March, June, July, Sept., 1995
Stream-aquifer interaction (south of Greeley, Colo.)	Major ions, nutrients, dissolved gases, stable isotopes of carbon, nitrogen, and sulfur, chlorofluorocarbons, tritium, and DOC were collected and analyzed to describe the processes controlling the fate of nitrogen-contaminated ground water near areas of discharge to the South Platte River.	Monitoring wells were installed along flow paths from recharge to discharge area. Wells were nested and sampled top, middle, and bottom of aquifer.	47	1 round of sampling (1992); 2 rounds in 1993; 2 rounds in 1994
Degradation study (Denver, Colo.)	Major ions, nutrients, dissolved gases, VOCs, stable isotopes of carbon, and DOC were collected and analyzed to determine the transport and degradation of VOCs in the alluvial aquifer.	Monitoring wells were installed and sampled along flow paths from a known VOC contaminant source to its discharge to South Platte River. Wells were nested and completed at multiple depths.	25	2 rounds in 1994; 1 round in 1995; 1 round in 1996

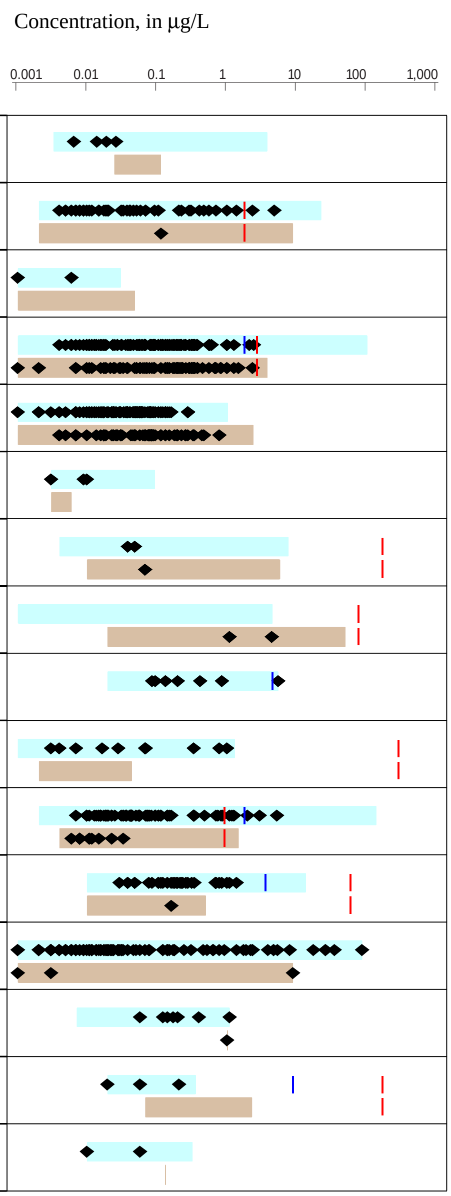
SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS: Compounds Detected in Surface and Ground Water in the South Platte River Basin.

The following tables summarize data collected for NAWQA studies from 1992–95 by listing results for the South Platte River Basin Study Unit compared to the NAWQA national range for each compound detected. The data were collected at a wide variety of places and times. In order to represent the wide concentration ranges observed among Study Units, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1,000), rather than the precise number. The complete data set used to construct these tables is available upon request.

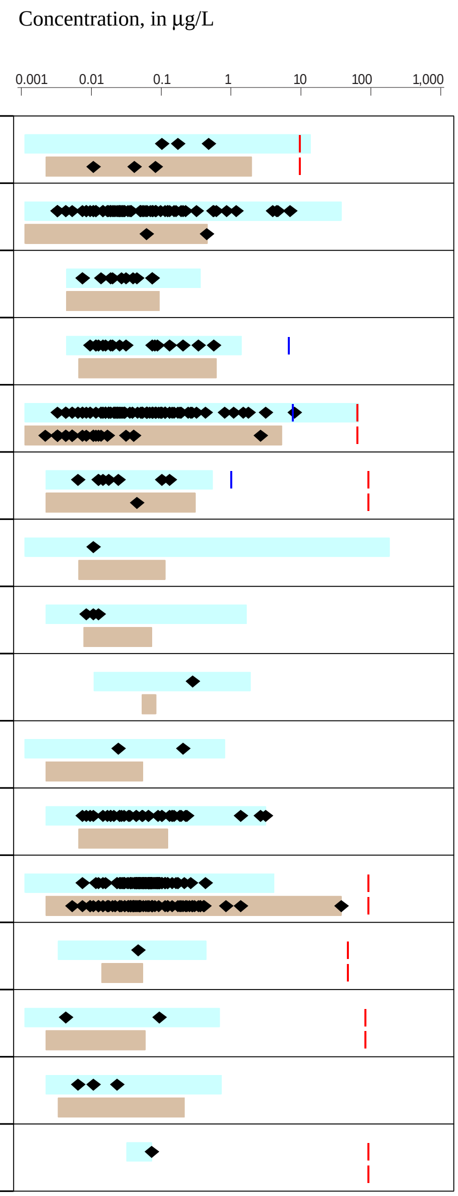
Concentrations of pesticides, volatile organic compounds, and nutrients detected in ground and surface waters of the South Platte River Basin Study Unit. [mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter, %, percent; <, less than; - -, not measured; trade names may vary]



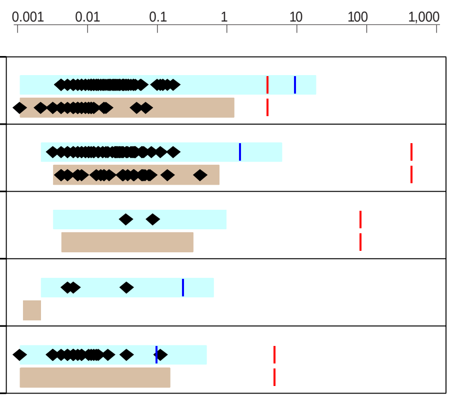
Herbicide (Trade or common name)	Rate of detection [b]
Acetochlor	6% 0%
Alachlor (Lasso)	21% 1%
2,6-Diethylaniline	<1% 0%
Atrazine (AAtrex)	90% 61%
Deethylatrazine[c] (Atrazine metabolite)	61% 54%
Benfluralin (Balan, Benefin)	1% 0%
Bentazon (Basagran)	1% 1%
Bromacil (Bromax 90, Urox B)	0% 2%
Bromoxynil (Buctril, Brominal)	5% 0%
Butylate (Sutan +)	4% 0%
Cyanazine (Bladex)	45% 5%
2,4-D (2,4-D and many others)	24% 1%
DCPA (Dacthal)	50% 1%
Dacthal, mono-acid (Dacthal metabolite)	5% 1%
Dicamba (Banvel)	2% 0%
Dichlorprop (2,4-DP)	1% 0%



