# HAIL SUPPRESSION AND SOCIETY

by

Barbara C. Farhar*
Stanley A. Changnon, Jr.†
Earl R. Swanson**
Ray J. Davison††
J. Eugene Haas*

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## FOREWORD

*This report, which is designated as a "User Summary," is based on an extensive technology assessment of hail suppression conducted by the Illinois State Water Survey, the University of Illinois, and several other research groups. Support came from the Research Applied to National Needs Program of the National Science Foundation (Grant ERP75-09980) and the State of Illinois.*

*The full project final report, upon which this summary report is based, is a 440-page document entitled* "Hail Suppression: Impacts and Issues." *A limited number of copies are available through the Water Survey, Box 232, Urbana, Illinois 61801. The report will also be available through the National Technical Information Service. The major final report is based on 37 working papers, some published and some unpublished, devoted to detailed studies of various phases of the project. This assessment was accomplished by a 13-person team plus several consultants. Numerous other specialists provided valuable reviews and comments on various parts of the study. A 6-person advisory panel for the project also gave very useful comments on the main final report. We extend our appreciation to the more than 75 people who contributed to this project and to those of the National Science Foundation who showed great interest in the project and offered many useful suggestions.*

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*Human Ecology Research Services, Incorporated
† Illinois State Water Survey
**University of Illinois
†† University of Arizona

## How Hail Suppression Is Attempted

In simplest terms, the idea behind seeding clouds to prevent damaging hail is as follows. Hail is thought to form by the collection and freezing of tiny drops of cold cloud water around a nuclei (a particle of dust or an ice crystal). The updraft of moist air in a hail-forming cloud is so strong that the small hailstones are often recirculated in the upper part of the cloud, thus collecting extra coats of water which freeze so that the stones become so heavy that they fall out of the cloud to the ground.

To interrupt hail formation and growth, competition for the water available in the upper cloud can be increased by introducing more nuclei, each of which attracts its own portion of the cloud's water supply. Silver iodide, because it is similar to the ice crystal in structure, is an effective artificial nucleating agent.

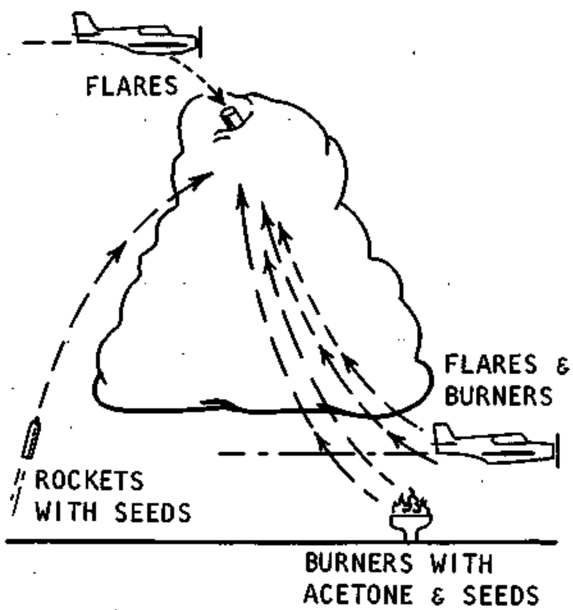


**Figure 3. Some methods of cloud seeding**

Silver iodide may be delivered to a potentially hail-forming cloud by a variety of means (see Figure 3). Delivery of the substance, by flares or generators burning it, may be accomplished by an aircraft flying under the cloud where the air is flowing up into it, or by flying through the cloud. Some European projects have used ground-based rockets or artillery to place the material in the cloud, and others in the U.S. have utilized ground generators that burn a smoke-producing mixture thought by some persons to be delivered to the cloud via its strong updrafts.

sarily been reached in a context of uncertainty about its effectiveness and possible side effects. The uncertainty implies that a degree of risk is involved, and, in general, risk-takers prefer to take their own risks, rather than to have such decisions made for them. Thus, the degree *of public participation* in the decision to implement a hail suppression project may affect whether or not the project finds ultimate acceptance in the community.

Adoption of hail suppression has tended to occur in high hail loss areas where hail destroys up to 20% of the crop. Those interested in adopting have included irrigating barley and lettuce growers, cotton, grain, and wheat farmers, and fruit growers. Where adoption did not occur even though hail losses were significant (mostly in the mid-Atlantic region), growers were generally unaware of the technology and did not perceive hail as a serious problem. Most of them relied on insurance to cope with crop loss to hail.

### Stakeholders in Hail Suppression

Other than agriculturists, who else is concerned about hail and its possible suppression? Those with a potential interest (i.e., those who might be directly or indirectly affected) include the following *"stakeholders":*

1) The atmospheric science research community, who have the responsibility for basic research and development
2) Commercial weather modification firms, who offer the service of hail suppression to client groups or sponsors
3) The crop and property hail insurance industries, which offer an alternative solution to the problem of hail losses
4) Potentially, consumers of the food produced in the nation, to the degree that the commodities they purchase are more readily available at reasonable prices as a result of successful application of the technology
5) Other groups seeking to affect and implement policy and legislation, including opponent groups, legislatures, and judicial bodies

Agriculture is the primary stakeholder group with respect to an effective hail suppression technology.

### Organizations Involved in Hail Suppression

A technological process floes not exist in a vacuum, but rather must be conducted in and affected by a variety of societal structures. Five basic types of organizations involved in hail suppression activities are:

1) Research organizations
2) Commercial firms
3) Sponsoring groups
4) Organized opposition groups
5) Regulatory and policy entities

The *research organizations* are basically of two types: either government agencies and laboratories or institutes such as the National Center for Atmospheric Research (NCAR), or various university groups. Most of the support for hail research activities has come from the National Science Foundation; the largest research endeavor involving hail has been the NCAR-conducted National Hail Research Experiment (NHRE) in northeastern Colorado at a cost of $23.5 million.

*Commercial firms* basically serve three groups: private and public sponsors for operational programs and public sponsors for research and evaluation. These firms typically have specially trained staffs (pilots, meteorologists, and technicians) and specialized facilities to serve their customers.

*Sponsoring groups* contract for hail suppression for two basic reasons, both economic — first, to avoid losses and second, to gain additional benefits or profits. The following groups have funded hail suppression projects: 1) federal sponsors such as the National Science Foundation and the Bureau of Reclamation, 2) various agricultural groups, 3) state and local governments (as in South Dakota), and 4) private industry, such as a beer manufacturer.

*Organized opposition groups* have emerged in various parts of the country where hail suppression has been implemented, e.g., Citizens Against Cloud Seeding in South Dakota and Farmers and Ranchers for Natural Weather in Texas. Because these groups have contended that hail suppression is not beneficial, or indeed that it is harmful, they have focused attention on the adequacy of mechanisms by which decisions to seed clouds are made and on the conditions that would need to exist to make the technology's application socially acceptable.

*Regulatory and policy entities* include the National Oceanic and Atmospheric Administration, which administers federal laws pertaining to weather modification, and the various state agencies (including state departments of agriculture, water resources, and natural resources) administering the state statutes, where primary regulation of the technology occurs. Of course, the U.S. Congress and the state legislators are important policy-formu-

**Functions of a Hail Suppression Project**

Functions that should be carried out in a proto-typical hail suppression project include:

1) A design or plan, including the area, time, and amount of seeding
2) Field operations, including equipment and personnel
3) An evaluation of the results
4) An assessment of the socio-economic effects
5) An information-communication effort

Not all projects actually fulfill all of these functions, but a properly designed field experiment should make provision for each of them. Operational projects typically have a plan for cloud seeding, but often do not include the last three functional elements given above. Research projects include the design, field operations, and evaluation components, but often have not included a systematic public information effort and usually not a socio-economic assessment. Obviously the more complex a project is, the more expensive it is to operate. In general, sponsors of operational programs want to increase their benefits at as low a cost as possible; more expensive research projects are conducted at public expense.

lating entities with respect to weather modification, as are research-funding agencies such as the Bureau of Reclamation and the National Science Foundation.

