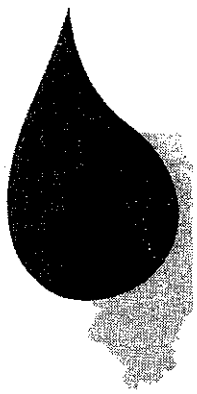

ATMOSPHERIC CHANGES AND MANAGEMENT ISSUES

SPECIAL REPORT NO. 2
OF THE
ILLINOIS STATE WATER PLAN TASK FORCE

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Prologue

This report addresses one of the 13 major water planning issues identified as a part of a multi-year effort of the Illinois State Water Plan. The planning activity began in 1980 with the appointment by Governor Thompson of state agency representatives to a task force. This reflected a general belief that the previous plan "Water for Illinois, A Plan for Action," and issued in 1967, had become obsolete.

The Governor's Task Force established a mission and focused on the significant water issues not being sufficiently addressed by current programs, or emerging issues which can be anticipated to lead to future problems or conflicts. After public interactions, a plan of study was developed in 1980 identifying 10 water issues and 2 crosscutting topics which have become the focus of the 1981 activities. These issues are described, along with the planning process, in greater detail in the "1981 Progress Report of the Illinois State Water Plan."

The Task Force has chosen to prepare more in-depth "special reports" on each of these issues as they become available. This special report on "Atmospheric Changes and Management Issues" was identified as one that largely reflects an emerging issue which is not well known in many sectors of Illinois, but which water experts believe to have importance both for water quality and quantity concerns.

Like many of the 12 issues, the Atmospheric Change and Management Issue crosscuts through several of the other 11 issues. Changes in atmospheric extremes, either due to nature or man's influence on the atmosphere, are important factors in five other issues. These include "Erosion and Sediment Control" which is directly effected by rainfall intensity and winds, both known to have changed systematically in recent years. The issue of "Integration of Water Quality and Quantity Management," is directly related to the pollutants scavenged in precipitation and brought to our streams, lakes, and underground waters. The weather/climate issue is a significant factor in the "Flood Damage Mitigation" issue since flood-producing conditions have worsened in recent years due to climatic changes (colder winters with heavier snow, and more heavy rainstorms). "Competition for Water" issue looks at future demands of irrigation for agricultural production as a major water user, and this concern is directly related to summer rainfall which has been increasing. "Drought Contingency Planning" is also an issue related to the atmospheric conditions and drought planning needs have been caused by recent droughts in southern Illinois and use of weather modification in attempts to bring more rain. Thus, changes in climate are integral to the water resources of Illinois, both as to their quality and quantity. Climate must be monitored and studied if we are to address adequately most other water issues. Means to manage to ameliorate the extremes of weather, either through planning based on long-range climate predictions or on modification of precipitation are an integral part of a comprehensive plan of action for the water resources of Illinois.

This report was written by Stanley A. Changnon, Chief of the Illinois State Water Survey and Richard G. Semonin, Assistant Chief. The Task Force reviewed and modified the draft document and have issued it as a Task Force document.

Introduction

Atmospheric changes are altering the quantity and the quality of the waters of Illinois. Some changes are slow, others rather sudden, and many are just being realized by scientists and the public. The atmospheric changes are due to natural fluctuations in climate and also to man's influence on the atmosphere. There are two emerging atmospheric-oriented capabilities to deal with these changes, weather modification and climate prediction.

The atmospheric concerns relate to three issue areas:

1) climate change and prediction of future climate conditions,

2) inadvertent weather and climate modification, and

3) planned weather modification.

All are at the margin of developing knowledge and public awareness, but the state must play a major role if they are to be addressed to benefit our water resources.

Issue: Climatic Changes and Prediction of Future Climate Conditions

Problem

The quality and quantity of Illinois' water resources are irrevocably linked to and dependent upon the climate. Precipitation contributes all of the water available to Illinoisians. However, not all of this water falls on the state; some of it is thousands of years old and buried in the ground, and some originates elsewhere and flows to the state in major rivers. The amount of water that escapes from Illinois in the form of evaporation and transpiration is also significant, and this loss is dependent on the humidity, temperature and winds, other major features of the climate of Illinois. The ability of the atmosphere to carry and then deposit natural and man-made pollutants also represents a major factor affecting the quality of the state's waters.

As a result, climate is an integrator and a controller of the state's water resources on all time and space scales. Hence, major changes in climate can be serious to Illinois' waters and its major uses, human consumption, crop growth, and energy production.

Climate is not static, as many perceive, and is constantly varying over time scales ranging from a few years, to decades, to centuries. If we look back at what has happened in Illinois in the past 140 years (Figure 1), we see that we are now in a period of declining temperatures and fluctuating but heavier precipitation. Since we will be dealing in the future with a climate different than that of the past 60 years, we will experience events that our current water systems have not been designed or developed for.

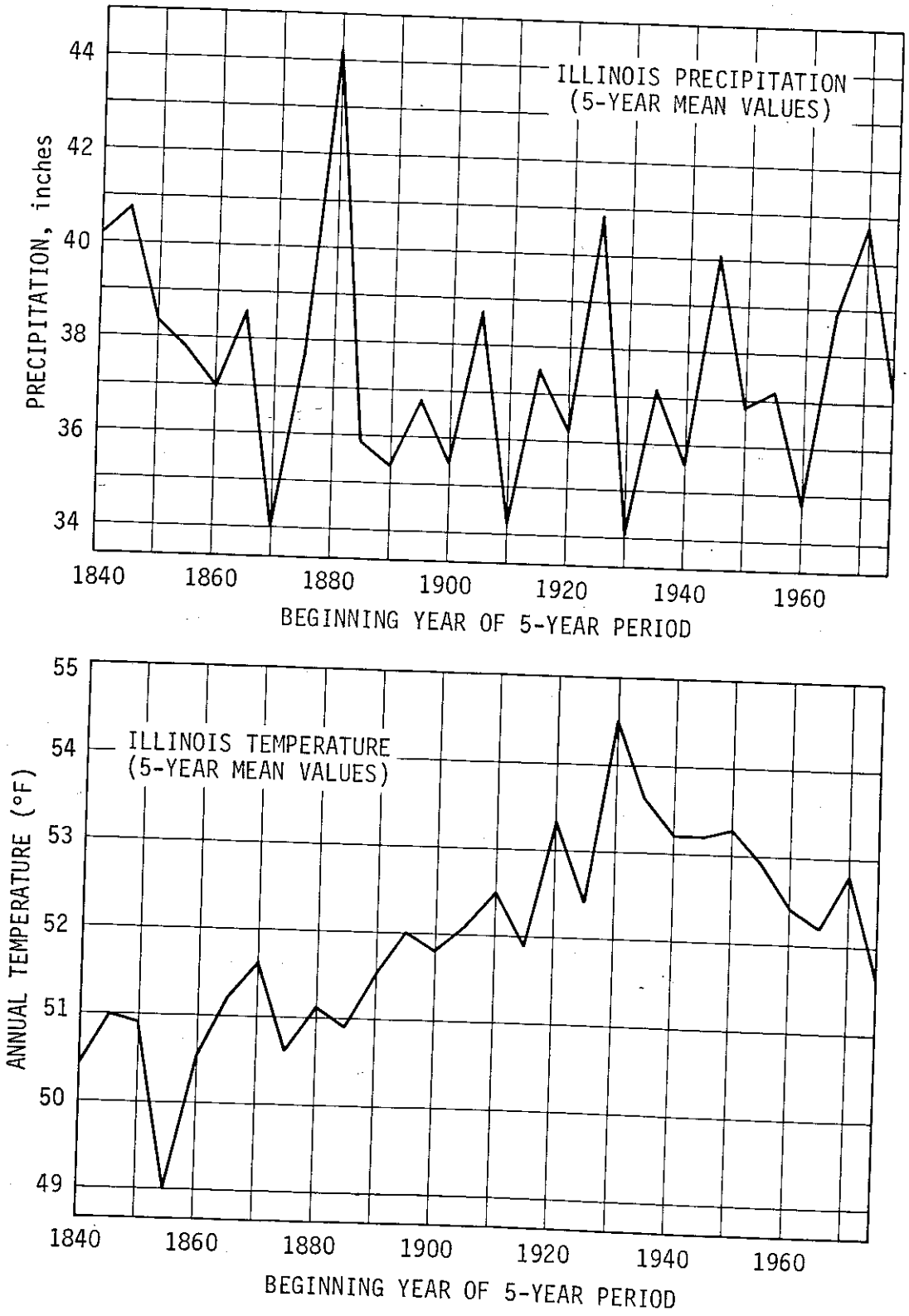

Figure 1. The precipitation and temperature trends for Illinois, 1840-1980.

Information for the proper assessment of the current climate, including its trends, changes in its variability from year to year, or alterations in extremes of weather, is integral to the planning and management of water. Water is intimately linked to agriculture and energy since both are great users and consumers of water. Climate's affect on Illinois' water resources is most easily visualized by the dramatic impacts on both floods and droughts. A change to more of these, or to more extremes of wet and dry conditions, would be of singular consequence to the state's economy and institutions. Figure 2 shows the droughts since 1905 with a near absence of them in 1956-75 but with a return to droughts (1976-77, 1980-81), each costing Illinois farmers and urban residents over $48 million.

