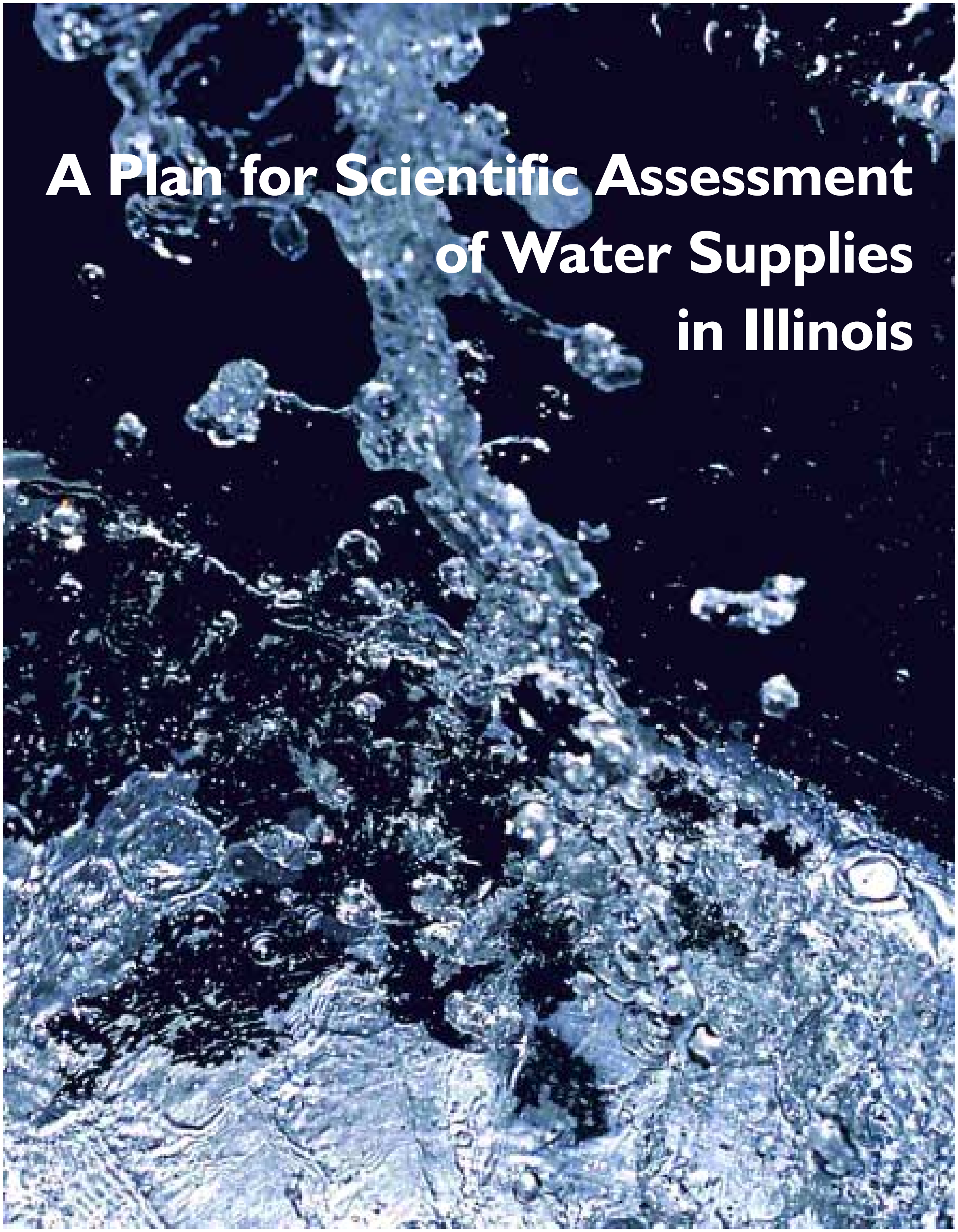
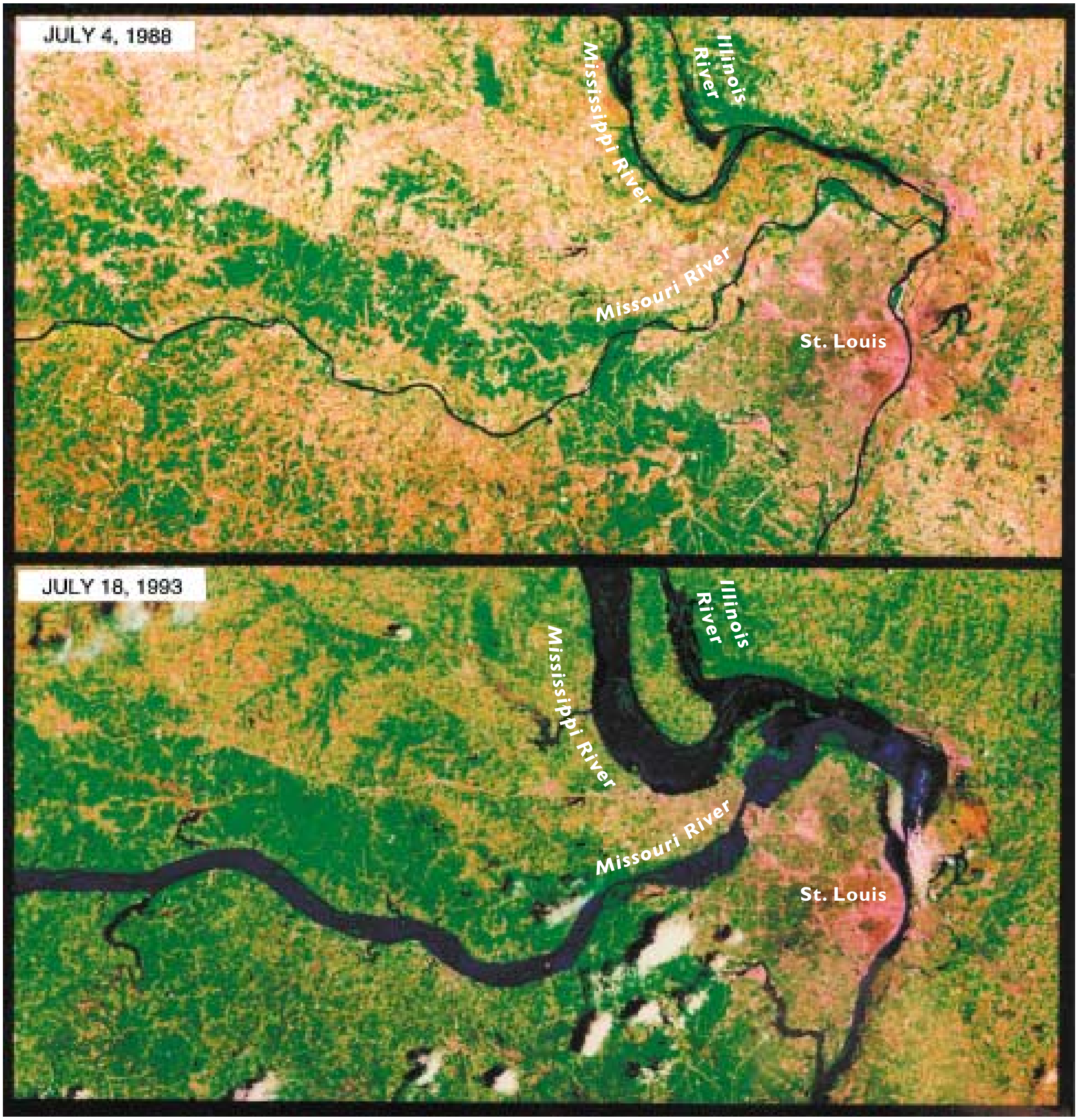
A Plan for Scientific Assessment of Water Supplies in Illinois



ILLINOIS STATE WATER SURVEY



Satellite images of the confluences of the Illinois, Mississippi, and Missouri Rivers during the 1988 drought and the 1993 flood.

A Plan for Scientific Assessment of Water Supplies in Illinois

ILLINOIS
DEPARTMENT OF
NATURAL
RESOURCES

Illinois State
WATER
SURVEY

ILLINOIS

Illinois State Water Survey
Information/Educational Material 2001-03

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The Need for Scientific Assessment of Water Supplies in Illinois

Recent projections by the Northeastern Illinois Planning Commission of population growth of one million and water shortages in the Chicago metropolitan area by 2020 are a wake-up call for action. Similar analyses and projections for the rest of Illinois have not yet been made.

Water is increasingly recognized as a precious renewable resource to be managed wisely. About two thirds of Illinois' daily water use comes from surface waters and one third from groundwater. Wise management of water resources is necessary to continue to provide adequate supplies of clean water at a reasonable cost, to protect the state's precious water resources and ecosystems, to reduce conflicts, and to support economic growth. Wise management is based on sound technical information and planning, taking into account such matters as climatic variations and change, renewable yields of surface waters and aquifers, opportunities for the conjunctive use of surface water and groundwater, and water conservation and reuse.

The mission of the Illinois State Water Survey (ISWS) is to characterize and evaluate the availability, quality, and use of the atmospheric, surface waters, and groundwater resources of the state and to make resulting data and information available to the public, decision makers, planners, and managers. This plan identifies studies that ISWS can conduct, in collaboration with others, to provide the technical data, information, tools, and training necessary for water supply planning and management. The plan addresses all major components of statewide water availability as part of the natural hydrologic cycle: atmosphere (precipitation); surface waters (rivers, streams, lakes, and reservoirs); and groundwater (glacial, shallow, and deep bedrock aquifers). The plan also addresses the quality of water to the extent that the quality of water influences both its suitability for use and the cost to supply clean water.