## SOCIETAL INFLUENCES ON HAIL SUPPRESSION

### Socio-Political Aspects

Hail suppression, as is true of every innovation, exists in the context of societal influences and constraints shaping development and application. Many of the innovations introduced into modern American society have been adopted by individuals. An individual can decide to plant hybrid seed corn or to use the birth control pill —adoption of these innovations is a personal matter requiring no particular decision on the part of the community once the technology is available.

Other new technologies, such as nuclear power plants, fluoridation, and weather modification require decision making at the community (or other social system) level for adoption to occur. As the technical performance of cloud seeding improved, as it began to depend more on public funding, and as it was used over more extensive land areas, awareness increased that the activity had implications for entire communities and regions. Adoption of weather modification thus became a *collective innovation decision,* or a public decision, requiring action on the part of a community or larger social aggregate in order for it to be adopted. A rather slow rate of adoption of innovations may be considered quite normal, and collective adoption decisions require more time to take place than individual adoption decision. Thus, widespread adoption of hail suppression technology can be expected to require at least the remainder of this century to occur, assuming that a very effective technology is developed.

Results of sociological surveys in agricultural areas on citizen attitudes, knowledge, and belief concerning weather modification have shown that *belief in the technology's effectiveness* in increasing rainfall and decreasing hail is a key predictor of favorability to having a cloud seeding project. About 40% of those sampled have consistently expressed concern about the unknown risks involved in human intervention in weather processes. However, most respondents have favored trying to controll the weather for the benefit of man. In general, environmental concern does not appear to be a basis for opposition to cloud seeding in agricultural areas of the country.

The relationship of a number of different socio-demographic characteristics (e.g., religious affiliation, social class, occupation, sex, age, urban-rural residence, etc.) to favorability has been examined. Findings show that sex, education, and social class appear to be most salient in explaining differences in attitudes toward weather modification. In general, 1) women tend to be more skeptical about cloud seeding than are men, 2) the higher the educational attainment of respondents, the more likely they are to be favorable, and 3) the higher the social class of respondents, the more likely they are to be favorable.

In general, survey findings have been notable for their marked consistency and comparability. Factors distinguishing areas that accept, or at least tolerate weather modification projects, from those areas where organized protest develops probably emanate from the social system or community level rather than from any unique local pattern of preexisting attitudes. Public response to cloud seeding projects is far more dependent on citizen observation or project effects themselves than on their initial favorability or unfavorability toward a project.

- If beneficial weather events are attributed by community members to the cloud seeding effort, acceptance is likely.
- If detrimental events are perceived to be caused by weather modification activity (as in the relatively frequent lay argument that hail suppression causes drought), then social rejection of the project is likely to occur.

The majority of citizens interviewed have expressed a preference for local decision control over implementation of weather modification. In one recent survey, the majority of respondents called for a vote to decide the matter. Widespread citizen preference for local control over cloud seeding is often in direct conflict with scientific and governmental agency desires to retain decision control over weather modification. This point of conflict between officials and citizens has played a role in more than one community dispute over weather modification.

Nevertheless, given the popularity of participative mechanisms and their increasingly extensive use, it seems unlikely that public participation in weather modification decision making will decline.

Preferred decision making regarding cloud seeding

**Who do you think should decide whether or not a hail or rain experiment will be started (or continued)?***

***In percent of number of respondents***

| *Response* | *Illinois 1974 <N = 274)* | *Colorado 1974 (N=221)* | *South Dakota 1974 (N = 293)* | *South Dakota 1976 (N = 430)* |
|---|---|---|---|---|
| Local | 54 | 56 | 59 | 50 |
| Nonlocal | 46 | 44 | 41 | 50 |

* Questions phrased slightly differently in each state

The active and forceful participation of representatives of groups — attentive minorities —having a direct stake in the outsomes of public decision processes can be expected.

Up until now, most weather modification projects have been implemented with a minimum of public involvement in the decision process. Since scientists and agency officials generally wish to retain control of the decisions concerning when, where, how, and for what purposes to conduct weather modification projects, and citizens in the areas seem to feel increasingly that they should have a voice in the decisions as to what will be done to their weather, *the conflict between them requires resolution by means of an adequate decision mechanism.* This mechanism for arriving at decisions will be an institutionalized procedure that is socially acceptable. It will most likely need to provide for rather extensive public participation if the field experimentation or use of weather modification is to occur with a minimum of community polarization.

### Legal Aspects

Weather modification, and thus hail suppression, is now regulated primarily at the state level, with 60% of the states having enacted a relevant statute. The federal government requires only that all weather modification activity in the nation be reported to the National Oceanic and Atmospheric Administration (NOAA).

States vary widely in the complexity and degree of regulation they impose on weather modification activity. Several states require weather modifiers to show competence and obtain a license; they may also require a permit for the conduct of each field project. In general, the federal government considers itself not answerable to state law; therefore, some federal projects have operated without any external regulatory control whatsoever.

Statutes in six states make it mandatory that public hearings be held prior to the granting of a permit to conduct field operations, while in several other states hearings are optional. Three states provide for funding of state-sponsored cloud seeding through general fund appropriations; however, most states provide minimal budgets for administration of weather modification statutes. Thus, proper evaluation of operational projects, including the required reports, is unlikely to occur.

There have been 15 major weather modification lawsuits filed. Of the 13 which have been decided, the defendants (weather modifiers) have won 11. The two they lost included a Texas case in which a temporary injunction against cloud seeding was issued, and a Pennsylvania case of criminal prosecution for hail suppression seeding. Plaintiffs in court generally have been unable to prove the causal relationship between the harm alleged by them and the cloud seeding.

### Environmental Concerns

Studies of the effects of cloud seeding on the environment, both in terms of silver iodide (the seeding agent most commonly employed) and of weather effects themselves (e.g., the effect of increased precipitation on natural ecological processes) suggest a general finding of minimal measurable short-term environmental effects. However, environmental researchers hesitate to make definitive statements because they perceive that serious environmental effects of silver iodide and precipitation changes might occur and too little research has been accomplished. Although it is; unlikely that serious adverse environmental impacts would result from widespread adoption of hail suppression, the possibility of adverse effects cannot yet be discounted.

The National Environmental Policy Act (NEPA) requires federal agencies to file environmental impact statements for projects which will have a significant effect on the human environment and this will apply to most weather modification projects they propose to conduct. A few states make provision for disclosure of environmental information prior to and after cloud seeding projects; in some cases the information may be used by state officials in determining whether or not to grant permits for weather modification activities.

## THE FUTURE

The future of hail suppression will be influenced by its past, by future conditions, and by policy decisions regarding its development and application. Several key factors are likely to affect the future adoption of food-production-increasing technologies such as hail suppression. These factors include the worldwide supply of food in the context of population pressures and distribution systems. The United States has unwritten commitments to be self-sufficient in many basic food commodities, to assist other countries in becoming self-sufficient, and to relieve famine when it occurs. Increased future demand for food might lead to higher market prices for agricultural products, and thus provide greater incentive for the adoption of hail suppression.

Significant climatic shifts in North America could hinder future agricultural production and thus make an effective hail suppression technology more desirable by protecting crops from further weather-related damage. The same result could ensue from several years of extreme weather fluctuations and concomitant crop losses.

