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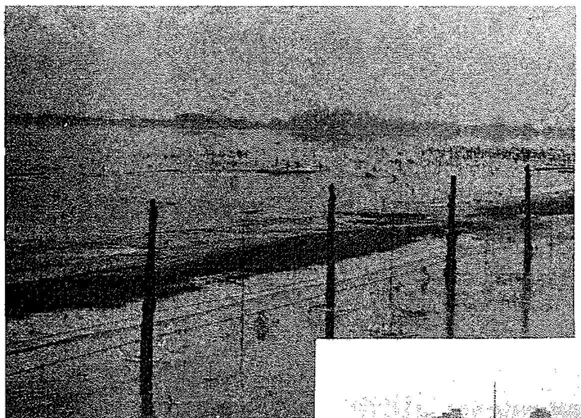
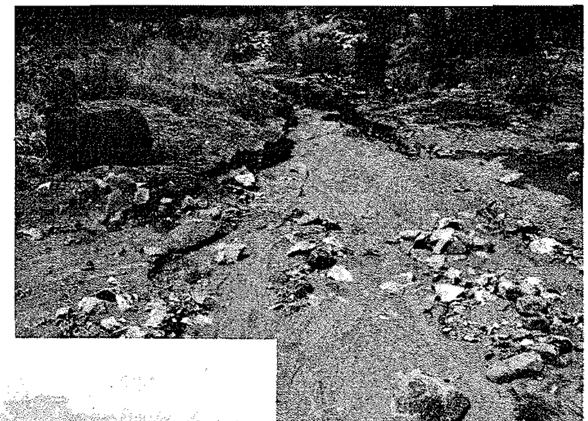
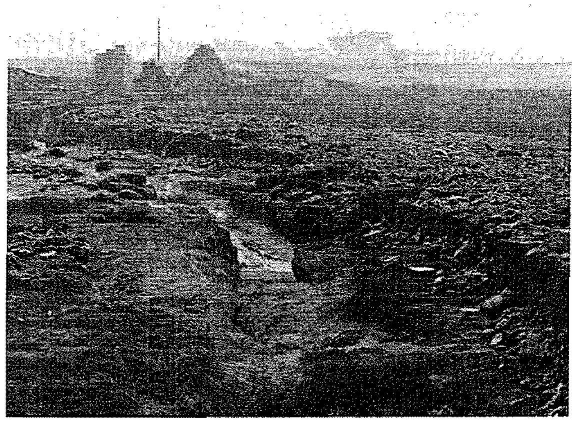
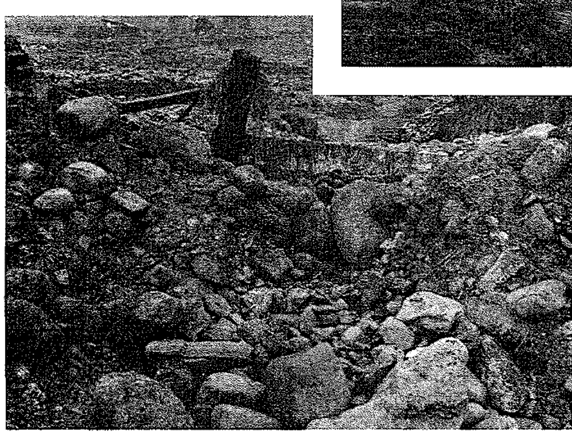


Utah Water Research Laboratory
Utah State University
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WATER RESOURCES PLANNING SERIES
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COVER

During the night of January 20, 1980 (while this report was being typed) heavy rains on frozen ground in northern Utah caused extensive flash flooding in Cache and Box Elder Counties. The damages were concentrated in the communities at the base of the Wellsville Mountains and smaller ranges to the north. Mendon was the worst hit community, and the flooding there was compounded by water collecting in an irrigation canal which broke in several places causing deep washes. The total damage in the two counties was about $3 million with 43 percent occurring to roads and bridges, 29 percent to land and livestock, and 28 percent to irrigation and other water control systems. Counts of water in up to 200 basements were reported, but no figures on damages to homes were published and indications are that they are a relatively small portion of the total. The pictures on the cover illustrate the kinds of damages caused by a flash flood in rural Utah.

During the week of February 17, 1980, another series of heavy rains caused repeat flooding, particularly concentrated in Mendon and Clarkston, that caused a similar amount of damage.

FLOOD DAMAGE MITIGATION IN UTAH

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ABSTRACT

Utah is subjected to flash flooding in mountain canyons, mudflows and shallow water flooding on lowlands at the canyon outlets, storm water flooding after thunderstorms in urban areas, and prolonged periods of inundation in certain lowland areas during snowmelt periods. In response to these problems, individuals are making private land use and flood proofing decisions, larger communities have storm water collection programs, three federal agencies are involved in structural flood control, and the Federal Emergency Management Agency is managing a National Flood Insurance Program designed to promote community floodplain management efforts.

A framework was developed of the dynamically interactive feedback process through which people at various levels and from various prospectives seek the benefits of floodplain occupancy, experience floods, and respond by changing their occupancy or the flows. That framework then became the background for identifying what state government should do in Utah to correct unsatisfactory aspects of the existing flood hazard and counter measures.

The data used in the analysis included magnitudes of major historical snowfall and precipitation events, estimates of 100-year flows for all 105 gaged locations with more than 20 years of record, envelope curves of 100-year flow versus drainage area for Utah basins, descriptions of the major historical floods (by order according to amount of damage 1. Salt Lake City canyons 1952 $6,74,000; 2. Ogden 1979 $1,000,000; 3. Virgin River 1966 $962,000; 4. Sheep Creek (Daggett County) 1965 $802,000), descriptions of the structural flood control projects built or being planned in Utah by the Corps of Engineers, Soil Conservation Service, and Water and Power Resources Service, data with respect to participation in the national flood insurance program of Utah's 251 communities, a survey of the flood hazard in 32 of those communities randomly selected from a stratified sample, and a detailed evaluation of the situations in 7 of them.

The study found that the flood hazard in Utah is much more concentrated in smaller basins than is so for other parts of the country and that the major problem lies at the base of the mountains where major damages are regularly being caused by flows at mountain hollows too small for hazard areas to have been mapped through the National Flood Insurance Program. Better methodology needs to be developed and applied for delineating hazard areas from mudflows and shallow water flooding on alluvial fans and other lowlands at the mountain base. Attention needs to be given to the effects of irrigation canals and bridges on the risk. Designs need to be developed that work with nature in dispersing the flood water and recharging much of it to underground aquifers instead rather than against nature in concentrating the flows in a downstream direction.

State actions recommended include 1) providing a continuing forum for interaction among federal agencies and local communities, 2) providing technical support for local communities including review of proposed designs for safety, 3) developing structural and flood proofing designs that will be effective in Utah conditions, and 4) interacting with federal agencies on behalf of the local communities.

ACKNOWLEDGMENTS

This project was completed at the Utah Water Research Laboratory with funding provided through its state appropriation (WA33) to study priority problems identified by its Citizen Advisory Council. The authors are also indebted to the support they received from the Utah Division of Water Resources, the Federal Emergency Management Agency, and the 35 Utah communities from which data for the study were collected.

