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Water Quality in the Upper Mississippi River Basin

Minnesota, Wisconsin, South Dakota, Iowa, and North Dakota, 1995–98

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

Circular 1211

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The companion Web site for NAWQA summary reports:

http://water.usgs.gov/nawqa/

Upper Mississippi River Basin contact and Web site:

USGS State Representative
U.S. Geological Survey
2280 Woodale Drive
Mounds View, MN 55112
e-mail: stark@usgs.gov
http://mn.water.usgs.gov/umis/index.html

National NAWQA Program:

Chief, NAWQA Program
U.S. Geological Survey
Water Resources Division
12201 Sunrise Valley Drive, M.S. 413
Reston, VA 20192
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Front cover: Mississippi River, St. Paul, Minnesota *(Bob Firth ©)*.

Back cover: Left, row crops in the Minnesota River Basin *(Scott Murray Photography)*; middle, St. Paul skyline (*Scott Murray Photography*); right, St. Croix River valley *(National Park Service)*.

Water Quality in the Upper Mississippi River Basin, Minnesota, Wisconsin, South Dakota, Iowa, and North Dakota, 1995–98

By J.R. Stark, P.E. Hanson, R.M. Goldstein, J.D. Fallon, A.L. Fong, K.E. Lee, S.E. Kroening, *and* W.J. Andrews

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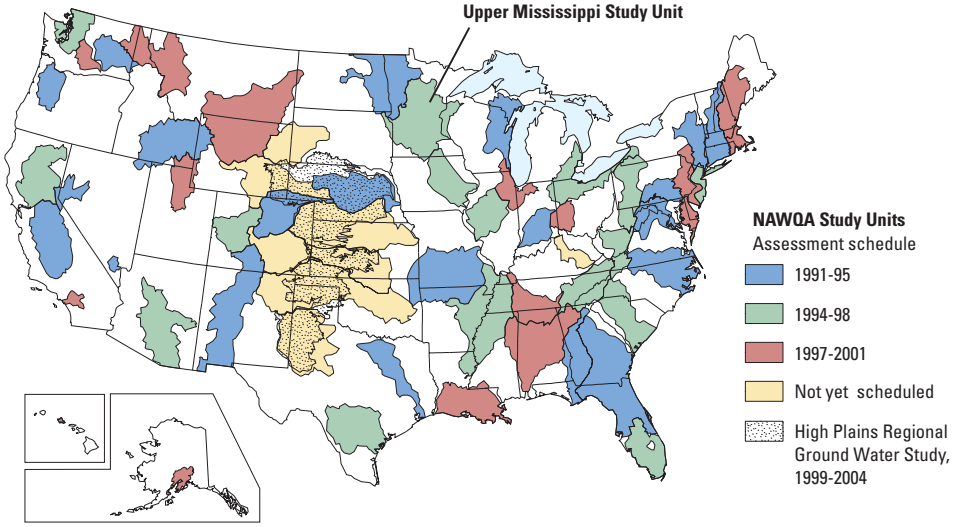
CONTENTS

THIS REPORT summarizes major findings about water quality in part of the Upper Mississippi River Basin (referred to as the Study Unit in this report) that emerged from an assessment conducted from 1995 to 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions in 36 NAWQA study areas, called study units, assessed to date. Findings are also explained in the context of selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality to the Nation's drinking water, such as by monitoring water from household taps. Rather, the assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. The comparisons made in this report to drinking-water standards and guidelines are only in the context of the available untreated resource. Finally, this report includes information about the status of aquatic communities and the condition of in-stream habitat as elements of the complete water-quality assessment.

Many topics covered in this report reflect the concerns of officials of State and Federal agencies, water-resource managers, and members of stakeholder groups who provided advice and input during the Study Unit assessment. Basin residents who wish to know more about water quality in the areas where they live will find this report informative as well.



THE NAWQA PROGRAM seeks to improve scientific and public understanding of water quality in the Nation's major river basins and ground-water systems. Better understanding encourages effective resource management, accurate identification of water-quality priorities, and successful development of strategies that protect and restore water quality. Guided by a nationally consistent study design and shaped by ongoing communication with local, State, and Federal agencies, NAWQA assessments support the investigation of local issues and trends, while providing a firm foundation for understanding water quality at regional and national scales. The ability to integrate local and national scales of data collection and analysis is a unique feature of the NAWQA Program.

