

**Georgia Water Series**  
**Issue 1: An Introduction to Water: Economic Concepts, Water  
Supply and Water Use**

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Faculty Series 98-13

## **ISSUE 1: AN INTRODUCTION TO WATER: ECONOMIC CONCEPTS, WATER SUPPLY AND WATER USE IN THE U.S.**

*As Public Water Suppliers and Resource Managers:  
We Should Not Treat Peoples Money Like Water -  
But Treat Water Like Money*

### ***Water Resources***

The world is made up mostly of water. There are 317 million square miles of ocean water in the world -- about two-thirds of the globe. However, that water cannot easily be used for human consumption. More than 75% of all the worlds fresh water supply is available only in the ice of the North and South Poles. Again, this water is unavailable for drinking. In fact, only one-half of 1% of all the fresh water in the world is usable in it's current state for humans.

While the worldwide water supply is about ten times the demand, people in many places face water shortages. It has been estimated that by the year 2000, worldwide supply will be only 3.5 times the demand due to population growth (Tietenberg, 1992).

People in the U.S. use three times as much water for all purposes --- about 1300 gallons per capita per day --- as the average person in a European country and much more than those in other countries in the world (National Geographic, Special Edition 1993). In the U.S., 339 billion gallons of ground and surface water are withdrawn every day. Although four trillion gallons of precipitation falls daily, most of that disappears through evaporation and runoff (National Geographic, Special Edition 1993). In sections of the U.S., water shortages have become commonplace. By the year 2000, 17 subregions in the midwest and southwest will face moderate or severe surface water problems, and an even worse ground water situation. Annual withdrawals in western aquifers exceed recharges by more than twenty-two million acre-feet (Tietenberg, 1992). Further development of water resources is slowing: only 9% of river miles in the lower forty-eight states remain undeveloped. In Georgia, total offstream water use from ground and surface water sources was estimated by the Georgia Geologic Survey to be 5,800 million gallons per day in 1995. The predominate water user was thermoelectric power. Ground water was the major source of water for agricultural irrigation while public supplies came mostly from surface sources (Fanning).

### ***The Economics of Scarcity***

To analyze water resources, it is necessary to begin with the basic definition of economics: a study of how people *choose* (with or without the use of money) to use *scarce* resources to meet *competing* ends. The concepts of choice, scarcity and competing uses summarize the issues surrounding water. Choices must be made about how to use water ---

urban drinking needs, agriculture, recreation, manufacturing, waste disposal, fish and wildlife habitat, or simply to admire. Often these uses are incompatible.

Scarcity is the most basic of economic ideas. In an economic sense, all goods are scarce. If all goods were free, shortages would be common, even for those goods like water that appear plentiful. There are six causes of water scarcity: drought (climate changes), degradation of water quality, depletion of the source faster than recharge, redistribution, consumption, and out-of-basin diversion or shortage (National Geographic, Special Edition 1993). To these, add an economic reason: water has been misused because its price has historically been so low as to encourage over consumption.

### *Water as an Economic Good*

Water is the most basic of natural resources and it must be shared, demanding cooperation. Also, water moves, carrying the effects of human and natural forces across boundaries. If water is polluted in one place, the pollution moves somewhere else. If water is used upstream, there is less for those downstream. Water flows do not respect political or geographic boundaries. Thus, water is often the object of disagreements, hostility, and intense competition.

Water is a multi-use commodity. It can be used for many purposes, from drinking to recreation. Consequently, to analyze the economics of water, accounting for these multiple uses is necessary. A typical dinner for four people will take 3,000 gallons of water to produce. Each glass of water in a restaurant requires another two to wash the glass. A week's supply of drinking water is used during one shower. It takes 150 gallons of water to produce a typical Sunday newspaper, 39,000 gallons to produce a car, with 2,000 gallons for the tires alone. One barrel of beer uses 1,500 gallons of water to produce. Forty gallons are used to wash a car. A lawn sprinkler uses 100 gallons of water per hour.

Additionally, water has characteristics of both a renewable and non-renewable resource. Each drop of water is billions of years old. Water has been here forever, is indestructible, and will always remain. Water is simply recycled through the hydrologic cycle. The total supply remains virtually constant. However, because water moves and is used in many different fashions, it has characteristics of a non-renewable resource at any one location. Sometimes, ground water cannot be recharged once depleted. Of the 16,000 trillion gallons of ground water estimated to be available in the US, only about 400 trillion gallons are renewable (Tietenberg, 1992).

## *Economic Concepts*

Issues of water quality, treatment, science and technology, regulation, law, economics, and finances will determine the management of natural resources in the future. Of particular interest is the need to understand economic principles and the use and organization of data to make informed water decisions. Gone are the days when water managers can succeed by just being good "water people." A knowledge of several economic ideas is necessary.

**Optimizing Economic Welfare:** The basic economic concept of much of water resource economics is welfare optimization. The goal is to optimize economic welfare and achieve both an efficient allocation of resources and social efficiency. Of course, when examining efficiency in water resources, distinguishing between water sources is necessary. For surface water, without storage, the economic problem is to allocate a renewable supply among competing users. Since future supplies depend on precipitation rather than just current withdrawals, it is not necessary to be as concerned with effects across generations. For ground water, on the other hand, allocation of a depletable resource over time is important (Tietenberg, 1992). From an economic perspective, efficiency exists when water is allocated so that marginal net benefits are equal for all users.

In order best to plan water resources, at the federal, state, regional, or local level; managers need some basis for decisions. Economics gives managers a method for making choices and setting priorities. Concepts that can help decision makers include supply and demand analysis, benefit/cost analysis, the economic value of water, inflation and interest rates (investment over time), externalities, pricing, price discrimination, and the idea of marginal changes including marginal cost pricing.

**Benefit/Cost Analysis:** The U.S. Bureau of Reclamation and the Army Corps of Engineers originally developed benefit/cost analysis as a way to evaluate large, federal water projects. By the time of the 1936 Flood Control Act, all water projects were subject to benefit/cost analysis. Economics deals with the fact that water use presents a problem of the allocation of scarce resources. When benefit/cost analysis was first developed, the problem was scarce capital for large projects. Today, the problem is more often one of scarce water. A new issue in the conduct of benefit/cost analysis is in externality evaluation: the protection and accounting for third party effects and instream uses (Kneese, 1993).

**Externalities:** One consequence of the movement of water across boundaries and river basins is the existence of externalities. For water utilities, the definition of an externality is costs (or benefits) that relate to water service but are external to the utility and are not a part of the utility's cost (or benefits) of service (Raftelis, 1993). This definition

illustrates the basic nature of an externality: that a utility uses resources for which it does not pay, or conveys benefits for which it is not compensated.

The inclusion of externalities will have an impact on the selection of new water resources, on the extension of existing supply sources and on utility costs and prices. Little agreement or knowledge exists in the water industry concerning how to incorporate, or "internalize" these costs.

The basic economic principles of environmental policy in the US are found in the theory of externalities (Cropper & Oats, 1992). This theory focuses on economic activity that creates side-effects ignored by the producer. The literature on externalities is huge -- hundreds of books and papers address external issues. Attempts to internalize the cost of externalities provides the justification for many of the regulatory practices in the US. Externalities have become defined in reference to market failures. Failure in this instance is one of the commons --- who owns the air or water resources of an area? This problem of market failure has led to efforts either to create a market where none exists or to find ways to simulate the price for scarce water resources.