The race to keep pace with these climate-related water problems and to seek their solutions, requires consideration of the climatic factors of today, and the knowledge of the shifts and trends that are developing. Means for the state government and climate-sensitive industry to adjust to future climate extremes basically fall in three classes: 1) reduced and delayed services and more difficult management (reaction approach); 2) allowance for greater flexibility in budgeting of personnel and materials to handle the unknowns (surplus management approach); or 3) use of long-term climate predictions in planning, budgeting, and operations (planning approach). Climate prediction offers a chance to act, not react, to future atmospheric vagaries. This issue area addresses climate variations, their impacts, and what should be done to ameliorate their effects on the water resources of Illinois.

On-going Programs

There are three general program activities in Illinois including collection of climate data, climate-change research, and an education-information program. The collection of data is largely the prerogative of the National Weather Service (NWS) and the Illinois State Water Survey (ISWS). The NWS operates 5 stations where all weather conditions are measured continuously, and 95 substations manned by volunteers where daily precipitation and temperature is measured (Fig. 3). These stations are the state's basic climatic network and are keys to monitoring changing climate. The ISWS has operated a series of special weather networks in various locations around the state to collect data on the smaller scale variations in climate (Fig. 3). In 1981, the ISWS also installed 6 special climate stations (Fig. 3) to measure weather conditions not being measured by NWS and seen as vital to water resources (soil moisture, solar radiation, atmospheric deposition of pollutants, winds, and precipitation).

Two of the primary problems in the existing collection of data to monitor climate and its changes relate to federal reductions in support. The NWS is reducing its support of climatic measurements as well as support of the dense networks needed for studies of variability. Monitoring climate change requires high quality data, collected in the same undisturbed location with long-term operations. Illinois long-term historical records are a legacy calling for a state commitment to maintain their operations and quality.

Another area of climate efforts relates to research. Research dealing with climate change and climate prediction is being federally funded and

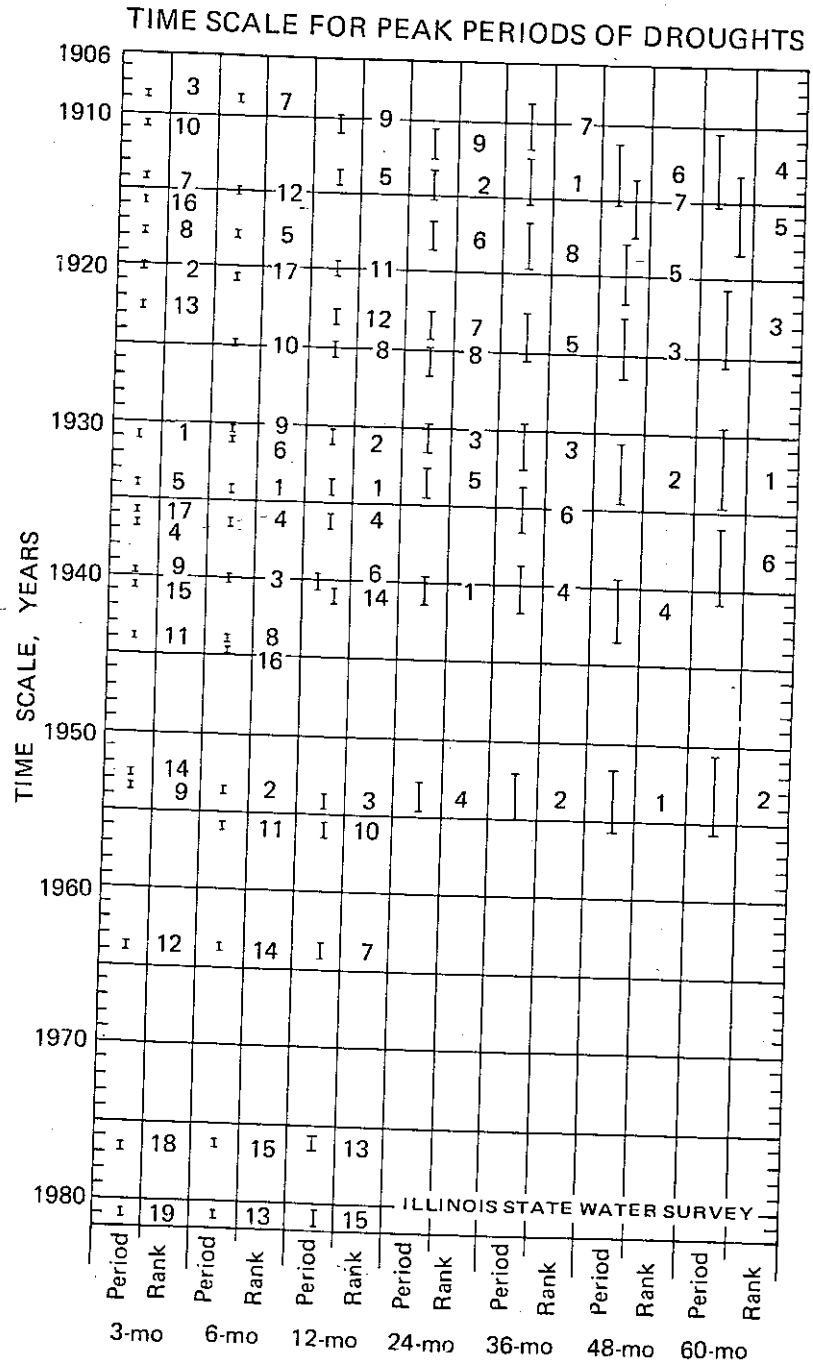

Figure 2. Illinois droughts in the 1906-1982 period.

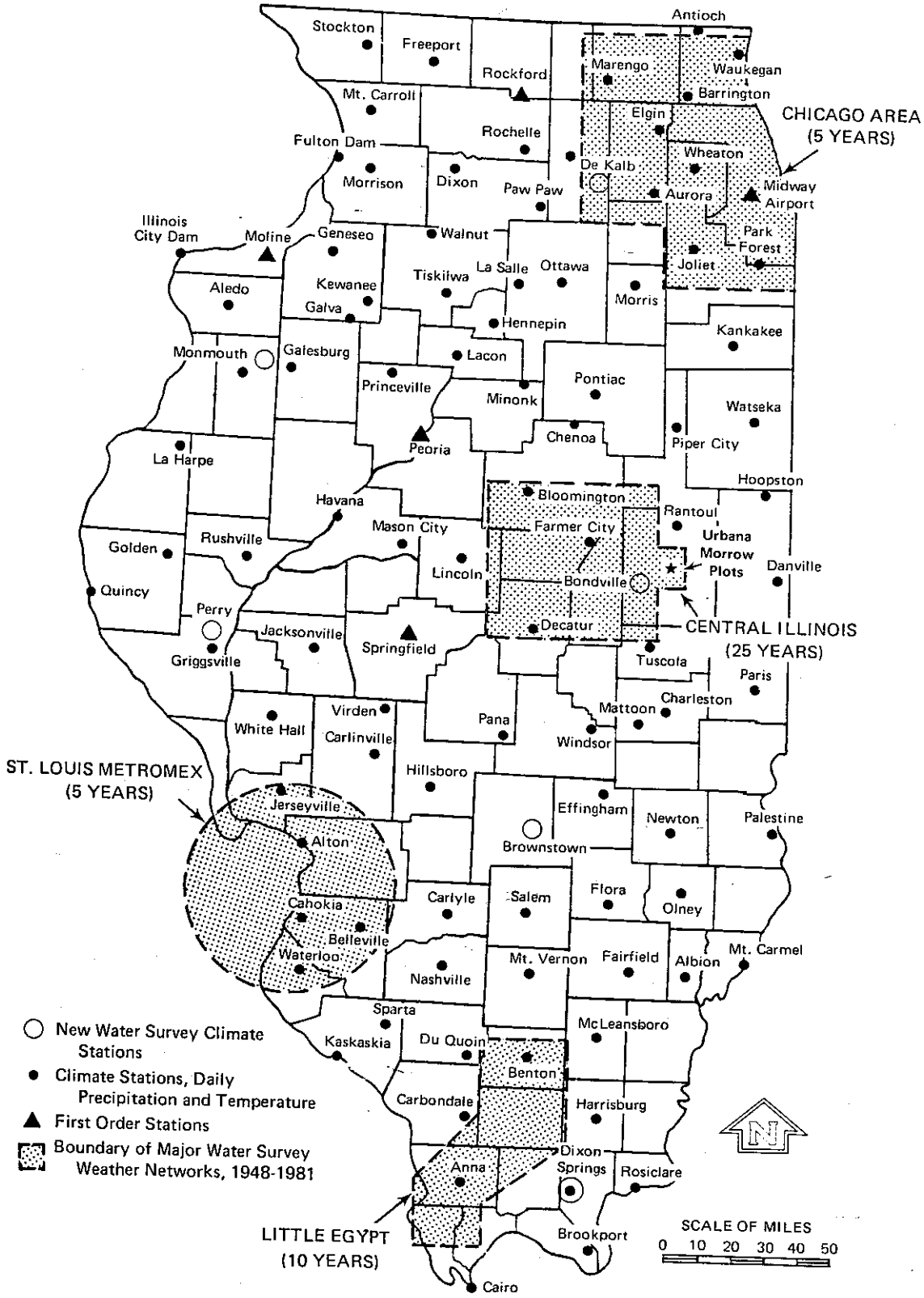

Figure 3. The long-term climate stations and special networks in Illinois.

conducted at the ISWS and at the University of Illinois, Northern Illinois University, and the University of Chicago. All efforts are slated to terminate by 1983, as are the ISWS federally-supported studies of climate change. Research on the climate prediction, supported by federal agencies and private companies, plus monitoring of the on-going conditions, faces an uncertain funding future beyond 1983.