The studies identified in this plan are consistent with the priorities identified in the deliberations of Governor Ryan's Water Resources Advisory Committee and the Strategic Plan for Water Resource Management of the Northeastern Illinois Planning Commission. The groundwater components of this plan also contribute to the requirements by the Illinois General Assembly for the Illinois Department of Natural Resources to prepare a plan to study the aquifers of the state (92 HR0365 and 92 SR0137). However, consistent with the ISWS mission, I believe that Illinois needs a comprehensive assessment of water resources that includes surface waters and climate variability and change, as well as groundwater. This comprehensive plan for water supply assessment helps direct and organize ISWS programs and serves to inform constituents that the ISWS, working with others, stands ready to provide an improved technical basis for water supply planning and management statewide. For these reasons, the scope of the plan is broader than the General Assembly requested in its resolutions, and a comprehensive statewide plan for aquifer assessment will necessitate additional input from other agencies and professionals.

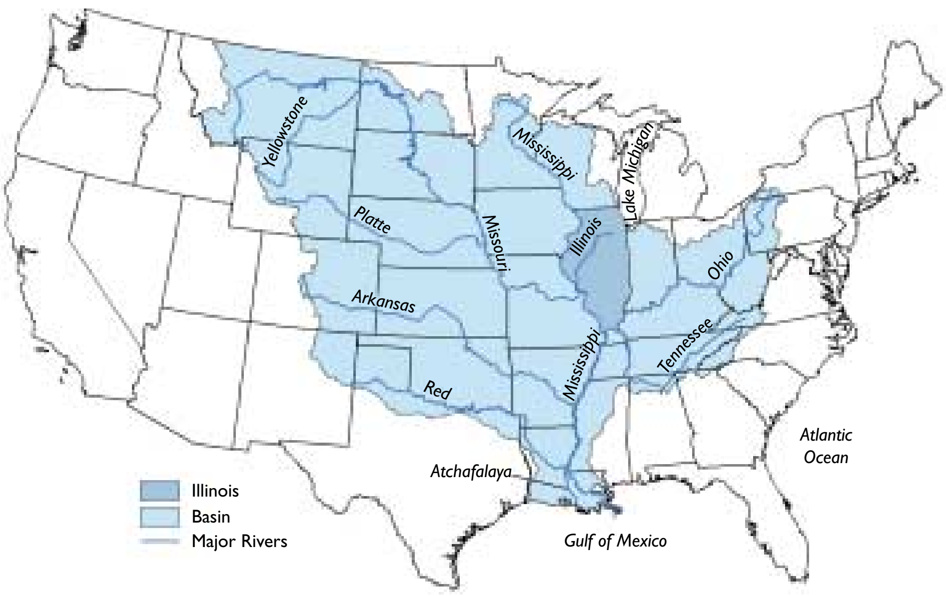
It is a plan that first marshals existing data and information to identify water resources in need of immediate management attention and then calls for the collection and analysis of new data, research, models, and training to improve permanently the state's water supply planning and management capabilities. Implementing the plan will require major efforts to improve and restructure ISWS data collection, management, and delivery systems, and modeling capabilities.

The plan does not include lists of ongoing projects and services at ISWS but rather identifies complementary and supplementary projects that can be implemented with additional resources and sustained effort over many years. Building on existing projects and implementing the plan in a phased approach can lead to improved operational water supply planning and management in the short-term and improved planning and management on the decadal time scale. However, continuation of existing funds and projects will be adequate to implement only a fraction of the plan in a timely manner. Clearly, the rate and order of implementation of the plan will depend on levels and sources of funds. I plan to work with state, federal, county, and local government officials and other professionals to coordinate and integrate relevant programs, set priorities, and seek funds to implement the plan. In addition to preparing and disseminating data and project reports on an ongoing basis, I will prepare an annual report that summarizes the progress made each year, whatever the level and sources of funding. I will also update the plan every three years.

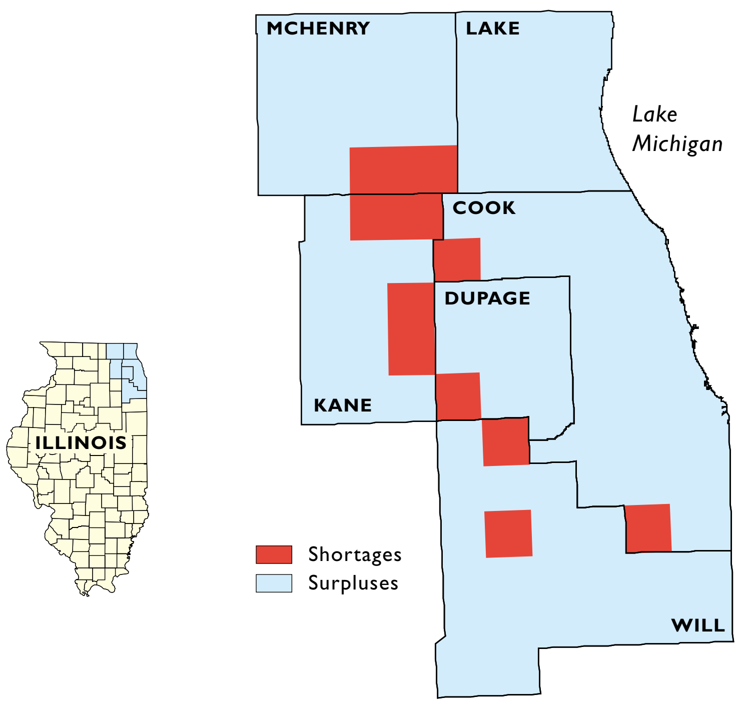
I thank members of the Illinois State Water Plan Task Force, the Governor's Water Resources Advisory Committee, state agency officials, and other water resources experts for their reviews of an earlier draft and their comments and suggestions for improvement.

Derek Winstanley
Chief, Illinois State Water Survey

Champaign, October 2001



The Mississippi/Atchafalaya River drainage basin.



Projected water shortages and surpluses in northeastern Illinois for the year 2020.

ABSTRACT

Demand for water in Illinois is increasing, and water shortages in the Chicago metropolitan area have been projected. There are, however, limits to the availability of clean water at a reasonable cost. Limits to water availability are imposed by a number of factors including droughts, legal requirements to maintain minimum flows in rivers and streams, water recharge rates, and a decree of the United States Supreme Court limiting withdrawal of water from Lake Michigan. In addition, the specter of regional climate change could pose the greatest threat to Illinois water supplies over the long term: some projections show the possibility of persistent floods, whereas other projections show persistent droughts.

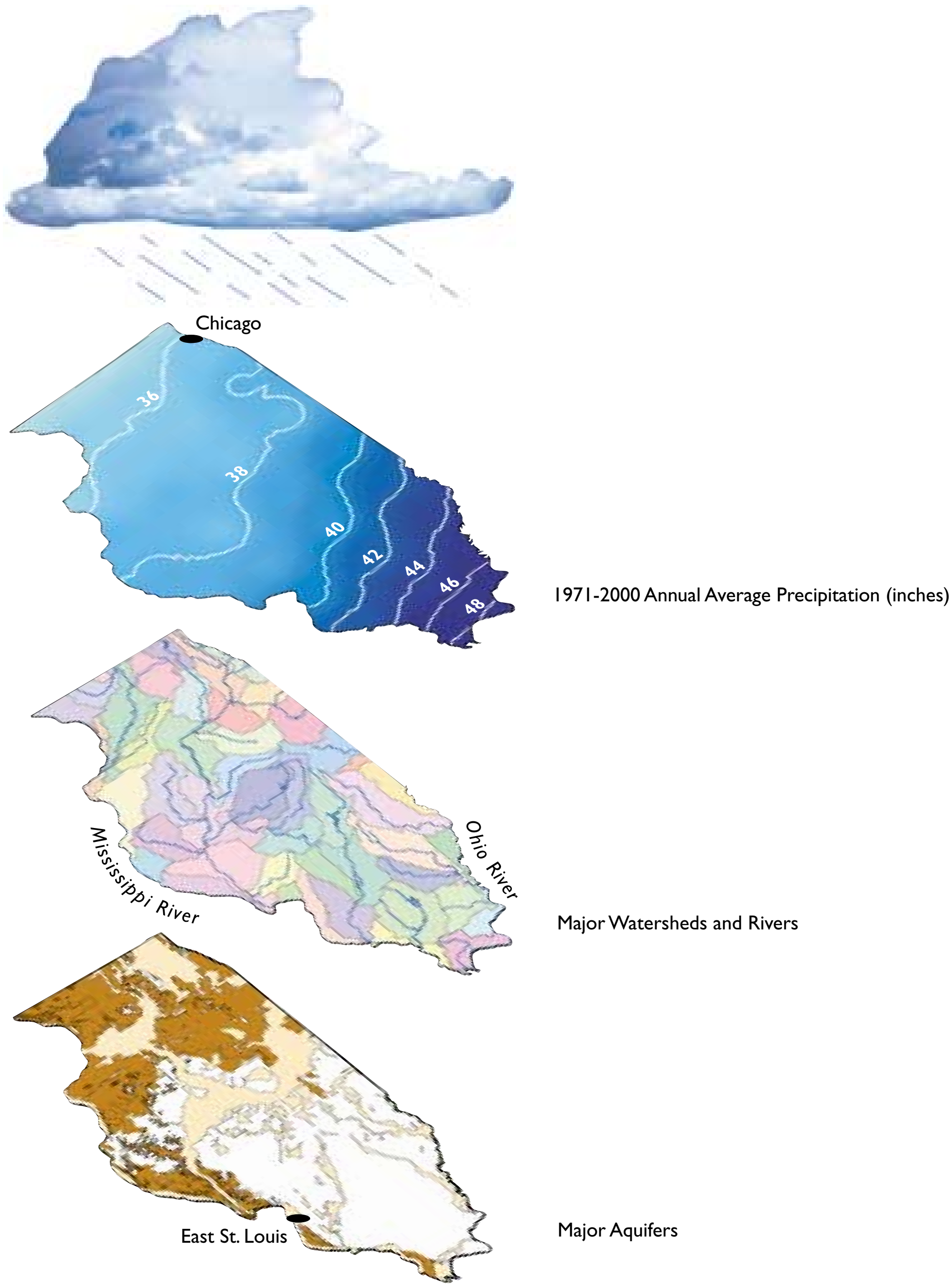
Additional sources of water do exist and can be tapped, but the cost of providing clean water increases with the necessity of water treatment, storage, and distribution, and the mitigation of impacts of new withdrawals on existing water supplies. Long lead times also are needed to construct major water projects. Unless the water supplies of Illinois are planned and managed in a comprehensive, regional, and visionary manner—based on the concept of renewable water supply capacity—water shortages could soon occur in some parts of the state. Water supply planning and management should be based on improved understanding and prediction of water supply and demand, and risk assessment.