The Upper Mississippi River Basin Study Unit is one of 51 water-quality assessments initiated since 1991, when the U.S. Congress appropriated funds for the USGS to begin the NAWQA Program. As indicated on the map, 36 assessments have been completed, and 15 assessments will conclude in 2001. Collectively, these assessments cover about one-half of the land area of the United States and include water resources that are available to more than 60 percent of the U.S. population.

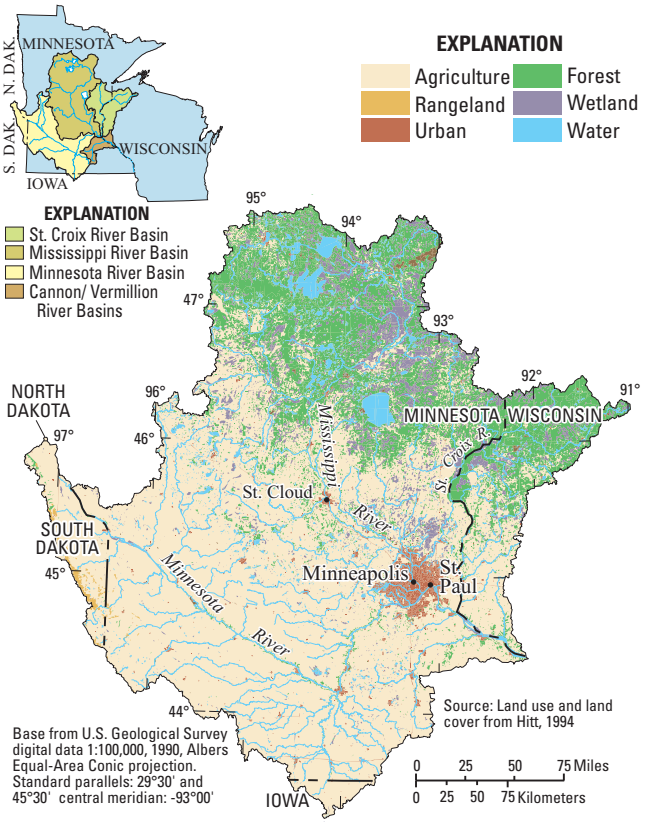
SUMMARY OF MAJOR FINDINGS

The Upper Mississippi River Basin Study Unit encompasses about 47,000 mi^2 (square miles) in Minnesota, Wisconsin, South Dakota, Iowa, and North Dakota and includes the Twin Cities (Minneapolis and St. Paul) metropolitan area (TCMA). The three major rivers in the Study Unit are the Mississippi, the Minnesota, and the St. Croix. In 1990, about 3.7 million people resided in the Study Unit, mostly in the TCMA. The Mississippi River is the primary source of drinking water for St. Cloud, Minneapolis, and St. Paul in Minnesota. Ground water is the primary source of drinking water in rural and suburban areas.

Highlights of Streams and Aquatic Biology

Elevated concentrations of nutrients (nitrogen and phosphorus) in water are potentially harmful to humans, livestock, and aquatic life. Major sources of nutrients to streams are commercial fertilizers applied to crops, lawns, and gardens; wastewater discharge; leaking septic systems; snowmelt runoff; and animal manure. The total amounts of nitrate and dissolved orthophosphate were greater in streams draining agricultural areas than in streams draining areas with other land uses. Although pesticides (herbicides and insecticides) were commonly detected, most concentrations were less than current drinking-water standards and guidelines and aquatic-life guidelines; however, not all pesticides detected currently have drinking-water standards and guidelines. Samples from most streams in the Study Unit met Federal and State drinking-water standards and guidelines and aquatic-life guidelines. Invertebrate and fish communities were most degraded in urban streams.

- Nitrate concentrations in streams in artificially drained agricultural areas exceeded the U.S. Environmental Protection Agency (USEPA) drinking-water standard of 10 mg/L (milligrams per liter) in about 20 percent of the samples.
- Insecticides and nonagricultural herbicides were detected most frequently in urban areas.
- Agricultural herbicides were detected in streams throughout the Study Unit.
- Urban streams have reduced invertebrate and fish species richness and diversity compared to agricultural streams.
- Algal productivity was greater in agricultural streams than in urban and forest streams, due in part to greater concentrations of nutrients.
- Agricultural streams with wooded riparian cover had greater fish and invertebrate species richness and diversity than agricultural streams lacking wooded riparian cover.