The ISWS generates publications and conducts workshops that relate to climate, and other Illinois researchers yield scientific reports. The level of educational and climate awareness activities is less than required for informed decisions about an important and complex subject.

Areas of Conflict

Conflicts relating to climate conditions can result largely from the impacts of short-term changes and climate extremes. The first of these are local and regional conflicts over water use. Increasing frequency or severity of droughts, heat waves and/or cold waves will lead to more use of water both for agriculture and energy production. These two uses in some regions will produce demands that local surface and groundwater supplies cannot satisfy. There will be in-state and interstate conflicts. This will require changes in state water policies, and possible development of new water law in Illinois (see Fig. 4). These conflicts can be partially resolved by greater climate awareness, contingency planning, and establishing of climate policy in the Executive Branch. Monitoring of climate changes and ensuing developments by major water users (irrigation and synfuel) will serve as signals about when to consider thoughtful revisions in state water law.

The second potential area of conflict relates to interagency assistance to those impacted by climate aberrations. The many agencies involved in drought and flood events leads to uncertainty and to possible conflict among agencies.

Policy and Program Issues

The goal of state policies relating to climate, climate change, and climate prediction are to improve the resilience of our water resources to climatic impacts. Modes of resiliency to climatic impacts exist not alone but within a total state political system. Figure 4 portrays some impacts resulting from the increases, as in the 1970's, of more weather extremes in our climate. These show a series of largely undesirable outcomes including higher taxes, local conflicts, and the loss of income to the state.

There are six *actions needed* relating to Illinois' resilience to climate.

Awareness that Climate Change is a Problem. The climate-society interaction, revealed in Fig. 4, indicates the complexity of the issue. This complexity coupled with lack of perception of change in climate means the public and most decision makers are not now aware and adjusting to the existence nor degree of climate change and its impacts on the waters of Illinois. One of the actions to pursue is 1) a program of research to better define the climate-society interactions, and 2) to launch a more ambitious program of information dissemination about these interactions to improve

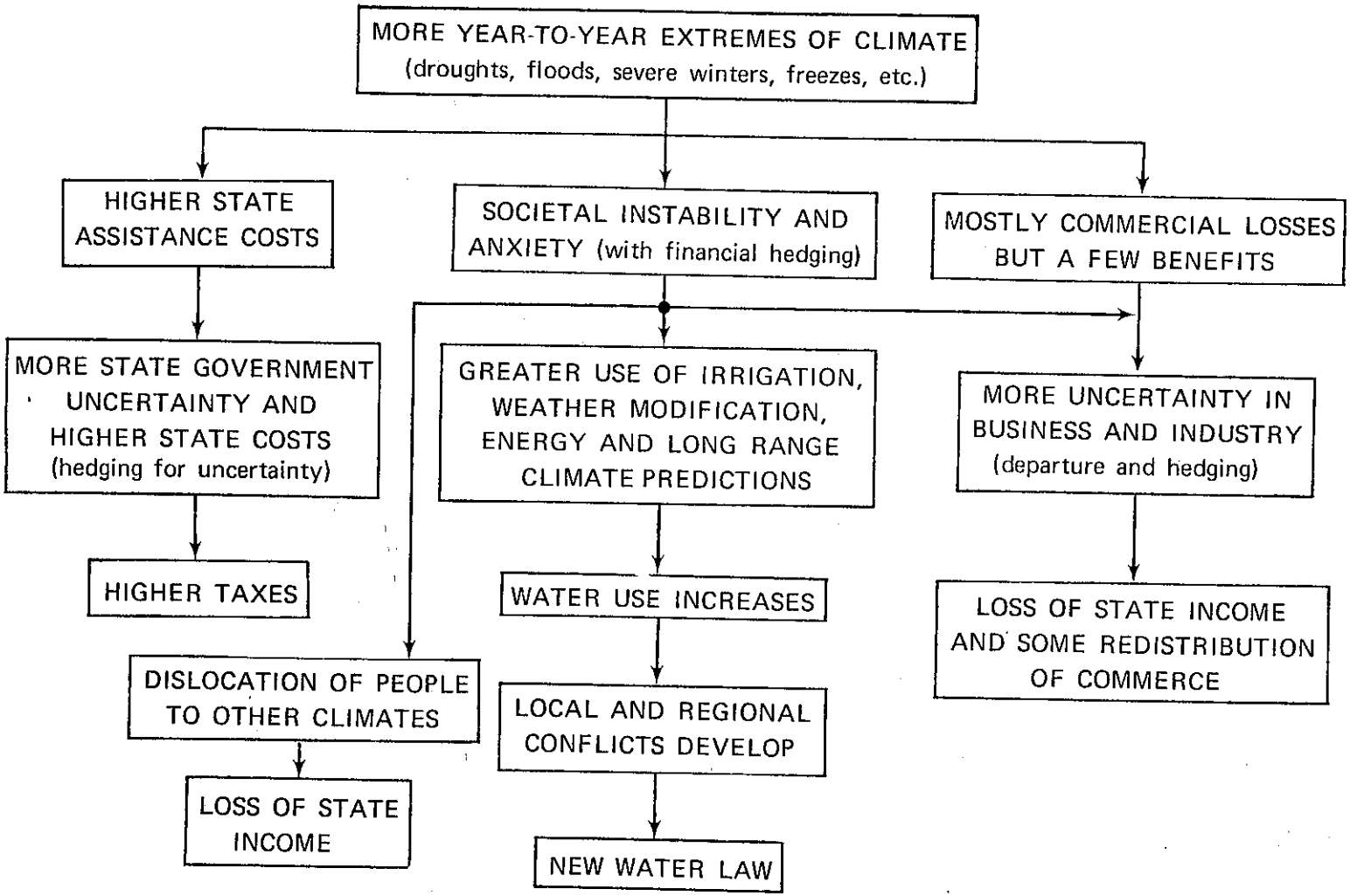

Figure 4. Some of the impacts and possible outcomes of additional short-term climate changes in Illinois.

awareness. Such a program will lead to increased knowledge, particularly in state government and commercial interest, to allow more informed decisions and adjustments for dealing with climate change. All in Illinois will benefit and this is seen as a state supported activity pursued by DENR/ISWS as a 2-year, high intensity effort.

Monitoring and Research of Climate Change. A key input to all action options is knowledge of the types of climatic changes deduced from monitoring, and of causes and impacts of changes (from research). These two activities are the heart of the information, planning, and decision process. These efforts are viewed as a joint activity of the state and federal government. Federal support, which has been predominate, is decreasing and the amount of state support should increase to sustain the effort. The primary action agency is ISWS for both monitoring and research with some universities also involved in research. The current costs of climate data collection are $2 million with $150,000 from Illinois. The state contributions should increase to $250,000 in the next few years. Research on change and predictions is being supported largely by federal agencies.

Direct Access to Quality Climatic Data and Predictions: Climate Information Center. Climate data (soil moisture, rainfall, snow melt, temperature extremes, etc.) and of predictions of climate (for months, seasons, and years ahead) have a wide variety of applications in water design, assessment of events, and operational issues. The primary action option for state institutions and businesses is to have climate data and predictions easily accessible in computer format at a state-operated climate center. Development of a centralized data bank and related information with real time access by climate-sensitive users is seen as an extremely important endeavor. State agencies and industries should have constant access to updated information on the status of all weather conditions in Illinois and to climate predictions on various time scales. The Water Survey's predictions of monthly precipitation values in three classes for 1981 appear in Table 1. One notes a perfect accuracy of 64% in this period, with 34% near misses. This is clearly a useful level of predictive accuracy for many water operational issues.

The installation of a data base-information system at the Illinois Climate Center, already operating at ISWS should be a *state task*. Data must be constantly collected, verified and entered in the data bank, clearly state activities. Hence, DENR/ISWS should establish the Climate Data and Prediction Center (CDAPC) using state funds. State agency and business users who desire access to the data and predictions would pay user fees to help sustain the Center. An advisory board to the CDAPC is recommended and would be composed of representatives of major users from the business community, university, and state agencies.

Developing Plans for Climatic Extremes. The climate will bring more or less frequent climatic extremes and in particular droughts and floods. Contingency plans relating to such events must be developed for more effective assistance in the management of water systems. Included should be disaster relief plans for short-term climatic changes (like droughts, floods, and heat and cold waves), and plans for economic and institutional conversions related to the longer-term changes such as ever colder temperatures and higher precipitation effective in the past 30 years. Development of these contingency plans

Table 1. Analysis of monthly precipitation outlooks made at beginning of each month in 1981.