The goal of this plan is to provide a framework for Illinois State Water Survey (ISWS) water supply programs and to document those studies that ISWS, working with others, needs to conduct to provide Illinois with comprehensive technical data and information, models, and training for water supply planning and management.

The following are the main tasks described in the plan:

- Collaborate with other organizations to coordinate and integrate relevant programs, set priorities, plan activities, conduct studies, and seek additional resources.
- Assemble, archive, digitize, analyze, and synthesize existing data.
- Determine areas of possible water shortages as a basis for setting priorities.
- Evaluate the quantity and quality of water resources throughout the state as they relate to water supply.
- Provide yield estimates for major aquifers and surface waters under variable and changing climatic conditions.
- Identify critical data gaps and conduct field studies to gather additional data and monitor the state's water resources.
- Evaluate opportunities for water conservation and reuse.
- Interpret and apply technical and economic data to assist and train water resource planners and managers.
- Develop and improve methods and models to evaluate water resources.
- Develop new quality-assured databases and an Internet-based decision support system to make data and models easily available for application by other agencies, professionals, and the general public.

The rate and order of implementation of these studies will depend upon the level and sources of funds and priorities and upon collaborative efforts with other organizations. Existing resources are addressing many of these topics, but resources are limited so progress will be slow. A major infusion of new resources is needed for timely implementation of the studies described.



Regional variability of water resources in Illinois.

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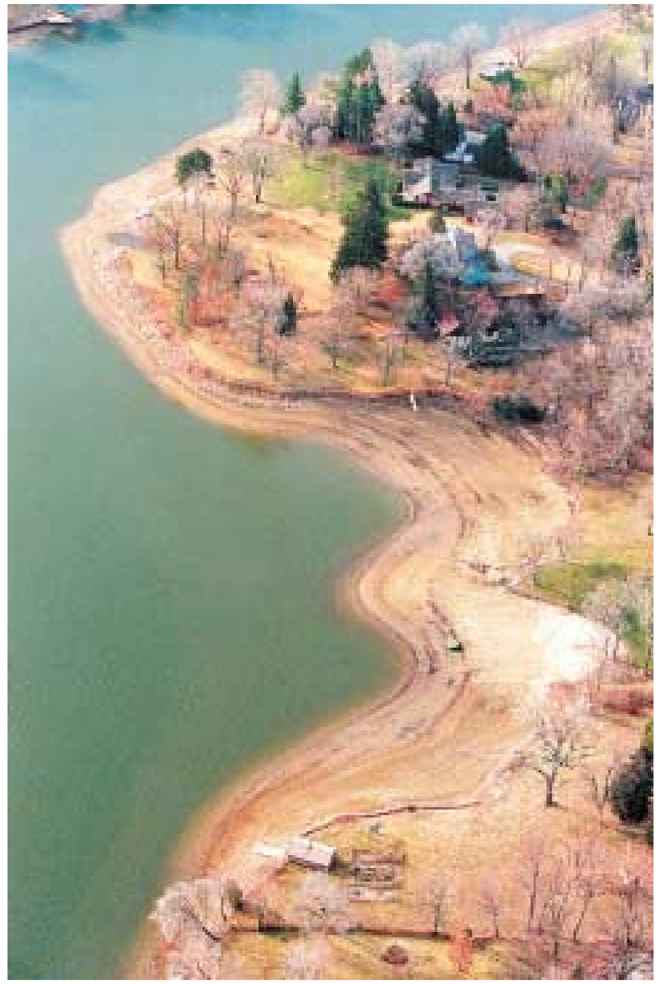
INTRODUCTION

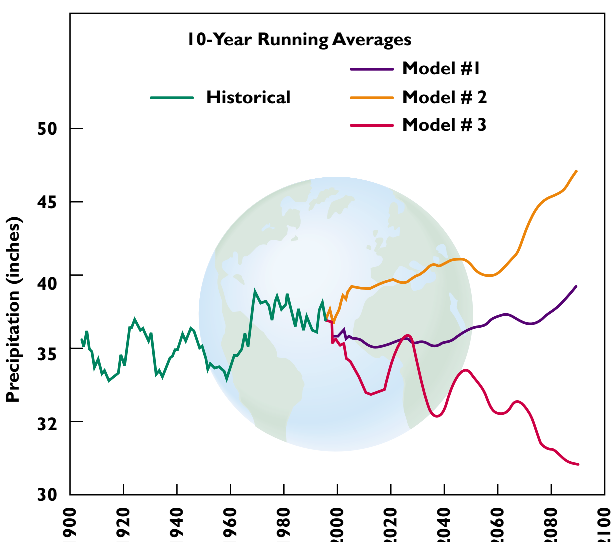
Based upon consideration of relevant factors, this plan contains an overall goal of supporting water supply planning and management in Illinois. The plan identifies Illinois State Water Survey (ISWS) strategies to achieve that goal with associated products and outcomes. Section 1 addresses water supply and demand projections; Section 2, surface water supplies and quality; and Section 3, groundwater supplies and quality. Section 4 focuses on the understanding and prediction of the hydrologic cycle in Illinois; Section 5, the reporting of water use; and Section 6, comprehensive water supply planning and management. Because the components of the hydrologic cycle are intrinsically linked, there are some necessary and unavoidable overlaps among sections. A list of ISWS contacts also is provided.

On average, Illinois receives about 38 inches of precipitation per year and has abundant water resources. About 20 billion gallons of water are used each day for domestic, municipal, commercial, agricultural, industrial, mining, power generation, recreation, navigation, and waste dilution purposes. Large quantities of water also are needed to sustain healthy ecosystems, including habitat for fish and other wildlife.

But it is not simply water that is needed: many uses require clean water. Naturally occurring pollutants, such as arsenic, radium, suspended solids, and chloride can limit the availability of clean water in Illinois and increase the costs of water treatment. Human activities that produce pollutants such as pesticides, metals, sediments, and nutrients can add to these problems and costs. Precipitation also contains chemicals, some natural, but many from human sources.

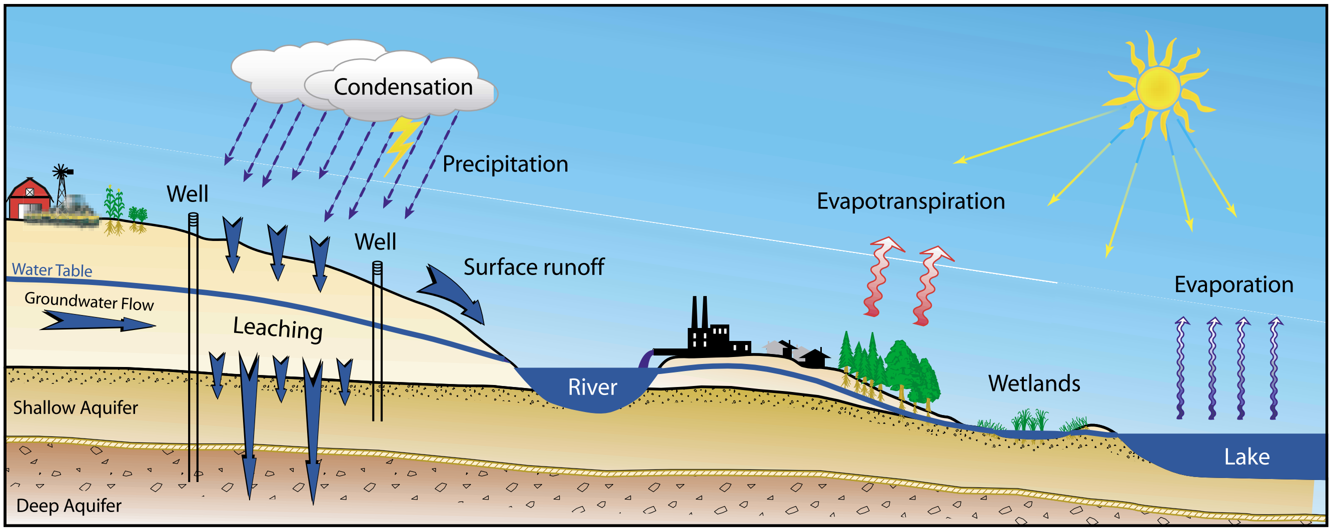


Aerial of Lake Springfield low lake level during the 1988 drought.



Historical 10-year annual average precipitation for the Illinois River basin (green) and projections from three different global climate models used by the United Nations (blue, purple, and red).