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CHAPTER I

THE ROLE OF STATE FLOOD CONTROL PROGRAMS

The Flood Control Planning Framework

Even though annual damage rates in Utah are only about 20 percent of the nationwide average, flooding is still a significant problem for the state. Flash floods rise quickly to destroy property and take lives in mountain canyons and on the alluvial fans at their base. Melting snowpacks prolong runoff out of the canyons and add to the damage in the communities below. Thunderstorms in urban areas cause drainage problems and widespread rainstorms bring larger streams to their highest peaks. In short, the problem is definitely severe enough to require remedial activity.

Individuals can do much (site selection, building construction methods, evacuation, etc.) to protect themselves and their property, but protection can often be achieved more economically through collective action. For example, a dam or a levee is much more effective and economical than flood proofing each building in a town. Federal programs were consequently established to provide the needed collective effort, but sole reliance on structural measures was found to be far more expensive than the national budget could afford. The response at the federal level has been to move toward supplemental regulatory efforts to restrict floodplain development. Conceptually, no expensive protection would be required, and no flood damages would occur if no property were exposed. Regulation, however, limits the freedom of individuals to develop their land and is prone to become unnecessarily restrictive. Certainly in Utah, where average annual flood damages are low on the national scale and the character of the flooding is not typical, as can be seen from the above examples, regulatory efforts must be designed to accommodate local needs to avoid becoming more restrictive than can be justified.

An effective flood program must be planned. The ideal planning framework is to examine the physical, economic, ecologic, social and other aspects of each flood problem and propose a plan of action best suited for the specific local situation. The result would be an optimal mix of structural and regulatory (nonstructural) measures and defined governmental actions to implement them. The use of local information is necessary but not sufficient for doing a good job because determination of the best suited plan requires objective criteria. Goal preferences vary among the federal government, the individuals making floodplain occupancy decisions, and the local governments in flood prone areas. Furthermore, these groups do not have equal status and resources in resolving preference clashes or differences arising during plan implementation. One objective of this report is to determine whether there is a role for state government in establishing planning criteria and achieving conflict resolutions more equitable for Utah situations.

The Floodplain Land Use Context

The flood control and floodplain management ideal is for a responsible planning unit to identify the optimal mix of structural and nonstructural measures and proceed to implement them. In practice, planned solutions to flood problems are seldom truly optimal because of limitations to the information and analytic capability available to planners. A generally far more limiting obstacle to achieving the desired flood damage reduction, however, is that planning authorities do not control the groups that must work together in implementing land use, flood proofing, and emergency measures.

The fact is that the flood damage reduction a planning authority can achieve is limited by the presence of many individuals and groups throughout society independently making and implementing decisions that directly or indirectly affect and collectively determine flood hazard, floodplain land use, and human response to flood emergencies. Some of these actions alleviate flood problems but others, inadvertently or in combination with simultaneous unanticipated actions by others, worsen them. Some alleviate from the viewpoint of those implementing them but are harmful from the viewpoints of others. The cumulative effect is a de facto, as opposed to an objectively planned situation with respect to the number of lives and amount of property at risk. If national flood losses are too high, this de facto situation must be changed.

Utah government has the opportunity to alter this de facto situation to achieve state goals. Converting this opportunity into an operational program, however, poses several challenging issues. How can a conceptually tractable state viewpoint and an effective action role for implementing it be defined in the context of all the other individual and group activity mentioned above? Can Utah state government really achieve sufficient results to make the effort worthwhile?

A Focus on Flood Problems in Utah

All 50 state governments take some role in flood control and floodplain management. A few have extensive programs. While some guidance for Utah could be obtained by reviewing the successes and failures of other state programs (Barkley 1970, Johnson 1970), Utah's flood hazard situation is so different, in ways explained later, from that of most other states that another approach was taken for this study. The approach here is to examine the de facto flood hazard situation, lives and property at risk balanced against the benefits from floodplain use, in Utah, to search out problems and appropriate ways for dealing with them.

Approaches to Flood Hazard Reduction

The de facto flood hazard situation resulting from the many independent actions directly or indirectly affecting flooding or flood damages is considered nonoptimal, unsatisfactory, or even unacceptable by those who want to eliminate all flood damages or protect all natural floodplain environments on basic principles. This viewpoint is found in those who advocate floodplain land use regulations to halt all further building in hazard areas no matter how valid the reason the prospective occupant may have for becoming exposed to the hazard, in environmentalists who would stop all structural flood control no matter how much benefits exceed cost or how small the environmental harm, or in automatic opposition to traditional structural solutions without giving due consideration to alternatives. It is also found in those who would automatically build all the structural measures needed to achieve full floodplain development. Neither extreme is effective. The first ignors major economic losses, and the second ignors major environmental harm.

A more effective approach is for those who perceive either economic losses or environmental harms to interact with key decision makers (where ever they are in the total decision process) in order to reduce the frequency or severity of the resulting problems. As an example relating to this study, Utah is in no position to change national policy found to be placing lives or property at risk unnecessarily or unduly restricting floodplain use in this state, but efforts properly targeted to change particular decisions or actions may be very effective.

In order to be effective in this role, it is necessary to begin by defining appropriate targeted efforts. The task includes identifying aspects of the current situation which are in the best interest of the state to change, defining the target from information on existing key decision makers and actions, and formulating a plan for obtaining action from the targeted decision makers. If the current situation is unsatisfactory and targeted action can achieve sufficient change to justify the effort, Utah needs a more active program for flood control and floodplain management. Otherwise, state action cannot be justified. To begin with then, who are currently the key decision makers whose actions determine flood risk?

Roles of the Principal Flood Control Institutions

Five principal participants or participant groups interact in formulating the national flood control program in the United States. First, large federal agencies construct reservoirs, levees, and channels in a nationwide program of structural measures to contain riverine and other major flood waters. Second, municipal governments construct smaller storage and conveyance facilities and generally provide a lesser degree of protection against inundation by local stormwater in urban areas. Third, the federal flood insurance program provides floodplain occupants the option to insure themselves against the financial losses caused by flooding but makes the availability of the insurance contingent on a community floodplain management plan as a means of inducing the communities to pass laws to reduce floodplain occupancy. Fourth, planning and zoning officials in individual communities enact and enforce regulations to reduce new floodplain development and encourage the flood proofing of exposed structures. Fifth, but perhaps the most influential of all on the amount of flood damages that occur, individual property managers make the land-use and building-design decisions that determine floodplain occupancy and make the responses to flood emergencies that determine resultant losses. In addition to these five, other participants engage in flood forecasting; urban, recreation, or transportation planning; and many other roles that are also important but less central to the overall program.

The decision makers in these five principal roles vary greatly (both within a role and between roles) in the a) range of actions at their disposal, b) area of jurisdiction, c) criteria or values, and d) time horizon. Listed below are the general situations, with respect to each of these four dimensions, of the decision makers in each of these five roles.

1. The federal agencies (principally the Corps of Engineers on the larger rivers and the Soil Conservation Service on smaller upland watersheds) a) implement programs of engineered construction, b) have a national program that draws on a nationwide cadre of expertise in most skills relevant to water management, c) formulate their designs on the

basis of the Water Resources Council Principles and Standards (1973, 1979) established through nationwide consensus on water planning goals, and d) evaluate feasibility based on 50-year planning periods.