Illinois Areas	FEB.		MAR.		APR.		MAY		JUNE		JULY		AUG.		SEPT.		OCT.		NOV.		DEC.		SUMMARY	
	P[1]	A[2]	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	Right	Wrong
North	N[3]	A[4]	N	B[5]	A	A	N	N	N	A	B	B	A	A	A	N	N	N	N	N	N	B	6	5
North Central	N	N	B	B	N	A	A	A	A	A	N	A	N	A	A	N	N	N	N	N	N	N	7	4
South Central	B	N	B	B	N	N	A	A	A	N	N	A	B	A	N	N	N	N	N	N	A	A	7	4
South	B	N	B	B	B	B	A	A	A	A	A	A	B	N	N	B	N	N	N	N	A	A	8	3
Number Correct	1		3		3		4		2		2		1		1		4		4		3		28	16
Number Near Misses (1 apart)	3		1		1		0		2		2		2		3		0		0		1		15	
Number Far Wrong (2 apart)	0		0		0		0		0		0		1		0		0		0		0		1/44	

SUMMARY

64% were correct
34% were near misses (1 level off)
2% were far wrong (2 levels apart)

[1] P = predicted value
[2] A = actual value
[3] N = near normal value (middle tercile)
[4] A = above normal value (upper tercile)
[5] B = below normal value (lower tercile)

is seen as a state activity, to be done jointly by DENR/ISWS, ESDA, DCCA, DOA, DOC, DWR, and the ICC who would form the Climate Detection and Assistance Board (CDAB). Costs will not be excessive, utilizing existing support. This activity should be under the leadership of DENR.

Implementation of Preventive-Adjustment Activities. A follow-on aspect of contingency planning for climatic extremes is implementation of action responses. This includes establishment of warning systems for droughts, heat waves, floods, and cold waves, dissemination of forecasts of future climate abnormalities, development of new control works, etc. These will benefit the public but primarily local and state governments and climate-water sensitive industry and commerce. The warning adjustment function is highly dependent on the monitoring function and research products, and is viewed as the responsibility of DENR/ISWS and EPA. A means of warning dissemination should be devised involving primary users. The cost is minimal, although adjustments involving altered water systems or control works would be expensive with costs undetermined.

Interaction of Illinois with Other States, Federal Government, and Other Nations. One of the confusing aspects of climate change is that climate is pervasive. Hence, at the state level there is a tendency to transfer the problem and costs of data collection, research, and public awareness to other states and the nation. Illinois, rich in a wide variety of natural resources and deeply concerned about energy usage, coal development, agricultural production, and water cannot transfer its responsibilities to actively participate in climate change issues. Further, it must interact, both in the programmatic areas and in the setting of the policies with other governmental entities. Recognition and understanding of the climate issues will lead to wise policy setting at the state level. This is seen as a task for the Office of the Governor with input from the CDAB at negligible costs.

Recommended Programs and Policies

One option for Illinois is to maintain the status quo. That is, to continue with its current programmatic approach (some data collection; research supported largely under now dwindling federal sponsorship, and a low level educational effort), allowing future external forces and climatic events to excite the system to develop future activities and to set policy in an ad hoc fashion. We do not consider this reactionary approach to be the proper option. Climate is a resource; as such it needs to be monitored using cost effective approaches to improve our water resources.

We recommend an action-oriented climate effort, done in two phases. The first phase includes: 1) use of state support to sustain the on-going efforts in data collection and research; 2) increase of state support for educational-informational activities; and 3) implementation of the Climate Data and Prediction Center (CDAPC). This is followed by the second phase of activities. Once the awareness level of climate was improved, the other activities should follow including the implementation of contingency plans and certain adjustment (warning) activities. A computerized climate data base and climate prediction capability accessible in the CDAPC would be established to serve climate-

sensitive state agencies and industry. Another key aspect would be to set policies for effective interaction with other states and the federal government.

A permanently established "Climate Detection and Assistance Board" comprised of state agencies is recommended. It would develop 1) state contingency plans, 2) the means of detecting climate aberrations, 3) the climate warning system, 4) provide means of assistance, and 5) it would help define agency roles relating to climate. The lead agency is DENR with ESDA, DWR, DCCA, DOA, DOC, IEPA, and ICC.

Several actions should be pursued by the Department of Energy and Natural Resources. Coordination of the state's climate program should be through the Illinois Climate Detection and Assistance Board chaired by DENR. Most of the actions are most effectively done by state agencies with university input. As such, the state should support the activities with federal assistance and data collection and research. Since climate is all pervasive, improved knowledge, awareness, and planning for climate changes will allow local and state management of water resources in a more effective and timely fashion. This will benefit everyone. Hence, the state has the major responsibility in this area.

Plans for the Immediate Future

The efforts in the next two years will include sustainment of two existing programs including 1) data collection efforts of the NWS and ISWS, and 2) climate change and predictive research of the ISWS and state universities. Increased state support will be needed as federal support continues to dwindle in both areas.

New activities to be accomplished in the next two years, given that added state and private support is available, include

1) educational-information project launched and completed (state);

2) establishment of the CDAPC system at the Illinois Climate Center (state, private, and federal); and

3) identification of climate change monitoring and warning activities at the Illinois Climate Center (state).

Policy-related activities to be launched include 1) development of state policies about climate change (interstate and international arrangements), and 2) the establishment of the Climate Detection and Assistance Board.

Issue: Inadvertent Weather and Climate Modification

Problem

Settlement in Illinois, begun in earnest 170 years ago, gradually began to alter the climate of the state. The changes of land use, prairie and woods to row crops and cities, have altered the earth-atmosphere radiation and moisture balances. In addition, the combustion of fossil fuels have added heat, gases, and particles to the atmosphere. These changes collectively affect the weather and in turn have altered the climate everywhere in the state. These man-induced climate changes are becoming sufficiently large to be evident in the quantities and qualities of our water resources.

Every aspect of the urban climate differs from that of adjacent rural climates. In and well beyond (east) large cities like St. Louis and Chicago, it is warmer, stormier, rainier, and less humid than in other rural areas west of these cities (Fig. 5). In all other parts of Illinois it is cloudier, with fewer temperature extremes and poorer visibility, and more polluted by more haze than it would be without man's presence. The waste heat of cooling towers and cooling lakes of our utilities and industries produces clouds and makes fog, and our high flying jet aircraft create clouds that reduce sunshine, evaporation and radiation. The magnitudes of our climatic conditions have been significantly changed by man. Figure 6 shows the change in cloudy days at Peoria (typical of changes elsewhere in Illinois), plus increases in days with smoke in the atmosphere. The two jumps in cloud cover occurred when we had major increases in pollutants (help form clouds) and in jet traffic (form high clouds).

Man has also altered the quality of certain climatic conditions. The various man-made pollutants including rain-caused eroded soil and windblown dust, both due to heavier rains and improper soil management, often mix with the clouds and rain and fall to earth in potentially harmful forms. Acid rain is one of the these impacts. The many gases released including CO_2 produce a range of air quality concerns including a reduction of the earth's productive ozone layer and increased global temperatures.

Man-made changes in climate, in the net, affect the state's major supply of water: the precipitation, both as to its amount and its quality. Several of the altered climate conditions also affect the rate of outgoing moisture through altering evaporation. Some of the important specific effects relating to water include acidic pollutants in rainfall and their effects on water supply, increased soil erosion due to heavier rainfall rates and higher winds, and the complex secondary impacts these produce. For example, these two factors affect the state's productivity by forcing higher pollutant removal costs for coal thereby reducing the level of coal development, as reflected in the nation's acid rain concerns. The added erosion due to higher rain rates and winds reduces the potential for higher crop yields. The key impacts resulting from the heavier rainfall due to the existence of St. Louis appear in Table 2.

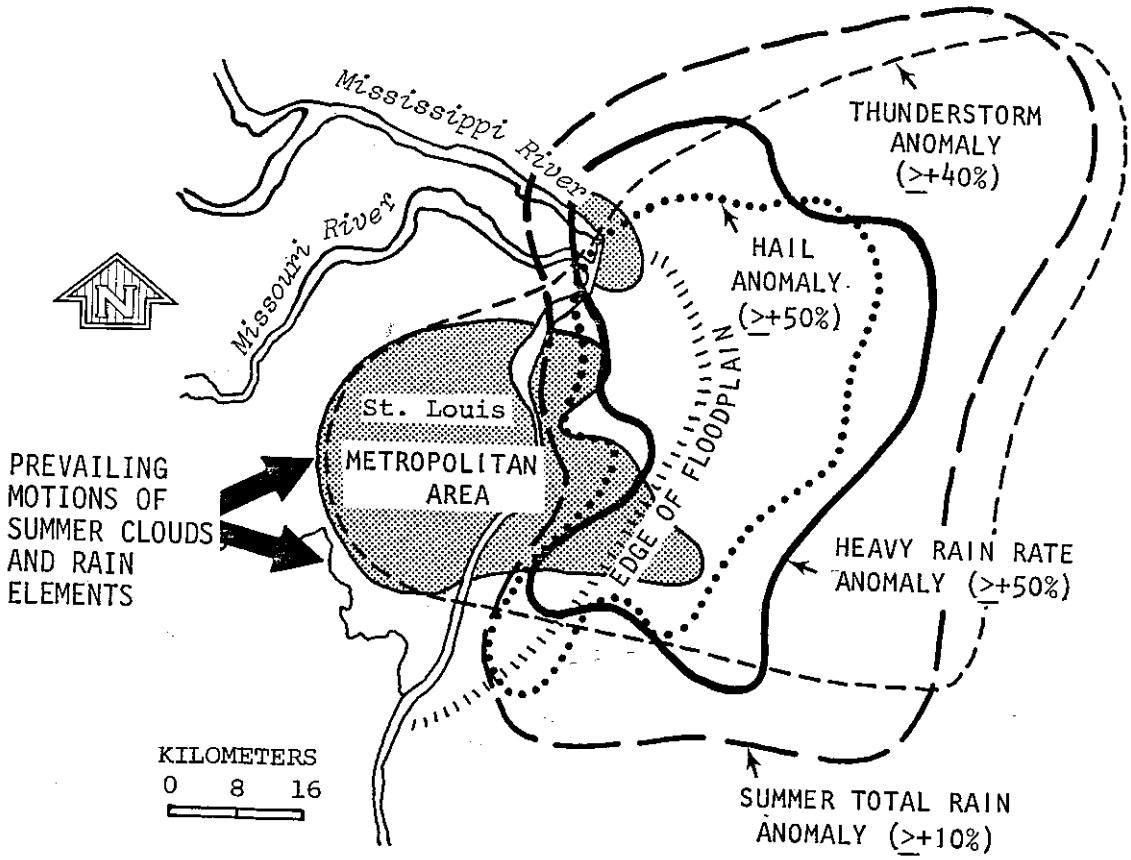

Figure 5. The climate anomalies found in summer rain and storms, caused by St. Louis.