The sources of water in Illinois are Lake Michigan, rivers, streams, lakes, reservoirs, shallow aquifers, and deep aquifers. Ultimately, all these sources are dependent on precipitation, and variations or changes in precipitation can affect the supply and demand for public and private water supplies. Excess water creates damaging floods, such as those that occurred in 1993. Drought, such as the one that occurred in 1988-1989, is a consequence of insufficient rainfall and, often, high temperatures.



The hydrologic cycle.

Water is usually in motion, and scientists use the hydrologic cycle to study the flow of water between the atmosphere, soils, vegetation, rivers, lakes, aquifers, oceans, and its return to the atmosphere. These components are linked and a systems approach is thus needed to understand and predict how these components interact and to provide a basis for comprehensive water resources planning and management.

Surface waters, soil moisture, and shallow aquifers respond fairly quickly to variation in precipitation: rainfall recharges the water supplies in rivers, lakes, reservoirs, and shallow aquifers; lack of rainfall causes these water supplies to dry up. In a relative sense, these rapid response systems have fast recharge rates measured in terms of days or years. Deep aquifers are different in that they contain water that is thousands or, in some cases, tens of thousands of years old. These aquifers are slow response systems with slow recharge rates. Given an equal amount of water in two aquifers, larger amounts of water can be withdrawn safely from those aquifers that have faster recharge rates.

Water supply managers need data and information on precipitation amounts, recharge rates, and other variables to determine available quantities of water for design of reservoirs, flood controls, well fields, and water distribution systems. This information is also necessary to protect the precious water resources of the state from overuse, depletion, and contamination.

This plan emphasizes comprehensive regional assessments of renewable water supply capacity commensurate with the scientific data needs for comprehensive regional water supply planning and management. Consequently, the scope of the plan is necessarily broad. Regional assessments will be based on watersheds, aquifers, and/or groups of counties. More detailed studies will be conducted at the county and/or local levels. The time scale for water supply planning and management must extend over decades, commensurate with the long lead times needed for infrastructure development and with the dimensions of possible regional climate change.

The rate and order of implementation of the studies will depend upon the level and sources of funds, priorities, and upon collaborative efforts with other agencies such as the Illinois State Geological Survey, Office of Water Resources, Illinois Environmental Protection Agency, and United States Geological Survey. Existing resources at ISWS address many of these topics, but resources are limited and progress will be slow. A major infusion of new resources is needed for timely implementation of the studies described.

Excessive rainfall leads to flooding.

FACTORS CONSIDERED IN DEVELOPING THE PLAN

A number of developments, issues, and trends in Illinois, the Nation, and the world influence water resources and the need for water resources studies in Illinois. These factors are identified below.

- Demand for water is increasing in many parts of the state, primarily as a result of growth in the population and the economy. The Northeastern Illinois Planning Commission (NIPC) projects that population in the Chicago metropolitan area will grow by about one million by 2020.
- The demand for water in some parts of the state already exceeds or soon will exceed practical renewable yields, for example, from the deep bedrock aquifer of northeastern Illinois. Water levels in some central Illinois reservoirs were reduced to critical levels in the moderate 1999–2000 drought. More severe droughts do occur naturally and will have more severe impacts. Even under normal climatic conditions, NIPC projects water shortages for 11 townships in the Chicago metropolitan area by 2020.
- Future water availability is highly uncertain, and the past may not be a reliable guide to the future. Some projections show that water availability in the Midwest could change dramatically as a result of climate change: some models used in the United Nations' assessments project mean annual precipitation in Illinois as low as 25 inches or as high as 50 inches by the end of the 21st century, with continuing changes thereafter. These projections, if borne out, would, under current water management schemes, mean a potentially disastrous situation of either persistent floods or persistent droughts in Illinois. Other models show more modest changes in mean annual precipitation, but with a higher frequency of floods and droughts from year to year.
- Scientific and engineering data, including risk assessments, are needed for water supply planning and management. Risk assessments include estimates of uncertainties on factors that control the quantity and quality of water resources.
- Water resources projects often require long lead times to plan and implement.
- Many of the state's waters contain natural minerals and human-made pollutants that impair water quality

A lack of rainfall parches the soil.

and either limit water availability or increase the cost of supplying clean water.

- The availability and quality of water varies regionally, posing challenges in meeting local and regional water demands. It is not known how much water can be withdrawn safely from many aquifers.
- The flows of surface waters and groundwater are linked and need to be studied and managed conjunctively.
- Estimates of water use are often quite inadequate, as many major uses are not reported.
- The geographical extent of watersheds and aquifers do not coincide, and political boundaries do not coincide with watersheds or aquifers.
- Withdrawal of water from Lake Michigan is set by decree of the United States Supreme Court and by agreement with other states and Canada. The allocation is almost fully used and is unlikely to be increased in the near future.
- Illinois does not have updated statewide or regional water plans for the efficient and effective management of water supplies.
- Technical data and models needed for water supply planning and management are often outdated, inadequate, or nonexistent.
- Management of the state's water supplies is fragmentary and decentralized.
- State laws permit reasonable use of water resources, but the courts often determine what is reasonable and resolve conflicts. Water withdrawals typically are not evaluated based on cumulative impacts or renewable yields.
- Weaknesses identified in current water laws relate to the protection of minimum instream flows, drought emergencies, and renewable yields from surface waters and aquifers. Various advisory bodies have recommended strengthening laws to protect minimum instream flows and groundwater resources and to improve drought management.

GOAL

The goal of this plan is to provide a framework for ISWS water supply programs and to document those studies that ISWS, working with others, needs to conduct to provide Illinois with comprehensive technical data and information, models, and training for water supply planning and management.

Strategies

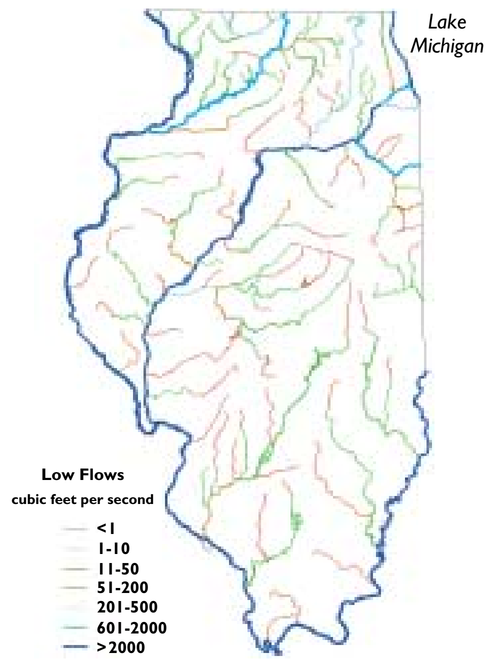
The following strategies will achieve this goal:

- Collaborate with other organizations and professionals to coordinate and integrate relevant programs, set priorities, plan activities, conduct studies, and seek additional funds.
- Assemble, archive, digitize, analyze, and synthesize existing data, including appropriate data from neighboring states.
- Incorporate estimates of uncertainty and risk in water supply assessments.
- Provide yield estimates for major aquifers and surface waters under variable and changing climatic conditions, including a worst drought scenario.
- Determine areas where water shortages are likely to be most critical over the next 20 years.
- Establish databases and models of sufficient resolution and accuracy for regional studies, which can be enhanced for local studies. These databases will include improved reporting of water use.
- As improved geological and hydrological data and models become available, use these in the development of improved water resources assessments.
- Identify critical data gaps and conduct field studies to gather additional data, and monitor the state's water resources to detect temporal trends in water supplies, water quality, and water use.
- Work with and train water supply planners and managers to interpret and apply scientific, engineering, and economic data to assist in water supply planning and management, including water conservation and reuse.
- Develop a decision support system on the Internet that presents and integrates databases and models for climate, watersheds, rivers, lakes, reservoirs, aquifers, and water use that can be readily accessed and used for any desired watershed, aquifer, geographical region, or political unit in Illinois.
- Provide regular updates of databases, models, and reports, and an annual summary of progress.

• 1 •

Water Supply and Demand Projections

The most important requirements in water supply planning and management are to know how much water is required over a period of time, the quality of water needed, and the water supply options available. Decisions then can be made on how to meet or reduce demand. Projections of water supply and demand inevitably include significant uncertainties, and the expression of uncertainties in future projections provides a basis for water resources planners and managers to conduct risk assessments and to plan for the future.



Average annual 2-year, 7-day low flows.

1.i. Preliminary Statewide Estimates of Water Supply and Demand

Issue. Increasing withdrawal of water from streams, rivers, reservoirs, lakes and aquifers threatens to exceed local water availability in some parts of Illinois, yet resources for scientific analysis of water availability and water resources management are limited. Cost-effective expenditure of limited funds will be facilitated by first conducting a coarse, statewide comparison of water availability and demand in order to identify priority areas for detailed analysis.

Activities. To accomplish this goal, the state will be subdivided into study units, and estimates of streamflow yield and groundwater availability will be developed for each study unit. A preliminary estimate of overall water availability will be provided for each study unit for comparison with current and projected water demand. Future water demand will be projected on the basis of present per-capita demand and economic and population projections.

Groundwater availability and streamflow yield will be treated somewhat differently in this prioritization study. For each study unit, groundwater availability will be estimated from available aquifer mapping and published estimates of natural recharge to these aquifers. Within a study unit, the upper limit on the amount of groundwater available from an aquifer will be the product of the recharge rate and the aquifer area within that study unit; actual well field yield will be less than the natural recharge rate. Streamflow yield is the amount of streamflow available to support all instream and offstream uses. A critical need is to define flow frequencies for various stream locations throughout the state. The criteria needed to identify potential regions of shortages and to prioritize regions for further study can be established by comparing the potential yield to current and/or future water demand.