Land use and land cover in the Upper Mississippi River Basin study unit

Trends in Stream-Water Quality and Aquatic Biology

Assessing trends in water quality and aquatic biology is difficult because historical data sets are discontinuous and sampling objectives and analysis methods have varied. Some observable trends are increased nitrate concentrations, based on historical data, and decreased ammonia concentrations in streams in the TCMA during 1984–1993 primarily because of process changes at wastewater treatment facilities. Breakdown products of the pesticide DDT, the use of which was discontinued in the 1970's, are still detectable in fish, streams, and streambed sediment.

Major Influences on Streams and Aquatic Biology

- Application of pesticides and fertilizers in agricultural and urban areas
- Discharges from wastewater treatment facilities
- Runoff from agricultural and urban areas
- Stream modifications and artificial drainage
- Destruction of riparian cover along streambanks
- Contaminants in precipitation and in the atmosphere

Highlights of Conditions in Ground Water

Shallow ground water in the TCMA (less than 50 feet below land surface) commonly contained pesticides, nutrients, and industrial chemicals and detectable concentrations of numerous volatile organic compounds (VOCs). Deeper ground water, typically used for public supply (water supplied for the general public by municipal and private purveyors), contained few pesticides and lower nitrate concentrations. With the exception of naturally occurring radon, deeper ground water met drinking-water standards and guidelines for most chemicals.

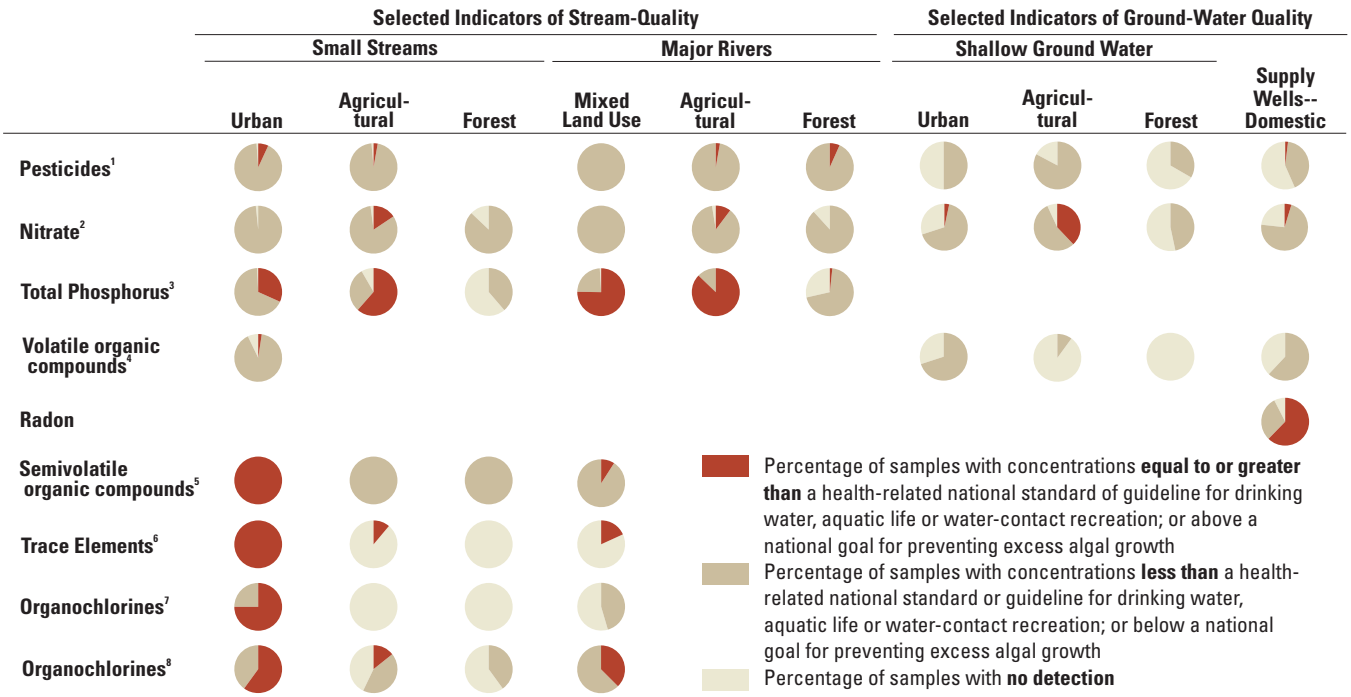
- Nitrate concentrations in water from nearly one-half of shallow ground water sampled beneath agricultural areas exceeded the USEPA drinking-water standard (10 mg/L).
- Road salt constituents (sodium and chloride) were detected at greater concentrations in shallow ground water underlying urban areas than other areas.
- Agricultural pesticides were commonly detected in all land-use settings. Concentrations were greatest in agricultural areas.
- Atrazine was the most frequently detected agricultural pesticide. Concentrations were greater in shallow ground water than in deeper ground water.
- Prometon was the most frequently detected herbicide in urban areas.
- Ground water in the Prairie du Chien-Jordan aquifer, an important source of drinking water, is protected by overlying confining units in some areas. Concentrations of nitrate, atrazine, and VOCs were lower in these areas than where confining units were absent.
- Radon exceeded the USEPA suspended drinking water standard of 300 pCi/L (picocuries per liter) in more than one-half of the water samples from the Prairie du Chien-Jordan aquifer.