In economics, markets are used to provide an efficient allocation of resources. The water industry presents major obstacles to using markets to allocate the resource. The noncompetitive conditions in many water markets, the issue of externalities, the lack of well-defined property rights due to the mobile and public nature of water, and the uncertain supply over time and space, make customary market solutions to water allocation difficult.

**Water Pricing:** A major source of inefficiency in water allocation is water pricing. Both water prices and rate structures have encouraged inefficient and wasteful water use. Efficiency requires that marginal, not average, costs be used to price water. The economics of water also differs from other public infrastructure goods because consumers pay for water directly by user fees. Payments for roads, bridges, and other public works, are from road taxes, or gas taxes, or general property taxes. Because water is paid for directly, people demand to know the costs and benefits of water and its safety.

### *New Water Era*

Throughout human history, the availability of water has been an important factor in economic and social development. Water has been and will remain a key determinant of population growth and distribution, economic development, social and political organization and the quality of life. The difficulty arises because water is hard to control, define, manage, negotiate and adjudicate (National Geographic, 1993). Water will determine how the competition between agriculture, urban and environmental forces is resolved.

Over the past 200 years, water management has focused on a search for new water supplies. Consequently, large scale development projects dominated water economics. Such projects today are becoming less likely. The best sites for reservoirs have been established and in those available areas, wetland concerns are dominating the selection process. In short, the economic feasibility of large scale projects is diminishing and a new type of water economics is needed. As Falkenmark noted, "as water demands increase in size and number, water management proceeds from being supply-oriented (focused on water storage and distribution) to being demand-oriented (focused on controlling demand)" (Frey, 1993). A shift is occurring from project development to an efficient and equitable allocation and reallocation of existing supplies (Kneese, 1993).

### *The Water Supply Industry*

Water is big business in the U.S. Although most water utilities are small, the water industry spends more than \$70 billion on water per year, not including the amount used for agricultural purposes. Half of that spending is done at the local --- city or county --- level. More than 90% of the U.S. population, or about 226,000,000 people get their water from one of 59,266 community water systems. There are 24,884 non-transient, non-community water systems (hospitals for example) and 114,000 non-community or private water systems (U.S. Environmental Protection Agency, Federal Reporting Data System.)

One of the most striking features of the U.S. public water system is that it is made up of primarily small utilities. As shown in Table 1, in 1992 87% of the 59,266 public utilities in the U.S. served populations of less than 3,300 and 94% served less than 10,000. The number of community water systems has declined 8% in the 1980s due to small system mergers. However, the largest 1,100 water systems serve about 50% of the entire U.S. population. In Georgia, the pattern is similar. There exists 527 public water systems in the state and nearly 2,200 private systems. Most are small and serve less than 3,300 customers. In a 1995 survey of Georgia water systems, 53% of the responding systems had less than 1,000 connections, 38% had between 1,000 and 10,000 connections and only 9% had more than 10,000 connections.

**Table 1. Size of U.S. Community Water Systems**

| System size | Population served | Number of systems | Percentage of total |
|-------------|-------------------|-------------------|---------------------|
| Very small  | 25 - 500          | 37,226            | 63                  |
| Small       | 501 - 3,300       | 14,456            | 24                  |
| Medium      | 3,301 - 10,000    | 4,238             | 7                   |
| Large       | 10,001 - 100,000  | 3,034             | 5                   |
| Very large  | Over 100,000      | 312               | 1                   |
| Total       |                   | 59,266            | 100                 |

From the same 1995 Georgia public utility survey, 58% of the systems provided both water and wastewater services with 89% only supplying retail services. The 315 systems that responded to the survey accounted for 1.8 million connections, covering population from 11 to 1.5 million. Over 6.3 million Georgians, or over two-thirds of the state, were served by these utilities. The average population served was 21,500. In terms of connections, systems ranged from just three to 365,045. The average number of residential connections was 4,602, with 352 non-residential and 845 connections served outside the utility's jurisdiction.

The total capacity of the surveyed systems was 1.8 billion gallons per day, with an average capacity of 8.6 million gallons per day (mgd) and average storage capacity of 4.5 mgd. The largest system had a 250 mgd capacity. The total capacity of the seven largest systems was 722 mgd — or 40% of the total capacity of all surveyed systems.

While 75% of the surveyed systems pulled their water from ground sources, 81% of the water used by the respondents comes from surface water sources. The largest systems in the state use surface water, while ground water is the primary source for most of the small water utilities in Georgia. This is a result of the geographic nature of Georgia. The largest systems in the state are primarily north of the fall line. Consequently, in north Georgia most systems use water from surface sources. In south Georgia where plentiful ground water is the predominate source, most utilities are small rural systems. Total water use was 826 mgd with 64% going to residential customers, 18% commercial, 14% industrial. The mean for unaccounted water was 11%.

The surveyed systems generated over \$575 million in revenue in 1994, with an average revenue of \$2.2 million — ranging from \$792 to \$127.3 million.

For the responding system, nearly 76,000 miles of distribution pipe and 3,344 miles of supply pipe were reported. The average amount of pipe in the distribution system was 384 miles with 20 miles in supply and transmission line. Fifty-two percent of the pipe was PVC,

followed by cast iron (15%), ductile iron (8%) and 19% used various combinations. The oldest water facility was reported to be 150 years old — the median oldest facility was 40 years. Wells and main supply lines represented the majority of old facilities. The average age of the newest facilities in Georgia was four years. Nearly 80% of the systems reported major new facilities in the last ten years. A total of 6,721 full time and 316 part-time employees were reported, averaging 22 full and one part-time worker. For the period 1995-1999, about \$2 billion in new capital expenditures was reported.

Of course, when water is produced, so is wastewater which also constitutes a large industry in Georgia. There are 404 total wastewater permits currently issued in Georgia, assigned to 269 entities. In a recent survey of Georgia's wastewater facilities, 44% characterized themselves as urban, 41% as rural, 15% as suburban. The average service area was 24 square miles, ranging up to 480 square miles. City or municipality ownership accounted for 93% of the respondents. Three percent of systems were owned by a public entity but operated by a private firm.

Besides wastewater, 80% of the systems also served retail water customers, 17% had a storm water service and 3% had a water reuse facility. The average size of the wastewater systems was 4,131 connections, ranging from 31 to 132,480. The average system treated 717 million gallons of wastewater in 1997. The smallest system treated 1.1 million gallons and the largest 12.9 billion gallons for the entire year. Revenues to the respondents ranged from \$9,265 for 1997 to \$54.8 million with a system average of \$1.53 million.

The average total permit capacity was 2.92 million gallons per day with the largest system having a permitted capacity of 56 mgd. Seventy-six percent of the respondents operated one wastewater facility, 17% operated two and 7% operated between three and seven facilities. Average daily flow was 1.98 mgd, ranging from 3,000 gallons to 35.4 mgd.

Activated sludge is the dominant treatment facility accounting for 50% of the systems while surface water discharge is used by almost all of the systems (87%). Sludge is mostly transferred to a landfill site (64%), although 26% of the systems use some kind of land application, compost or fertilizer method.

### ***Structure of the Water Industry***

The water industry is a mature industry --- technical innovation in water delivery advances slowly. Many water utilities are delivering water using an infrastructure developed decades ago. Across most of the U.S., only one source delivers water --- the local utility, whether public or private. A consumer has little choice of where to get water. In some areas, consumers can choose to drill their own wells, or purchase water from the local utility. For most, no choice exists except the costly one of buying bottled water --- an impractical

solution for all but drinking purposes. Consequently, the water industry can be characterized as a monopoly where no competition exists. Water systems are either private and regulated by a governmental entity or directly run as part of a governmental structure.