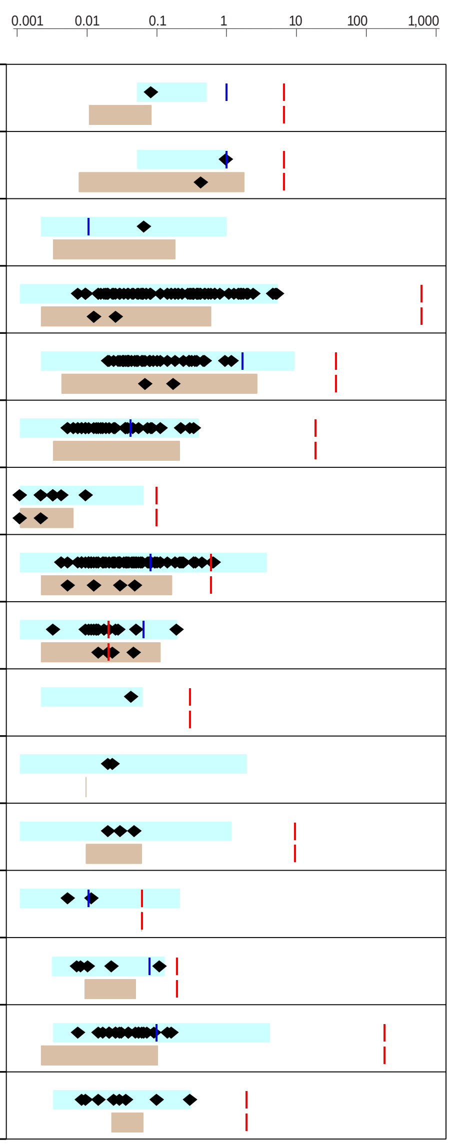
Herbicide (Trade or common name)	Rate of detection [b]
Diuron (Direx and many others)	2% 2%
EPTC (Eptam)	41% 2%
Ethalfluralin (Sonalan)	6% 0%
Linuron (Lorox)	10% 0%
Metolachlor (Dual, Bicep)	50% 10%
Metribuzin (Lexone, Sencor)	4% 1%
Molinate (Ordram)	1% 0%
Napropamide (Devrinol)	1% 0%
Oryzalin (Surflan)	1% 0%
Pebulate (Tillam)	1% 0%
Pendimethalin (Prowl)	20% 0%
Prometon (Pramitol)	93% 64%
Pronamide (Kerb)	1% 0%
Propachlor (Ramrod)	1% 0%
Propanil (Stampede)	1% 0%
Propham (IPC)	1% 0%



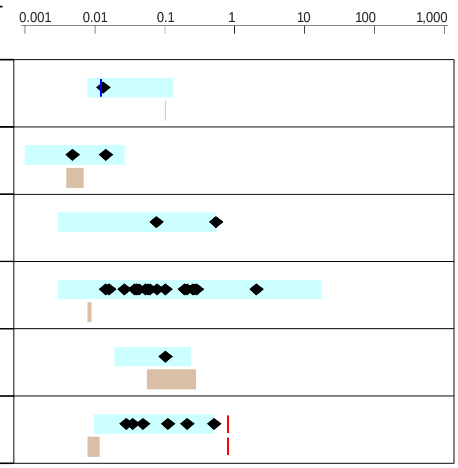
Herbicide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
Simazine (Aquazine, Princep)	43% 13%	
Tebuthiuron (Spike, Graslan)	26% 15%	
Terbacil[c] (Sinbar)	1% 0%	
Triallate (Far-Go)	1% 0%	
Trifluralin (Treflan and many others)	5% 0%	



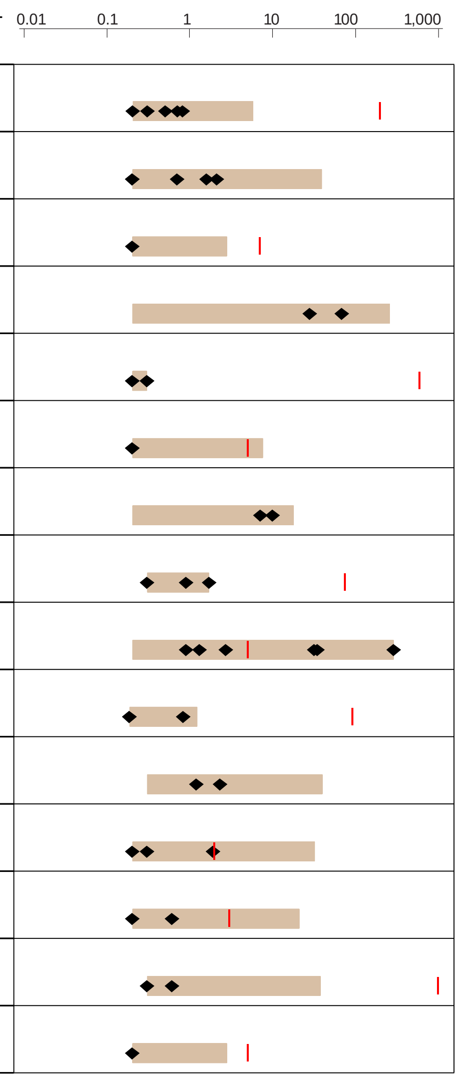
Insecticide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
Aldicarb[c] (Temik)	1% 0%	
Aldicarb sulfoxide[c] (Aldicarb metabolite)	1% 1%	
Azinphos-methyl[c] (Guthion)	1% 0%	
Carbaryl[c] (Sevin)	48% 3%	
Carbofuran[c] (Furadan)	25% 2%	
Chlorpyrifos (Dursban, Lorsban)	15% 0%	
p,p'-DDE (*p,p'*-DDT metabolite)	<1% <1%	
Diazinon	48% 3%	
Dieldrin (Dieldrex, Dieldrite)	9% 3%	
Disulfoton[c] (Disyston and many others)	1% 0%	
Ethoprop (Mocap)	1% 0%	
Fonofos (Dyfonate)	2% 0%	
alpha-HCH (*alpha*-BHC, *alpha*-lindane)	1% 0%	
gamma-HCH (Lindane)	2% 0%	
Malathion (Malathion)	13% 0%	
Methyl parathion (Penncap-M)	4% 0%	