2. Municipal stormwater programs (generally directed by a municipal engineer) a) implement programs of engineered construction that are designed at a much smaller scale than those of the federal agencies, b) are active only within their own municipal boundaries and have much more limited access to planning resources and expertise, c) formulate their designs based on applications of familiar engineering standards to meet the perceived needs of local citizens under guidance supplied by leaders in municipal government, and d) evaluate financial as opposed to economic feasibility and that based on planning periods often tied to statutory limitations on the life of municipal bonds and averaging around 20 years.

3. The federal flood insurance program a) provides information on flood hazard and uses its program as an inducement to get local communities to reduce development at hazard, b) is active nationwide and has limited (but increasing) expertise in many of the disciplines relevant to flood control planning and technology, c) does not follow the Principles and Standards but employs uniform scaling rules based on such physical criteria as a 100-year floodplain or a one-foot allowable floodway backwater, and d) implements its program based on current conditions with no allowance for increased risk caused by future intensification of upstream watershed land use.

4. Municipal planning and zoning boards (normally staffed by people trained as generalists) a) pass and enforce land use regulations, b) are active only within their own municipal boundaries and seldom have significant expertise related to flood control technology, c) formulate plans from criteria that are not explicitly defined but generally comply with accepted practice within the planning profession and are responsive to pressures from local citizens and state and federal authorities, and d) generally target on meeting community needs over the next 10 to 30 years.

5. The managers of individual properties a) occupy their land and sometimes construct facilities on it, b) have control only over their own property (though they may influence and be influenced by neighbors) and seldom have expertise in any relevant professional discipline, c) respond to vaguely defined individual needs and personal goals rather than to formal criteria, and d) vary greatly in their time frame for analysis depending, among other things, on whether they are seeking investment income or a permanent home for themselves and their children (James 1968).

As a consequence of these multiple roles and the multiple actors within each role, the exposure of property to flood risk is determined by dynamic interaction among many decision makers. Actions by one group conflict with actions by another, and differences are resolved as individuals interact in prevailing institutional arrangements. Since the five groups named above act at three levels (national, community, and private) and vary greatly in resources, authority, and expertise, the efforts of any one group to reduce the amount of property at risk often have unforeseen consequences and their effectiveness is very difficult to predict. Some hints, however, can be found by exploring the role in more detail.

Role Interaction in the Existing Program

Historical Role Development

The Flood Control Act of 1936 institutionalized nationwide federal funding for structural flood control in the United States. The program began with the reservoirs and levees built by the U.S. Army Corps of Engineers to protect floodplains along larger rivers. The Soil Conservation Service later became active in developing projects on smaller tributaries and in upland areas. The Bureau of Reclamation has included flood control storage in its multipurpose reservoirs but does not implement single purpose flood control projects. All three agencies have active flood control programs in Utah, but the programs are less extensive and individual projects are smaller than in parts of the country where a more humid climate and greater rainfall intensities cause greater flood problems.

The 1936 Act also institutionalized the economic efficiency criterion for federal water resources planning (James and Rogers 1979) by decreeing that federal monies could only be used to finance structural flood control if benefits, equaling the damage reduction achieved, exceeded costs. Other rules prevent the federal effort from protecting areas where the inundation because of long duration, small volume, frequent occurrence, or local source is considered a drainage rather than a flood problem (James and Lee 1971, p. 229). Municipal drainage programs have focused on these localized problems.

Over the years, implementation of the federal program for structural flood control proved increasingly costly. What was worse, total flood damages nationwide continued to increase. The federal response was to promote floodplain management (Levin 1970). Zoning was recommended to keep damage-prone property from high flood risk areas, and building codes were recommended to require less damage-prone (flood proofed) construction when floodplain development occurred. Under the new flood control policy the ideal flood control planning mode considered both these nonstructural options along with the structural flood control measures and selected the optimal mix.

Implementation of such an integrated program is, however, a problem. The constitutional separation of powers gives the federal government authority to construct flood control facilities that promote the general welfare but leaves to the state and, as delegated by the states, local government authority for land use planning and regulations through zoning and building codes. Consequently, the federal government cannot directly implement the nonstructural components of a flood control program but rather has to use incentives to encourage state and local implementation efforts. State and local governments, on the other hand, do not have the finances, or in some cases the authority, to implement the structural measures they may consider essential for the welfare of their communities. Consequently, governments at these lower levels frequently use their influence to encourage federal project construction.

State and local efforts to procure structural flood control have lessened with the environmental movement and the resulting gain in favor of the nonstructural approach. Even where local pressures for construction continue, the federal agencies are increasingly likely to decline (or indefinitely delay) construction of flood control structures, and communities with flood problems are forced more and more to turn to the nonstructural measures that they can implement. In this mode, the federal government encourages local nonstructural programs, and the local governments seek federal acceptance of their nonstructural efforts as qualifying them for flood insurance. These are just a few examples of how the alternative of influencing others is for many more viable than any direct action alternative.

The Federal Influencing Mode

Haimes (1977, p. 63) lists three ways that higher echelons in a hierarchy can manipulate choices made at lower levels. These are 1) intervention to make local goals conform more closely to national ones, 2) information dissemination to make local expectations of the outcome of actions in national disfavor seem less attractive or those in national favor seem more attractive, and 3) constraint intervention to complicate or make impossible local implementation of alternatives in disfavor at higher levels. The federal flood control program has used all three.

One goal intervention is found in the subsidization within the federal flood insurance program of flood insurance for buildings that were constructed in the floodplain before the program began but only if the community (city or county for rural areas) has adopted a floodplain management program certified by the Federal Emergency Management Agency (FEMA) (formerly by the Federal Insurance Agency, FIA) as adequate under 24 CFR 1910.3 (c) and/or (d) and 24 CFR 1910.5. Communities with significant flood problems are thus pressured to adopt strong management regulations, not because they really believe them needed, but so that their citizens can obtain the insurance and thus reduce their expected flood loss.

A second goal intervention is found in the direct subsidy to pay the cost of nonstructural program components. The flood proofing of existing buildings may be outside the financial capabilities of the owners even though analysis shows economic justification by benefits in excess of cost. Partial federal payment of the costs can then alleviate the shortage of funds. Individuals, who make comparisons in terms of out-of-pocket expenditures, will be more likely to flood proof.

The federal information dissemination effort has sought to reduce floodplain occupancy by broadcasting the results of hydrologic and hydraulic studies to map flood hazard areas. The program reduces the number of people moving onto the floodplain unaware of danger, but the results have been less than successful from the national viewpoint because many people are willing to assume greater risk than they should according to the accepted national viewpoint. McCrory et al. (1976) estimate the average annual expected damage to a home just outside the margin of the average 100-year floodplain to be about 0.23 percent of its market value. They then cite survey results of Atlanta floodplain residents indicating that the average person seriously considers moving off the floodplain when experienced average annual damage reaches 2.0 percent, and they estimate that the threshold value for moving onto a floodplain would be about 1.0 percent. Disseminated flood risk information is thus not going to disuade people from moving onto mapped floodplains where the risk lies in this intermediate range between 0.23 and 1.0 percent. In Utah, the highest risk found by Woolley (1946, p. 57) in compiling 89 years of flood history was about 1 in 15 or 6.67 percent. Most risks are far lower, and Utah probably has, because most flooding is quite shallow, a larger percentage of its mapped floodplains having risks less than 1.0 percent. In fact shallow flooding suggests less than the average damage rates of 0.23 percent. The conclusion must be that flood hazard information can generally be expected to be less effective in Utah than in most places in reducing floodplain occupancy.