Another factor affecting the development of hail suppression is the governmental tendency to continue to develop a technology once the effort has begun — a kind of self-perpetuation of the tech-

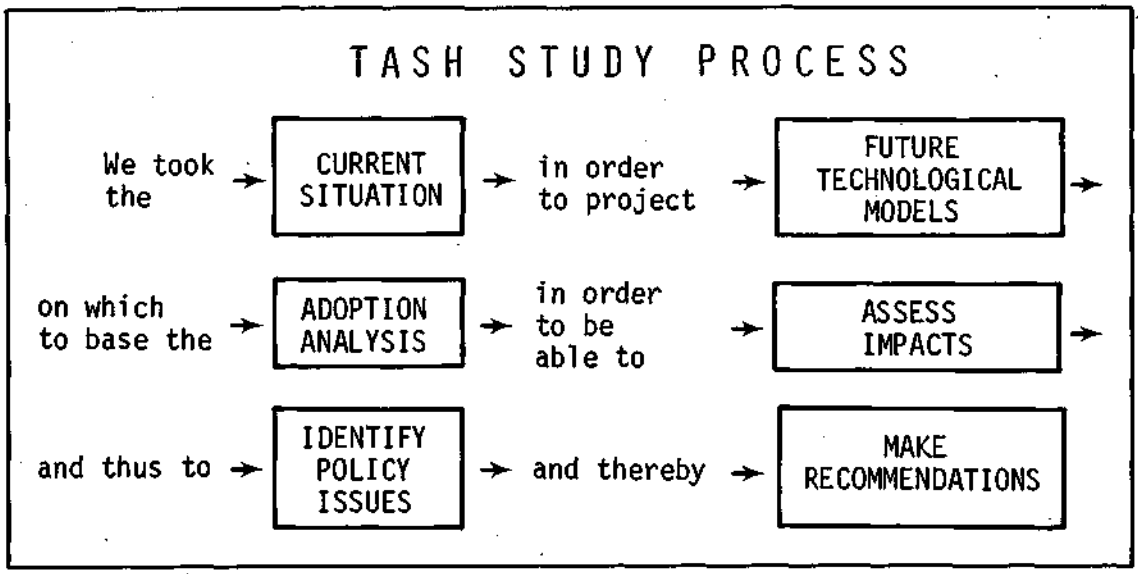


**Figure 4. The TASH study process**

nology itself. Once a technology exists, it tends to be used.

The main objective of the TASH project was to assess the societal effects of an effective hail suppression technology.

### Technological Models

Since an established hail suppression technology does not currently exist, or is ill-defined, it was necessary for us to project the capabilities into the future — to develop *future technological models.* Three such projections, called models, were developed, based on the three basic scientific opinions about the current state of the art in hail suppression — optimistic, slightly optimistic, and pessimistic. Once the models were developed, each exhibiting a different investment in research funds and effort, project scientists were able to analyze how widespread the adoption of each technological model would be and then to examine the societal impacts of that level of hail suppression's utilization. The research team was also able to identify policy issues associated with the process of development and utilization, and to make policy recommendations. This analytical process is depicted in Figure 4.

The three numbered models are presented in one map (Figure 5). A current (1975) capability is estimated for each of three levels for the eastern and western United States. The geographical division was necessary because of the great differences in hailstorms between east and west, and because more experimentation has occurred in the western part of the country. Future hail values in the models are season-long averages over a seeded area and are *expressions of changes achieved in property and crop-hail damages.* A capability to suppress hail will likely affect the amount of rainfall an area receives; therefore, the estimated rainfall effects presented in the models are those anticipated as a result of the hail suppression activity itself. The lack of any information on the possible effects of hail suppression on hail or rain beyond the area of suppression activities led to the conclusion that such effects should be excluded from the models.

Each model reflects a series of reasonable and possible scientific and technical developments and could best be described as "educated scientific estimates." However, they could all be inaccurate estimates of what the future capabilities may be and are not intended to be predictions of the future capability. Again, they served only as the basis for ascertaining impacts of widely varying levels of future capabilities, *should they develop.*

*Model 1* follows the first alternative route of the technology's potential development, starting from a slightly optimistic assessment of the current capability in the west, and of no capability in the east.

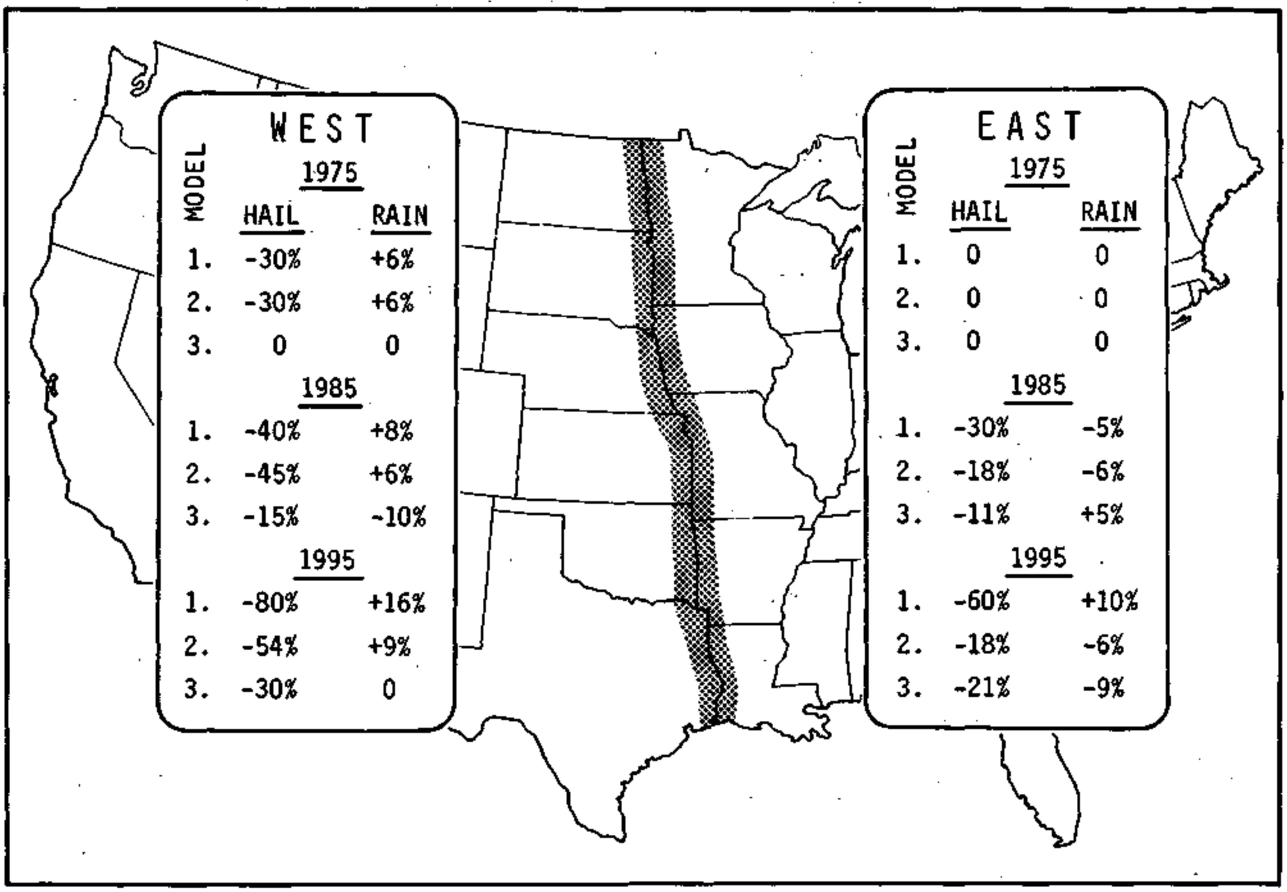


**Figure 5. Three alternative future models of hail suppression capability (and associated rain changes resulting from hail suppression)**

This route is characterized by relatively extensive concurrent usage and experimentation, with a major scientific breakthrough occurring by 1995. Such a breakthrough might occur in the understanding of cloud behavior, in improved storm forecasting, and in better approaches to nocturnal storm seeding, and is expected to provide for the high level of effectiveness predicted for 1995 (with as much as 80% reduction of hail damage in the west).

*Model 2* follows a second route of potential technological development, which involves intermittent applications and experimentation based on existing findings with moderate advances. This model also begins with a slightly optimistic view of the current state of the art in the west and of no capability in the east. In the west, moderate advances in technical skill would occur, but no major scientific breakthrough would be achieved. These activities would lead to a capability by 1995 of reducing hail damage by about 50% in the west, and by about 20% in the east.

*Model 3,* representing a third route of potential development, involves little usage anywhere in the nation and has instead an experimental focus. It is based on a pessimistic view of current capabilities for both west and east. Decreases in rainfall associated with hail suppression in the western half of the country would minimize usage, but careful evaluation of experimental results by 1985 would be sufficiently encouraging to support further research after that date, leading to a modest capability (30% reduction of hail damage in the west) by 1995.