Insecticide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
Parathion (Alkron and many others)	1% 0%	
cis-Permethrin[c] (Ambush, Pounce)	1% 0%	
Phorate (Thimet and many others)	1% 0%	
Propargite (Comite, Omite)	11% 0%	
Propoxur (Baygon)	1% 0%	
Terbufos (Counter)	4% 0%	



Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
1,1,1-Trichloroethane (Methylchloroform)	-- 5%	
1,1-Dichloroethane (Ethylidene dichloride)	-- 5%	
1,1-Dichloroethene (Vinylidene chloride)	-- 1%	
1,2,4-Trimethylbenzene (Psudocumene)	-- 2%	
1,2-Dichlorobenzene (*o*-Dichlorobenzene)	-- 4%	
1,2-Dichloropropane (Propylene dichloride)	-- 2%	
1,3,5-Trimethylbenzene (Mesitylene)	-- 2%	
1,4-Dichlorobenzene (*p*-Dichlorobenzene)	-- 3%	
Benzene	-- 6%	
Chlorobenzene (Monochlorobenzene)	-- 3%	
Chloroethane (Ethyl chloride)	-- 2%	
Chloroethene (Vinyl Chloride)	-- 3%	
Chloromethane (Methyl chloride)	-- 2%	
Dichlorodifluoromethane (CFC 12)	-- 2%	
Dichloromethane (Methylene chloride)	-- 1%	



Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.01, 0.1, 1, 10, 100, 1,000)
Dimethylbenzenes (Xylenes (total))	-- 4%	
Ethylbenzene (Phenylethane)	-- 3%	
Isopropylbenzene (Cumene)	-- 5%	
Methylbenzene (Toluene)	-- 3%	
Naphthalene	-- 3%	
total Trihalomethanes	-- 6%	
Trichloroethene (TCE)	-- 4%	
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)	-- 6%	
n-Butylbenzene (1-Phenylbutane)	-- 3%	
n-Propylbenzene (Isocumene)	-- 3%	
p-Isopropyltoluene (*p*-Cymene)	-- 1%	
sec-Butylbenzene	-- 4%	
tert-Butylbenzene	-- 2%	
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)	-- 1%	

Volatile organic compound (Trade or common name)	Rate of detection b	Concentration, in µg/L (0.01, 0.1, 1, 10, 100, 1,000, 10,000, 100,000)
Methyl *tert*-butyl[d] ether (MTBE)	-- 26%	
Tetrachloroethene (Perchloroethene)	-- 11%	

Nutrient (Trade or common name)	Rate of detection [b]	Concentration, in mg/L (0.01, 0.1, 1, 10, 100, 1,000, 10,000, 100,000)
Dissolved ammonia	91% 88%	
Dissolved ammonia plus organic nitrogen as nitrogen	82% 74%	
Dissolved phosphorus as phosphorus	77% 80%	
Dissolved nitrite plus nitrate	97% 78%	

Other	Rate of detection [b]	Concentration, in pCi/L (1, 10, 100, 1,000, 10,000, 100,000)
Radon 222	-- 100%	

Pesticides, volatile organic compounds, and nutrients not detected in ground and surface waters of the South Platte River Basin Study Unit.

Herbicides

2,4,5-T

2,4,5-TP (Silvex, Fenoprop)

2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone)

Acifluorfen (Blazer, Tackle 2S)

Chloramben (Amiben, Amilon-WP, Vegiben)

Clopyralid (Stinger, Lontrel, Reclaim, Transline)

Dinoseb (Dinosebe)

Fenuron (Fenulon, Fenidim)

Fluometuron (Flo-Met, Cotoran, Cottonex, Meturon)

MCPA (Rhomene, Rhonox, Chiptox)

MCPB (Thistrol)

Neburon (Neburea, Neburyl, Noruben)

Norflurazon (Evital, Predict, Solicam, Zorial)

Picloram (Grazon, Tordon)

Thiobencarb (Bolero, Saturn, Benthiocarb, Abolish)

Triclopyr (Garlon, Grandstand, Redeem, Remedy)

Insecticides

3-Hydroxycarbofuran (Carbofuran metabolite)

Aldicarb sulfone (Standak, aldoxycarb, aldicarb metabolite)

Methiocarb (Slug-Geta, Grandslam, Mesurol)

Methomyl (Lanox, Lannate, Acinate)

Oxamyl (Vydate L, Pratt)

Volatile organic compounds

1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA)

1,1,2,2-Tetrachloroethane

1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113)

1,1,2-Trichloroethane (Vinyl trichloride)

1,1-Dichloropropene

1,2,3-Trichlorobenzene (1,2,3-TCB)

1,2,3-Trichloropropane (Allyl trichloride)

1,2,4-Trichlorobenzene

1,2-Dibromo-3-chloropropane (DBCP, Nemagon)

1,2-Dibromoethane (EDB, Ethylene dibromide)

1,2-Dichloroethane (Ethylene dichloride)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,3-Dichloropropane (Trimethylene dichloride)

1-Chloro-2-methylbenzene (*o*-Chlorotoluene)

1-Chloro-4-methylbenzene (*p*-Chlorotoluene)

2,2-Dichloropropane

Bromobenzene (Phenyl bromide)

Bromochloromethane (Methylene chlorobromide)

Bromomethane (Methyl bromide)

Dibromomethane (Methylene dibromide)

Ethenylbenzene (Styrene)

Hexachlorobutadiene

Tetrachloromethane (Carbon tetrachloride)

Trichlorofluoromethane (CFC 11, Freon 11)

cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)

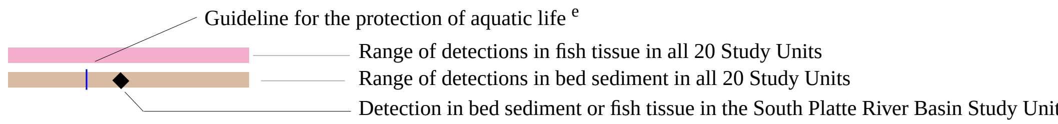
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)