Trends in Ground-Water Quality

Temporal trends in ground-water quality are difficult to define because limited information exists. Spatial trends include greater nitrate and pesticide concentrations in agricultural areas, greater VOC concentrations in urban areas, and few detections of pesticides or VOCs in forested areas.

Major Influences on Ground Water

- Application of pesticides and fertilizers
- Confining units and depth to water
- Urban contaminants (road salts, VOCs)
- Naturally occurring radon gas



[1]Insecticides, herbicides, and pesticide metabolites, sampled in water. [2]Nitrate (as nitrogen), sampled in water. [3]Total phosphorus, sampled in water. [4]Solvents, refrigerants, fumigants, and gasoline compounds, sampled in water. [5]Byproducts of fossil-fuel combustion or components of coal and crude oil, sampled in sediment. [6]Arsenic, mercury, and metals, sampled in sediment. [7]Organochlorine compounds including DDT and PCBs, sampled in sediment. [8]Organochlorine compounds including DDT and PCBs, sampled in fish tissue.

The Upper Mississippi River Basin Study Unit (Study Unit) includes the drainage of the Mississippi River from its source at Lake Itasca, Minnesota, and its major tributaries (the St. Croix and Minnesota Rivers) to the outflow of Lake Pepin, Minnesota (fig. 1). Natural and human factors (climate, hydrology, geology, water use, land use, and land cover) affect surface- and ground-water quality, and aquatic biology in rivers and streams.

Natural Factors Affect Water Quality and Aquatic Biology

Differences in precipitation, evaporation, evapotranspiration, air temperature (fig. 1), and drainage basin characteristics (drainage area, slope, geology, and the capacity of soils to transmit water) affect hydrology and water quality. These differ most from southwest to northeast. Mean annual runoff, which is related to precipitation and evaporation, ranges from less than 2 inches in the headwaters of the Minnesota River to greater than 14 inches in the headwaters of the St. Croix River.

The range from minimum to maximum streamflow is greatest in spring and early summer as a result of rain and melting snow. Streamflow variation is greatest during late summer and fall, when precipitation ranges from drought conditions to locally heavy rains (fig. 2). Streamflow varies least during winter, when ground-water discharge to streams is dominant. During the period of sampling (1996–98), precipitation was greater than the 30-year average, resulting in increased runoff and streamflow. As a result, the amount of sediment, nutrients, pesticides, and other contaminants reaching streams may have been