Future growth of hail suppression activities will require attention to the design of systems with several key program elements, including design, operations, evaluation of effects, and public information systems. The likely regional nature of future applications (in response to the spatial distribution of hail events) will necessitate sophisticated pro-

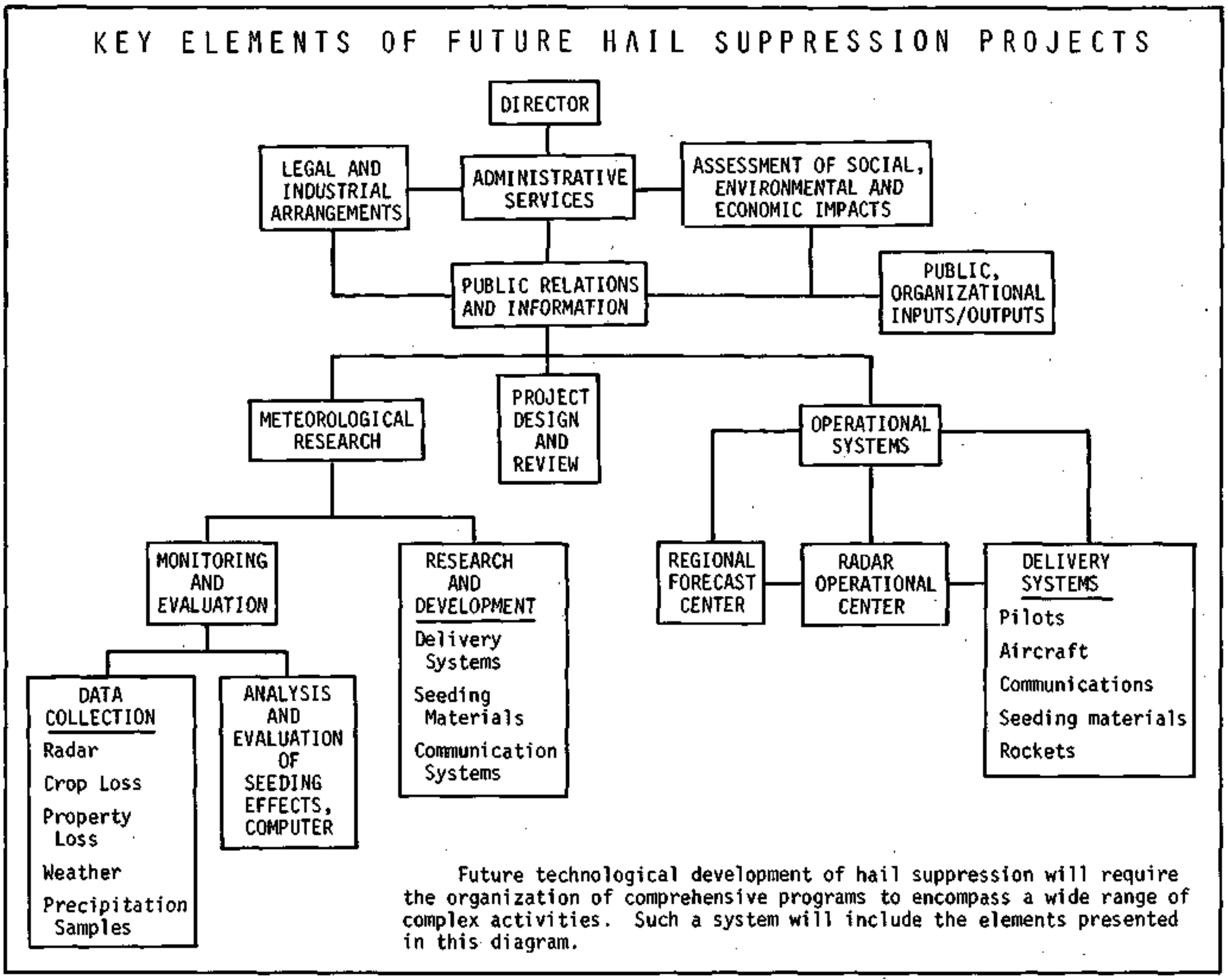


**Figure 6. Key elements of future hail suppression projects**

gram designs. Areas of effective operations will likely be 5,000 to 15,000 square miles in extent. Operational efforts will potentially involve three types of seeding systems( aircraft dispensing material at cloud base or inside storms, and a less likely use of surface rockets). Adequate forecasting and storm monitoring will be necessary and all components of the system will require specially trained staffs. Operational costs (in 1975 dollars) would be $1 per planted acre.

### Future Adoption of Hail Suppression

Given the three alternative models of hail suppression's potential development, future adoption patterns were projected on the basis of several important economic, legal, and socio-political variables. Adoption refers to the utilization of hail suppression technology either experimentally or operationally in an area. Data on the variables were integrated by crop-producing regions of the United States for each technological model at 1985 and 1995. This analysis was a *key integrative effort* for the TASH project, making possible an assessment of national economic and other societal impacts.

Variables utilized in the adoption analysis included: 1) *an economic incentive index* based on an analysis of individual farm operators and on national economic modeling, 2) a *legal receptivity index* based on data concerning the extent of legal regulation of hail suppression and of state governmental support through appropriations, the extent and direction of trends in administrative law, and the occurrence of litigation and their outcomes, 3) *indices on the social incentive* to adopt hail suppression based on each region's severity of hail losses and severity of drought and on the importance of agriculture in the area's economy, 4) *indices on the heterogeneity of weather needs in* each region with regard to rain and hail representing the conflict potential for that region, 5) the *political stance* of each region as represented by statute wording, 6) the *level of scientific consensus* estimated to be associated with each technological model, and 7) an *estimate of the social acceptability* of each model's effects by region. These data were coded for each crop-producing region and for each model for 1985 and 1995, and analyzed to discover whether their summarized value exceeded a predetermined threshold value for adoption. Threshold values were determined by examining the data in relation to past and present actual patterns of adoption.

Results should be viewed as projections or forecasts of adoption by crop-producing regions conditional on the occurrence of the scientific models. As can be seen on the maps of projected adopting areas, the most extensive adoption predicted was for a highest level of technology (80% reduction in hail damage accompanied by a 16% enhancement of rainfall) in 1995. The Great Plains area of the nation would be most heavily involved in hail suppression, with a few scattered projects in California and the Pacific Northwest. Notably, hail suppression was not projected to occur in the Midwest or East Coast areas. A low-level technology in 1995 would result in virtually no adoption in the nation.

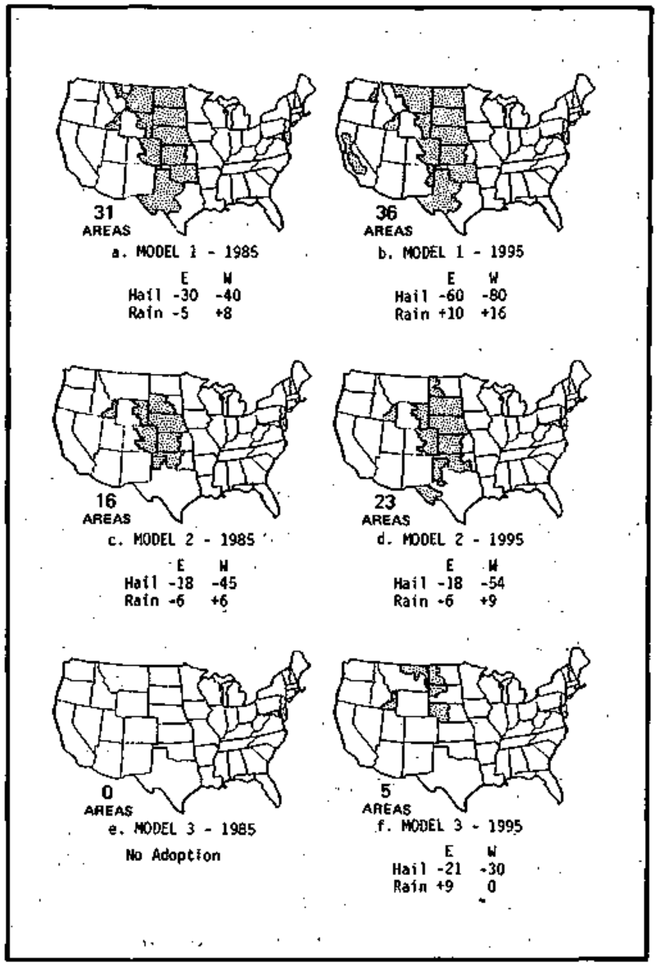


**Figure 7. Maps of projected adoption areas**

## IMPACTS

### Impacts on Agriculture

Given the adoption patterns projected for the nation with the three technological models, what will be the savings in resources required to meet projected domestic and foreign demand for crops in future years? Resource savings are reductions in the costs of production and transportation that occur as hail suppression is adopted.