Nutrients

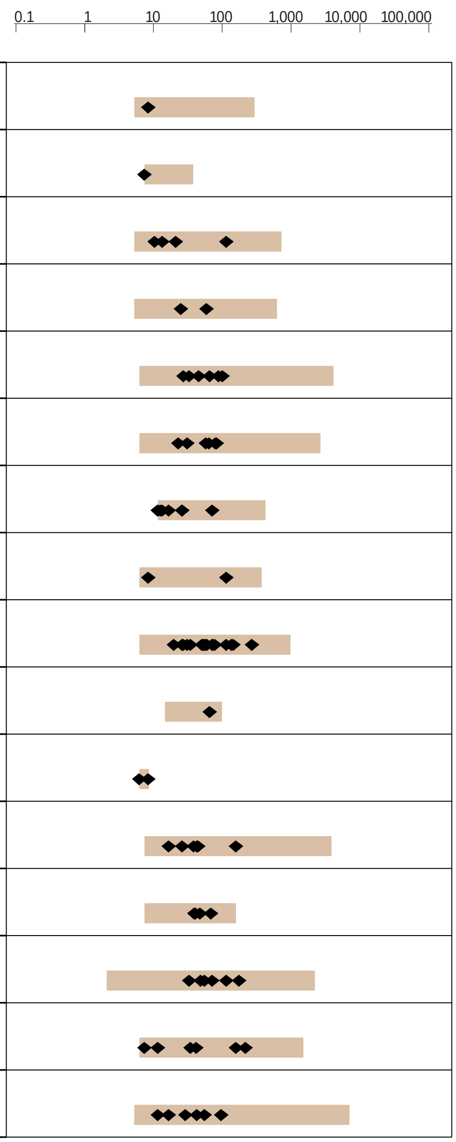
No non-detects

Concentrations of semivolatile organic compounds, organochlorine compounds, and trace elements detected in fish tissue and bed sediment of the South Platte River Basin Study Unit. [µg/g, micrograms per gram; µg/kg, micrograms per kilogram; %, percent; <, less than; - -, not measured; trade names may vary]

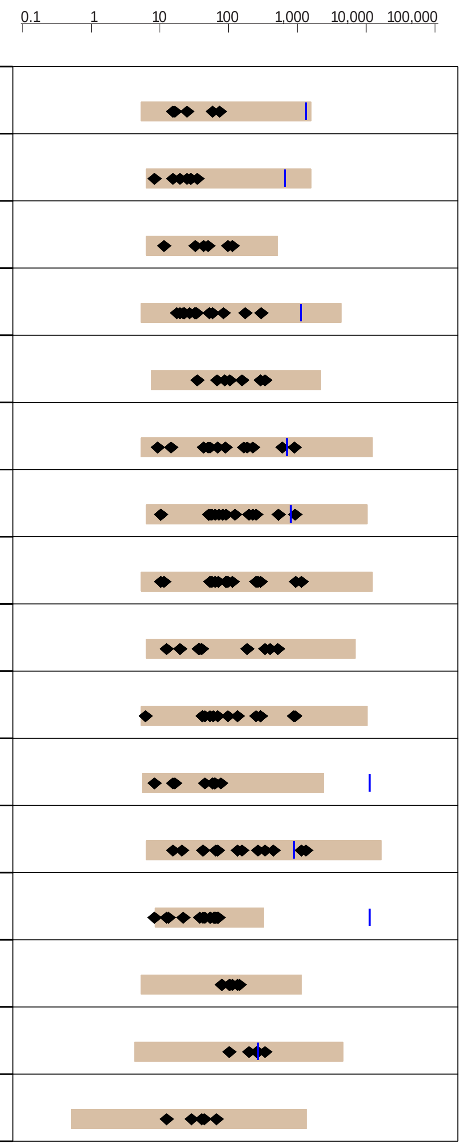
EXPLANATION



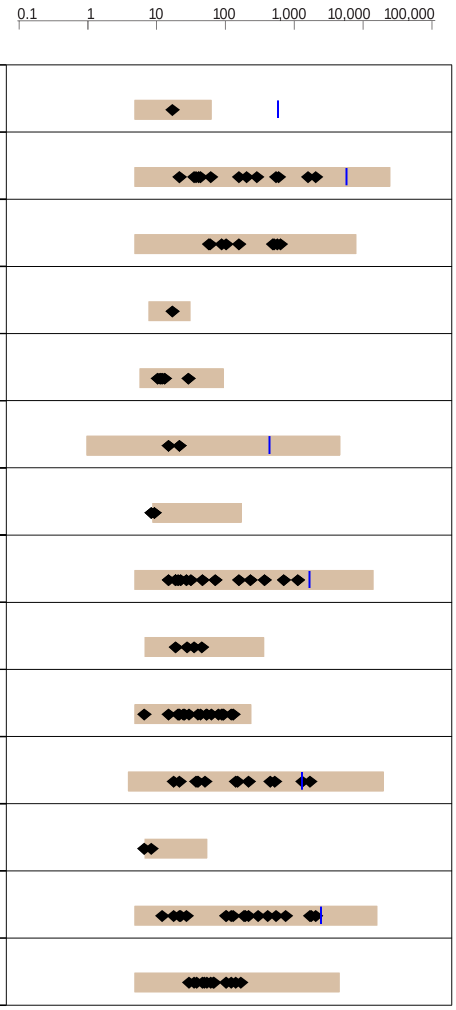
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
1,2-Dimethylnaphthalene	-- 5%	
1,3-Dichlorobenzene	-- 5%	
1,6-Dimethylnaphthalene	-- 20%	
1-Methyl-9H-fluorene	-- 10%	
1-Methylphenanthrene	-- 30%	
1-Methylpyrene	-- 32%	
2,2-Biquinoline	-- 40%	
2,3,6-Trimethylnaphthalene	-- 10%	
2,6-Dimethylnaphthalene	-- 90%	
2,6-Dinitrotoluene	-- 5%	
2-Chloronaphthalene	-- 10%	
2-Methylanthracene	-- 30%	
3,5-Dimethylphenol	-- 20%	
4,5-Methylenephenanthrene	-- 30%	
9H-Carbazole	-- 30%	
9H-Fluorene	-- 30%	