**Theory of Natural Monopoly:** In the general economy, the structure of a market largely determines how an individual firm arrives at price and quantity decisions. The supply of water is often characterized as a natural monopoly; due to constantly decreasing long-run average costs, it is best to have only one water supplier that is regulated by the government or owned by a municipality.

A natural monopoly arises because of economies of scale. Economies of scale occur when average costs decline as output increases. While water utilities experience economies of scale for the treatment process, it is not clear that such scale economies occur over the entire system. In fact, diseconomies of scale --- where average costs rise as output increases --- may exist in the distribution system. It is also unclear whether economies of scale are related to size or the density of population served by a water utility (Beecher and Mann). If each community had many small producers, water would be unaffordable. While it is not desirable to have many firms, it is equally undesirable to have a monopoly that can restrict output and raise prices to reap profits by virtue of large-scale production. Therefore, water is either regulated through a utility commission or run directly as part of a government entity.

Four principal components of regulation distinguish the regulated sector from other sectors in the economy. First the control of entry to the industry is regulated. Once a license is provided for a water utility, the regulator does not allow other firms to enter the industry and compete. Second, prices are fixed not by the effects of supply and demand but by the regulatory or government agency. Third, the regulatory agency has the role of prescribing the quality and conditions of service. Finally, regulated firms have an obligation to serve all applicants under reasonable condition.

**Unique Features:** A fundamental characteristic of the water supply industry is the capital intensity of its operations. Utilities face high fixed costs compared with variable costs. The average capital to revenue ratio for the water industry varies between \$10 and \$12, making the water industry three to four times more capital intensive than the electric industry and five to six times that of railroads (Haneman). Investments in water production are usually high and “lumpy.” Capacity is added in large increments that results in excess capacity. For small systems, investments are large compared to their resources. Consequently such systems often have trouble attracting capital for investment.

Unlike the electric industry, all but the smallest water utilities are more often publicly- as opposed to investor-owned. For utilities serving more than 3,300 people, 85% are public enterprises (Haneman). However, forty-six state public utility commissions do regulate

water systems with 10,000 systems coming under their jurisdiction. Of these, half are investor-owned. Only fifteen commissions have some jurisdiction over public systems (Beecher and Mann).

Water is also distinguishable from the electric industry in that while water is easier to store, transporting it is more difficult. To meet peak demands, and provide for fire protection, utilities must have storage capacity. It is expensive to transport water, and it is difficult to change water movements on short notice or over any distance. Nothing exists for water like the electricity spot market.

The water supply industry also faces unique demand characteristics that affects performance. A utility must not only meet normal demand but must meet the peak, or the maximum, demand imposed on a system. Peak demand is often unknown and depends greatly on weather factors. Peak demand is also temporal. Both time-of-day peaks and seasonal peaks must be met. For most water systems, meeting average daily demand requires only 50% of its capacity. The rest is reserved for peak periods. Thus, nearly half a system's capacity is being unused most of the time, and meeting peak demand is expensive.

While water has no substitute, there are different ways to deliver water and alternative levels of water quality. Water can come from a faucet, but it can also be bought. If the price of water is high, some customers can arrange for alternative supplies, from digging a well to building a system. Industries can relocate, recycle, and conserve. Nevertheless, the demand for water can be characterized as inelastic. With few alternatives, consumers may not be responsive to price changes in the short-run.

Water is, of course, important to the national economy. A 1996 report issued by the USEPA, found that people in the U.S. make 1.8 billion visits to beaches, rivers, and lakes, spending \$300 billion in recreation and tourism in water related activities. Clean water supports a \$45 billion commercial fishing and shell fishing industry. Manufacturers use thirteen trillion gallons of water a year including twelve billion for soft drinks alone. The \$70 billion agricultural industry irrigates about 15% of U.S. farmland.

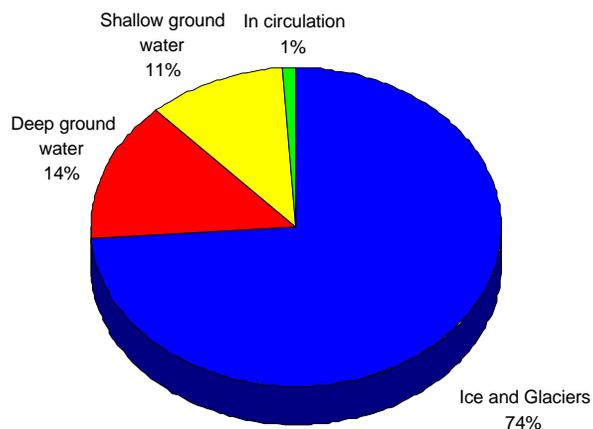
The water industry can be characterized as many small suppliers, producing as a natural monopoly that is capital intensive with high fixed costs, large investment requirements, lumpy assets, and an inelastic demand; that creates a large asset to the nations economy.

### ***Water Use***

While the earth is made-up predominately of water, 97% of it is in the world's oceans (Table 2 and Figure 1). Of the 3% of water that is fresh, most is in ice and glaciers. As

shown in Figure 2, nearly three-fourths of the fresh water is unavailable for consumption. Most of the world's water that is in circulation is in lakes (Figure 3) with more than 40% either in Russia's Lake Baikal or in the Great Lakes in the U.S. (Figure 4).

**Figure 1. Distribution of Water on Earth (in percent)**



Source: Black, 1991

**Figure 2. Distribution of Fresh Water (in percent of total fresh water)**



Source: Black, 1991

**Table 2. Estimated World Water Supply and Budget**

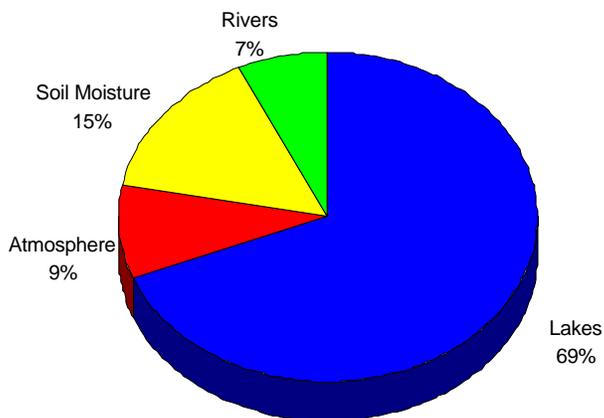
| Water Item   | Volume (Thousands) |                  | Percent of<br>Total<br>Water |
|--|--------------------|------------------|------------------------------|
|  | Cubic Miles        | Cubic Kilometers |                              |
| <b>Water in land areas:</b>                            |                    |                  |                              |
| Fresh water lakes                                      | 30                 | 125              | 0.009                        |
| Saline lakes and inland seas                           | 25                 | 104              | .008                         |
| Rivers (average instantaneous volume)                  | .3                 | 1.25             | .0001                        |
| Soil moisture and vadose water                         | 16                 | 67               | .005                         |
| Ground water to depth of 4,000 m (about<br>13,100 ft.) | 2,000              | 8,350            | .61                          |
| Icecaps and glaciers                                   | 7,000              | 29,200           | 2.14                         |
| Total in land area (rounded)                           | 9,100              | 37,800           | 2.8                          |
| <b>Atmosphere</b>                                      | 3.1                | 13               | .001                         |
| <b>World ocean</b>                                     | 317,000            | 1,320,000        | 97.3                         |
| Total, all items (rounded)                             | 326,000            | 1,360,000        | 100                          |
| <b>Annual evaporation:<sup>1</sup></b>                 |                    |                  |                              |
| From world ocean                                       | 85                 | 350              | 0.026                        |
| From land areas  | 17                 | 70               | .005                         |
| Total  | 102                | 420              | 0.031                        |
| <b>Annual precipitation:</b>                           |                    |                  |                              |
| On world ocean   | 78                 | 320              | 0.024                        |
| On land areas  | 24                 | 100              | .007                         |
| Total  | 102                | 420              | 0.031                        |
| <b>Annual runoff to oceans from rivers and icecaps</b> | 9                  | 38               | 0.003                        |
| <b>Ground water outflow to oceans<sup>2</sup></b>      | .4                 | 1.6              | .0001                        |
| Total  | 9.4                | 39.6             | 0.0031                       |