In conducting the analyses of the national economic impact of hail suppression, a national computer model was used, the cost for operations was taken at $1 per planted acre, expenditures for research and evaluation costs were estimated, the adoption patterns were included, and the future demand for food was projected.

The high-level hail suppression capability (Model 1) would result in a resource savings of 1% in 1985 and 3% in 1995. The low-level capability (Model

3) has such minimal adoption that virtually no resource saving would occur.

**Future Changes in Agricultural Production Costs Due to Hail Suppression**

*(Dollar cost in millions)*

| Basic cost of production | Model 1 Dollars | Model 1 Percent | Model 2 Dollars | Model 2 Percent | Model 3 Dollars | Model 3 Percent |
|---|---|---|---|---|---|---|
| | *Reduction in cost* | | | | | |
| 1985: $15,840 | 206 | 1 | 152 | 1 | 0 | 0 |
| 1995: $15,850 | 493 | 3 | 263 | 2 | -2 | 0 |

The annual benefit (resource savings) derived from the high-level technology (Model 1) by 1995 is $493 million, with the cost of operations ($1 per acre) already subtracted. This value is nearly twice the benefit obtained with the moderate technology (Model 2 at $263 million). The low-level technology (Model 3) exhibits an increase of $2 million in costs, indicative of a lack of national economic incentive to adopt this technology.

In a sense, hail suppression technology can be viewed as a substitute for land. Because yields per acre increase, less farmland is required to meet projected demands. Therefore, land rents and land values tend to decline slightly in nonadopting areas, but they increase in adopting areas. The overall effect at the national level is estimated to be a slight reduction in land rents.

The adoption of hail suppression would also affect the comparative market advantage of the crops in various regions. The resulting changes in location of crop production would not appear substantial when compared to recent year-to-year changes in crop acreages by state.

Which of the three alternative routes of technological development promises to be the best investment for public funds? A *benefit-cost analysis* was performed to answer this question. The benefits associated with each of the three models were based on the resource savings accomplished by their predicted adoption. The costs included the requisite research, development, and information system expenses estimated to be associated with each model. Using an 8% discount rate, the high-level technology (Model 1) has an estimated benefit-cost ratio of 14.6/1, the moderate technology (Model 2) has a ratio of 16.6/1, and the low level technology (Model 3) a ratio of -0.4/1, as shown in the table. Use of substantially higher discount rates did not affect the relative ranking of the models, although it did reduce the benefit-cost ratios. Although the benefit-cost ratio is highest for Model 2 (because of lower predicted expenses for research and development than in Model 1), the total benefits produced by Model 1 are much greater. The difference between the benefits of Models 1 and 2 ($1,124 million) can be compared with their difference in costs ($91 million). Thus, the benefit-cost ratio of going from Model 2 to Model 1 is 12.3/1, indicating why Model 1 is the best choice.

These benefit-cost ratios for Models 1 and 2 appear high because: 1) much prior research has been done and expenditures incurred to provide a base for the expected development under each assumed funding level and 2) there is no risk discounting to reflect the uncertainty of obtaining the specified technology level, given the funding level.

**Present Values of Benefits and Costs**

| | *Model 1* | *Model 2* | *Model 3* |
|---|---|---|---|
| **Present value of benefits (millions)** | **+2,840.235** | **+1,715,870** | **-7.555** |
| **Present value of costs (million $)** | **+194.186** | **+102.758** | **+20.839** |
| **Benefit-cost ratio** | **14.6:1** | **16.6:1** | **-0.4:1** |

As we have noted, agriculture is the primary stakeholder in an effective hail suppression capability. If high-level technology (Model 1) is developed, one major effect will be on the income of crop producers in adopting areas. Agriculturists would receive immediate economic benefits from increased farm output. After an adjustment period of several years, however, the national prices for these commodities would reflect the increased production, and some of the income advantage of the first regions to adopt would be lost. These producers would still benefit from increased stability of production. In contrast, producers of the same crops in nonadopting regions would receive neither output increases nor greater production

**Impacts on Agribusiness**

Although no impacts on agribusiness are projected for the low-level technology; an advanced hail suppression capability would be likely to have the following minor impacts at the national level:

1) Increased profitability to farm equipment firms
2) Increased sales of fertilizers
3) Increased sales of herbicides and pesticides
4) More investment and personnel for mobile harvest
5) Increases in numbers and favorability of loans
6) Change in emphasis on new crop varieties
7) Additional pressure on national energy resources

stability and therefore would be economically disadvantaged relative to the adopters. Landowners in adopting areas would experience a *2%* land value increase, while those in nonadopting areas with the same crops would experience about a 10% decrease in land values.

In adopting areas, to the extent that farm income stability is increased, farmers should have less need for emergency loans, less need to default on loans, and be able to obtain new loans more easily and on better terms. There would likely be some alteration of cropping patterns due to readjustments in the market price of farm products.

With a low-level technology (Model 3), the effect on agriculture would be limited. Because only five crop-producing regions (representing about 1% of the national output) would have adopted hail suppression, their increase in crop production would result in less downward price pressures than with Model 1. Thus, an estimated increase in net crop income of 1 to *2%* would occur in the adopting areas. Further, reductions in hail loss would contribute to stability of income for these agriculturists. A slight increase of farm land values would also be experienced in adopting areas, and a minor reduction would occur in the tendency toward larger farms.

**Impacts on Other Stakeholder Groups**

In the next three boxes, impacts of future hail suppression technologies on specific stakeholder groups, specifically the 1) atmospheric sciences research groups, 2) hail suppression industry, and 3) hail insurance industry, are presented.

Because the environment affects us all, and in a variety of ways, a general discussion of anticipated environmental impacts of hail suppression is presented here. On the basis of our present knowledge, it is unlikely that widespread operational hail suppression would have serious adverse environmental impacts —especially impacts that would affect man importantly in the discernable future. The possibility of such adverse impacts should not, however, be completely ruled out. The geographic regions where adoption would occur are agriculturally productive, so adverse environmental impacts in these regions could influence crop productivity.

Most of the concern about possible adverse effects centers around silver iodide dispersal in the ecosystem. Annual deposition is estimated at 0.1 pounds per square mile. Several responsible researchers have cautioned that in the very long run the use of silver iodide might produce specific environmental impacts. These could include synergistic effects with other substances in the environment, influence on the growth, development, and reproduction of insect populations, and several effects on the plant-soil system including altered plant growth and populations of microorganisms.

The reduction of hail itself would likely reduce hail-induced injury and mortality of certain species of wildlife and plants, although to what extent is presently unknown. Future laboratory and field research covering various environmental aspects of hail suppression programs will reduce some of the current uncertainties about them, but will undoubtedly disclose new uncertainties not currently evident.

Silver iodide may be supplanted as the major nucleating agent in cloud seeding. The potential environmental effects of other agents would have to be studied as well. However, the most extensive use of silver envisioned (Model 1, 1995) would involve 4% of current national usage of silver for all purposes. Neither the availability nor the cost of silver will be limiting for its future use in hail suppression.

Another consideration is the possibility of complex ecological interactions that might occur among cloud seeding, pesticide applications, and air pollution. Possibly, silver iodide dispersal might eventually inhibit soil microorganism activity. If this occurred, there could be a slowing in the rate of organic carbon return to $CO_2$. Some ecologists are concerned that the large-scale utilization of fossil fuels and the subsequent release of $CO_2$ may result in an increase in the $CO_2$ content of the air beyond acceptable limits, creating a "greenhouse effect." If this tendency began to occur, an increased organic matter retention resulting from the use of silver iodide could aid in maintaining ecosystem stability.