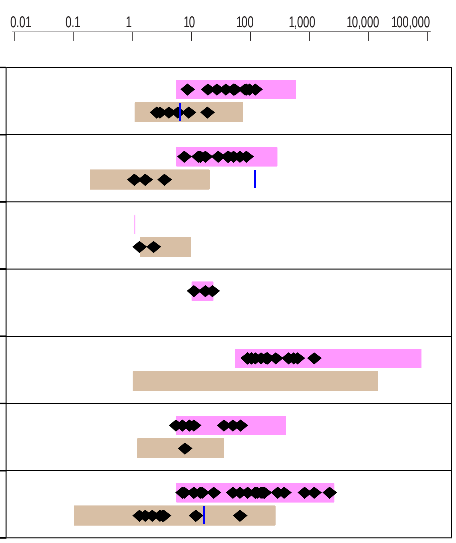
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
Acenaphthene	-- 30%	
Acenaphthylene	-- 35%	
Acridine	-- 30%	
Anthracene	-- 65%	
Anthraquinone	-- 35%	
Benz[*a*]anthracene	-- 63%	
Benzo[*a*]pyrene	-- 75%	
Benzo[*b*]fluoranthene	-- 75%	
Benzo[*ghi*]perylene	-- 45%	
Benzo[*k*]fluoranthene	-- 70%	
Butylbenzylphthalate	-- 42%	
Chrysene	-- 65%	
Di- *n* -butylphthalate	-- 85%	
Di- *n* -octylphthalate	-- 40%	
Dibenz[*a,h*]anthracene	-- 25%	
Dibenzothiophene	-- 25%	



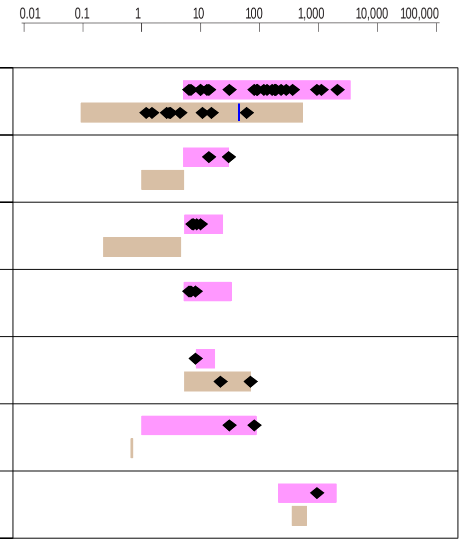
Semivolatile organic compound	Rate of detection [b]
Diethylphthalate	-- 5%
Fluoranthene	-- 74%
Indeno[1,2,3- *cd*] pyrene	-- 45%
Isophorone	-- 5%
Isoquinoline	-- 25%
Naphthalene	-- 10%
Pentachloronitrobenzene	-- 10%
Phenanthrene	-- 70%
Phenanthridine	-- 20%
Phenol	-- 100%
Pyrene	-- 68%
bis(2-Chloroethoxy)methane	-- 15%
bis(2-Ethylhexyl)phthalate	-- 100%
p-Cresol	-- 70%



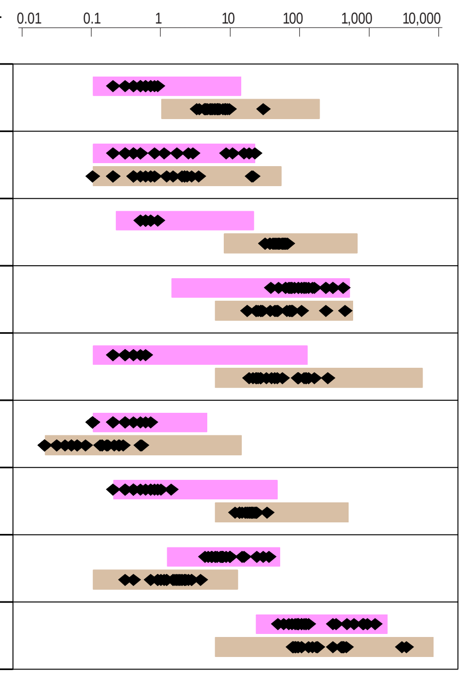
Organochlorine compound (Trade name)	Rate of detection [b]
total-Chlordane	38% 30%
Dieldrin (Panoram D-31)	42% 25%
Endosulfan I (*alpha*-endosulfan)	-- 10%
Endrin (endrine)	12% 0%
PCB, total	62% 0%
DCPA (dacthal, chlorthal-dimethyl)	27% 5%
p,p'-DDE	85% 45%



Organochlorine compound (Trade name)	Rate of detection [b]
total-DDT	85% 45%
gamma-HCH (lindane)	8% --
Heptachlor epoxide (heptachlor metabolite)	15% 0%
Hexachlorobenzene	12% --
p,p'-Methoxychlor (Marlate)	4% 33%
Pentachloroanisole	8% 0%
Toxaphene (camphechlors)	4% 0%



Trace element	Rate of detection [b]
Arsenic	70% 100%
Cadmium	91% 100%
Chromium	65% 100%
Copper	100% 100%
Lead	39% 100%
Mercury	83% 92%
Nickel	70% 100%
Selenium	100% 100%
Zinc	100% 100%



Summary of Compound Detections and Concentrations tables were designed and built by Sarah Ryker, Jonathon Scott, and Alan Haggland, U.S. Geological Survey.

SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS: Compounds Not Detected in Fish Tissue and Streambed Sediment in the South Platte River Basin.

Semivolatile organic compounds, organochlorine compounds, and trace elements not detected in fish tissue and bed sediment of the South Platte River Basin Study Unit.

Semivolatile organic compounds

1,2,4-Trichlorobenzene

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

2,4-Dinitrotoluene

2-Chlorophenol

2-Ethylnaphthalene

4-Bromophenyl-phenylether

4-Chloro-3-methylphenol

4-Chlorophenyl-phenylether

Azobenzene

Benzo [*c*] cinnoline

C8-Alkylphenol

Dimethylphthalate

N-Nitrosodi-n-propylamine

N-Nitrosodiphenylamine

Nitrobenzene

Quinoline

Organochlorine compounds

Aldrin (HHDN, Octalene)

Chloroneb (chloronebe, Demosan, Soil Fungicide 1823)

Endrin (Endrine)

Heptachlor (Heptachlore, Velsicol 104)

Isodrin (Isodrine, Compound 711)

Mirex (Dechlorane)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

beta-HCH (*beta*-BHC, *beta*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

cis-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

delta-HCH (*delta*-BHC, *delta*-hexachlorocyclohexane, *delta*-benzene hexachloride)

o,p'-Methoxychlor

trans-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

Trace elements

No non-detects

[a] Selected water-quality standards and guidelines (Gilliom and others, in press).