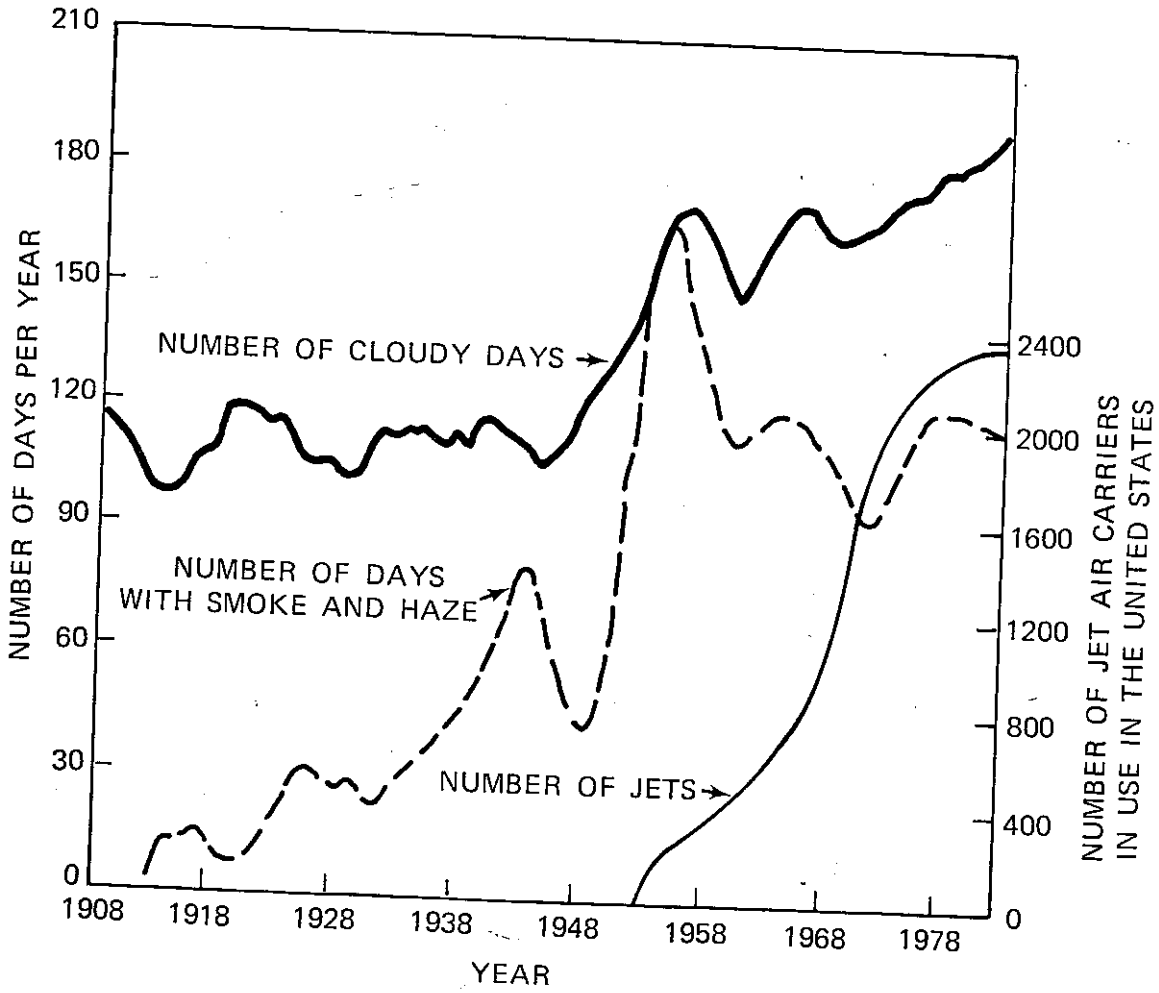

Figure 6. Changes in the number of cloudy days at Peoria and potential causes reflected in the number of days of smoke and haze in the air at Peoria and the number of jet aircraft flying in the U.S.

Table 2. Impacts of higher rain rates and more heavy rainstorms in Illinois due to the existence of St. Louis and its effects on the climate.

Impacts
More bypasses of sewage treatment plants (+40%)
More fluctuations in groundwater levels (+100%)
More frequent urban flooding (+100%)
Increased automobile accident (+20%)
Increased soil erosion in uplands (+34%)
Increased sedimentation of streams (+10% to +30%)
Sedimentation in floodplain facilities (+5% to 40%)
Added operations and management of floodplain water facilities (>100)
Additional drainage systems (value unknown)
Altered designs for hydrologic structures (cost unknown)
Added soil losses on crop production (value unknown)
Delays and danger to air transportation (+5% to +25%)
Decreased visibility and increased crime (+30%)
Inequitable local taxing for water management facilities (not quantified)
Higher costs to government agencies for water management, treatment, and planning (not quantified)

The primary conclusions about the current state of knowledge:

- The climate resource is of ever greater importance to Illinois because our water resources are now more heavily used and thus more sensitive than before to climate.
- Man is helping to change most aspects of weather and climate.
- Some of these changes appear beneficial, others insignificant, and others very harmful to water resources.
- Certain inadvertent changes like higher rainfall rates, more total rainfall, more polluted rainfall, added cloudiness, and higher temperatures are serious problems for many surface water activities.
- The public and most decision makers are unaware, confused, or not concerned about man's role in these complex atmospheric interactions and their impacts on our water resources.

Thus, a key aspect of the inadvertent modification issue relates to State awareness and action. The complexity of the issue has made it a topic difficult to identify and to understand by those not directly involved. Furthermore, certain changes have long time horizons, at least until some of the atmospheric changes become more obvious and more critical. There is a strong necessity for a 3-pronged state initiative: 1) to sustain a critical level of research; 2) to ensure the monitoring and data collection to measure the magnitude of the problems; and 3) to launch an educational effort so the public can understand and government react wisely to issues like acid rainfall, carbon dioxide, and soil erosion that are partially or largely, a result of man's influence on the atmosphere.

Areas of Conflict

Conflicts relating to inadvertent weather and climate change are evident. These relate largely to the identification of "who is at fault." For example, the total urban area influences regional climate and water, and this area includes a multitude of urban entities: towns, cities, townships, and counties which have no regional authority. Another potential area of conflict relates to interstate issues as the St. Louis and Chicago influences extend over at least two states. There is already national and international conflict over acid rain, with Canada and northeastern states specifically blaming Illinois and other states as a major source of its acid-producing pollutants.

On-Going Programs

The Illinois State Water Survey (ISWS) has pioneered in studies of inadvertent weather and climate modification. There has been a lack of similar studies elsewhere in the Middle West. Hence, Illinois stands alone with data, knowledge, and expertise for most aspects of inadvertent climate modification, both as to degree and causation. The National Atmospheric Deposition Program composed of 90 stations, with 6 in Illinois, utilizes the ISWS expertise and facilities as the Central Analytical Laboratory for the nation.

Recently completed studies including those on the atmospheric effects of waste heat from cooling lakes and towers have led to an adequate definition of their influence on the atmosphere. The studies of urban effects on weather and climate have been extensive and the most definitive in the world. Current research is studying the effects of Chicago on precipitation, both over the city and over Lake Michigan which serves as the region's principal water source.

Another on-going program relates to studies of regional inadvertent modification. These include data collection and research dealing with 1) the effect of jet-induced contrails on cloudiness in Illinois and the Midwest, 2) releases of gases and particulates to the atmosphere, and 3) the sources, transport, and deposition of man-made pollutants including acid rain.

One particular area of concern is the material being deposited on the surface of Illinois, including acid rainfall. The sources, transport, transformation, and deposition of pollutants, plus their impacts on the water resources of Illinois largely represent a major and potentially serious unknown.

The national energy policy for the future seems to be directed toward increased use of fossil fuel, particularly Illinois' abundant reserves of high sulfur coal. In recent years, construction of tall stacks has resulted in the release of gaseous by-products (sulfur dioxide and other pollutants) into upper levels of the lower atmosphere. A consequence of this strategy is that most areas of the United States are now in compliance with the federal standards for near-surface air concentrations of most pollutants. However, new standards for particulate sulfur are now on the horizon in response to not only estimated health effects but also to perceived questionable effects on precipitation quality, such as acid rainfall.