These conclusions must remain speculative until further research is completed. Given these considerations, the environmental impact of a high-level hail suppression capability (Model 1) was that the following minor impacts were likely to occur: 1) reduced loss of wild plants and small animals, 2) increased runoff and erosion, 3) increased growth of wild plants and small animals, and 4) marginal impact on soil microorganisms. For the low-level hail suppression technology (Model 3), environmental effects were assessed as being minimal and non-adverse.

**Major Impacts from a High Technology**

Four societal impacts of hail suppression were judged to be the most important among those iden-

**Impacts on Atmospheric Research**

Research stakeholders are those who perform and support the research. Rapid increases in levels of funding are not likely to occur, and scientific breakthroughs are therefore less likely. However, research will probably continue for a variety of reasons mentioned elsewhere in this summary. As findings accumulate, the current lack of scientific consensus will likely shift to a more stable scientific situation. There exists at present no national policy setting a priority for hail suppression research, but a national study is currently under way to establish such a policy for weather modification and thus for hail suppression.

Those federal agencies that will fund future hail suppression research are uncertain. The National Science Foundation funded the National Hail Research Experiment, and other agencies such as the U.S. Department of Agriculture and the National Oceanic and Atmospheric Administration could become involved. NSF has considered sizable future expenditures. States are unlikely to assume financial responsibility for costly research projects.

The major scientific involvement will likely occur at the institutes, laboratories, and universities in the Rocky Mountains and Great Plains areas, where hail is a regionally recognized problem.

With the high-level technological development predicted in Model 1, a federal lead agency would establish a national laboratory for weather modification research. A larger number of university research groups will receive funding than is now the case. There will be emphasis on applied research programs, with increases in employment opportunities for meteorologists, cloud physicists, and statisticians. More research will be conducted on the social, economic, legal, and environmental aspects of hail suppression. Improved hail suppression could eventually have a major positive impact on weather modification research generally.

With the development of a low-level technology (Model 3), impacts on the research community are likely to be minor, but negative. The number of scientists involved in hail research would decline, and the funding for related research would be sharply reduced.

### Impacts on the Hail Suppression Industry

By most standards, the hail suppression industry is not a large one. Four companies grossed $1.45 million in 1975, representing about 25% of their total business income. The year-to-year fluctuation in projects requires considerable business flexibility. Supporting industries (suppliers of seeding materials and equipment) are generally well diversified into other endeavors.

The industry seems to fear governmental encroachment into its specialty areas —seeding techniques and operations. Conversely, they desire federal support of research involving evaluation of their results, confident of the reliability of their efforts.

The small monetary and political power of the industry makes its fears of governmental control and regulation appear realistic. As projects of the future develop, state and federal government involvement and control will increase, but the companies still expect expanded hail suppression activity to be of benefit to them.

If a high-level technology (Model 1) is developed, the following impacts on the hail suppression industry are quite likely to occur:

1) Companies will have reduced decision involvement in projects.
2) Expenditures for liability insurance will increase.
3) Larger, better trained staffs will be developed.
4) Responsibility for added monitoring and better record keeping will increase.
5) Profits will increase.
6) Large corporations will buy some small firms.
7) Aircraft and radar manufacturers will have increased income.
8) Silver iodide producers and suppliers will increase their income.
9) Smaller companies will experience increased stability of income.
10) The industry will invest more in research and development.

Impacts on the industry from a low-level hail suppression capability (Model 3) are likely to be minor. They would include increased profits and expansion for a few companies, slightly increased income for suppliers, and a slight increase in aircraft and radar rentals.

tified as significant or major. Agriculture would receive the most significant national effects of an advanced hail suppression capability. Producers in earlier adopting areas would receive immediate benefits from increased farm output. After a period of adjustment, the economic advantage would be decreased somewhat, but increased stability of income could remain.

Consumers of agricultural products would benefit through slightly lowered prices. Although the economic benefit to any one individual would be small, the number of individuals benefited would be very large.

Governmental agencies involved in regulating hail suppression activity, in supporting research and development, and in working out interstate arrangements would experience pressure for implementing these changes.

Finally, an increased stature for weather modification generally would result from favorable experience with hail suppression in adopting areas.

All other impacts of an advanced hail suppression capability were judged to be minor. At the individual level, farmers in adopting regions would experience not only increased income but also greater stability of income, allowing more long-range planning for farm family activities and investments. Property-hail losses would be reduced. Improved weather forecasts would be necessary for the suppression to be effective at this level with all of its side benefits, as in planning daily activities.

Net farm income from crops grown in nonadopting regions would be negatively affected as compared with the same crops grown in adopting regions. Farm land in nonadopting areas would thus decline slightly in market value and in property taxes generated.

Within particular communities or regions, some

### Impacts on the Hail Insurance Industry

The probable impacts of hail suppression activities on the insurance industry may be summarized as follows. The need or use of crop insurance will not be displaced; the use of all-risk insurance could be increased because of eventually lower rates. Forms of coverage and pricing structures would probably be modified, with lowered rates, but there would be a fairly long delay until this was accomplished. If damaging weather effects, such as increased wind or lightning, accompanied hail suppression, claims handling and litigation could be a problem to insurance companies. Third party liability (as for weather modifiers) represents a serious problem, since numerous allegations of harm could be made in hail suppression operations with difficulty in disproving them. The areal exposure involved and the potential for class action may make such liability protection impossible. Small, one-state companies could actively promote hail suppression since their businesses are more affected by a major loss event. Most of the insurance industry, however, will neither support nor oppose hail suppression.

The following national-level impacts on the insurance industry would occur with a high-level technology (Model 1):

1) Dealys in downward adjustments of insurance premiums, resulting in some financial benefit to the companies
2) Increased purchase of crop-hail and all-risk insurance
3) Little financial impact on the industry as a whole
4) Changes in recording of various types of losses
5) Emergence of hail suppression liability insurance as a problem

From a low-level capability to suppress hail damage (Model 3), the impacts on the insurance industry would be quite minor, but similar to those listed for Model 1.

will gain and others lose from the effects of hail suppression. For example, the heavy rain that nourishes the row crops on one farm will ruin the cut hay on another farm. If there continues to be an absence of a generally accepted compensatory mechanism, controversy between segments of the community will occur. Evidence from the economic, legal, insurance, and social analyses indicated that the impacts of decreases and increases in rainfall associated with the hail suppression models tended to be at least as important as the effects of reductions in hail damage itself.

Local government is likely to be involved in decisions concerning hail suppression operations, and some local revenues will be diverted to support the program. Public information efforts are likely to increase.

In adopting areas where agricultural activities are dependent on migrant laborers, the proportion of migrants would increase with concomitant social effects. In adopting areas, increased stability in local business activity would occur and population outmigration would slow down. In nonadopting areas, a slight negative economic impact on agriculture would be felt in the local business communities.

Since hail suppression projects would likely be regional in scope, they would often be conducted irrespective of political boundaries. State and federal governments would need to work out appropriate institutional arrangements for such projects. With 80% reductions in crop-hail loss by 1995, $493 million, a decrease in state-initiated requests for federal disaster declarations would occur.

Problems of air traffic control would increase on a few peak hail suppression activity days.

Some legal battles concerning alleged damages from cloud seeding activity are likely to be fought. This would contribute to the clarification of legal issues, such as project effects crossing state boundaries, compensation schemes, increased comparability of state regulations, and liability theory.

Downwind areas might be subject to both benefits and harm from weather changes due to hail suppression; however, these impacts were judged to be less than those for adopting areas. If notable effects occurred in downwind areas, major social and legal issues could arise.

With an advanced hail suppression technology would come increased governmental involvement in the record keeping, monitoring, and evaluation of projects. Some regulation would likely occUr at the federal level, with the possibility of operational control. A lead agency would likely play the central role in all federal involvement in hail suppression. Adjustments in weather and climatic records kept by governmental agencies would need to be made. Federal agencies involved in farm subsidies, air traffic control, crop insurance, and international treaties would be slightly affected.