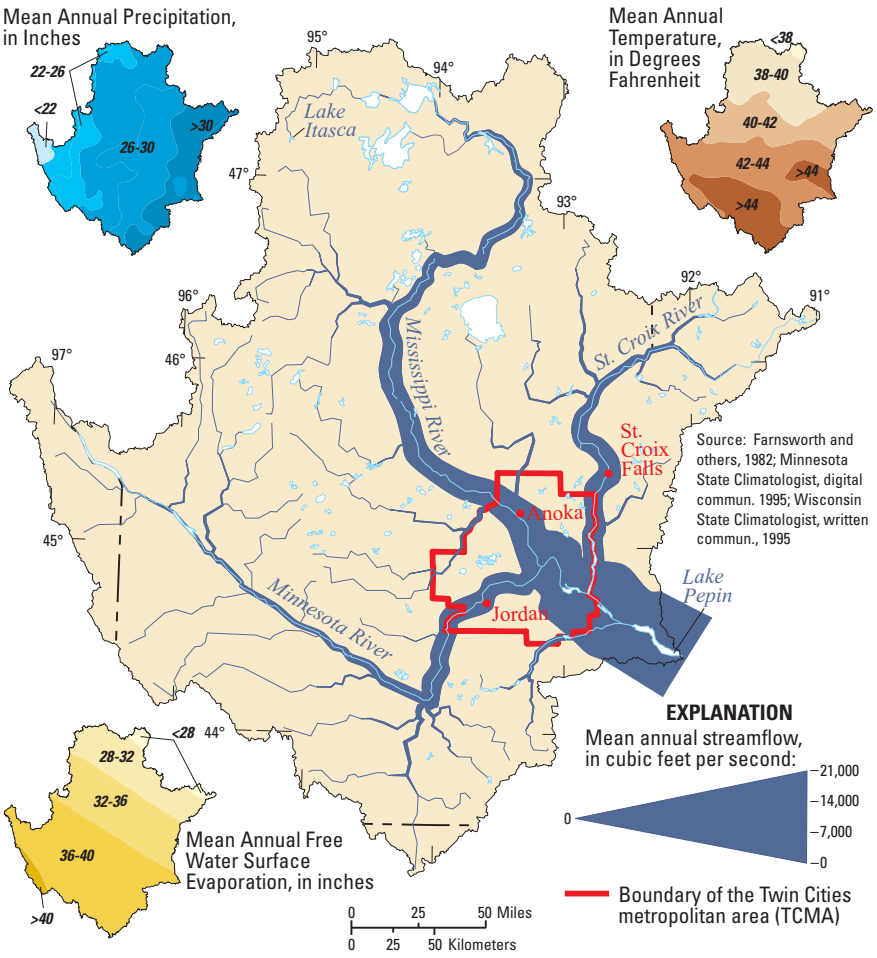


Figure 1. Climatic variables such as precipitation, temperature, and evaporation affected streamflow in the Study Unit, 1961-90.

greater than during periods of normal streamflow.

Water quality is also affected by geologic materials. Most streams in the Study Unit drain the Central Lowland physiographic province, which is underlain by clay-rich, calcareous (calcium carbonate) glacial deposits (fig. 3). Fewer streams drain the Superior Upland physio-

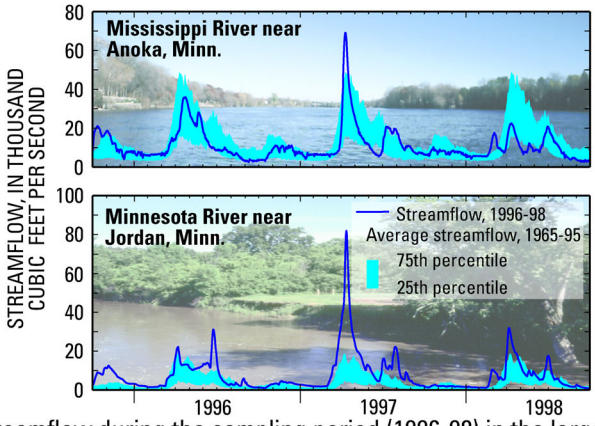


Figure 2. Streamflow during the sampling period (1996-98) in the large rivers in the Study Unit differed from their 30-year average, 1965-95.

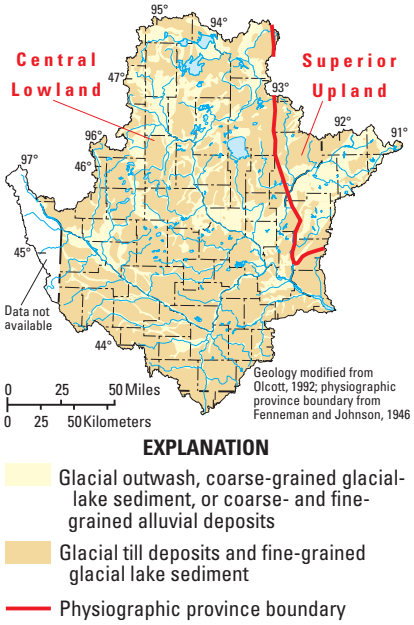


Figure 3. Surficial geology and physiographic provinces can affect water quality in the Study Unit.

graphic province, which is primarily underlain by siliceous (rich in silica), sandy glacial deposits. Water in streams draining the Central Lowland generally has greater alkalinity and greater concentrations of suspended sediment than water in streams draining the Superior Upland.