<sup>1</sup>Evaporation (420,000 km<sup>3</sup>) is a measure of total water participating annually in the hydrologic cycle.

<sup>2</sup>Arbitrarily set equal to about 5 percent of surface runoff.

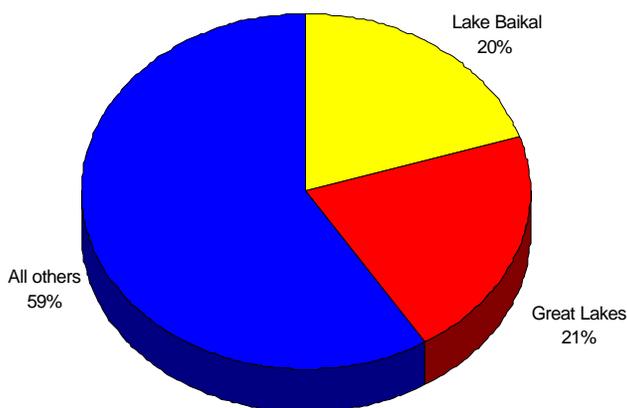
Source: Nace, 1967

**Figure 3. Water in Circulation (in percent)**



Source: Black, 1991

**Figure 4. Water in lakes (in percent)**



Source: Black, 1991

A 1995 World Bank report noted that eighty countries with 40% of the world's population already have water shortages that can harm agriculture and industry. More than 40% of the world's population live on rivers shared by more than one country. In 95% of the world's urban areas, raw sewerage is dumped into water sources. To deal with world water needs, it is estimated that \$600 billion to \$800 billion will need to be spent over the next ten years for water projects in developing countries. The World Bank can only contribute \$30 to \$40 billion.

From 1960 to 2025, the report estimates an 8% drop in renewable water supply. Pressures from the environment are also affecting water supplies. In California, fish, wildlife habitats,

wetlands, and recreation waters in lakes and rivers now use 45% of the total resources, compared with 42% for agriculture.

While the world has plenty of water, numerous severe local problems exist. This is a result of under investment in water resources, the problem of rivers crossing international boundaries, and poor water management. Water problems in most countries stem from the inefficient and unsustainable use of water. The global water problem is less an issue of water supply than of water demand. Yet there remains an absolute water crisis in many countries. Twenty-six countries with 232 million people fall into the water scarce category. These countries, mostly in Africa and the Middle East, have annual water supplies of less than 2,740 liters per person per day (1,000 cubic meters)(Postel).

There has been a geometric rise in world water demand for industrial, agricultural, and municipal use over the past thirty years. In the US, demand has grown faster than the ability to find new water sources. While the US population increased 52% between 1960 and 1990, total water use increased by 300%.

The water inventory of the U.S. includes 3.5 million miles of rivers and streams, forty-one million acres of lakes, 58,000 miles of shoreline, 34,400 square miles of estuaries, 278 million acres of wetlands, and 33,000 trillion gallons of ground water. Meanwhile, about 40% of the nation's rivers, lakes, and coastal waters are unfit for swimming or fishing and 2,000 beaches were closed in 1994 because of bacteria and health threats (USEPA, 1996).

Estimates of water use by the US Geological Service (Solley, Pierce and Perlman, 1993; Solley, 1997) show that per capita daily water use declined from 2,000 gallons per day in 1985 to 1,620 gallons in 1990. The highest off stream water use in the US was in power generation where 195 billion gallons a day are used (Table 3). Withdrawal in 1990 from lakes, reservoirs, streams, wells, and springs was estimated at 408 billion gallons per day, up from 1985 but 7% less than in 1980. By 1995, the estimated water use was 400 billion gallons per day—a decline of 2% from 1990 and nearly 10% from the peak year of 1980. Of that total water use, withdrawals from surface water were 81% or 323 billion gallons per day in 1995, down 1% from 1990. Ground water withdrawals of 77.4 billion gallons per day were down 4% from 1990. The use of reclaimed water of about 1.76 billion gallons per day in 1995 is more than double the 1990 use.

Per capita residential use in the US in 1990 was 79 gallons per day for those people drawing water from their own systems and 105 gallons for those on public water systems. Regarding consumptive use---that which is not immediately returned to its source --- agricultural irrigation used 137 billion gallons per day, or 81% of total consumptive use. Agricultural irrigation declined to an estimated 134 billion gallons per day in 1995.

Water demand varies across states depending mostly on weather and population. California used forty-seven billion gallons of water each day in 1990 followed by Texas, Idaho, Illinois and Florida. These five states used 31% of all US withdrawals, mostly due to agriculture. California used more water than Texas and Idaho combined (Figure 5). Figures 6 and 7 show the breakdown of withdrawals by surface and ground water. For 1995, California water use was estimated to have declined slightly to 45.9 bgd, followed by Texas, Illinois, Florida and New York. Idaho had dropped to the sixth highest water use state in 1995.

Most differences among states in water use are attributable to irrigation use. Fresh water consumptive use in the western U.S. accounted for 44% of freshwater withdrawals in 1990 (Figure 8). This is because 90% of the total water withdrawn for irrigation occurred in the west (Figure 9). For per capita fresh water withdrawals (Figure 10), the highest values are in thinly populated areas with large irrigated acreage, particularly in the western plains (Maddock & Hines 1995).

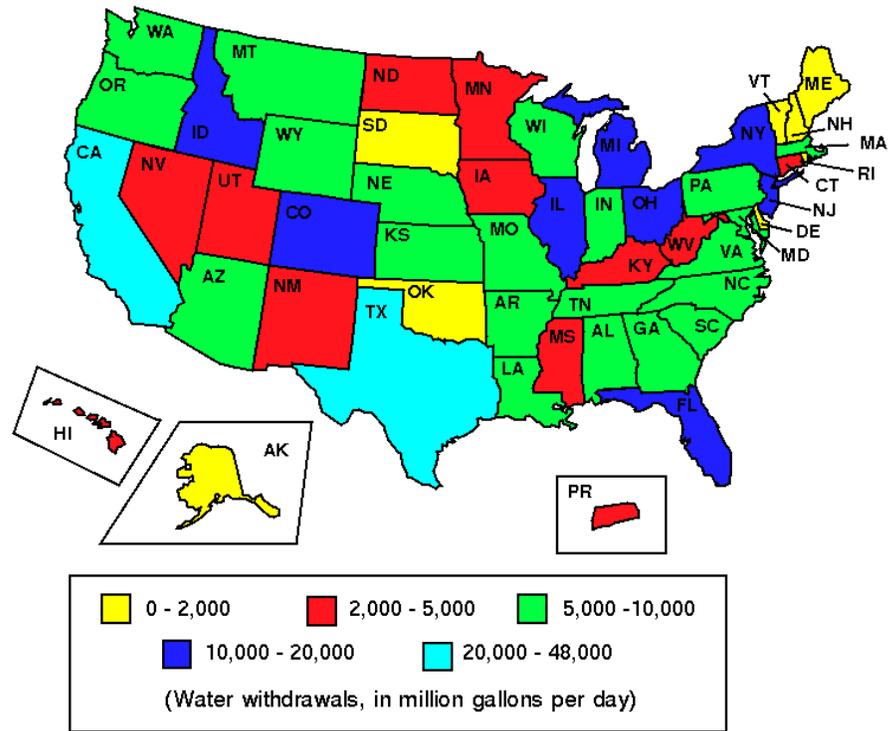
**Table 3. Trends in Water Use in the United States, 1950 - 1990**