Products. Preliminary statewide estimates of surface water and groundwater availability and water demand will be provided. A map illustrating the ratio of projected water demand to water availability will be developed and published for each study unit.

Outcome. Resource analysts and managers will be able to use the data to focus limited resources on data collection, scientific analysis, and management in areas where projected water demand exceeds, or threatens to exceed, water availability. Study units having the highest proportion of projected demand to overall water availability will be given priority for further in-depth study.

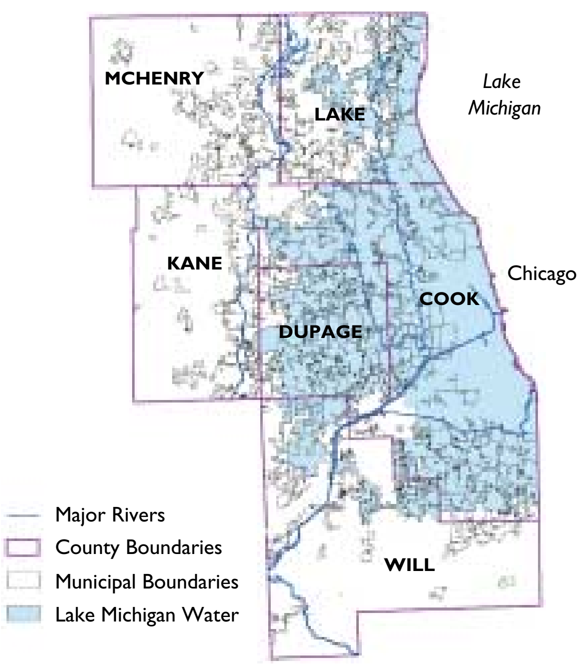
• 2 •
Surface Water Supplies and Quality

About two-thirds of the water supplies in Illinois are from lakes, rivers, streams, and reservoirs. In northeastern Illinois, about 2 billion gallons of water are withdrawn from Lake Michigan each day. In southern Illinois, where groundwater resources are not very abundant, there is heavy reliance on surface waters. The amount and quality of water available are dependent upon climate factors, human activities, land use, sedimentation in the reservoirs and lakes, requirements for the maintenance of minimum instream flows, and the economics and financing of water storage and distribution systems.

Barges on the Illinois, Mississippi, and Ohio Rivers require 9 feet of water when fully loaded.

2.i. Streamflow Yield Analysis, Including Minimum Instream Flows

Issue. Meeting the water demands of a growing population and economy using the concept of practical renewable yield provides a scientifically sound framework for the protection of our streams and natural resources through water supply planning. A working definition of "adequate water supply" is needed. Water uses must be prioritized in the event that demand exceeds supply, be it during a short-term drought or over the long-term.



Communities using Lake Michigan water.

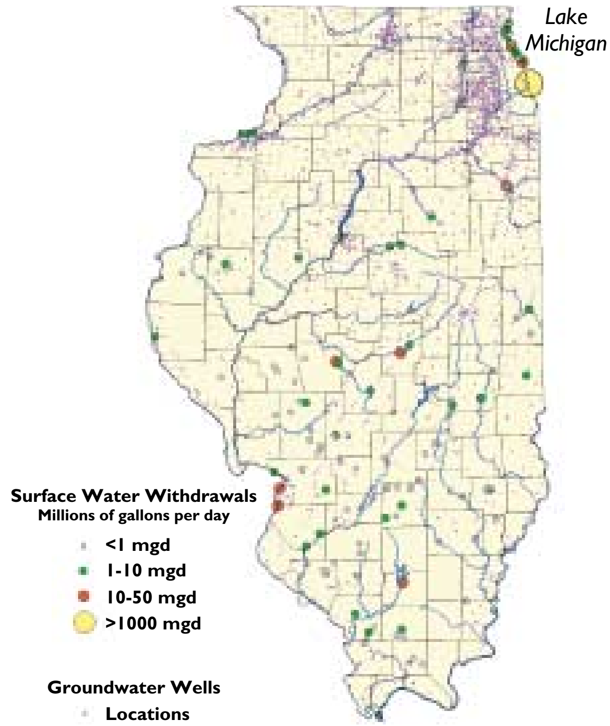
An understanding of streamflow magnitudes and frequencies for stream locations throughout Illinois is critical for estimating the availability and yield needed to support all instream and offstream uses. Currently only the 7-day, 10-year low flow is defined for all streams in the state. Other important flow frequency characteristics, such as the 90 percent and 75 percent levels of flow exceedence have been proposed for developing instream flow requirements, but yield data for these flow frequency values have been established only at United States Geological Survey (USGS) streamgage locations. Additional regional studies and analyses are needed to define flow frequency yields and associated water quality for ungaged locations throughout the state. Additional streamgage locations, particularly for monitoring smaller watersheds, are needed in support of these regional analyses.

In Illinois, primary instream uses include water needed for fish and wildlife habitat, water quality, hydropower, navigation, recreational and aesthetic interests, and overall biological integrity. Instream flows refer to the amount of water required to protect instream uses and to maintain sufficient water for offstream users downstream. Acceptance of instream flows as a legitimate water use, with rights similar to other water uses, is important to be able to provide protection for instream uses. To date, protection of the stream environment in Illinois has focused on water quality. But there is growing recognition that water quantity is integral to water quality and river health.

Activities. Building on existing designations, streams and watersheds with the highest level of use will be identified. An inventory of stream factors will be developed for use in identifying both regions of intense use and potential conflicts in use. These factors include water withdrawals and diversion, biological significance, water quality, waste assimilation, commercial navigation, recreational use, hydropower, and aesthetic value.

Existing and allocated offstream water uses will be identified and compared with streamflow yield. For most streams in Illinois, the quantity of water needed for instream uses has not been identified and will require substantial future study. Surrogate values of instream flow requirements, such as the 7-day, 10-year low flow, 90 percent flow duration, etc., will be used to identify streams/regions of potential shortage. Alternative approaches for defining shortages and the adequacy of the water supply will be investigated. Streams/regions will be identified where streamflow yields are currently inadequate to provide all existing and/or allocated uses using the surrogate estimates of instream flow. In addition, areas with potentially large increases in water use will be evaluated for their potential future impacts on water quality and instream uses.

Products. Instream uses will be identified. An inventory will be developed that lists streams, rivers, lakes, and watersheds having the greatest potential for water use conflicts and shortages based on surrogate levels of instream flow requirements and water quality. Basic data will be collected and analyzed to refine estimates of water availability and establish a defensible criterion for renewable yields.



Community water supplies.

A range of flow frequency characteristics will be provided. Reports and Internet databases on streamflows, water uses, and streams/regions of potential shortage will be produced.

Outcome. Resource analysts and managers will be able to use the inventory to focus limited resources on protection and restoration of streams with the greatest potential for water shortages and water-use conflicts. Aquatic habitat quality and abundance will be able to be linked to return periods, and risk assessments can be performed.

2.ii. Drought Assessment, Preparation, and Management

Issue. Surface water supplies are particularly vulnerable to potential water shortages during drought periods. The practical renewable yield from a surface water source is dependent upon both the flow characteristics of the river or stream and the volume of raw water storage made available through reservoirs that store water during high flow periods.

In certain locations, yields from surface water sources also can be manipulated to meet demand during low flow and drought periods by conjunctive use of surface water and groundwater.

Surface waters are the source of most public water supplies in southern and central Illinois, both from direct withdrawals from streams and, more commonly, through reservoirs formed by stream impoundment. During drought conditions, it is vital to monitor both stream and reservoir water levels. Streamflow data on larger rivers and reservoirs are generally available to evaluate the water supply potential and drought status for many larger public water supply systems in the state—for example, Rend Lake—but data to evaluate smaller public systems often are lacking. During the drought of 1999–2000, potential water shortages threatened a number of these communities. Only a few of these reservoirs have continuous monitoring of water levels or inflow. The current monitoring practice is wholly inadequate to provide information critical for decision-making during drought periods. Detailed water level and inflow data also are needed to develop water budgets and to assess yields from these reservoirs for planning purposes and drought preparation.

For water supply reservoirs, additional data related to volume, sedimentation rates, and evaporation rates during drought conditions also are sorely needed for risk assessment, long-term planning, and drought management. Volumetric measurements are available for only a few water supply reservoirs, and estimates of volume are often grossly inaccurate. Regular sediment surveys also need to be conducted approximately every 10 years to monitor changes in volume. These are necessary for long-term planning and vital for drought planning and estimation of critical draw-downs and possible water shortages. In addition to providing quantitative information on surface water resources, the sedimentation data can be used to evaluate regional sediment-delivery rates. Evaporation losses represent a significant percent of the gross yield from a reservoir, up to 25 percent during droughts, and estimates of this fundamental process are crude.

Instruments measure precipitation, wind, soil moisture, temperature, and humidity.

Activities.

1. Identification of Drought-prone Communities. Drought-prone community water supplies will be identified and prioritized using published data comparing current water withdrawals and 50-year drought yields. Once these communities are identified, a drought plan will be proposed for each community that sets limits on the safe yield, identifies cumulative rainfall deficits that trigger water conservation measures, and suggests other actions to reduce the risk of water shortages.

2. Reservoir Water-Level Monitoring. A network of continuous, real-time, water-level monitoring stations will be implemented at selected reservoirs used for water supply. Real-time data collection will provide valuable information during drought periods. Long-term data collection will provide information for development of water budgets and resource planning. Continuously recording staff gages will be installed over a 5-year period. After this period, the program will continue data collection, equipment replacement, and rehabilitation.

3. Reservoir Sedimentation Monitoring. A long-term program of reservoir sedimentation monitoring will be established. Reservoirs throughout the state will be surveyed initially and then re-surveyed on a rotational basis. Reservoir sediment surveys will be conducted continuously through summer and fall as weather permits. Approximately five lake surveys will be conducted each year. Public water-supply reservoirs will have top priority for surveys, particularly those reservoirs identified as being at-risk during droughts.