One constraint intervention that the federal program uses to influence local decision making is a policy to install structural measures only when supplemented by appropriate nonstructural alternatives (Water Resources Council 1979, p. 30211). Other constraint interventions are provisions in the Flood Disaster Protection Act of 1973 that prevent many lending institutions from financing floodplain development in communities without approved nonstructural program and the provisions of Executive Order 11988 (May 24, 1977) which require federal agencies to avoid floodplain occupancy or actions that stimulate floodplain occupancy by others.

State and Local Influencing Modes

The chief ways that lower echelons have to influence higher levels in a hierarchy are to 1) apply for technical or financial assistance, 2) use political influence within the decision making process, and 3) interact, either informally or through institutionalized public participation processes, with agency employees charged with program administration. All of these avenues are frequently used in flood control. Communities and individuals seek federal assistance of many sorts and use their political influence to promote favorable responses to their requests. Technical people working for communities interact with counterparts in federal agencies, and individuals with special problems often bring these to the attention of government officials.

Guidelines for Formulating a State Program

The need for Utah to become more active with respect to flood control is strongly related to the fact that national decision making biases the federal program toward needs in average flood hazard situations whereas Utah situations are not typical of others nationwide. The problems caused by this difference in physical context, as well as by any differences in goals, are accentuated by the lack of resources in local government to formulate well-structured policies and negotiate differences with the federal government on anything like an equal basis.

If Utah is to become more active, the effort should focus on targets where it will be cost effective. Specific recommendations for formulating a targeted state action program require a standard that can be used to assess the effectiveness of proposed actions. The standard should ideally be defined through a political process in which value judgments balance pros with cons while interacting to a consensus. The standards used to formulate structural flood control projects and the rules used to manage the flood insurance program have resulted from these sorts of interactions at the federal level. This study to define a state role needs to consider the differences in the standard one could expect from a Utah consensus.

The federal flood control program was formulated from a national viewpoint and yet requires cooperative implementation at levels from the federal government, through state and local jurisdictions, to individuals making their own floodplain occupancy decisions. The fundamental problem for the federal government in implementing its flood control program lies in this separation between the locus of decision making for policy formulation and the locus of control for implementation of the selected measures. Since states have even less control, their problem in this regard can be expected to be even greater.

Study Objectives

The general study objectives are 1) to identify where the existing flood control effort in Utah is unsatisfactory from state and local viewpoints and 2) to determine what state government might do to improve the total flood control effort. Specific subobjectives include the following:

1. To identify situations in which the current program is proving unnecessarily elaborate and costly from the state and local viewpoints and suggest courses of action for the state that would help reduce the program to become more in tune with local needs.

2. To identify situations in which the current program is not providing adequate protection from flood hazard from the state and local viewpoints and suggest courses of action for the state that would effectively expand the program to meet these needs.

3. To recommend any further studies needed to refine our understanding of situations and alternatives in order to proceed with the above determinations.

Study Organization

The organization of the material to follow begins in Chapter II by presenting a framework for understanding the dynamically interactive feedback processes through which people seek benefits from floodplain occupancy, experience sequences of flood events, and respond by modifying their occupancy or the pattern of flooding. Through these processes, society balances benefits against risks. Efforts made by government to alter this balance generate additional impacts, some beneficial and others detrimental. The result is a foundation for use in deciding how to weigh the de facto balance between benefits and risk and governmental efforts to change this balance from the Utah perspective.

The study then proceeds to describe the existing situation in Utah. Chapter III summarizes empirical data on flood risk. Chapter IV examines the decisions being made at the national, local, and individual levels to reduce the hazards of floodplain occupancy. Chapter V surveys situations in selected Utah communities. Chapter VI probes selected situations in greater detail to try to find causes for the identified problems. The final chapter analyzes the information presented in the earlier chapters through the framework of Chapter II to identify needs for program improvement.

CHAPTER II

A CONCEPTUAL FRAMEWORK FOR DEFINING A STATE PROGRAM

Introduction

The policy objectives for flood control or any other program area in a democratic society should express public preferences. Formal processes to set objectives should provide concerned citizens opportunity to express their preferences and lead to an unbiased resolution of revealed differences. Actual consensus-seeking processes fall short of this ideal; and, more important for the purposes here, political consensus making is only capable of setting public policy with respect to a few topics simultaneously. This means that the issues with respect to a given program area must reach a certain level of salience before they surface politically. Flood problems in Utah have not been sufficiently salient for this to occur.

This historical lack of political salience means that flood problems in Utah are handled administratively rather than politically. Action in the executive branch of state government is important because floods can bring disaster, flood programs formulated at other levels can have important adverse consequences for the state, and it is in the public interest for government to act to remedy incipient problems. Action requires identifying incipient problems and moving to prevent them from magnifying. Specifically, it is in the interest of the people of Utah to prevent excessive flood damages or dissatisfaction with a national flood control policy from increasing to the point of becoming an important statewide political concern.

Decisions throughout both the public and private sectors interactively determine floodplain land use, flood hazard, urban growth patterns, etc. It is these decisions that could, if unwatched, generate political issues in Utah. The decisions that are being made need to be examined with respect to their potential for leading to future problems, and the interactive processes generating the problem decisions need to be examined in order to define alternative approaches for counteracting them.

This chapter begins by presenting a conceptual framework for understanding the impact of flood events on a local community and the responses made at various levels to those impacts. The analysis goes on to examine the reasons for differences among the various groups working to solve flood problems at different levels and how those differences can be amplified by a dynamic interactive feedback process. Finally, the current state flood control program is described and used with the above background as a foundation to suggest promising directions for improvement if supported by needs revealed in the empirical descriptive data to follow.

Components of the Conceptual Framework

Initial Conditions

At any given time in any given floodplain, some state of occupancy and hazard to that occupancy exists. The occupancy can be defined in terms of the physical use and environmental state of the floodplain. The occupancy provides some amount of economic gain (or loss) to the occupants and also provides certain social satisfaction (or dissatisfaction) not easily translatable into economic values. Very severe events pose some risk of cultural or governmental change that create uncertainty and may substantially add to the loss. The occupants hold some mix of cultural values and are ruled by some hierarchy of governments. The hazard can be defined by integrating these occupancy conditions with the hydrologic risk and expressed in terms of expected (in the probabilistic sense) average annual economic loss. Added dimensions can be specified in terms of expected environmental or social loss.

The Stimulus

At any point in time, a flood may occur, a new reservoir may be built, extensive new urban development may occur upstream, a strict floodplain zoning law may be passed, an individual may flood proof his house, or a state flood control planning program may be inaugurated. All such stimuli can potentially change the floodplain conditions. The change may follow the action or precede it as people anticipate the action in advance. As an example of the latter, people begin to react to plans to build reservoirs long before those plans culminate in construction. For this study, the establishment of an expanded state flood control planning program is the stimulus to be examined.

Consequences

The consequences of the stimulus may be defined as the changes that it causes to the initial conditions. All changes are theoretically relevant; but for practical evaluation, one must define a lower threshold below which consequences will not be noted. The consequences may be conveniently classified along the five dimensions of Figure 1 (Larson et al. 1979). In each dimension, the consequences or impacts are first experienced by individuals who find that the stimulated changes have past their detection threshold. More severe stimulations cause consequences that pass the thresholds of larger groups.