|   | Year              |                   |                   |                   |                   |                   |                   |                   |                 |                   |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-----------------|-------------------|
|   | 1950 <sup>1</sup> | 1955 <sup>1</sup> | 1960 <sup>2</sup> | 1965 <sup>2</sup> | 1970 <sup>3</sup> | 1975 <sup>4</sup> | 1980 <sup>4</sup> | 1985 <sup>4</sup> | 1990            | 1995 <sup>8</sup> |
| <b>Population, in millions</b>                    | 150.7             | 164.0             | 179.3             | 193.8             | 205.9             | 216.4             | 229.6             | 242.2             | 252.3           | 267               |
| <b>Offstream use:</b> (1000's of million gallons) |                   |                   |                   |                   |                   |                   |                   |                   |                 | 400               |
| Total withdrawals                                 | 180               | 240               | 270               | 310               | 370               | 420               | 440 <sup>5</sup>  | 399               | 408             | 40.2              |
| Public supply                                     | 14                | 17                | 21                | 24                | 27                | 29                | 34                | 36.5              | 38.5            |                   |
| Rural domestic and livestock                      | 3.6               | 3.6               | 3.6               | 4.0               | 4.5               | 4.9               | 5.6               | 7.8               | 7.9             |                   |
| Irrigation  | 89                | 110               | 110               | 120               | 130               | 140               | 150               | 137               | 137             |                   |
| Industrial:                                       |                   |                   |                   |                   |                   |                   |                   |                   |                 |                   |
| Thermoelectric power use                          | 40                | 72                | 100               | 130               | 170               | 200               | 210               | 187               | 195             |                   |
| Other industrial use                              | 37                | 39                | 38                | 46                | 47                | 45                | 45                | 30.5              | 30              |                   |
| <b>Source of water:</b>                           |                   |                   |                   |                   |                   |                   |                   |                   |                 |                   |
| Ground:   |                   |                   |                   |                   |                   |                   |                   |                   |                 |                   |
| Fresh   | 34                | 47                | 50                | 60                | 68                | 82                | 83 <sup>5</sup>   | 73.2              | 79.4            | 76.3              |
| Saline  | ( <sup>6</sup> )  | .6                | .4                | .5                | 1                 | 1                 | .9                | .65               | 1.22            | 1.13              |
| Surface:  |                   |                   |                   |                   |                   |                   |                   |                   |                 |                   |
| Fresh   | 140               | 180               | 190               | 210               | 250               | 260               | 290               | 265               | 259             | 263               |
| Saline  | 10                | 18                | 31                | 43                | 53                | 69                | 71                | 60                | 68              | 59.7              |
| <b>Reclaimed sewage</b>                           | ( <sup>6</sup> )  | .2                | .6                | .7                | .5                | .5                | .5                | .6                | .75             | 1.76              |
| <b>Consumptive use</b>                            | ( <sup>6</sup> )  | ( <sup>6</sup> )  | 61                | 77                | 87 <sup>7</sup>   | 96 <sup>7</sup>   | 100 <sup>7</sup>  | 92 <sup>7</sup>   | 94 <sup>7</sup> |                   |
| <b>Instream use:</b>                              |                   |                   |                   |                   |                   |                   |                   |                   |                 |                   |
| Hydroelectric power                               | 1,100             | 1,500             | 2,000             | 2,300             | 2,800             | 3,300             | 3,300             | 3,050             | 3,290           |                   |

<sup>1</sup> 48 States and District of Columbia.<sup>5</sup> Revised.<sup>2</sup> 50 States and District of Columbia.<sup>6</sup> Data not available.<sup>3</sup> 50 States, District of Columbia, and Puerto Rico.<sup>7</sup> Fresh water only.<sup>4</sup> 50 States, District of Columbia, Puerto Rico, and Virgin Islands. <sup>8</sup> Estimates for 1995 from USGS Open-File Report 97-645