4. Stream Monitoring. New gages will be added to the Illinois Streamgage Network operated by USGS. New streamgage locations on smaller watersheds will be identified, with priority on gages placed near reservoir systems that are most at-risk for drought impacts.

5. Reservoir Evaporation Monitoring. A network of seven long-term evaporation-monitoring stations will be established at selected reservoirs across Illinois. Weather stations at reservoirs will measure the meteorological parameters required to accurately calculate evaporation from the water surface. Data collected at these stations will be used to establish relationships between water surface evaporation and parameters routinely measured at standard weather stations and to develop models that simulate the effects of evaporation on reservoir capacity. Long-term monitoring also will provide information to track climate change impacts on evaporation, and statistical analyses of data sets will assess water reliability.

6. Hydrologic Analysis. From historical data and the data collected above, improved methodologies will be developed for the assessment and design of yields for water supply systems. This includes the development of regional models for estimating drought streamflow conditions for existing water supply systems as well as ungaged stream locations throughout the state. Worst drought scenarios will be defined. Approaches for drought forecasting and management strategies during drought conditions also will be examined.

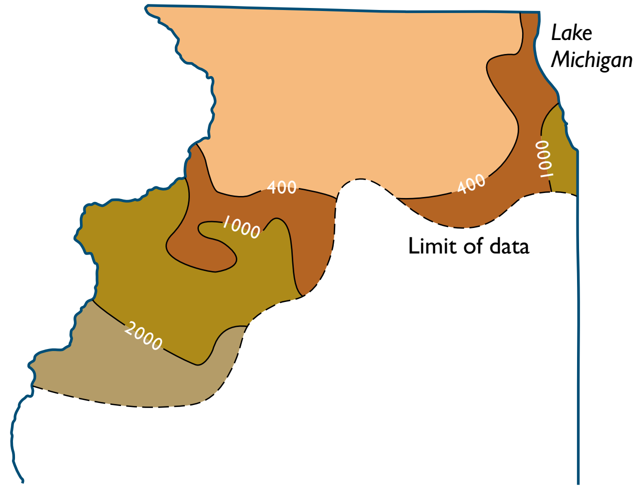
Products. Reports and databases that identify drought-prone communities will be prepared, disseminated, and made available on the Internet. Assistance will be provided to at-risk communities and, with their cooperation, water supply and drought management plans will be prepared. Continuous, real-time water levels on streams and reservoirs will be measured, and data collections and analyses will be provided on the Internet and in reports. Real-time monitoring will provide critical information for assessing potential drought and flood conditions and for system management during these extreme events. Data for reservoir budget analysis and long-term data sets will provide information for improved water supply management. Data collections and data analyses of estimated volume losses for measured and unmeasured reservoirs will be provided in reports and on the Internet. Data from streamgages will be used for developing better regional models that estimate flow characteristics on ungaged streams.

Outcome. Communities will be better able to plan and manage water supplies for drought emergencies, thus minimizing the risk of water shortages. Water supply planners and managers will be better able to track the water supply status of reservoirs during droughts, develop water budget and reservoir models to forecast drought impacts on individual water supplies, and analyze the adequacy of systems. High-flow data also can be used to improve regional relationships of flood discharge and frequency. Assessment of appropriate options for rehabilitating reservoirs and maintaining adequate water supplies will be based on data and knowledge of the rate of sedimentation.

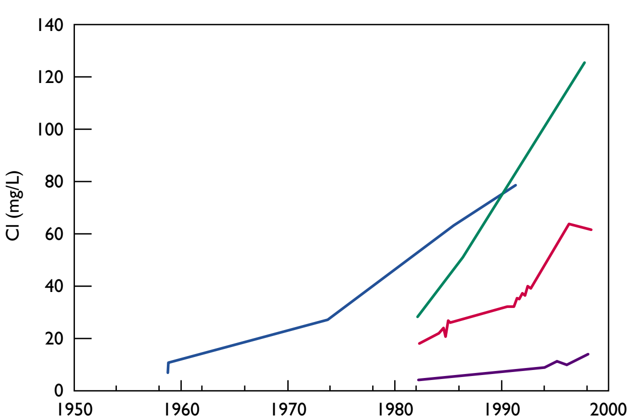
• 3 •
Groundwater Supplies and Quality

Groundwater is withdrawn for large public, industrial, and commercial purposes from three principal categories of aquifers in Illinois: (1) unconsolidated sand-and-gravel aquifers contained within the glacial drift, (2) shallow bedrock aquifers, and (3) deep bedrock aquifers. The amount of groundwater that can be withdrawn safely varies tremendously from aquifer to aquifer, as does the quality of the water. In addition, thousands of private wells tap water in the shallow aquifers. Withdrawals of groundwater in Illinois average about 1 billion gallons per day and serve about a third of Illinois' population.

Many factors influence the practical renewable yield of aquifers and water quality, and these factors have not been quantified well enough to permit an accurate statewide assessment of renewable yields and water quality. Records of aquifer characteristics are needed to establish the aquifers' physical and hydraulic properties, groundwater withdrawals, spatial and temporal changes in groundwater levels and groundwater quality, and to provide input to mathematical computer models. However, comprehensive digitized records of the hydrologic, hydraulic, and water quality properties of the state's aquifers either do not exist or need to be updated and made more accessible: agencies have their own databases, and much ISWS data remain to be digitized. The need for improved databases is revealed every time a groundwater flow model or statistical assessment of aquifer properties is conducted.



High concentrations (mg/L) of dissolved solids limit the use of water in southern parts of the deep sandstone aquifer.



Change in chloride concentrations in four municipal wells (<200 feet deep) in Kane County.

High-capacity wells also may have adverse impacts on nearby wells and the base flows of rivers and streams, regardless of whether or not the practical renewable yield of the source aquifer is exceeded. Unfortunately, modern computer flow models that can simulate aquifer conditions and calculate renewable yields and the impacts of new wells on existing wells do not exist for Illinois aquifers. In addition, adverse impacts are not well defined.

3.i. Regional Aquifer Characterization and Monitoring

Issue. For decades, the ISWS has collected important groundwater data for many of Illinois' major regional aquifer systems. However, the ISWS does not have comprehensive, easily accessible digital records of the spatial and temporal distribution of many key aquifer characteristics. Data resolution is very inconsistent across the state, many data gaps exist, and many data sets need to be updated.

Activities. Existing data will be assembled and organized to characterize the shape, depth, physical (hydraulic) properties, boundary conditions, rates of recharge under normal and drought conditions, hydraulic heads, locations of wells and groundwater withdrawals, and water quality in the state's major regional aquifers. Existing ISWS databases will be updated with additional data collected through the multitude of projects previously conducted by ISWS and other scientists. New databases will be created from data mined from ISWS paper files and publications. A comprehensive literature review will be conducted to glean data from previous ISWS investigations. Original well-construction records will be scanned and digitized. Priority will be placed on those aquifers most in need of study and management attention, based on the use-to-yield analysis discussed previously. A preliminary list of the state's major aquifers is provided below.

Drilling a well to tap groundwater.

- The "deep bedrock" aquifer system of northeastern Illinois (Cambrian-Ordovician System)
- The Mahomet aquifer of east-central Illinois from Indiana to the Illinois River
- The shallow sand-and-gravel and bedrock aquifers in northeastern Illinois
- The Sankoty aquifer of Lee and Whiteside Counties and from Hennepin to Washington
- The alluvial aquifer systems along the Mississippi River
- The shallow dolomite in Kankakee, Iroquois, Will, and Cook Counties
- The Saline Valley in Saline and Gallatin Counties
- The alluvial system along the Wabash River Valley
- The alluvial system of the Lower Illinois River from Beardstown to Alton
- The alluvial system of the Rock River from Wisconsin to Sterling
- The alluvial system of the Kaskaskia River Valley
- The alluvial system of the Cache River Valley
- The alluvial system of the Embarras River Valley
- The "ridged-drift" aquifer near Taylorville

Products. Data will be assimilated, disseminated, and made available in reports and via the Internet. Existing ISWS databases to be updated for documentation of water use, aquifer hydraulic properties, groundwater levels, and groundwater quality include the Private Well Data Base, the Public-Industrial-Commercial Survey, and the Illinois Water Inventory Program. Improved links to other databases will be established (e.g., Illinois State Geological Survey geological records and Illinois Environmental Protection Agency and Illinois Natural History Survey water quality records) and efforts strengthened to minimize overlap and duplication. Guidelines for the definition of adverse impacts will be provided.

Outcome. Scientists, analysts, and decision makers will be able to access a wealth of groundwater data statewide. These data will be useful as data input to the development of regional and local aquifer models. The outcome will be more scientific and reliable water supply planning and management across the state and conflict resolution.

3.ii. Preliminary Groundwater Modeling

Issue. Groundwater flow models are needed to determine renewable yields from aquifers, capture zones of wells, water quality, and to evaluate the

Irrigation of crops uses large quantities of groundwater in some parts of Illinois.

impacts of water withdrawals. The ISWS has developed flow models for only a few aquifers, and these models are not up to date. Flow models need to be constructed and/or updated for all the major aquifers in the state.

Activities. As data are assembled and organized on Illinois' high priority aquifers, simple groundwater models will be constructed to provide estimates of groundwater availability (practical renewable yield) and water quality for that aquifer. Existing models will be evaluated, updated, and used as appropriate. Priority will be placed on those aquifers most in need of study and management attention, based on the use-to-yield analysis discussed previously.