[b] Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by only counting detections equal to or greater than 0.01 µg/L to facilitate equal comparisons among compounds that had varying detection limits; a value of <1% signifies that there were only detections below, or <1% above, the 0.01 µg/L level. Some herbicides and insecticides were not reliably detected as low as the 0.01 µg/L level, so frequencies may be underestimated for some compounds. For other compound groups, all detections were counted and detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in all groups are summarized in (Gilliom and others, in press).

[c] Detections of these compounds are reliable, but concentrations are determined with greater uncertainty than for the other compounds and are reported as estimated values (Zaugg and others, 1995).

[d] The guideline for methyl *tert*-butyl ether is between 20 and 40 µg/L; if the tentative cancer classification C is accepted, the lifetime health advisory will be 20 µg/L (Gilliom and others, in press).

[e] Selected sediment-quality guidelines (Gilliom and others, in press).

This Report was Based on the Following Publications:

Bruce, B.W., and McMahon, P.B., 1996, Shallow ground-water quality beneath a major urban center—Denver, Colorado, USA: Journal of Hydrology, v. 186, p. 129-151.

Bruce, B.W., and McMahon, P.B., 1998, Shallow ground-water quality of selected land-use/aquifer settings in the South Platte River Basin, Colorado and Nebraska 1993-95: U.S. Geological Survey Water-Resources Investigations Report 97-4229, 48 p.

Colborn, T., VomSaal, F.S., and Soto, A.M., 1993, Developmental effects of endocrine-disrupting chemicals in wildlife and humans: Environmental Health Perspectives, v. 101, p. 378-384.

Colorado Climate Center, 1984, Colorado average annual precipitation 1950-80: Fort Collins, Colorado, 1 pl.

Dennehy, K.F., Litke, D.W., McMahon, P.B., Heiny, J.S., and Tate, C.M., 1995, Water-quality assessment of the South Platte River Basin, Colorado, Nebraska, and Wyoming—Analysis of available nutrient, suspended-sediment, and pesticide data, water years 1980-92: U.S. Geological Survey Water-Resources Investigations Report 94-4095, 145 p.

Dennehy, K.F., Litke, D.W., Tate. C.M., and Heiny, J.S., 1993, South Platte River Basin—Colorado, Nebraska, and Wyoming: Water Resources Bulletin, v. 29, no. 4, p. 647-683.

Denver Regional Council of Governments, 1997, Regional population and household estimates: Regional Report, v. 30, no. 7.

Fegeas, R.G., Claire, R.W., Guptill, S.C., Anderson, K.E., and Hallam, C.A., 1983, Land use and land cover digital data: U.S. Geological Survey Circular 895-E, 21 p.

Gallant, A.L., Whittier, T.R., Larsen, D.P., Omernick, J.M., and Hughes, R.M., 1989, Regionalization as a tool for managing environmental resources: EPA/600/3-89/060, 152 p.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the national water-quality assessment program: occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Gilliom, R.J., Mueller, D.K., and Nowell, L.H., in press, Methods for comparing water-quality conditions among national water-quality assessment study units 1992-95: U.S. Geological Survey Open-File Report 97-5890.

Goodbred, S.L., Gilliom, R.J., Gross, T.S., Denslow, N.P., Bryant, W.L., and Schoeb, T.R., 1997, Reconnaissance of 17β-estradiol, 11-ketotestosterone, vitellogenin, and gonad histopathology in common carp of United States streams—Potential for contaminant-induced endocrine disruption: U.S. Geological Survey Open-File Report 96-627, 47 p.

Heiny, J.S., and Tate, C.M., 1997, Concentration, distribution, and comparison of selected trace elements in bed sediment and fish tissue in the South Platte River Basin, USA, 1992-93: Archives of Environmental Contamination and Toxicology, v. 32, p. 246-259.

Kimbrough, R.A., and Litke, D.W., 1996, Pesticides in streams draining agricultural and urban areas in Colorado: Environmental Science and Technology, v. 30, no. 3, p. 908-916.

Kimbrough, R.A., and Litke, D.W., in press, Pesticides in the South Platte River from Henderson, Colorado to North Platte, Nebraska during the 1994 growing season, and comparison of pesticide occurrence in two nested urban basins in Denver, Colorado: U.S. Geological Survey Water-Resources Investigations Report 97-4230.

Knopf, F., 1991, Ecological succession and conservation confusion in the South Platte floodplain, *in* South Platte River Resource Management: Finding a balance (Conference Proceeding), R.C. Woodring, ed., Colorado Water Resources Research Institute, Information Series no. 66, 27 p.

Litke, D.W., 1996, Sources and loads of nutrients in the South Platte River, Colorado and Nebraska, 1994-95: U.S. Geological Survey Water-Resources Investigations Report 96-4029, 57 p.

Litke, D.W., and Kimbrough, R.A., 1998, Water-quality assessment of the South Platte River Basin, Colorado, Nebraska, and Wyoming—Environmental setting and water quality of fixed sites, 1993-95: U.S. Geological Survey Water-Resources Investigations Report 97-4220, 61 p.

McMahon, P.B., 1995, Some bacteria are beneficial!: U.S. Geological Survey Fact Sheet FS-102-95, 2 p.

McMahon, P.B., and Böhlke, J.K., 1996, Denitrification and mixing in a stream-aquifer system—Effects on nitrate loading to surface water: Journal of Hydrology, v. 186, p. 105-128.

McMahon, P.B., and Bruce, B.W., 1997, Distribution of terminal electron-accepting processes in an aquifer having multiple contaminant sources: Applied Geochemistry, v. 12, p. 507-516.

Mueller, D.K., and Helsel, D.R., 1996, Nutrients in the Nation's waters—Too much of a good thing?: U.S. Geological Survey Circular 1136, 24 p.

National Academy of Sciences, National Academy of Engineering, 1973, Water-quality criteria 1972, Ecological Research Series: EPA-R3-73-033, 594 p.

Omernick, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of

American Geographers 77, p. 118-125.

Schrader, L.H., 1989, Use of the index of biotic integrity to evaluate fish communities in Western Great Plains streams: Fort Collins, Colorado State University, Master's thesis.