The effects of acid precipitation are estimated to be numerous, but the scientific evidence to quantify such estimates is largely lacking. The most obvious conceptualized effects include 1) increased pollution of water resources, 2) corrosion of building materials and statuary, 3) alteration of natural ecosystems (especially lake and stream systems), and 4) adverse impacts on agricultural and forest crops. While much research is underway, none of these impact areas have been documented scientifically to directly respond adversely to precipitation chemical quality.

Formidable scientific questions must be addressed to assess the magnitude of the acid rain issues. Among these are 1) what is the current trend of precipitation acidity?, 2) what is the response of natural precipitation chemistry to increased fossil fuel consumption?, and 3) what is the response of Illinois waters, soils, weather and agriculture to precipitation chemistry? The questions are critical. Research at the Water Survey has, for example, addressed the national concern over a rapidly changing trend to greater acidity. Figure 7 shows the 1955-1956 pH pattern, as revised by Survey scientists, to allow for the effect of dust in that drought period, and the current pattern. The changes in acidity over the past 25-years are much less than believed by many.

The other principal gaps in data and understanding relate to hemispheric-global issues. These include information on the sources, transport and deposition of pollutants; and lack of information on the effects of CO_2 and

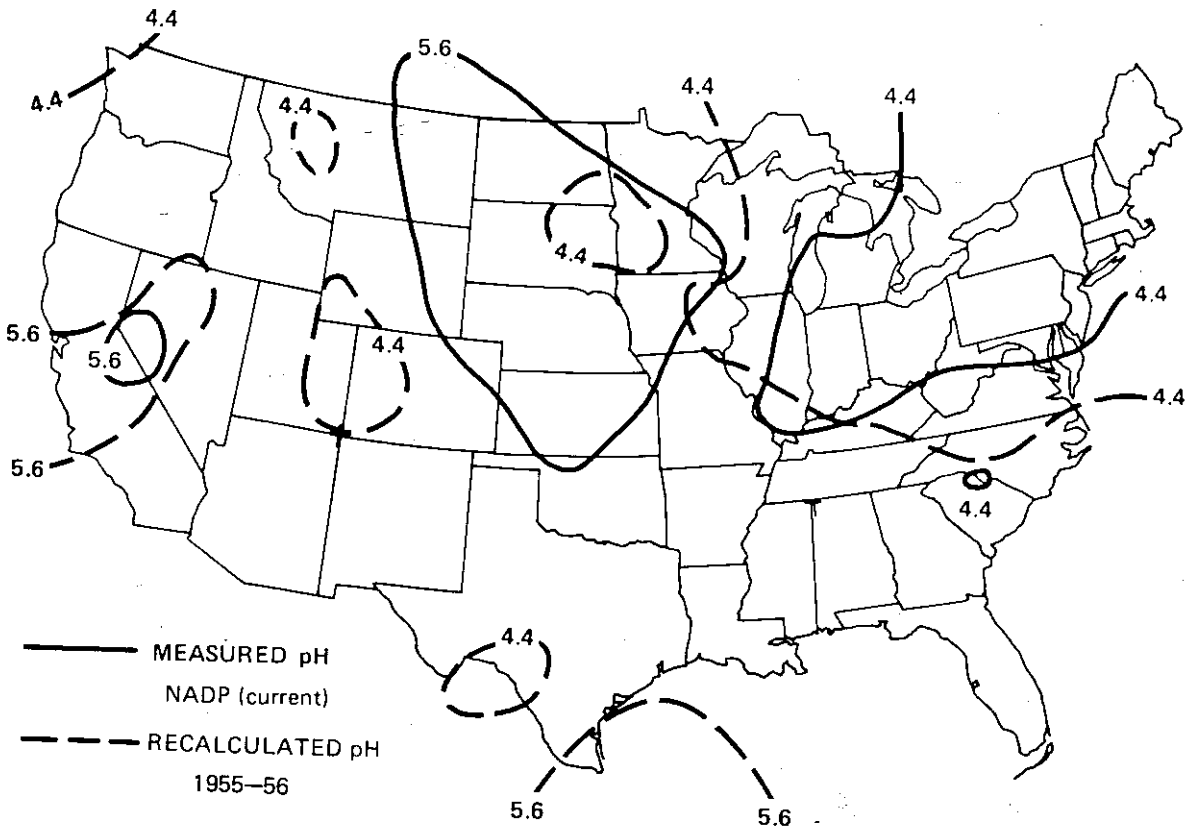

Figure 7. The current pH in rainfall and that of 25 years ago adjusted for the dust in the atmosphere. This shows the changes in acidity over the years are much more subtle than was initially conceived.

particulates on climate and in turn on future water resources in Illinois. There is very little research or study of the impacts of these changes in Illinois; and there are major gaps in our knowledge.

Program and Policy Issues

The goal of state policy relating to inadvertent weather and climate modification is to understand the changes caused by Illinois and their impacts, and to establish policy positions and regulations relating to unfavorable modification for the benefit of Illinois and the nation. Ill-defined inadvertent weather and climate changes including acid rainfall, CO_2 effects, and jet aircraft crosscut our state's economy, our environmental regulations (as they relate to water and air quality), and perpetuation of our natural resources. The implications of possible interstate and international atmospheric transport of materials and climate changes like acid rain that may be produced by Illinois are enormous. Illinois must be prepared to justify its current economic status and future growth in the face of potential degredation of the climate inside and beyond its borders. Because of the lack of scientific certainty in some of these areas, several programmatic activities stand before Illinois for consideration.

Monitoring and Research. Research here includes data collection and monitoring. Defining regional climate changes due to jet aircraft will require a minimum of 5 years of effort and added financial support. The studies of effects of CO_2 and particulates on climate have just begun and will require at least 10 years to resolve.

A key research area relates to atmospheric chemistry and involves acid rain. This area will require 10 years to achieve major answers as to causes, impacts, and controls. These research efforts, if funded, will be pursued by ISWS, INHS, and state universities. These would be largely federally funded, although federal interest in these areas is dwindling. Each of these research areas requires continued monitoring of solar radiation, deposition, visibility, and other special conditions. Efforts to provide data to monitor changes will be pursued by ISWS.

Policy Actions. The results about man-altered climate, including atmospheric transport and deposition of pollutants (acid rain), pertain to the missions of government agencies concerned with the environment and land use management. Knowledge of climate-induced changes in water quantity and quality impact on local, state, and regional agencies involved in the design and operation of water management facilities. In essence, *every state agency with a stake in water resources is effected.*

Two major metropolitan areas of Illinois, and adjacent suburban and rural areas representing 5% of Illinois land and 70% of the state's population experienced major man-induced weather and climate changes. Nature and international concerns over acid rain affect regulations that greatly impact on Illinois. Urban changes have produced a myriad of impacts, mostly major local problems for the water resources of these populous areas. Little if anything is consciously being done by local, state, or regional officials to either manage the climate anomalies or to adjust to their impacts, often because natural variations in rain make it difficult for the lay person to detect the

added rain. The institutional means for identifying these problems, for designing facilities to address them, and to operate water systems in an optimal way are not in existence. Hence a public and institutional problem-recognition effort is essential. Information and guidance should be provided by DWR, EPA, DOA, and DCCA to inform users and designer groups in urban and downwind areas affected by rain changes. DENR is the source of information for these activities. The entire policy development effort should be a function of the recommended Climate Detection and Assistance Board (CDAB).

The areal scale and complexity of this water issue point further to the need for local and regional involvement as well as state actions. These problems often exist on scales that are beyond any single institutional jurisdiction, do not fit existing regional planning entities, and overlap the responsibilities of several state agencies. The scale of changes also make this an interstate issue. The major urban changes involve two-state causation and impact (Missouri-Illinois for St. Louis, and Illinois-Indiana for Chicago). A further challenging aspect is that the impacts of the urban-changed water quantity and quality differ because of site differences in and east of St. Louis and Chicago. Hence the problems are site specific and call for different institutional solutions.

Information Program. The third action concerns the launching of an information effort primarily to educate urban and regional planning groups, federal agency staffs, leaders of major cities, and state agencies. This program would present results about inadvertent modification and potential interpretation of the actions to be taken. Future activities will likely include new designs for sewer and storm drain systems. This is a 2-year effort of DENR/ISWS.

Recommendations for Programs and Policies

Given the complexity and lack of awareness and understanding of the inadvertent weather and climate modification issue, and of the subsequent impacts on water quantity and quality, several actions need to be pursued. Illinois could do nothing other than maintain the status quo (largely research).

Other choices relate to future consideration of policies and regulations to address the weather-climate changes caused by man. Although unlikely, one can envision the establishment of new regional government entities to address the changes in the altered climate areas. These "climate sheds" would provide the mechanism for dealing with the costs, regulations, and actions needed in the effected areas. We recommend that the Climate Detection Advisory Board be responsible for these concerns.

Another policy question concerns formulation of state positions on key issues of acid rainfall, urban climate change, soil sedimentation (due to increased winds and rainfall rates), and additional particulates and CO_2 in the atmosphere. These issues all have dimensions extending beyond Illinois. Thus policies are needed for interstate relations, for national programs and

legislation on air and water quality, and for addressing international concerns. The Office of the Governor should address these with policy guidance from DENR and the CDAB.