Levels of Impact

Society functions (whether informally or through formal organizations) at many levels. For example, the functions of government are exercised at levels from small communities or special districts up to national governments and the United Nations. Each higher level (e.g., state) is an aggregation of lower level units (e.g., counties).

The consequences which are first experienced at the lowest level of the individual person aggregate to be experienced at the next higher level provided that the aggregate effect passes the detection threshold of the higher level. As shown on Figure 1, effects on individuals can potentially aggregate to effects on household groups, and on to larger groups with the highest level effects being of national or international significance.

Dimensions of Impact

Five impact dimensions are shown on Figure 1. Impacts in the physical-environ-

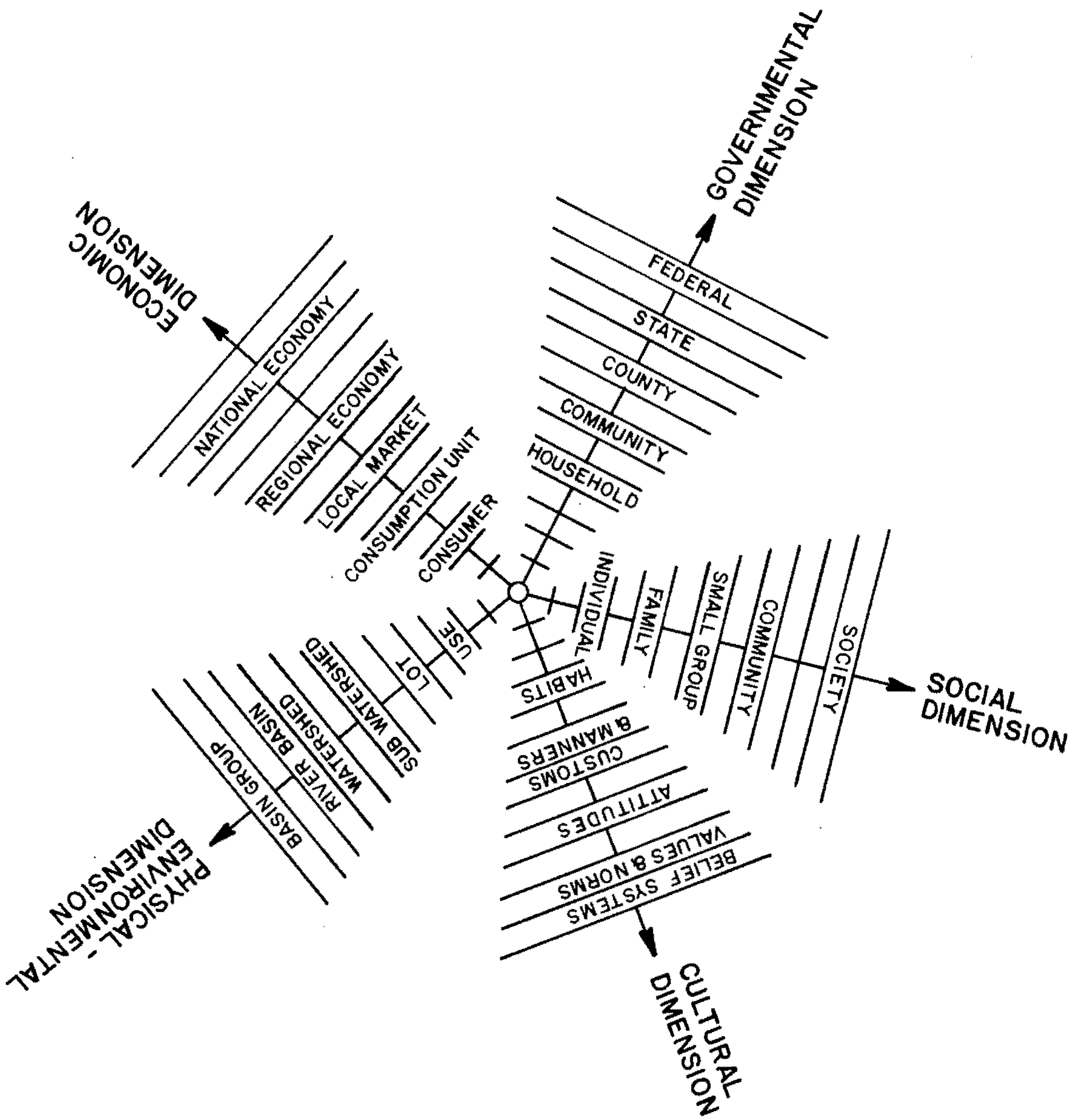


Figure 1. Impact dimensions of an implemented action.

mental dimension begin at the first level with changes in suitability of small areas for given uses because of changes in land forms (e.g., through construction), flood hazard, or natural environment. Changes in small areas alter overall use of a lot by an individual. As many lots are affected, consequences aggregate (through hydrologic, ecologic, meteorologic, and other linkages) to affect subwatersheds and eventually larger areas.

A given stimulus turns out to be both necessary and sufficient to produce certain impacts and a contributory cause to many more, and the degree of contribution generally lessens at progressively higher levels. As the degree of contribution decreases, the difficulty increases in assigning or blaming an impact to a considered or implemented action for planning or monitoring purposes.

Impacts in the economic dimension begin at the first level as the stimulus causes consumers monetary loss or gain by causing them to buy (e.g., supplies for flood proofing), sell (e.g., property at hazard), or live in a lower state of satisfaction. The buying and selling affect firms supplying or purchasing the goods. Effects at a higher level are the sum of those experienced by component lower level units.

In the cultural dimension, individuals change their perception of good behavior as they observe events in nature and the actions of others. As the stimuli are greater, more frequent, or affect more people, additively and interactively, changing attitudes change beliefs, values, and eventually cultural norms.

Socially, stimuli alter individual satisfactions with the quality of life and cause life adjustments other than those expressed as consumers make marketplace decisions. Changes in life quality experienced by individuals aggregate as changes for families, small social groups, communities, and eventually to society as a whole.

In the fifth and final dimension, individuals may change the ways they govern their own lives. The next level of government may be thought of as the household where decisions are made on conduct for family members. Household decisions, whether by voting or interaction with public officials, can influence the rules used to govern communities; and these interact to change rules at higher levels all the way up to the national.

Loci of Decision Making

Each impact node (level along a dimension) is also a locus of decision making for reacting to the impact. A consumer, for example, does not ignore the effects of the stimulus on the markets in which he buys and sells but rather evaluates any changes in the price or availability of goods and alters his decisions to buy or sell accordingly.

At the first level, a locus of decision making exists for every individual. He makes decisions in all five dimensions; each decision is influenced by consequences perceived in all five dimensions. As examples of decisions in the five dimensions, the individual may alter his use of the land, buy or sell different items for different amounts, modify his pattern of behavior, interact differently with others in order to achieve personal or group goals, and communicate new desires by contacting key individuals in various levels of government. Obviously, decisions made in one dimension affect those made later in others, and this is the reason for showing all five in Figure 1. For example, cultural change can have a major impact on the success of federal nonstructural flood control programs.