Products. Estimates of groundwater availability, with uncertainty estimates, and water quality characterizations will be provided for each major aquifer in Illinois. For those aquifers experiencing potential water-use conflicts, a computer flow model will be constructed such that estimates of well interference on groundwater levels and streamflows can be provided.

Outcome. These models will provide tools for water planners and managers to assess regional groundwater availability, water quality, and impacts of withdrawals. In tandem with surface water assessments, alternatives for new water-resource developments to alleviate water shortages can be examined. In addition, such models can provide important feedback to help identify additional data needed to reduce model uncertainty. This will form the basis for additional new data collection efforts.

3.iii. Field Studies

Issue. Preliminary groundwater models will contain a fairly high degree of uncertainty because specific field studies have not been conducted to gather data for model development and validation. However, these models will provide a basis for planning aquifer-specific field studies.

Activities. Based on model uncertainties and priority aquifers, field studies will be conducted to collect new data through short-term sampling and long-term monitoring. Priority will be placed on those aquifers most in need of study and management attention, based on the use-to-yield analysis discussed previously. Such new data collection activities will include:

- Improving estimates of groundwater recharge and estimates of the impacts of climate variability and change on recharge.
- Determining surface water/groundwater interactions under normal and drought conditions.

- Determining aquifer hydraulic properties in untested areas.
- Improving geologic maps to provide better estimates of aquifer physical properties.
- Collecting water-level data for the creation of potentiometric surface (water-level) maps.
- Collecting water samples to characterize water quality.

Products. Databases, graphics, and maps for Illinois' major aquifers, providing improved spatial resolution of aquifer physical, hydraulic, and chemical properties, will be produced. These products will be disseminated in reports and made available via the Internet.

Outcome. Improved resolution of field data will provide input for the development of more detailed and accurate groundwater flow models and for managing water-use conflicts.

3.iv. Detailed Mathematical Computer Models

Issue. Decision makers need "living" numerical computer models to evaluate alternative strategies for resource development. Such models must be capable of a) accurately simulating hydraulic head and transport of chemicals in the aquifers, b) estimating practical renewable yields of the state's major aquifers, c) identifying capture zones around public water supply wells, d) identifying interference drawdown, and e) providing scientific input for management of groundwater resources.

Activities. All existing data and the results of field studies will be incorporated into detailed groundwater flow models of the state's major regional aquifers. Priority will be placed on those aquifers most in need of study and management attention based on the use-to-yield analysis discussed previously. Models will be updated routinely as new data are collected to improve model calibrations and predictive capabilities. Computer flow models will be migrated to new software and hardware platforms for improved model performance.

Products. Computer flow models for Illinois' major aquifers, with uncertainty analysis, will be placed on Internet-based decision support systems (see Section 6) for use by analysts in evaluating water management options. The flow models will include the transport of chemicals.

Outcome. With higher resolution data, detailed computer groundwater models can be constructed to make more accurate predictions of impacts of withdrawals on water levels, water quality, surface water interactions, and, ultimately, aquifer yield. Such models can be applied to evaluate:

- Long-term practical renewable yields from the state's major aquifers.
- Impacts of withdrawals on the quality and quantity of the resources.
- Interaction between shallow groundwater supplies and streamflows.
- Options for the artificial recharge of aquifers.
- Water use conflicts.

The overall outcome will be the protection of groundwater resources, the identification of options for the renewable use of groundwater resources, and the resolution of water-use conflicts.

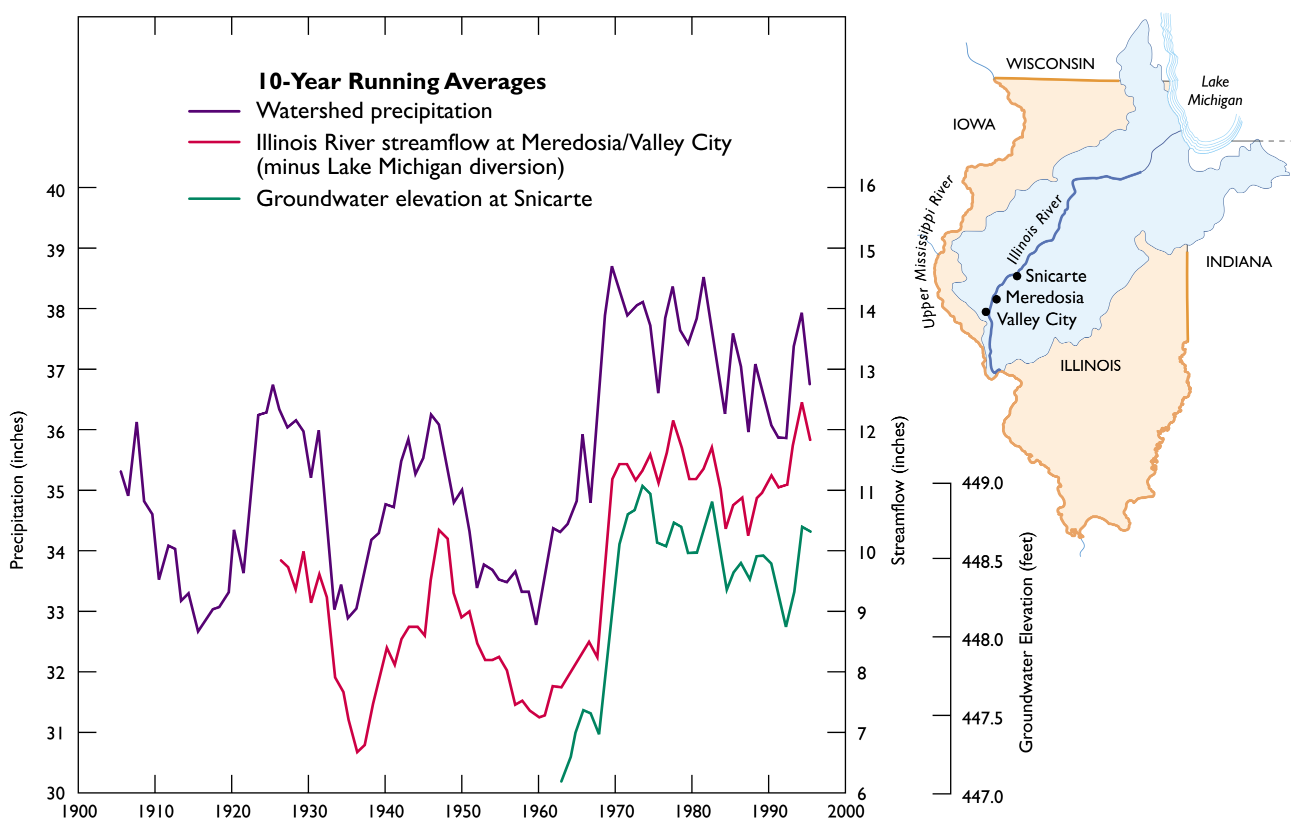
• 4 •
Understanding and Predicting the Hydrologic Cycle and Water Resources

All components of the hydrologic cycle are interdependent: precipitation affects soil moisture and surface water; soil moisture also affects precipitation and aquifer recharge; and surface waters and aquifers are interconnected. It is, therefore, appropriate and necessary to study the hydrologic cycle and water resources in Illinois as a system. Mathematical computer models provide an opportunity to simulate this system and to possibly predict future changes of this system and water resources in Illinois. Such a systems approach provides a scientific basis for comprehensive regional water supply planning and management (Section 6).

Mean annual precipitation varies from about 34 inches in northern Illinois to 50 inches in southern Illinois. Precipitation in any given year is much more variable and can be as low as 25 inches in the north to as high as 65 inches in the south.

These climate variations fundamentally influence the amount of water available in rivers, streams, lakes, reservoirs, and aquifers. Statewide, about 25 percent of the precipitation runs off the land surface or infiltrates the soil in an average year. Statewide, about 75 percent of precipitation is returned to the atmosphere through evapotranspiration in an average year. During droughts, this percentage approaches 100 percent, leaving little precipitation for runoff or aquifer recharge.
The amount of water that runs off the land surface or percolates into the soil also is influenced by temperature, the nature of the land cover, and drainage systems.

For the above reasons, climate variables are important to the water resources of Illinois. In addition, climate regimes change naturally and could change in response to human modifications of the climate system. The buildup of pollutants in the atmosphere has given rise to projections that regional climate conditions could change



A comparison of 10-year running averages of Illinois River watershed precipitation, streamflow (minus Lake Michigan diversion), and groundwater level.

dramatically due to global warming caused by an enhanced greenhouse effect. The fact that different models produce different scenarios of climate change points to the large scientific uncertainties that exist in projecting climate change. Nevertheless, there are risks that climate change, even in the next 20 years, could impact water resources in Illinois due to changes in precipitation and temperature and to changes in the frequencies of droughts and floods. It would be shortsighted to assume that the future climate of Illinois will be the same as the present climate to which ecosystems, society, and the economy have adapted. The risk of climate change and the possible impacts of climate change on Illinois water resources need to be evaluated.

4.i. Monitoring of Climate, Soil, and Land-use Changes

Issue. A 19-station array of sensors across the state provides continuous observations of climate and soil conditions. Data from the Illinois Climate Network (ICN) are becoming increasingly important to a growing number of governmental, university, private enterprise, and public users. Data are used by the Illinois State Water Plan Task Force to monitor and evaluate water and soil conditions across Illinois and to plan for drought emergencies. For security and station longevity considerations, the network's original stations were placed on state or university property. Increased demands for data often are not met because the existing distribution of stations is not sufficiently dense.

In addition, runoff into rivers, streams, and reservoirs can be altered from present rates by changes in land-use cover and related variables within a basin—for example, crops, reforestation and restoration. A better understanding of the overall impacts of changes in these variables on water supplies can be achieved by monitoring key climate, land-use, and other watershed conditions at selected locations within a basin and then developing a model to extend these analyses to other basins and other conditions.