An enlarged informational program should be launched by DENR/ISWS. It is the basis for the action options on regulation and legislation, and that relating to the formulation of state policies on key in-state, interstate, and international issues over climate change.

Issue: Planned Weather Modification

The Problem

Planned weather modification offers a potential means to increase water supplies in Illinois. The era of modern weather modification was initiated in the mid 1940's. Modification normally involves the controlled release of chemical, such as dry ice or silver iodide, into the atmosphere using airplanes or ground-based generators. Main types of weather modification tested are fog dispersal, precipitation augmentation (rain and snow), and hail suppression. Largely due to the field's relative youth and science's incomplete knowledge of the physics of weather, the effectiveness of most forms of weather modification have not been established within scientifically acceptable limits of certainty. Only cold fog dispersal and snow augmentation in the mountains are considered technically ready for routine application. In short, weather modification is an emerging technology that could increase water resources.

Illinois farmers and agribusinesses have spent $0.5 million in the past 5 summers to support cloud seeding projects with hopes of increasing rainfall in parts of central and southern Illinois (Fig. 8). Federal agencies have financed $7.8 million for research on weather modification in Illinois.

Planned enhancement of precipitation in Illinois is viewed by some as a functioning technology for increasing water. However, rain modification still has major scientific uncertainties and complex societal implications. Research has been adequate to illustrate that if rain could be increased, sizable agricultural benefits would accrue in most years but not during severe droughts nor in extreme wet periods. Research has shown that midwestern corn and soybean yields are quite dependent upon July and August rainfall. Figure 9 shows this relationship for corn yields and rainfall for several Illinois counties. One sees that when July rain is normal, corn yields are not optimum, and that major increases in yields occur with 1 to 6 inches more rain than normal. The social and environmental complexities, and the potential for controversy, means that the use of weather modification must be carefully managed and controlled.

Planned rainfall enhancement, if it works, has decided cost advantages over irrigation. Rainfall modification, done at the best scientific level cost approximately $0.25 per planted acre in 1980, as compared to $35 to $40 for

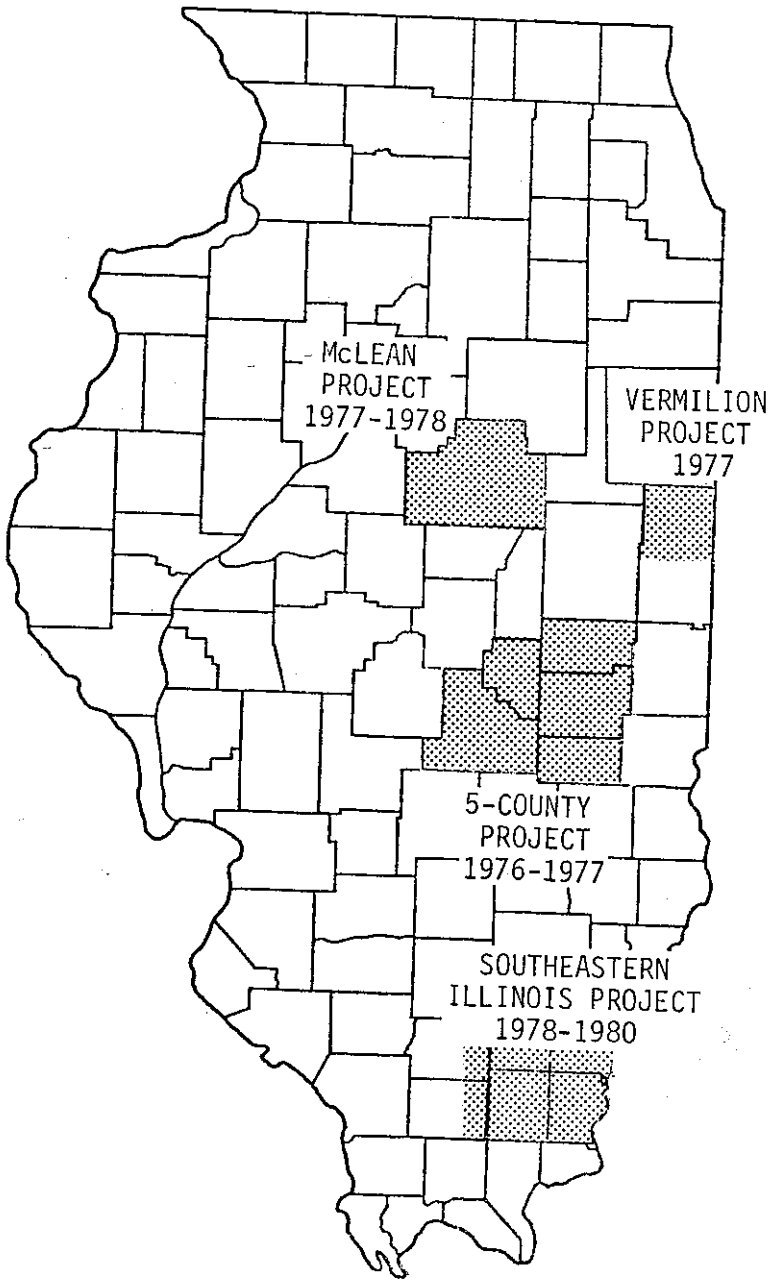

Figure 8. Illinois weather modification projects during 1976-1980.

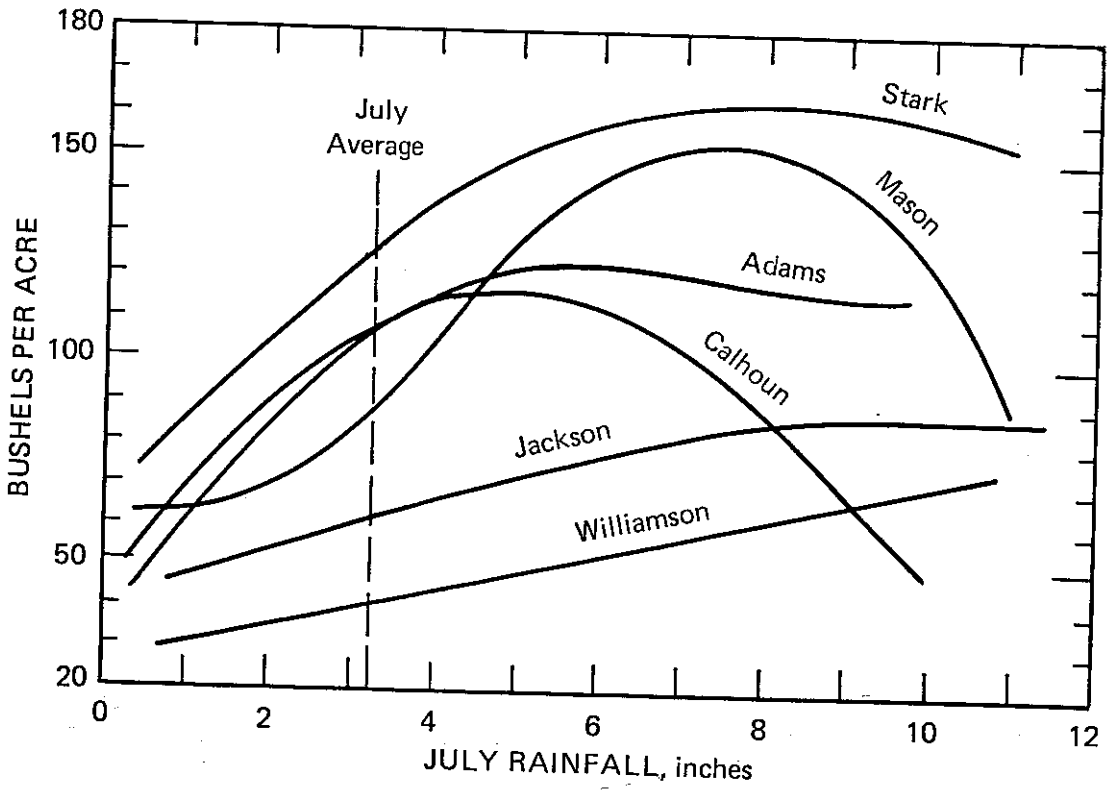

Figure 9. Relationship of corn yields with July rainfall in selected Illinois counties.

irrigation. However, weather modification is not a certain technology. Moreover, even if the expected rain increases of 15 to 30% could be achieved during summer representing 1.7 to 3.4 inches, the increase still would not satisfy, in certain years, the needs for water that irrigation could provide. However, irrigation has other limitations in addition to its high costs. The best estimates reveal that only 20 to 25% of Illinois' agricultural lands could be irrigated, based on limitations set by slopes, soil types, and available water supplies. Hence, irrigation cannot be applied as widely in Illinois as weather modification could. More definitive study needs to be performed on both alternatives, but the ultimate spatial limitations of irrigation and its high costs suggest there would be value from a rain enhancement technology, particularly in the southern half of Illinois.

Research on the actual and potential environmental impacts resulting from increased precipitation has focused on three general areas. One is altered precipitation quality, another is the effects on water quantity, and the third on effects to other environmental conditions such as small game animals. The changes in precipitation quality, due either to materials used to seed clouds or to the scavenging of air pollutants, were found to be negligible, increasing the air pollutant load from 2 to 5%. Effects of increased precipitation through urban-produced weather modification, as measured at St. Louis, showed a 15% increase in summer runoff associated with a 25 to 30% increase in summer rainfall. Much of the increased precipitation at this level remains in the soils and is then evapotranspirated by crops. Water available in ponds and reservoirs was increased by 5 to 10% with an improvement in streamwater quality related to the additional water. A third area of study has related to impacts on selected indicator species, such as small game animals capable of reflecting changes in behavior or population due to precipitation changes. Studies of game animals indicated that changes in summer precipitation at the levels likely to be achieved in planned weather modification, 15-30% increases, would not produce detectable effects on animal populations.