At the first level of decision making, individuals responding to larger stimuli can number in the millions. At higher levels, the loci are fewer, the actors participating in the decision making at a given locus are more, and the decision making process is more formal. Decisions are influenced by actions taken at lower levels and constrained by rules made at higher levels. The actors participating in group decision making at a given higher locus vary greatly in the amount of effort directed to collecting and analyzing relevant information either directly or by using technical staff, thought given before taking a position, goals, previous alliances, depth of conviction, and influence. The decisions of the group are determined by the individual positions and the interactions among the actors. Each decided action (and many expectations of probable action) becomes a new stimulus and generates new impacts in the five dimensions.

One message of this paradigm is that the decisions which determine floodplain occupancy and the hazard to that occupancy are not all made at the federal level in the governmental dimension. That is probably the most influential single locus, but it is far from the only one. Since it is but one of many decision making loci, the effectiveness of the federal program is largely determined by how well it complements and how much it conflicts with the decisions being made at all the other loci.

Alternatives

Decisions are made among alternative courses of action in order to change existing conditions or reduce changes that would otherwise occur. The alternatives may either be options which can be exercised directly at the locus of decision making or desires for action at some other locus. In the first case the decision maker follows through to implement his decision, while in the second case he tries to influence others. As examples of the latter, individuals express desires for action they would like to see taken at higher levels, and higher level loci generally expect lower levels to comply with their choices. In either direction, the alternative courses of action become alternative means of exercising influence on other decision levels. The higher the level of a decision locus, the more it will have to rely on exercising influence rather than direct implementation. Governmental nonstructural flood control programs are essentially efforts to influence lower level decision making, and the alternative courses of action are alternative means of exercising that influence (James 1975).

Relevant Information

The information relevant to deciding among alternative courses of action is that describing differences among the consequences they stimulate. Information on situations that would be the same no matter which alternative is chosen is irrelevant. To be practical, small differences must be ignored, and relevance is defined in terms of a difference large enough to matter to the decision maker. Some individuals are more sensitive to differences in one dimension (e.g., economic) while other individuals are more sensitive to differences in other dimensions (e.g., cultural). Decision makers vary in their threshold of what matters. Consequently, information that seems relevant to one seems irrelevant to others.

Guidance for Decision Making

Decision making processes vary all the way from instantaneous snap judgments made by individuals unaware of many of their alternatives and uninformed or misinformed as to the consequences of the actions they select, to, at the other extreme, a long, carefully considered process of defining alternatives, eliminating infeasible ones, and choosing from among the optimal and near optimal through interactions within a collective body of decision makers. While the magnitude of the effort does not alone determine the wisdom of the decision, decision making is generally improved by accurate information on relevant points and sound analytic procedures.

The most commonly used guidance system at the higher levels in the private sector is the engineering economy study. Public sector water resources planning adds inputs from welfare economics to evaluate alternatives through the framework of benefit-cost analysis (James and Lee 1971) or multiple objective planning (Haimes 1977). According to the framework of the Principles and Standards (Water Resources Council 1973, 1979), values are expressed as basic principles, and all the rules in the standards and procedures and their interpretations in program administration are the guidance system. The environmental impact statements required by the National Environmental Policy Act of 1969 are supplemental guidance information.

These guidance systems need to be considered as they relate to the five impact dimensions of Figure 1. Decision making at a locus associated with each impact dimension, as shown in Figure 2, emphasizes a different feasibility question and optimization goal. In the physical-environmental dimension, the feasibility assessment determines whether it is physically or environmentally (biologically) possible for the action to achieve the desired results. Many would separate physical or engineering consequences from environmental or ecological consequences, make an economic appraisal of the first, and consider the second as a constraint. The purpose here is not to advocate either approach but rather to note that actions generate consequences which can be predicted (with varying degrees of certainty) and that the nature of those consequences determines whether the desired results are possible. The probability of achievement is essentially a scientific determination. One example of optimization in this dimension alone would be a determination to add irrigation water until maximizing crop yield.

Commonly used guidance systems also consider the economic dimension of whether the action will pay (from the viewpoint of the decision locus). A more limited view of this general question of economic feasibility is the question of will it pay in ways that will monetarily recompense those who pay the bills. Optimization in this dimension is to maximize net benefit (or net revenue from the more limited financial perspective). One would stop applying irrigation water when the value of the increased crop yield no longer exceeds the cost of the water.

Guidance procedures commonly used for flood control planning explore legal feasibility in the governmental dimension but do

Dimension	Feasibility Question	Optimization Goal
Physical-Environmental	Is it possible?	Maximize production
Economic	Will it pay?	Maximize net benefits
Social	Is it wanted?	Maximize net satisfaction
Cultural	Is it allowed?	Minimize conflict
Governmental	Is it legal?	Maximize public welfare

Hough, Granville W., "Technology Diffusion," Mt. Airy, Md.: Lomond Books, 1975, p. 33, 406 p.

Figure 2. Feasibility issues by impact dimension.

very little with the social and cultural feasibility questions and optimization goals shown in Figure 2. This very fact may cause considerable difficulty in coordinating federal plans with the actions of individuals because decision makers using informal guidance procedures are likely to concentrate their attention on these dimensions. Any state flood control effort should carefully establish a suitable guidance procedure and modify it as applications suggest promising improvements. An arbitrarily guided state effort is highly unlikely to be productive.

Differences Among Decision Loci

Limitations in Use of Guidance

No decision making locus uses a comprehensive and fully objective guidance procedure. Much relevant information is never obtained because it is too time consuming or costly to collect. Information storage and retrieval systems are not capable of delivering all useful data expressed in understandable terms for every decision making need. Many consequences of the alternatives being considered cannot be credibly predicted, in large part because of the change that exogenous events and decisions made at other loci cause in the situation context over a period of analysis. Explicit techniques are not available for dealing with the diminishing causality attributable to an initial effect with the passage of time (Larson et al. 1979). Finally, forecast consequences cannot be fully expressed in terms of gains and losses within the framework of a generally accepted value system, and conflicting value preferences cannot be reasoned to an objective conclusion.

In addition to these technical limitations to the current state of the guidance art, limitations which can be overcome by technological and analytic advances, a more fundamental problem is found in the fact that people feel more comfortable with decisions tempered with human judgment. The very the suggestion of a comprehensive and objective mechanical guidance system to replace human decision making scares people. We fear a mechanical optimality devoid of truly human values, a dictator that will make us do what is "best" whether we like it or not, and the possibility that someone will remold the system for personal gain.

Resource management decision making is expected to combine objective analysis with subjective evaluation of intangible considerations. The practical factor controlling the combination of the two is that the amount of information which can be obtained through objective guidance procedures overloads human decision making. Consequently, human decision makers select which guidance they will use and which they will ignore.

The process used to select how much of the total body of available or obtainable information to use in decision making may be called a perception filter. The filter is seldom a conscious selection of which identified facts to use but rather the outcome of accumulated experience with facts ignored without ill effects.