Activities. Twelve additional ICN sites need to be installed in Illinois to provide improved water resources data across the state. The sites need to be equipped with weather and soil observation sensors, towers, dataloggers, weather shelters, and communications and other equipment.

Also, a small stream basin will be selected for intensive monitoring. One criterion for basin selection will be the availability of streamgages and reservoir water-level monitors. To represent likely within-basin differences in evapotranspiration and soil moisture, four sites will be selected for routine monitoring of, for example, upland crop, upland forest, lowland crop, and lowland forest. Each site will be instrumented to obtain measurements of precipitation, evapotranspiration, soil conditions, vegetation, and related variables. Data will be collected routinely for 10 years to establish temporal variations in the relationship of these elements to runoff. Data will be analyzed and a model developed to simulate a water budget for the basin. Once the validity of the model is established, it can be applied to other basins.

Products. Continuous observations of weather and soil conditions statewide, a 10-year record, and a model of the water budget in a basin will be provided. Data sets, models, and reports will be prepared, disseminated, and made available via the Internet.

Outcome. Water supply planners and managers, weather- and climate-sensitive industries, and the public will be able to incorporate the data into improved operational models and decision making. The effects of land-use changes on water supplies will be quantified, and the basin model will be applied to better plan and manage water resources under changing basin conditions.

4.ii. Modeling the Linked Climate/Surface Water/Groundwater System

Issue. Potential future climate variability and change pose threats to water supplies. Assessment of the effects of climate variability and climate change on water resources requires data at the spatial scales of watersheds. Watersheds feed many water supplies much smaller than the resolution of global climate models. Therefore, the projections by these models cannot be used directly to assess impacts on specific water supplies. Regional climate modeling is required to address these issues. However, regional climate models are still under development, and more research is required to improve model accuracy so that they can be applied with confidence to address water resources issues. The ISWS has initiated a regional climate modeling program, but limited resources restrict progress on this very important issue.

Activities. Four major activities will be undertaken to improve the usefulness of regional climate model information for water resources applications.

One activity will focus on improvement of the model through a sequence of model simulations of selected historical events, comparisons of model results with observed events, and identification of potential model improvements to enhance model capabilities to simulate droughts and heavy precipitation events that cause flooding. The goal will be to accurately simulate these events for a variety of climate conditions under which they occur. Accurate simulations of past events will increase confidence in the ability of models to project future climate extremes and climate changes.

The second task, undertaken in parallel with the first, will be the coupling of the regional climate model with surface hydrologic models to directly produce estimates of runoff, discharge, and infiltration.

The third task will be to link climate, surface hydrology, and groundwater flow models to evaluate system impacts of possible climate variations and changes.

The fourth task will be to apply the linked models, embedded in a global climate model, to project possible future climate and water resources conditions in Illinois.

Products. Assessments will be made of the risks and possible consequences of future climate change on water resources in Illinois. Resulting data sets will be disseminated in reports and made available via the Internet.

Outcome. Policy makers and water supply planners will be able to use the new data on possible future water resources conditions in Illinois to conduct risk assessments, to evaluate alternative policies and strategies, and to make far-sighted decisions.

4.iii. Assessment of Climate Change Model Projections

Issue. Climate models are complex mathematical computer programs that scientists use to project possible climate changes due to natural and human factors. Research groups around the world are improving these models. However, large model-to-model differences in future projections of precipitation and temperature for Illinois reflect scientists incomplete understanding and model simplifications of the global climate system. It is important to evaluate model differences and to assess the credibility of new model projections, since the climate and water resources of the 21st Century could be significantly different from those of the 20th Century.

Activities. Projections of Illinois' climates produced by different models will be assessed and their implications for Illinois water resources evaluated.

Products. Reports on a range of possible future climate conditions will be provided, along with assessments of the uncertainties of these projections. Explanations will be provided why models using essentially the same drivers—emissions associated with natural processes and population and economic growth—produce different climate projections.

Outcome. Governments and private industry will be able to use these projections, with interpretations and uncertainty estimates, as guidance for risk assessment in water resources planning and management. The information and knowledge gained also will provide valuable guidance for the regional climate modeling activity to decide which models to use for more detailed assessments of water resources.

• 5 •
Reporting of Water Use

Water supply planning requires comprehensive and detailed information on water withdrawals, uses, transfers, and returns. Assessment of water availability is fundamental, but it is equally essential that the demands on that resource be quantitatively and geographically identified. Water withdrawal information is necessary to develop water budgets, calculate adjustments to streamflow records, monitor trends in water demand, as input to develop and calibrate hydrologic models, and resolve conflicts.

5.i. Reporting and Analysis of Water Withdrawal, Use, Transfer, and Return

Issue. The ISWS has a long-standing program of water withdrawal data collection, analysis, and reporting for surface waters and groundwater. However, more comprehensive, detailed, and precise data collection, analysis, and reporting are required for self-supplied users, trend analysis, integration and analysis of water returns, and accounting of water transfers.

Fresh Water Withdrawals 1995 (MGD)

	Surface Water	Ground Water	Total
Domestic and Public Supply	1450	500	1949
Self-Supplied Industries	422	183	606
Livestock and Irrigation	2	234	236
Thermoelectric Power	17,100	11	17,100
Total	18,974	928	18,891

Source: USGS Circular 1200

Freshwater withdrawals in millions of gallons per day (mgd) from surface water and groundwater, 1995.

Activities. Building on existing data, expertise, and resources, ISWS will a) coordinate work with other governmental organizations to collect, archive, and disseminate water data; b) expand current data collection activities to increase annual reporting return rates to approach 100 percent for major users; c) assimilate water withdrawal, use, transfer, and return data; d) develop a coordinated, Internet-based database; e) expand and refine data quality control and quality

Electric power generation is the major use of water in Illinois.

assurance for the data; f) analyze consumption, returns, and inter-basin transfers; and g) provide water use data to communities and engineers engaged in facility design and watershed and water supply planning.

Products. Databases and reports on surface water and groundwater withdrawals, transfers, uses, and returns will be disseminated and made available on the Internet.

Outcomes. Fuller accounting of water withdrawals, uses, transfers, and returns will enable water supply planners and managers to develop water budgets, calculate adjustments to streamflow records, monitor trends in water demand, prioritize water withdrawals, calibrate hydrologic models, and resolve conflicts. As a result, the state's water resources can be used more wisely.

• 6 •
Comprehensive Water Supply Planning and Management

Water use in Illinois is largely unregulated and controlled by a market economy. Surface water and groundwater resources are usually studied and managed separately, yet there are many opportunities for the conjunctive use of these resources. To date, there is little conservation or reuse of water in Illinois, but many opportunities for doing so exist. The above studies will provide large quantities of quality-assured data that must be assembled, synthesized, analyzed, and made easily available to other agencies and the general public for appropriate use.

6.i. Decision Support

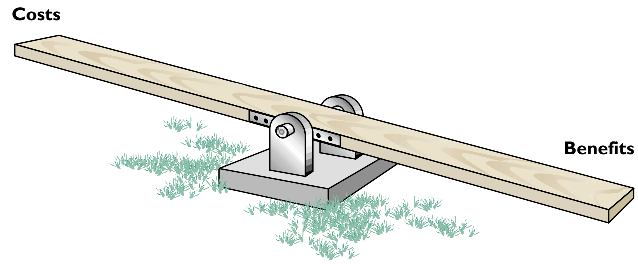
Issue. The management of water resources in Illinois is complicated by the spatial and temporal

Decision support for comprehensive water resources planning and management.

variability of water resources, climatic uncertainty, groundwater/surface water interactions, a diversity of constituent interests, social and economic considerations, and legal constraints. Wise and optimal use of water supplies requires evaluating options for and the consequences of water management policies and strategies, which can come only from accurate, unbiased data interpreted and analyzed for water resources planners. Comprehensive water supply planning at the regional and local scales can increase efficiencies, lower costs, and ensure the future availability of adequate supplies of clean water at a reasonable cost.

Activities. Three major activities are identified.

1. Develop quality-assured databases, tables, graphics, and maps related to water supply (climate, surface water and groundwater), demand, withdrawal, use, and interbasin transfer. These databases will be compatible and constructed by geographical (watersheds and aquifers) and political units.
2. Develop and maintain an accessible, comprehensive Internet-based decision-support system that will include:
   a. Quality-assured databases;
   b. Research results to address key social, hydrologic, and economic uncertainties (e.g., the value of nonmarket use of water, the impact of climate variations on aquifer recharge); and
   c. Tested computer models for evaluating alternative hydrologic and economic strategies for the optimal conjunctive use of water resources (e.g., cost minimization or net social benefit maximization) and water conservation and reuse.
3. Interact with local, state, and national water resource planners to construct plausible management scenarios and to translate data and model results into actionable knowledge. Provide training to regional and local officials on water supply planning and management under variable climatic conditions.



Evaluating the costs and benefits of water supply, conservation, and reuse options.

Products. These activities will organize data products and information and disseminate these as reports and as multimedia presentations, including models, via the Internet. Methods for analyzing the optimal conjunctive uses of surface water and groundwater resources, together with water conservation and reuse strategies, will be made available in reports and via the Internet. ISWS will train personnel in water supply planning.

Outcomes. Comprehensive water supply planning can lead to the optimal use of limited resources for minimum financial and environmental costs. Economic models developed by these activities will provide a rational basis for determining water management strategies. Water resource planners and managers will be able to use their training and the new data to design and develop water supply, treatment, and distribution projects.

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Starved Rock Lock and Dam on the Illinois River.

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