Important to a proper understanding of the effects of precipitation increases is awareness that the likely rain increases of 10 to 30%, and not accomplished in all years, are well within the year-to-year natural variations in precipitation. As a result, environmental species already have the capability to adjust to the envisioned precipitation changes. The Presidential Advisory Board on Weather Modification, in a two-year study reported in 1978 that "environmentalists who have seriously considered weather modification suggest minimal measurable effects for most short term (5 years or less) weather changes." Environmental monitoring is a desirable feature of all experimental projects, and efforts to monitor environmental indicators are recommended for operational weather modification projects in Illinois.

Basically, four major issues must be addressed if Illinois is to move towards an enlightened and responsible policy for the use of rainfall modification.

- One is the resolution of the technology to enhance rainfall.
- Second, the actions needed to manage and institutionalize on-going non-research (operational) projects.

- Third is the public information and user assistance effort.
- Research and monitoring of environmental effects.

Areas of Conflict

Weather modification is an activity that has a portent for conflict. These controversies might be based on such factors as perceived and real environmental concerns, differences in religious or moral values, and suspected inequities in benefits. However, such controversies are not apt to occur in areas where the majority decides on projects and where information efforts are adequate.

Lawsuits in the United States to get weather-induced losses paid by cloud seeders, or to stop projects, have all failed because of an inability to prove that seeding at a given time produces a specific and harmful weather change. The Illinois Regulatory Act removes the state from liability in such situations. The proposed new districts could be targets for such lawsuits.

Another conflict that could arise would be interstate in nature. The conduct of operational and experimental projects in Illinois could bring claims from adjacent states that Illinois is detrimentally affecting their weather. The Illinois Regulatory Act assigns DENR the role of interstate communication on weather modification issues, and information exchange is seen as a primary means for negating interstate conflicts.

On-Going Programs

The complex scientific research required to prove whether and how precipitation can be increased, and by how much, is only partially complete. A major midwestern rain change experiment is needed to complete the on-going research effort. The Precipitation Augmentation for Crops Experiment (PACE) as designed by ISWS, was marginally launched in 1978 as a 4-state effort involving scientists from Illinois, Indiana, Michigan, and Ohio with federal and state funding, but future federal support seems doubtful because of federal spending reductions. Such an effort needs multi-million dollar support for up to 10 more years to achieve desired answers.

The second major on-going activity concerns management, assessment, and regulation of non-experimental (operational) cloud seeding projects. These are rooted in the user's belief that cloud seeding will increase summer rain for agriculture. These locally-supported projects represent opportunities for research and also create policy questions for the state. Currently there are two legislative acts pertaining to weather modification. Such projects are regulated by a model state law that ensures the public safety and welfare. Secondly, supporters of cloud seeding have obtained 1981 legislation that allows voters to form weather modification districts and levy taxes for the financial support of these projects. Past operational projects have been evaluated by the ISWS to discern possible changes in rainfall, a difficult but important task that can inform both the supporters and the state as to the general effectiveness of current techniques. Support, largely from federal research grants, allowed statistical evaluations of several projects.

State functions in planned weather modification currently include:

1. Research being done by the ISWS largely with federal support.

2. Public information is being supplied largely by ISWS with assistance from Agricultural Cooperative Extension Service and is totally state funded.

3. Evaluation of operational projects being done primarily by ISWS and largely funded by federal grants.

4. Regulation being done by DENR with state support.

5. Guidance-assistance to projects done with guidance from ISWS, with future assistance to come from newly formed districts.

Illinois has the best state effort in planned weather modification in the nation. Nevertheless, the heavy dependence on federal funds in two areas, research and project evaluation, makes the state program very vulnerable, particularly for developing a more certain technology for increasing water resources.

Policy and Program Issues

The goal of state policy is to develop a rainfall enhancement capability within a societal and environmentally sound framework. Study of the impacts of a capability to enhance rainfall has revealed sizable benefits to water supplies and particularly to agricultural water needs. The changing of weather over hundreds of square miles will have an immense impact on the public's welfare. Because of its influence over wide areas, a weather modification effort has a great potential for benefit; but if failure occurs, it has the potential for real or perceived damages. A potential for community conflicts exists. The five issue areas follow.

Research and Development. After years of preparatory research at ISWS, scientific progress has reached the point where a definitive summer experiment, PACE, is the critical and final R & D step. The results of PACE should indicate how, where, and when one can increase rainfall in Illinois in a predictable fashion. If a capability cannot be developed, we need to know this. The primary beneficiaries of a working technology will be Illinois farmers and agribusinesses (and state government due to a greater income), with secondary values to cities and industries dependent upon surface water supplies, aquatic ecosystems, river transportation, and water recreation. The pervasiveness of the benefits of this type of capability leads to the conclusion that the federal and state government should support R & D costs. Illinois' lead state agency is DENR/ISWS with strong involvement of the University of Illinois. The cost of PACE will vary from several million dollars (6 to 10 years) with the cost depending on how rapidly key milestones are achieved. Illinois needs to actively pursue and seek federal interest and support in PACE.

Evaluation of Operational Projects. Evaluation of operational projects concerns both statistical and physical studies of data collected during locally-sponsored projects. The lack of evaluation by skilled scientists makes

it impossible to ascertain the degree of change produced. Evaluation can also provide useful scientific information. A special form of operational project would have even greater value to the R & D effort. The possibility of "piggy-backing" scientific measurements on locally-supported projects offers a unique way to gain useful knowledge at lower costs. To be effective and to attract federal support, an operational project would have to persist for at least 3 years to provide a sufficient sample size.

The primary beneficiaries of evaluations of operational projects are the potential users of a fully developed capability, and in larger sense the public, the user payers of the projects, and the state agencies concerned with water supplies. The potential benefits to agriculture make the state a major beneficiary and Illinois should support the effort. The values of the R & D findings will apply elsewhere and this suggests that the federal government should also be its supporter. Finally, the user-payers of the projects also benefit and should be contributors to the funding. The project permit fees paid by users should be set sufficiently high to help pay up to 50% of the evaluation costs. Evaluation of a typical 1-summer operational project costs between $20,000 and $40,000, depending upon project length and extent of evaluation. The 1-year costs of an adequate piggyback study of an operational project would be $250,000, to be borne by the federal and state government. Since evaluation is a complex statistical and meteorological effort, the ISWS should lead this program effort.

Regulation. It is extremely important that Illinois continue to regulate this activity. The public cannot afford the risk associated with unregulated weather modification. The existing regulatory act has provided for the orderly performance of weather modification projects in Illinois over the past 6 years including 8 projects. Since everyone benefits, the state should pay for this activity. The current regulatory assignment is to DENR at a cost of $15,000 per year.

Information Program. Development and use of a new and complex technology requires broad dissemination of information. The potentially controversial nature of weather modification also necessitates a balanced presentation of the facts and uncertainties. Information on all aspects is currently being done under the leadership of the ISWS with assistance from Cooperative Extension Service, the Illinois Agricultural Association, and user groups.

Organizational Assistance. Development and sustainment of operational projects have been difficult with locally pledged funds. Basically too few area residents paid. New legislation will remedy this situation by allowing people in discrete areas to vote for the formation of weather modification districts with project funds raised through local taxes. The option for forming districts within adjoining counties will lead to the need for guidance and assistance in contracting for weather modification firms and project evaluation. Such assistance will make large area projects more feasible, easier to operate, and more cost effective. The major beneficiaries will be to those in the districts. Since these projects will be scattered across the state, this advisory-organizational assistance will likely fall to the state government. The ISWS and DOA should provide this support.

Recommended Actions

The top weather modification priority for Illinois is to develop a rain modification capability that can deliver useful amounts of water for agricultural applications and other water sources. The status quo will not achieve these objectives.

To achieve this goal, two program options must be pursued. The R & D program and the project evaluation program both need additional support. In both instances, long-term and more sizable federal support is needed. The PACE experiment is the top objective. If federal support fails to be sustained, the piggybacking of science on Illinois operational projects is a meaningful second activity to pursue. Current state support for PACE and evaluation efforts is not adequate. Added support for evaluation could be obtained from higher project fees. Major experiments in weather modification, when conducted, should include a major effort in monitoring of effects on water supplies, crop production, and other environmental conditions apt to be influenced by small to moderate changes in rainfall. The other three options (information, regulation, and state assistance) are currently being pursued adequately by ISWS.

Immediate Plans

The existing regulatory, informational, and assistance activities will be pursued at current levels in the foreseeable future. A major effort to promote federal and state support for PACE, and/or the piggyback research of operational projects will be pursued in 1982-1983. Research will continue on PACE until available funds terminate in 1982. The piggyback project seems a likely option in view of the current reduced governmental funding stance. However, it requires that a local district make a long-term commitment for a multi-year effort, and then federal and state support for the scientific effort must be secured. Another activity will include implementation of approaches to secure additional funding for costs of evaluating operational projects. Taxing and permit fee options will be investigated.