Human Activities Affect Water Quality and Aquatic Biology

The greatest effects on hydrology, water quality, and aquatic biology occur in areas with the greatest human population densities or where disruption to the natural land cover is substantial. The population of the Study Unit in 1990 was about 3.7 million—16-percent increase from 1970. Seventy-five percent of those people reside in the TCMA.

Land use and land cover in the Study Unit can be categorized into three zones: an agricultural zone across the southwest, a forested zone across the northeast, and a transitional zone between these areas (fig. 4). About 63 percent of the Study Unit is agricultural (cropland and pasture). The remaining land use and land cover consists of forests (about 22 percent), water and wetlands (about 13 percent), urban (about 2 percent), and other categories (less than 1 percent).

The uses of water and the disposal of wastewater also can affect water quality and streamflow. Based on data from 1990, a daily average of 413 Mgal/d (million gallons of water per day) was used for public supply (including drinking water) in the Study Unit—59 percent from ground water and 41 percent from surface water (fig. 5). The total of all water used for public supply is equal to about 7 percent of the average streamflow of the Mississippi River upstream from the TCMA, near Anoka, Minn. Wastewater is discharged to streams from about 270 facilities located throughout the Study Unit (Kroening and Andrews, 1997).

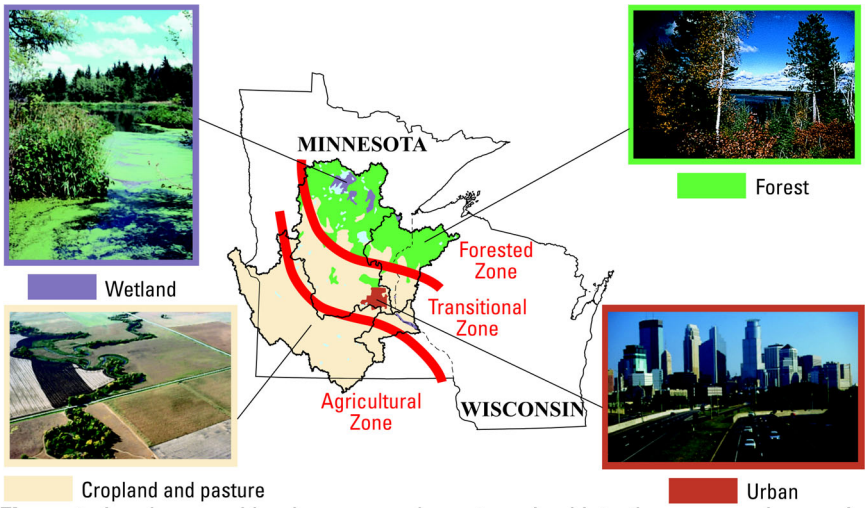


Figure 4. Land use and land cover can be categorized into three general zones in the Study Unit.

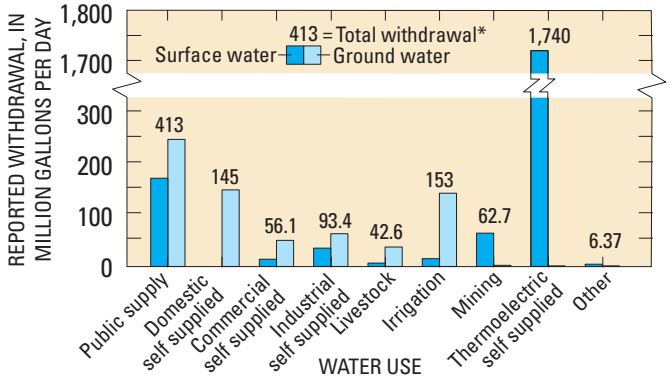


Figure 5. Ground water supplies the majority of the public drinking water in the Study Unit in 1990. (* Total refers to the combination of surface and ground water in each category.)