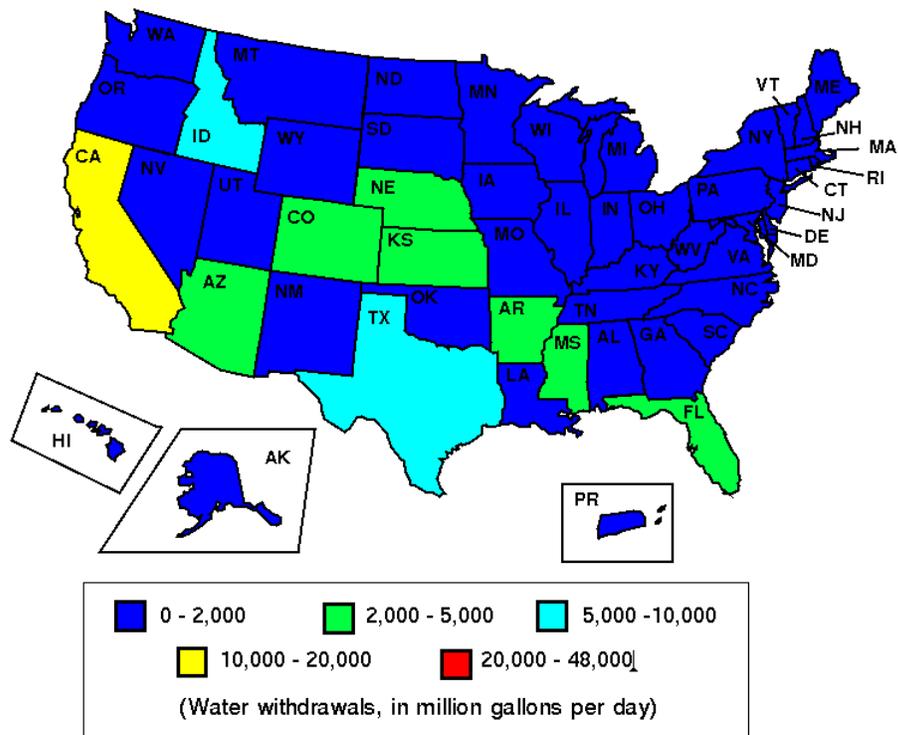
Source: USGS Circular 1081

Figure 5. Total Water Withdrawals for 1990



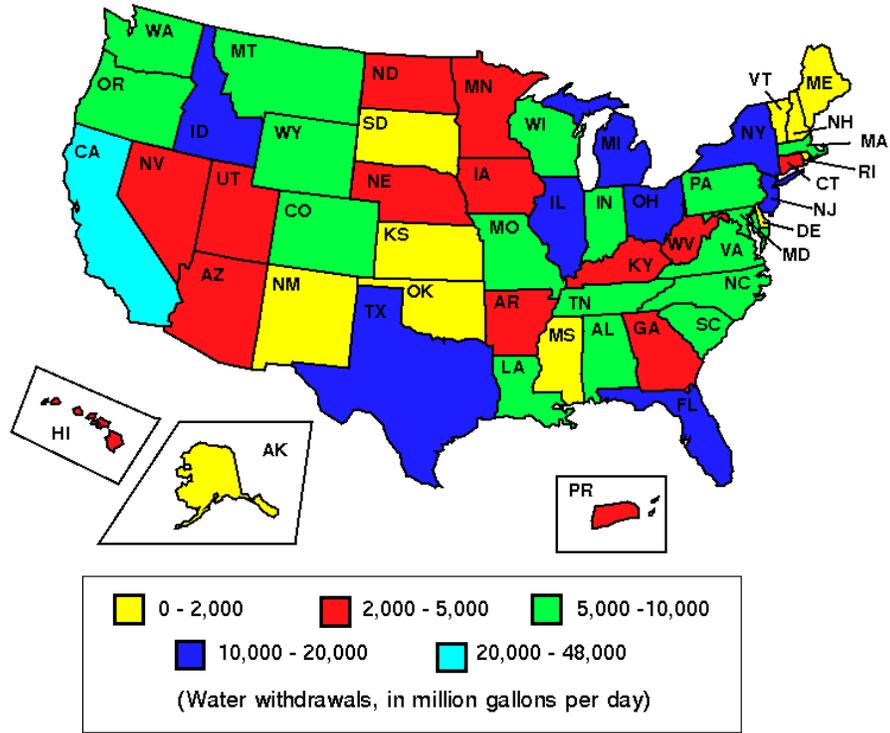
Source: USGS Circular 1081

Figure 6. Total Surface Water Withdrawals for 1990



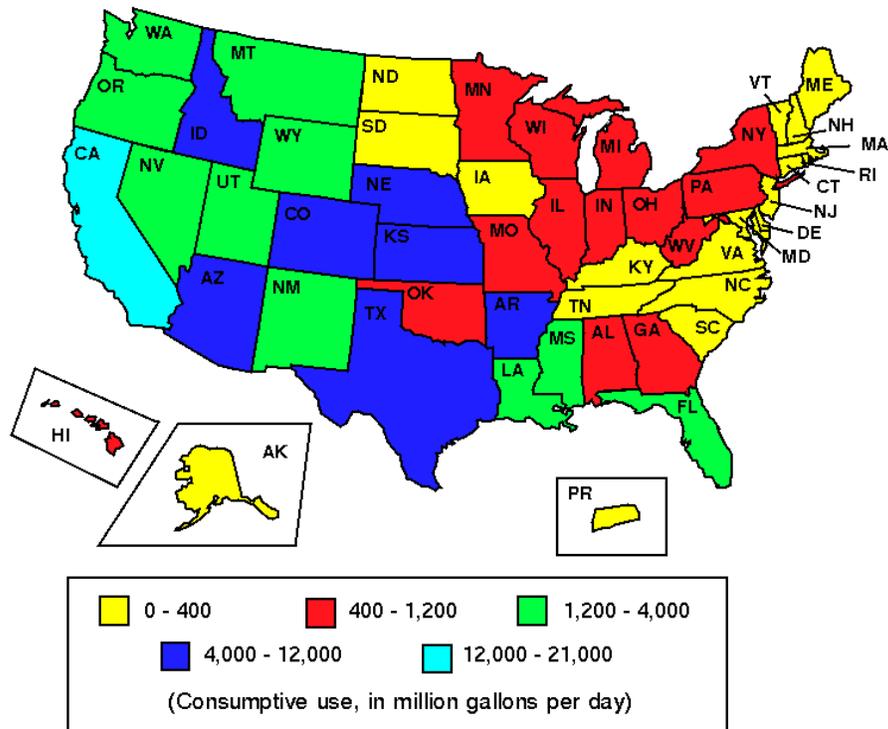
Source: USGS Circular 1081

**Figure 7. Total ground water withdrawals for 1990**



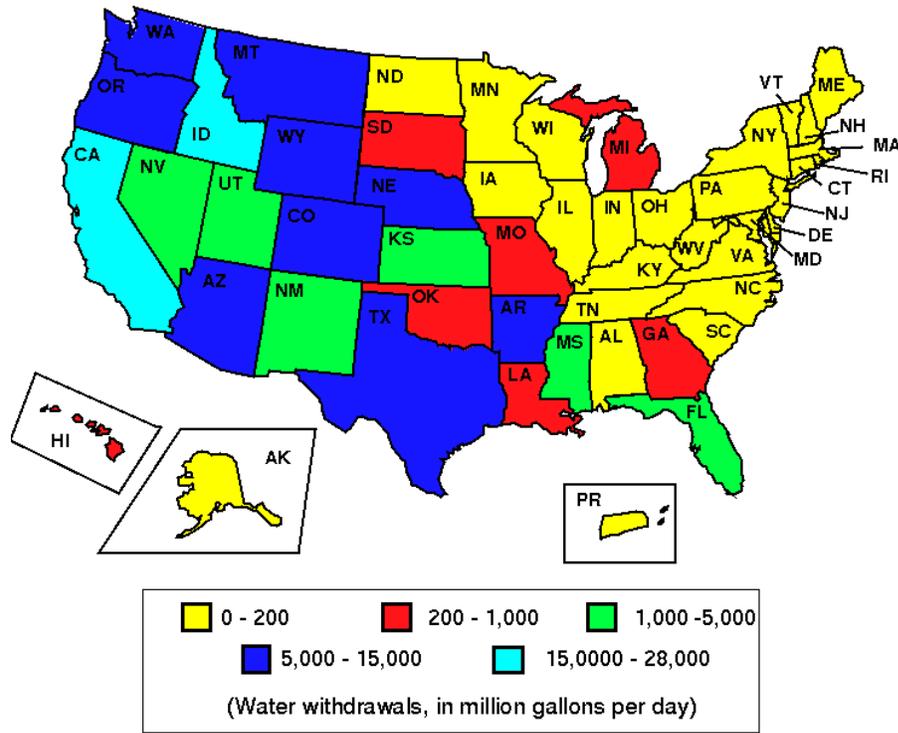
Source: USGS Circular 1081

**Figure 8. Total fresh water consumptive use for 1990**



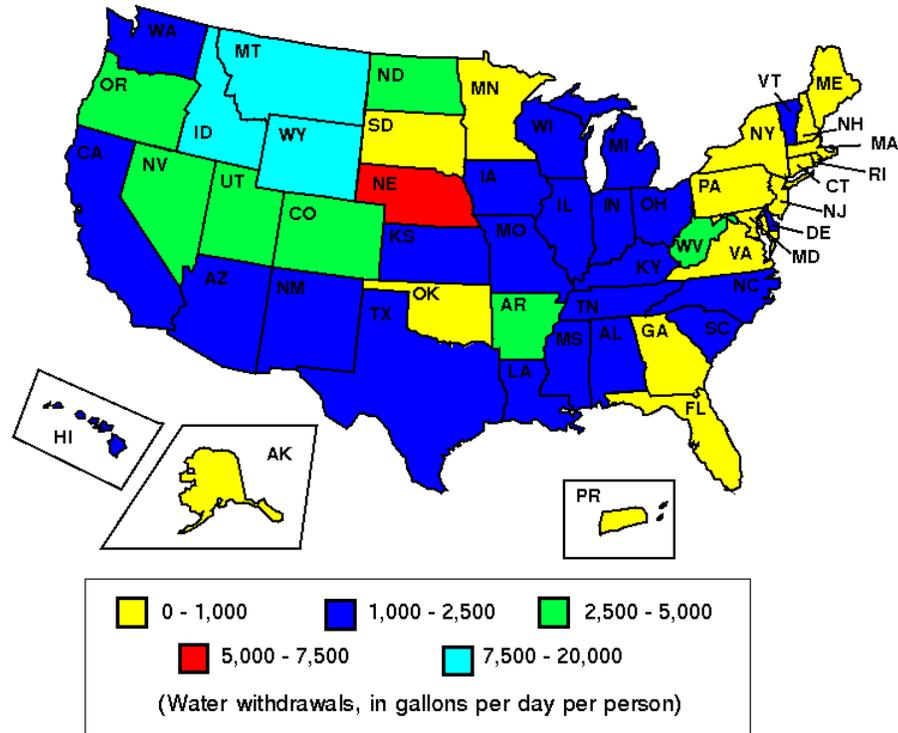
Source: USGS Circular 1081

**Figure 9. Total irrigation withdrawals for 1990**



Source: USGS Circular 1081

**Figure 10. Intensity of fresh water withdrawals per capita for 1990**



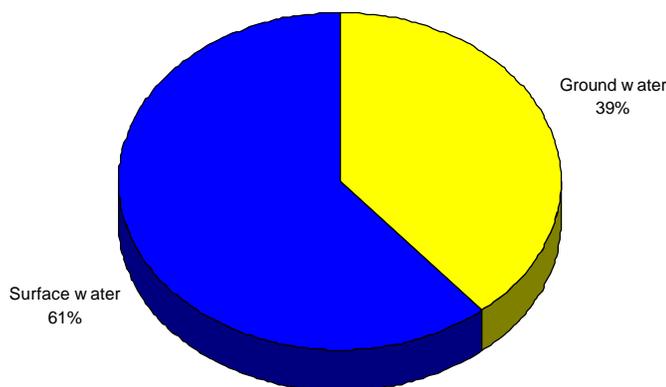
Source: USGS Circular 1081