Sjodin, A.L., Lewis, W.M., Jr., and Saunders, J.F., III, 1997, Denitrification as a component of the nitrogen budget for a large plains river: Biochemistry, v. 39, p. 327-342.

Tate, C.M., and Heiny, J.S., 1995, The ordination of benthic invertebrate communities in the South Platte River Basin in relation to environmental factors: Freshwater Biology, v. 33, no. 3, p. 439-454.

Tate, C.M., and Heiny, J.S., 1996, Organochlorine compounds in bed sediments and fish tissue in the South Platte River Basin, USA, 1992-1993: Archives of Environmental Contamination and Toxicology, v. 30, p. 62-78.

U.S. Department of Commerce, Bureau of the Census, 1991, 1990 Census population and housing: Washington D.C., Data on CD-ROM.

U.S. Environmental Protection Agency, 1986, Quality criteria for use, 1986: U.S. Environmental Protection Agency Report 440 14-86-001, [variously paged].

U.S. Environmental Protection Agency, 1990, Maximum contaminant-levels (subpart B of 141, National primary drinking-water regulations) (revised July 1, 1990): U.S. Code of Federal Regulations, Title 40, Parts 100-149, p. 559-563.

U.S. Food and Drug Administration, 1989, Compliance policy guide 7141.01, Pesticide residues in food of feed—Enforcement criteria, Attachment B, Action levels for unavoidable pesticide residues in food and feed commodities: U.S. Food and Drug Administration.

Wylie, B.K., Wagner, D.G., Hoffer, R.M., Maxwell, S., and Shaffer, M.J., 1993, Spatial distribution of nitrate leaching 'hot spots' and nitrate contributions to the South Platte River Basin aquifers: Fort Collins, Colorado Water Resources Research Institute Report 181, 12 p.

Zaugg, S.D. and others, 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected-ion monitoring: U.S. Geological Survey Open-File Report 95-181, 49 p.

South Platte NAWQA Study Unit Bibliography--Additional References:

Bradely, P.M., McMahon, P.B., and Chapelle, 1995, Effects of carbon and nitrate on denitrification in bottom sediments of an effluent-dominated river: Water Resources Research, v. 31, no. 4, p. 1063-1068.

Bruce, B.W., 1995, Denver's urban ground-water quality: Nutrients, pesticides, and volatile organic compounds: U.S. Geological Survey Fact Sheet FS-106-95, 2 p.

Dennehy, Kevin F., 1991, National Water-Quality Assessment Program—South Platte River Basin: U.S. Geological Survey Open-File Report 91-155, 2 p.

Dennehy, Kevin F. and Ortiz-Zayas, Jorge R., 1993, Bibliography of water-related studies; South Platte River Basin—Colorado, Nebraska, and Wyoming: U.S. Geological Survey Open-File Report 93-106, 278 p.

Heiny, J.S., 1995, Review of sediment data in the South Platte River Basin, Colorado, 1980-92: U.S. Geological Survey Fact Sheet FS-153-95, 2 p.

Heiny, J.S., 1997, Organochlorine compounds and trace metals in streambed sediment and fish tissue, South Platte River Basin—Colorado, Nebraska, and Wyoming: U.S. Geological Survey Fact Sheet FS-040-97, 4 p.

Kimbrough, R.A., 1995, Are streams in agricultural and urban areas contaminated by pesticides?: U.S. Geological Survey Fact Sheet FS-104-95, 2 p.

Litke, D.W., 1995, Nutrients in the South Platte River, 1993-95: U.S. Geological Survey Fact Sheet FS-105-95, 2 p.

McMahon, P.B., Litke, D.W., Paschal, J.E., and Dennehy, K.F., 1994, Ground water as a source of nutrients and atrazine to streams in the South Platte River Basin: Water Resources Bulletin, v. 30, no. 3, p. 521-530.

McMahon, P.B., Lull, K.J., Dennehy, K.F., and Collins, J.A., 1995, Quantity and quality of ground-water discharge to the South Platte River, Denver to Fort Lupton, Colorado, August 1992 through July 1993: U.S. Geological Survey Water-Resources Investigations Report 95-4110, 71 p.

McMahon, P.B., Tindall, J.A., Collins, J.A., Lull, K.J., and Nuttle, J.R., 1995, Hydrologic and geochemical effects on oxygen uptake in bottom sediments of an effluent-dominated river: Water Resources Research, v. 31, no. 10, p. 2561-2569.

McMahon, P.B., Böhlke, J.K., and Litke, D.W., 1996, Nitrate in the South Platte River alluvial aquifer, Colorado: U.S. Geological Survey Yearbook, p. 39-41.

Minter, J.B., 1996, Comparison of macroinvertebrate communities from three substrates in the lower South Platte River: Fort Collins, Colorado State University, Master's thesis.

Pfenning, K.S., and McMahon, P.B., 1996, Effect of nitrate, organic carbon, and temperature on potential denitrification rates in nitrate-rich riverbed sediments: Journal of Hydrology, v. 187, p. 283-295.

Pocernich, M., and Litke, D.W., 1997, Nutrient concentrations in wastewater-treatment plant effluents, South Platte River Basin: Water Resources Bulletin, v. 33, no. 1, p. 205-214.

Qi, S.L., 1995, Use of ARC/INFO in the National Water-Quality Assessment Program—South Platte River Basin Study: Proceedings of the Fifteenth Annual Environmental Systems Research Institute, Inc. (ESRI) Users Conference, May 22-26, 1995, Palm Springs, California, 9 p.

Qi, S.L., and Dennehy, K.F., 1997, World Wide Web home page for the South Platte NAWQA: U.S. Geological Survey Fact Sheet FS-242-96, 2 p.

Sjodin, A.L., 1996, Nitrogen processing in a large plains river: Boulder, University of Colorado, Master's thesis.

Tate, C.M., and Martin, L.M., 1995, Fish communities in the plains region of the South Platte River, August 1993 and 1994: U.S. Geological Survey Fact Sheet FS-154-95, 2 p.

Tate, C.M., and Ortiz-Zayas, J.R.,1995, An inventory of biological investigations related to streamwater quality in the South Platte River Basin, Colorado, Nebraska, and Wyoming, 1891-1994: U.S. Geological Survey Open-File Report 95-379, 12 p.