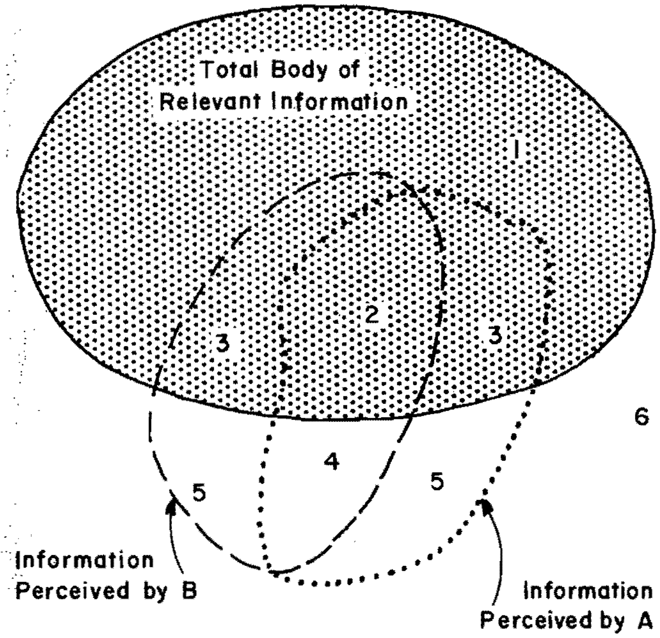
Operationally, each actor only uses information that he perceives relevant to achieving his goals, considering the capabilities and resources he has available (Bates 1965). The filtered-down guidance system, called a perspective by Moline (1968, p. 95), 1) limits the operational goals used to ones the decision maker feels comfortable in pursuing, 2) operationalizes specific evaluative criteria to pursue those goals, 3) regards information outside the scope of those evaluative criteria as irrelevant, 4) biases interpretation of incoming information in favor of the defined goals and favored alternatives for achieving them, and 5) leads toward alliances with others of common perspective. Each actor is relatively open to external inputs when he is inexperienced in a given area of decision making and, over time, filters out increasingly more information. Only an experience of ill effects because key facts were ignored is likely to reverse the trend and broaden one's perspective.

It is thus the adopted perspective, not relevance as defined objectively, that determines what is considered or not considered by a given actor at a given locus of decision making. Consequently, different actors, who have different experience histories, adopt different perspectives and come to conflicting decisions among the alternatives.

It is the perspective of actors at the federal level on the governmental dimension of decision making that filters the information used in formulating federal flood control policy. It is the perspective of a local government that sets community policy on floodplain management. It is the perspective of an individual that determines his reactions to the federal and community programs. Obviously, the perspectives are going to differ among these levels and among loci (communities or individuals) within a given level. Assuming that Utah is not interested in the direct implementation of a structural flood control program, a state flood control program can only reduce flood damages by changing perspectives so that decision making by others changes floodplain occupancy decisions or flood hazard situations.

Differences in Information Used

The total body of information relevant in that it describes differences among alternatives may be represented by the shaded area in Figure 3. When decision makers A and B choose among the alternatives, they a) do not perceive all of the differences, b) perceive some consequences as different which in fact will not be, and c) vary in the



Summary of Six Information Types

1. Relevant information not perceived from either perspective
2. Relevant information perceived from both perspectives
3. Relevant information perceived from only one perspective
4. Information that is not relevant even though it is perceived so from both perspectives
5. Information that is not relevant even though it is perceived so from one of the perspectives
6. Information that is not relevant and is not perceived relevant from either perspective

Figure 3. Conceptualization of overlapping information sets.

differences they perceive. The difference in perception filters between the two leads to differences in the information considered relevant and to classification of the six information types shown on Figure 3.

Several applications of Figure 3 apply to the floodplain management problem:

1. Type 1 information implies decisions made in ignorance of their consequences. A large body of Type 1 information suggests an opportunity for state government to obtain this information and disseminate it to the decision makers so that they are less likely to be caught unawares.

2. Type 2 information is relevant and perceived by all decision makers. Any floodplain management program must in order to alter floodplain use decisions do one of a) add to the Type 2 area (distribute flood hazard information), b) change consequences in the Type 2 area (impose fines on nonconforming land uses), or c) change perceptions of those consequences (create an atmosphere of social nonacceptability). For the many property managers on a real floodplain, the Type 2 information, that is perceived by all of them, is likely to be quite small. This situation leaves the implementation alternatives of adding to the area or working with Type 3 information that pertains to most of the decision makers. One potential state role is to make sure that federal implementation efforts do not conflict with state interests.

3. Type 3 information is relevant and perceived by some but not all of the decision makers. Many times, only a few floodplain users disregard floodplain management programs. If the Type 3 information they perceive can be identified, changing these consequences or perceptions of them, particularly when it can be done economically, may be the most cost effective implementation method.

4. Type 4 information relates to consequences perceived by all decision makers as varying among alternatives even though it really does not. Operationally, floodplain management programs could supplement or alter Type 4 as well as Type 2 information, but ethically one should question efforts to influence others by disseminating false information. Type 4 information works to bias floodplain land use decisions and consequently suggests a possibly important state role of disseminating correct information to reduce these misconceptions.

5. Type 5 information is perceived as varying by some decision makers even though it does not. Better floodplain land use is furthered by eliminating these misconceptions as well.

6. Type 6 information does not pertain to the decisions at hand and no one thinks that it does; however, one continually finds a great deal of space in government reports on flood control alternatives and environmental impact statements in particular taken by Type 6 information. Every effort should be made to direct studies toward more productive information gathering.

7. One of the many units involved in a flood control program is the state itself. If the state is to have an effective program, effort needs to be made to expand state perception of relevant information and reduce state-perceived consequence differences that do not exist.

Elements of Perspective

Since floodplain management program implementation is made more effective by better understanding of how decision makers vary in the information they consider relevant to floodplain use decisions, a taxonomy for defining how perspectives vary can be very useful. Larson et al. (1979) define perspective in terms of four elements: range of actions, scope of control (jurisdiction), favored values, and time frame. The summary descriptions of these elements for the five principal participants noted in Chapter I in the National Flood Control Program can at this point be considered in greater depth.

The range-of-action element is established by the actions that those holding a perspective have the power to implement. At the federal level, structural agencies can provide or withhold structural measures or technical or financial resources to supplement certain local nonstructural activity. The Federal Emergency Management Agency (FEMA) can use incentives to promote community flood control programs. Communities can implement local structural flood control programs and employ floodplain zoning and regulation of building practices. Decision makers at the individual level vary in perception from those who see themselves entirely at the mercy of flood disasters to those with faith in their ability to plan their land use and construction practices so as to go relatively unharmed no matter what floods occur (James et al. 1971). Decision makers at all levels only employ actions within their range. Consequently, each is more interested in information that affects the performance of actions within his range than in information that primarily relates to other sorts of action.

The scope-of-control element defines the geographical area in which a group can act, the extent of its functional expertise, and the degree to which it has the power to implement that its plans. At the federal level, the construction agencies have proven power to construct and maintain structural measures as designed. The insurance program does not yet have a proven track record of achieving sustained successful community floodplain management programs and is considerably disadvantaged by the fact that instead of being able to implement with its own forces, as do the structural agencies, it must influence each community to influence its citizens. An indirect implementation process is always far less controlled than is a direct one. With respect to function, the structural agencies have long been weak in capabilities related to land use management but have recently made significant staff expansions to remedy this deficiency. FEMA has suffered from weakness in hydrologic and engineering capabilities. Communities vary greatly in strength and weakness of functional expertise and are as a rule weaker in technical areas than are their federal counterparts. As is the case for the federal government, community expertise is normally divided between engineering departments responsible for structural measures and planning departments responsible for nonstructural programs. At the individual level, functional expertise and financial resources are very limited, a lack that causes many actions to be taken which later fail to function as intended (physically-environmentally infeasible). As one goes to higher levels (Figure 1), one finds the principal feasibility constraints to tend to move from technical and financial to social and cultural. As to the geographical aspect of scope of control, the higher levels serve larger areas and find themselves constrained by pressures for uniform policy to treat all areas equally despite variations in local needs. The lower levels identify with the specifics of a particular local situation.