Looking at the water supplied to the public by water utilities, most (61%) comes from surface water sources (Figure 11). Nearly 60% of that water goes to domestic use (Figure 12). Withdrawals in California, Texas and New York accounted for 31% of the nation's 38.5 billion gallons per day public supply withdrawals (Figure 13).

Most people get their domestic water from a public supply. In 1990, 86% of domestic water was delivered by a public supply source (Figure 14), with 23% of the domestic water going for consumptive use (Figure 15). Ground water was the source of 96% of domestic withdrawals. More than 50% of the people in the U.S. are dependent on ground water for domestic use.

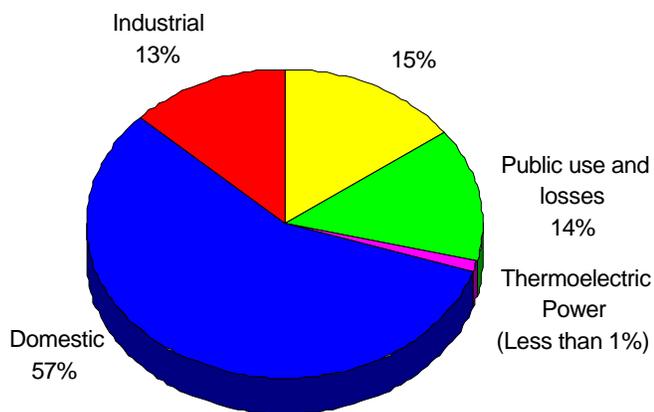
The USGS has tracked the trends in water use since 1950. As shown in Figures 16, 17, and 18, water use in the U.S. increased from 1950 to 1980 and declined in 1985. Total offshore use (Figure 18) in 1990 was 2% more than 1985 but 8% less than 1980 estimates. By 1995, water use declined 2% from 1990 and 10% from 1980.