Wagner, D.G., and Hoffer, R.M., 1994, Determination of land use by processing satellite images, Lonetree Creek Basin—Final report: Fort Collins, Colorado State University, 18 p. [Requisition 93-4608-0437]

GLOSSARY

The terms in this glossary were compiled from numerous sources. Some definitions have been modified and may not be the only valid ones for these terms.

Acre-foot - A volume of water equal to 1 foot in depth and covering 1 acre; equivalent to 43,560 cubic feet or 325,851 gallons.

Basic Fixed Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.

Bed sediment - The material that temporarily is stationary in the bottom of a stream or other watercourse.

Bed sediment and tissue studies - Assessment of concentrations and distributions of trace elements and hydrophobic organic contaminants in streambed sediment and tissues of aquatic organisms to identify potential sources and to assess spatial distribution.

Bioaccumulation - The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process whereby a substance enters organisms through the gills, epithelial tissues, dietary, or other sources.

Channelization - Modification of a stream, typically by straightening the channel, to provide more uniform flow; often done for flood control or for improved agricultural drainage or irrigation.

Community - In ecology, the species that interact in a common area.

Denitrification - A process by which oxidized forms of nitrogen such as nitrate (NO_3^-) are reduced to form nitrites, nitrogen oxides, or free nitrogen: commonly brought about by the action of denitrifying bacteria and usually resulting in the escape of nitrogen to the air.

Dissolved solids - Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Effluent - Outflow from a particular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.

Eutrophication - The process by which a body of water becomes, either by natural means or by pollution, excessively rich in dissolved nutrients, resulting in extensive algal growth.

Fish communities - *See* Community.

Front Range - Eastern slope of the Rocky Mountains, in Colorado, it generally extends from Colorado Springs in the south to the Colorado State Line to the north. When referred to as the Front Range urban corridor in this report, it extends from Denver to Fort Collins along the mountain front.

Intensive Fixed Sites - Basic sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Invertebrate - An animal having no backbone or spinal column.

Invertebrate density - The number of individual invertebrates found within a known area.

Ions - Elements or molecules that have a positive or negative charge that are responsible for the salinity of stream water and can indicate the source of the water.

Irrigation return flow - The part of irrigation applied to the surface that is not consumed by evapotranspiration or uptake by plants and that migrates to an aquifer or surface-water body.

Land-use study - A network of existing shallow wells in an area having a relatively uniform land use. These studies are a subset of the Study-Unit Survey and have the goal of relating the quality of shallow ground water to land use. *See also* Study-Unit Survey.

Load - General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Main stem - The principal course of a river or a stream.

Maximum contaminant level (MCL) - Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCL's are enforceable standards established by the U.S. Environmental Protection Agency.

Metabolite - A substance produced in or by biological processes.

Nonpoint-source contaminant - A substance that pollutes or degrades water that comes from lawn or cropland runoff, the atmosphere, roadways, and other diffuse sources.

Nutrient - Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Occurrence and distribution assessment - Characterization of the broad-scale spatial and temporal distributions of water-quality conditions in relation to major contaminant sources and background conditions for surface water and ground water.

Organochlorine compound - Synthetic organic compounds containing chlorine. As generally used, term refers to compounds containing mostly or exclusively carbon, hydrogen, and chlorine. Examples include organochlorine insecticides, polychlorinated biphenyls (PCBs), and some solvents containing chlorine.

Pesticide - A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other “pests.”

Point source - A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Polychlorinated biphenyls (PCBs) - A mixture of chlorinated derivatives of biphenyl, marketed under the trade name Aroclor with a number designating the chlorine content (such as Aroclor 1260). PCBs were used in transformers and capacitors for insulating purposes and in gas pipeline systems as a lubricant. Further sale for new use was banned by law in 1979.

Salinity - The total quantity of dissolved salts, measured by weight in parts per thousand.

Semivolatile organic compound (SVOC) - Operationally defined as a group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and Polycyclic aromatic hydrocarbons (PAHs).

Species - Populations of organisms that may interbreed and produce fertile offspring having similar structure, habits, and functions.

Specific conductance - A measure of the ability of a liquid to conduct an electrical current.

Study unit - A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Study-unit survey - Broad assessment of the water-quality conditions of the major aquifer systems of each Study Unit. The Study-Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of three to five aquifer subunits.

Suspended (as used in tables of chemical analyses) - The amount (concentration) of undissolved material in a water-sediment mixture. It is associated with the material retained on a 0.45- micrometer filter.

Suspended sediment - Particles of rock, sand, soil, and organic detritus carried in suspension in the water column, in contrast to sediment that moves on or near the streambed.

Synoptic sites - Sites that are sampled within a selected time period so that samples represent similar hydrographic conditions.

Taxon (plural taxa) - Any identifiable group of taxonomically related organisms.

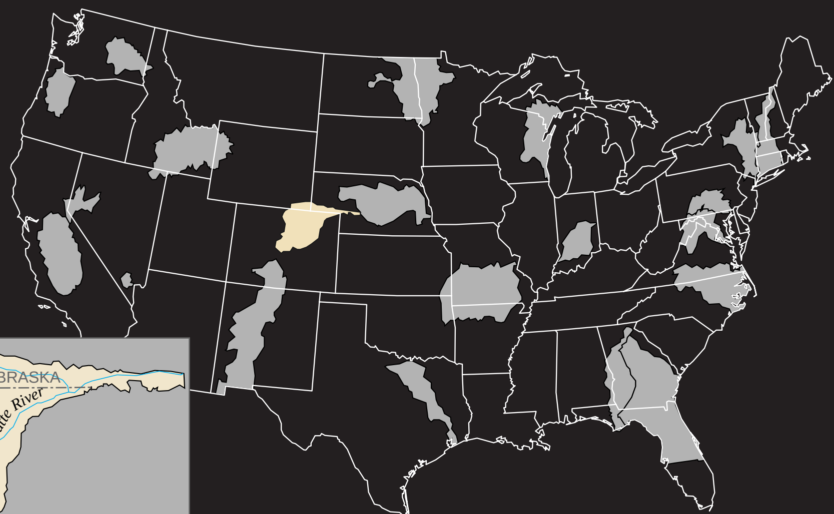
Tissue study - The assessment of concentrations and distributions of trace elements and certain organic contaminants in tissues of aquatic organisms.

Trace element - An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Volatile organic compounds (VOCs) - Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

NAWQA

National Water-Quality Assessment (NAWQA) Program
South Platte River Basin



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