### Major Impacts from a Low Technology

Two major impacts were projected to occur as a result of the Model 3 technology. Within the adopting areas, producers would experience an increase in average income as well as in stability of income. For the nation as a whole, it is likely that a general disillusionment with the concept of hail suppression would occur because of the inability to produce major decreases in hail damage.

All other impacts derived from a low hail suppression capability were classed as minor, and many of these (e.g., reduction in outmigration, greater stability of local business in adopting areas) are identical to impacts for the high-level technology, but with less significance.

However, few different impacts were projected for the low-level technology. The lesser degree of scientific consensus associated with this capability and the probable exclusion of opponents from the decision process would contribute to the more frequent occurrence of interest group controversy and community polarization. These controversial events would further hinder adoption of hail suppression and public support for its continued development. There would be little impact on governmental agencies involved in regulation or in affiliated interests. Environmental interest groups would probably exhibit minimal concern and undertake no serious effort at generating political pressure against hail suppression.

## POLICY ISSUES

The term *public policy option* implies choice for deliberate, purposeful action on the part of some person or organization. Policy actions emanate from any level of government as well as from private groups and individuals who may be crucial actors in accomplishing public policy goals.

The most significant policy question with regard to hail suppression at all levels of government is to what extent the development of hail suppression technology should be supported, both financially and institutionally. Assuming that national goals of adequate food supplies for the entire population while maintaining environmental quality and other societal values are served by (or at least not violated by) an effective hail suppression technology, then *removing the scientific and technical uncertainties is the major policy action to be taken.*

Removing these uncertainties will require 1) orderly federal management and adequate long-range funding with a lead agency addressing the modification of severe convective storms and 2) a scientific research group dedicated to a well-designed program of basic and applied research. The utilization of hail suppression technology will most probably not await the final resolution of all scientific uncertainties. Application, discouragement, encouraging research results, scientific argument and fairly prolonged debate will most likely characterize the technology's scientific and technical development. Consideration of normative implications of the capability *has not* and *will not* await the "mature" technology.

Other important policy questions identified in the study related to the primary policy decision of the technology's development. These are:

- *What shall be the sources of funding?* In general, federal funding of research and user funding of operations have been prevailing patterns. However, policy options can involve federal funding of the evaluation of operational projects and taxpayer funding of operations.

- *Should compensation be provided the losers?* If so, how? Since some may gain and some may lose as a result of hail suppression activity, the possibility of compensating losers must be considered. The question of causation of effects has been a substantial barrier to the development of a compensation mechanism, but this difficulty may be overcome with technological and scientific improvements. Several policy options with regard to this question may be considered, but no workable arrangement for compensation has yet been institutionalized.
- *What is the appropriate division of responsibility between the states and the federal government in regulating hail suppression?* Throughout this study, the atmosphere has been considered a common property resource, and thus public regulation of its intentional modification has been viewed as inevitable. Heretofore, regulation has resided at the state level; however, regulation need not be viewed as an either/or proposition between the federal government and the states. Federal involvement in regulation might arise in conjunction with its financial role in support of hail suppression.
- *In what way and to what extent shall the federal government be involved in multi-state operations?* Various options for such federal involvement include the creation of multi-state voluntary cooperative agreements, the development of more formal interstate compacts, and the authorization by Congress of a federal corporation for the management of operational programs.
- *How, if at all, shall stakeholders be involved in hail suppression policy decisions?* Decision-making systems can be devised which broaden public representation beyond those most directly interested. The development of specific institutional arrangements to accomplish broad public participation may be left to states and local communities.
- *What administrative arrangements for operational hail suppression programs are most appropriate?* Various options include federal agency administration, local districts, and state agency management, or combinations of these. In part, the most appropriate policy choice would depend on the scope of the projects being administered.
- *To what extent shall monitoring, record keeping, and evaluation be required and utilized?* Where operational programs are conducted, a contribution to scientific knowledge can be achieved by adequate data collection, analysis, and evaluation. Policy decisions are needed on who should fund and conduct these evaluations.

In general, policy decisions on hail suppression revolve around two basic issues: whether or not to stimulate the further development of hail suppression technology and how to handle the implications concomitant with its development and application.

## CONCLUSIONS

From our interdisciplinary study of hail suppression and its impacts, we reached a number of conclusions and derived recommendations for action that would most nearly achieve the objectives of beneficial use and minimum harm from the technology. Our conclusions cover in broad brush strokes the detailed findings of the study and what the team inferred from them.

- The United States experiences about $850 million in direct crop and property hail losses each year, not including secondary losses from hail. The key characteristic of hail is its enormous variability in size, time, and space.

- Among the alternative ways of dealing with the hail problem, including crop insurance, hail suppression, given a high level of development, appears to be the most promising future approach in high hail loss areas. Economic benefits from effective hail suppression vary by region of the country, with the most benefit to be derived in the Great Plains area. Any alterations in rainfall resulting from hail suppression would importantly affect its economic consequences.

- The effects of cloud seeding on rainfall are more significant than its effects on hail from economic and societal standpoints.

- At the present time there is no *established* hail suppression technology. It may be possible to reduce damaging hail about 25% over the growing season in a properly conducted project.

- Reducing the scientific uncertainties about hail suppression will require a substantial commitment by the federal government for long-term funding of a systematic, well-designed program of research. For the next decade or so, monitoring and evaluation of operational programs will be important.

- Benefit-cost analysis revealed that investment in development of the high-level technology would result in a ratio of 14:1, with the present value of benefits estimated to total $2.8 billion for twenty years. The low-level technology showed a negative benefit-cost ratio. Research and development to provide the high-level technology is the best choice from an economic standpoint; a minimal level of support would be nonbeneficial. In a word, if we are going to develop hail suppression technology, we would need to do it right.

- Effective hail suppression will, because of the hail hazard, technological approach, patterns of adoption, and institutional arrangements, lead to regionally coherent programs that embrace groups of states, largely in the Great Plains.

- Some would gain and others would lose from widespread application of an effective hail suppression technology. Farmers within adopting regions would receive immediate benefits from increased production. After several years this economic advantage would be diminished somewhat, but increased stability of income would remain. Farmers growing the same crops outside the adopting areas would have no advantages and would be economically disadvantaged by commodity prices lower than they would have been with no hail suppression. The price depressing effects result from increased production in adopting areas. Consumers would benefit from slightly decreased food prices. The impacts generated by a highly effective technology include both positive and negative outcomes for various other stakeholder groups in the nation. For the nation as a whole, the impacts would be minor and beneficial. On balance, the positive impacts outweigh the negative impacts if a high-level technology can be developed.

- An adequate means of providing equitable compensation on an economically sound basis for persons suffering from losses due to cloud seeding has not been developed. Some better procedure for compensating losers will be necessary. In addition, present decision mechanisms and institutional arrangements are inadequate to implement the technology in a socially acceptable manner. Some mechanism for including potential opponents in the decision-making process will be required.

- It is unlikely that widespread operational hail suppression programs would have serious adverse environmental impacts, although lack of sufficient knowledge indicates that adverse impacts should not be ruled out. Long-term environmental effects are not known at the present time.

## RECOMMENDATIONS

Several key recommendations from the complete set presented in the TASH Final Report have been selected for inclusion in this summary. The recommendations pertain to two major areas: public policy and research. Public policy recommendations deal with federal and state governmental actions regarding hail suppression. Research recommendations consider needed interdisciplinary, scientific and technical, socio-political, economic, legal, and environmental studies.

### Public Policy

1. *The federal government should attempt to develop hail suppression having a high level of effectiveness.* If the federal government follows this recommendation, support of hail suppression research should be at a level of at least $3 million annually and should be sustained at least 20 years or until it is clear that a highly useful technology is developed or cannot be developed. Low level support is not warranted.

2. *One federal agency should have the responsibility for the primary funding of research and development in hail suppression, providing the long-term stability in funding required to accomplish the needed experimental work. Agencies studying severe convective storms should attempt to better coordinate their programs.*

3. *The role of the federal government should be largely one of stimulation and of providing financial support for research and development of an effective hail suppression technology.* The development of an effective hail suppression capability would be in the nation's interest, and public appropriations provide the broad level of support necessary for the technology's development.