**Figure 11. Public-Supply Source, 1990, in percent**



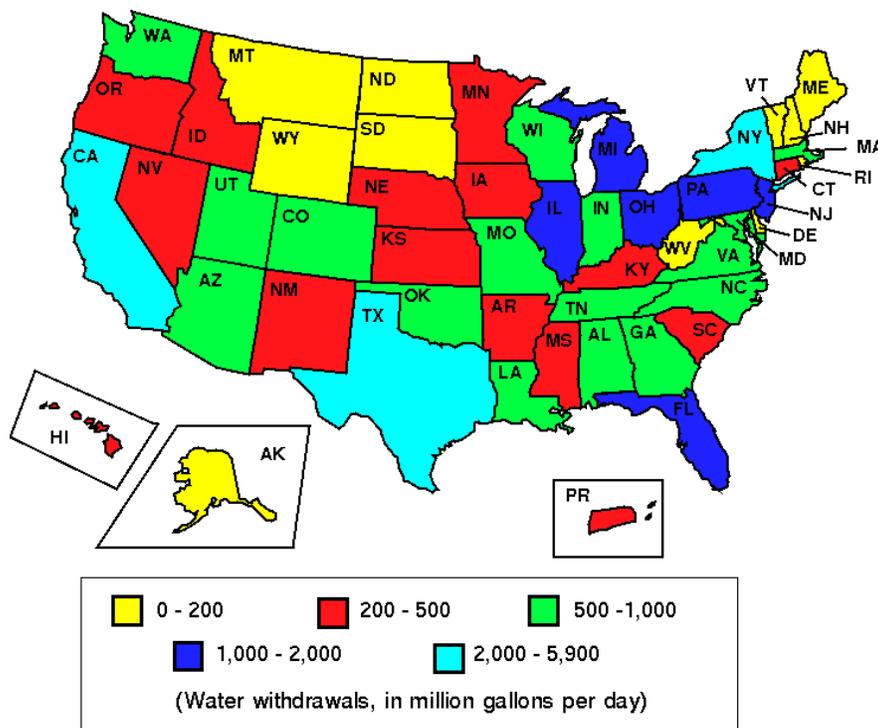
Source: USGS Circular 1081

**Figure 12. Public-Supply Delivery, 1990 (in percent)**



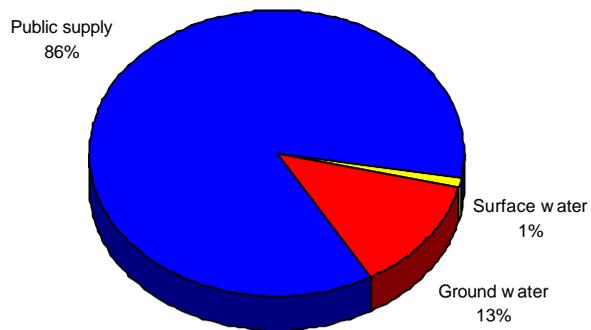
Source: USGS Circular 1081

**Figure 13. Total Public-Supply Withdrawals for 1990**



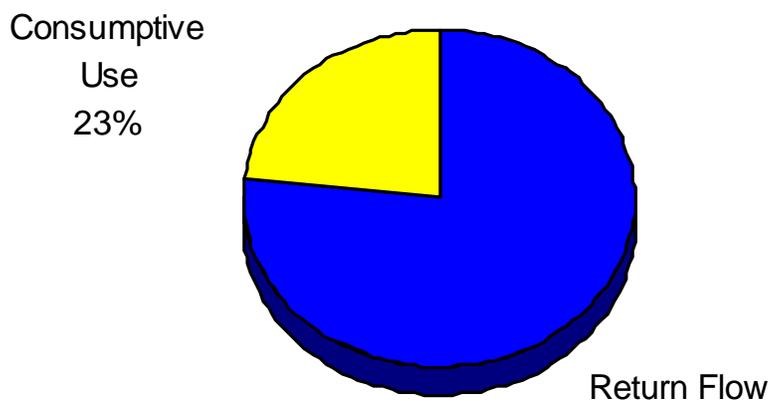
Source: USGS Circular 1081

**Figure 14. Domestic Source, 1990 (in Percent)**



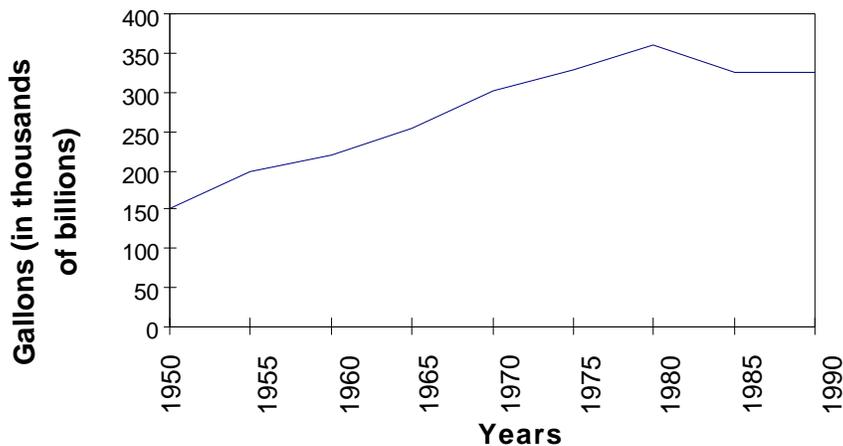
Source: USGS Circular 1081

**Figure 15. Domestic Disposition, 1990 (in Percent)**



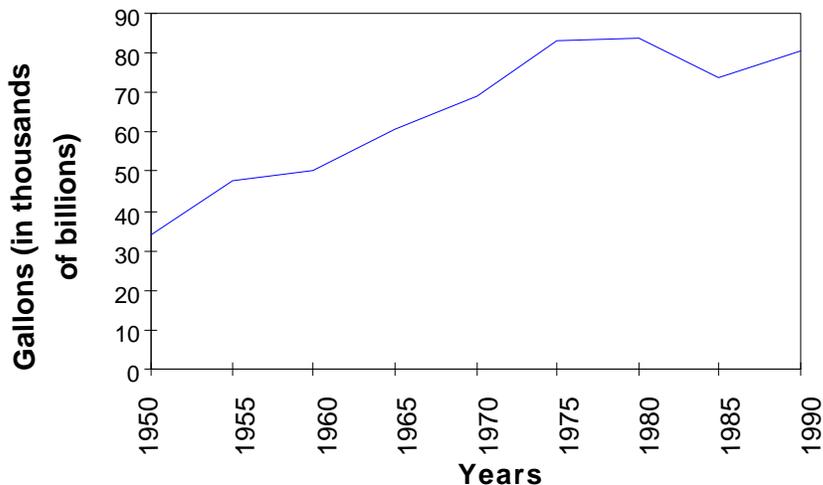
Source: USGS Circular 1081

**Figure 16. Surface Water Use 1950-1990**



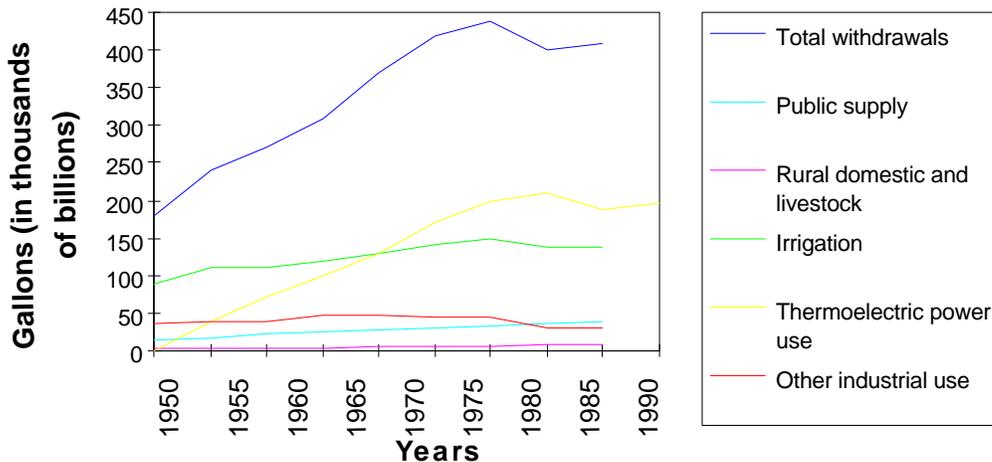
Source: USGS Circular 1081

**Figure 17. Ground Water Use 1950-1990**



Source: USGS Circular 1081

**Figure 18. Offstream Water Use 1950-1990**



Source: USGS Circular 1081

## Water Use in Georgia

Georgia has both abundant water resources and significant rainfall. With annual precipitation of 50 inches per year and an extensive system of surface water sources and aquifers, Georgia still experiences water-related problems.

Georgia's water resources include over 20,000 miles of streams, 418,000 publically owned acres of lakes and reservoirs and 594 square miles of estuaries. In addition, four major aquifers (Florida, Claiborne, Clayton, and Cretaceous) are major sources of water in south Georgia. However, population pressures in north Georgia have begun to strain the surface water sources that supply Atlanta and its environs. During several recent drought periods, stream flows in north Georgia were at or near their lowest this century. Abundant ground water supplies in south Georgia have become limited in some areas. In a 24-county area of southeast Georgia, ground water pumping has reduced the Florida aquifer system at Brunswick by 65 feet since pumping began in the last 1800s (USGS Fact Sheet 10-96). Salt water intrusion is being experienced in southeast Georgia and restrictions on water use are being imposed. Water use in southwest Georgia is also causing concern for aquifer levels.

For all uses of water, per capita fresh-water use in Georgia declined to 799 gallons per day in 1995 from 816 in 1990. This compares with per capita use of water of 1,130 gallons per day in California and 14,700 gallons per day in Wyoming. Georgia's use of 1.19 bgd of ground water in 1995 was up from .996 in 1990. Surface water uses of 4.63 bgd in 1995 were also up from the 4.36 bgd in 1990. Total water withdrawals in Georgia increased almost 9% between the 1990 and 1995 USGS estimates.

Water use estimates for 1995 show the largest increase in water withdrawals for irrigation purposes. Irrigation in 1995 was estimated to be 720 mgd, up 63% from 1990. Public water supply use increased 19% from 1990. The increase in irrigation use was particularly felt by Georgia's ground water resources. Ground water irrigation use increased 81% by 1995 over 1990 and 36% for surface water irrigation.

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