4. *Monitoring and evaluation activities in connection with operational projects should be funded primarily from federal sources.* Such monitoring is needed by atmospheric scientists and federal agencies for a variety of purposes, by adopting-area residents in order to understand the consequences of projects, and as a basis for determining the extent to which compensation should be made.

5. *Operational hail suppression programs should be permitted only under conditions of full disclosure to a governmental agency.* "Full disclosure" includes revelation of all advertising, contract, and promotional material, as well as reports on project effects. Operational project should be required by law to provide sufficient data to independent government agencies (on a cost-reimbursement basis) that monitoring and evaluation of project effects will be expedited.

6. *Regulation of hail suppression projects should continue for the present to be a state responsibility. Federal standards for monitoring and evaluation should be incorporated into state regulations. States should appropriate more funds for the administration of weather modification statutes, especially to allow more extensive analysis of records being kept.*

7. *The decisions to authorize, interrupt, or discontinue any hail suppression effort should be made at the local and state levels. Such decisions should involve active participation of potentially affected groups, and, if tax funds are to be used, possibly all citizens within the potentially affected areas should vote on a referendum.*
8. *Some type of compensation mechanism is needed to provide for payment to those with legitimate damage claims. Discretion to develop such compensation mechanisms should be left to the states.*

### Research

Our major research recommendations concerning each relevant disciplinary area may be found in the boxes on the following page. Our research recommendation for interdisciplinary, scientific, and technical studies are presented below:

1. *Advancement of the capability to suppress hail can be accomplished through a two-pronged scientific effort.*
   *a*. a well-defined experimental-analytical research program with strong continuity and a focus on all the atmospheric science issues, and a parallel effort to monitor closely and evaluate operational hail suppression projects with a continuing program to integrate the findings from both efforts, and
   *b*. storm modification hypotheses of the future to consider the whole convective storm process so as to attempt to suppress hail and reduce strong surface winds attendant with hail.
   These hypotheses should include a simultaneous goal and study of producing no change or an increase in rainfall and to address extra-area effects.

2. *Certain specific basic and applied research activities should be followed:*
   *a*. in-cloud measurements throughout the lifetime of storms;
   *b*. sufficient regional and climatic sampling to insure transferability of results;
   *c*. a study of forecasting issues to improve design and operation of future programs.

3. *The technical aspects of integrating the advanced understanding of atmospheric processes achieved through the studies recommended above should be developed. Such aspects as seeding technologies and delivery systems need further development.*

4. *A national technology assessment study on the modification of precipitation should be conducted.* Based on our findings that rainfall effects were more important than hail effects in economic and socio-political impact, we feel strongly that a technology assessment on the societal effects of precipitation management technologies is needed.

**Socio-Political and Economic Research Needs**

1. We recommend a comprehensive study of potential compensatory mechanisms that would be economically feasible as well as socially and legally acceptable.
2. We recommend that research be conducted to further refine the parameters of feasible and socially acceptable decision-making mechanisms.
3. We recommend that analysis of alternative administrative arrangements for operational hail suppression programs be conducted. Administrative arrangements may need to vary depending on funding sources.
4. We recommend that economic studies on the effects of hail suppression on local area economies and on the agricultural market be conducted in conjunction with monitoring and evaluation of operational projects.

**Legal Research Needs**

1. Work begun on the development of a model weather modification law for interested states should be continued.
2. We recommend that a special study be conducted to explore the legal problems involved in the adoption of weather modification (including hail suppression), with the purpose of determining the most appropriate legal theories and approaches to bring to bear, and to aid in the development of model compensatory mechanisms.

**Environmental Research Needs**

Our conclusions have indicated that widespread operational hail suppression would not result in any serious adverse environmental impacts, but that the possibility of adverse effects should not be discounted. The major areas of concern are the effects of silver and altered precipitation on the environment.

The following specific studies are recommended:

1. The effects of altered precipitation on ecosystems
2. Basic studies on plant and microorganism adaptation to seeding agents
3. The potential for combination of seeding agent silver with other metals, pesticides, power plant emission products, and other pollution sources
4. Tracer studies of nucleants in seeded storm cells to locate their deposition in the environment
5. Monitoring of silver levels and dynamics in the soil-plant-aquatic environment before and after cloud-seeding activities over the long term.

## EPILOGUE

To be effective, this study should not be the end of the assessment of hail suppression. Several recommendations in the final report have called for continuing research and policy research efforts, as well as for monitoring and re-evaluation of findings. A continuing assessment of the hail suppression capability, and another in-depth assessment should occur in the years ahead.

## THE ASSESSMENT TEAM AND MAJOR CONTRIBUTORS

This study, entitled Technology Assessment of the Suppression of Hail (TASH), began in August 1975. The project was organized around five sub-groups. The overall project management and supervision was provided by the Illinois State Water Survey (ISWS) under Professor Stanley A. Changnon, Jr., Head of the Atmospheric Sciences Section. He, Griffith M. Morgan, Jr., and J. Loreena Ivens of the Water Survey contributed to various aspects of TASH. ISWS consultants in the weather modification area included Dr. D. Ray Booker and Thomas J. Henderson; in the environmental area was Dr. Donald Klein; and in insurance areas were E. Ray Fosse and Don G. Friedman. Dr. Martin V. Jones of the Impact Assessment Institute provided guidance on the study's methodology. The Human Ecology Research Services, Inc. (HERS) concentrated on socio-political aspects, adoption analyses, impact assessment, and policy issues. The HERS team, guided by Dr. Barbara C. Farhar and composed of Professor J. Eugene Haas, Julia Mewes, and Ronald Rinkle, was aided materially by Professor Dean Mann. Legal aspects were handled by Professor Ray J. Davis of the College of Law at the University of Arizona and his team of graduate students. Agricultural economists at the University of Illinois, under the direction of Professor Earl R. Swanson, conducted the economic analyses. They included Dr. Steven T. Sonka, Dr. Jon van Blokland, and Dr. C. Robert Taylor.

The TASH team received extremely useful advice and assistance from its Advisory Panel. The Panel met with the team and patiently reviewed the key project documents, including the final report, *Hail Suppression: Impacts and Issues.* The Panel included:

Eugene Bollay, Private Citizen, Santa Barbara, California
Stewart W. Borland, Agriculture Canada
John W. Firor, National Center for Atmospheric Research
Wayne L. Fowler, DeKalb AgResearch, Inc.
William A. Thomas, American Bar Foundation
Charles P. Wolf, Office of Technology Assessment

To help select materials for this summary, the TASH team also conducted two "User Workshops" in Boulder, Colorado, during November 1976. The TASH research effort had indicated the breadth of potential stakeholders, or people affected by hail suppression; therefore the purpose of these workshops, conducted by five TASH team members, was to consult with people representing these stakeholder groups. A total of 34 persons attended, read the final report, and selected findings they believed to be most relevant to the *interest group they represented.* The attendees represented associations and federal agencies concerned with weather modification, housewives from weather modification areas, county farm agents, various segments of the hail insurance industry, executives from weather modification companies, proponents of and opponents to weather modification, farmers, lawyers, environmentalists, judges, state legislators, state weather modification board members, research scientists, agribusinessmen, and federal policy advisors. They worked diligently to offer constructive advice on the potential contents of this Summary and we wish to acknowledge our indebtedness to them. However, the presence and participation of the following attendees at the User Workshops does not necessarily constitute endorsement, approval, acceptance, or agreement with the final report and this summary, or with any statements, conclusions, interpretations, or recommendations found therein.

The workshop attendees included:

Normal Baguley
David Blanchard
Wilbur Brewer
Keith J. Brown
Vern Butler
F. F. Flip Calhoun
Marc Changnon
Melvin Cotner
Herschal Crow
Larry Davis
James Dawson
Robert DiGiovanni
Currie S. Downie
Esther Edie
Dave Gabriel
Lewis Grant
Frank R. Hammill
Ray E. Hawkins
William Hillhouse
Henry Lansford
Ron Lavoie
Carlos Lucero
John A. McComb
S. Ted Rice
Wallace N. Robinson, III
Jim Rose
David Schilling
John B. Shawcroft
Howard J. Sjogren
Billy G. Smith
Don Thompson
Don Veal
Eric Walther
Ethel Williams