The favored-value element describes the objectives pursued. The federal agencies responsible for structural flood control follow the Principles and Standards of the Water Resources Council (WRC 1973, 1979). The Federal Emergency Management Agency is one of two agencies with major water resources management programs (the other being the Environmental Protection Agency) that does not use the Principles and Standards. The program is managed to promote floodplain management the country and make flood insurance available to all who want it and does not require feasibility analysis to determine their appropriateness in specific floodplain situations. State and local goals are not explicitly defined, tend to be somewhat volatile as leadership changes through the political process, and are generally oriented toward the needs of the local people. Individual goals vary widely from person to person and change over time. Many value conflicts are found at lower levels but are resolved at the higher levels as actors give and take in group decision making. Nevertheless, value conflicts become an extremely important obstacle to implementation of a cooperative program such as floodplain management. The program was defined by national values and then is to be implemented at state, local, and individual levels, where those holding different values are inclined to occupancy decisions that conflict with preferences determined by planning at the national level. Some compensating incentive is needed to bring the local actions in line, and development of effective incentives is the one key to successful federal programs.

The time frame element of perspective has become standardized at 50 years for planning federal structural flood control measures and has not been defined but is implied to be quite long for the federal nonstructural program. Lower levels of decision making generally plan toward somewhat shorter time horizons, and this difference in time frame complicates reconciliation of differences in values.

Classification of Conflict Sources

The decisions affecting floodplain occupancy and hazard being made at the many loci often conflict or lead to efforts that influence others in conflicting directions. When such conflicts occur, one needs to identify their sources as a first step in correcting the situation. If this is done, most conflicts can be identified with differences in perspective among decision makers. The four elements of perspective thus provide a convenient taxonomy for understanding the conflicts. As shown on Figure 4 (Larson et al. 1979) and described most extensively by those authors, one obtains a suggestive list of conflict sources that can be examined more thoroughly when specific conflicts are identified. For example, identified conflicts between federal flood control programs and desired state programs may become attributable to specific sources, and knowing which ones can be helpful in resolving the conflict.

Decision Dynamics

Overview

The immediate impacts of a stimulus change with time as the stimulating force moves from a prediction, to an experience, to a continuing situation. They wax and wane as the stimulation intensifies or withdraws. It then takes time for the impacts to aggregate from lower to higher levels where perceptions of them are delayed and averaged over time.

	Temporal	Values	Jurisdiction	Actions
Temporal	Different horizons Conflicts in sequencing coordination	Short run vs. long run goals Value changes Salient and satiation cycles Time lags in value aggregation	Changing boundaries Creation and termination of agencies Changes in authority	Sequencing of actions Implementation time lags Technological advances Changes in staffing expertise Changes in financial resources
Values		Polarities and affinities Different orderings Aggregation Acceptability of conflict resolutions	Aggregative and distributive effects Assignment of appropriate functions Local interest variations	Criteria of achievement "Accidental" conflicts
Jurisdiction			Aggregation Integration Externalities Duplication and overlap Creation and termination of agencies Area vs. function	Coordination Duplication Capacity and utilization Thresholds
Actions				Exclusivity Specialization Unintended consequences

Figure 4. Conflict types associated with various differences in elements of perception.

The impacts from one stimulus can never be separated from those of many others because exogenous events don't wait for an impact to stabilize. They continue to occur. The reactive decisions at a given locus change not only in response to fuller understanding of the impacts of past actions, but also as exogenous events cause new impacts. In many cases the decision maker does not even try to sort out the various causes of the situation before reacting.

Some impacts perceived at a decision making locus are considered favorable, and decisions are made to reinforce perceived causes of their happening. Other impacts are considered undesirable, and decisions are made to counter their causes.

As time goes by, an impact must be credited less to its first cause (e.g., dam construction) and more to subsequent reinforcing actions (e.g., maintenance and operating policy). Thus when one projects impacts over 50 years for estimating benefits, he is mixing certain consequences with other consequences to which the initial action is a contributing cause; and there are no generally accepted rules for determining when a level of contribution has dropped to a point where it should no longer be counted. One can say, however, that a longer time lag from the cause to the effect reduces the probable degree of contribution. This is only another way of saying that predictions become more uncertain as they are extended further into the future.

As time passes, the above continuous, dynamic interactions in multiple feedback loops (Forrester 1961) change the current state of floodplain occupancy and hazard to some other state. Any representation of this process must consider not only the feedback dynamics within the process but also such external actions or changes as those in nature (e.g., major floods), cultural norms, social values, national economic and fiscal policy, federal programs in areas other than flood control, etc. Knight (1971) attempted to model water quality dynamics with such a feedback system, but no one has attempted holistic modeling of the dynamics of floodplain occupancy even though considerable basic data have been collected and used in specialized modeling (Kates 1962, Doehring and Smith 1978, Andrews et al. 1978, Hopkins et al. 1976, Morin and Shin 1977).

Flood Impacts

Flooding inflicts adverse impacts in the five dimensions of Figure 1. Events are large enough to be a problem when they are detected in any of these dimensions. An event is first experienced at the lowest or first level as individuals find the physical and environmental characteristics of their property or of areas in which they engage in various activities changed (physical-environmental dimension), suffer monetary loss or spend money to rectify physical or environmental changes (economic dimension), suffer loss which cannot be evaluated monetarily (social dimension), experience dissonance when reflecting how their own past actions or behavioral patterns have contributed to the loss (cultural dimension), and resolve to change their behavior to make themselves less vulnerable in the future (governmental dimension). The physical-environmental impacts may be caused directly by inundation by the flood water or indirectly through flood-caused disruptions to communication or transportation facilities, market place transactions, etc. In numbers increasing with the size of the flood, individuals experience some or all of these kinds of impacts, and the experiences of no two individuals are identical.

The first level impacts aggregate as the individuals who compose a given second level unit share their experiences and work to overcome common problems (or potentially dispute over what should be done, even to the point of causing a rearrangement of unit membership). Any one individual belongs to a number of second level units. For example, if the flood forces closure of a place of employment, an individual may share at the second level in the physical dimension with his fellow workers, in the economic dimension with his family, in the social dimension with his friends, in the cultural dimension through his church, and in the governmental dimension through his community. In some dimensions, an individual may be a member of more than one second level unit (e.g., he may have more than one circle of friends).

The aggregation process at the second level in a given dimension sums the impacts in that same dimension experienced by members of first level units. The aggregation is affected by information on impacts suffered by other units and by members of the unit in other dimensions. Similar aggregation processes occur as one goes from the second to the third level and upward to the higher levels.

The aggregation from a lower to a higher level in a given dimension may be linearly additive or nonlinear in either the expanding or the damping direction. For illustration in the economic dimension, the total loss to a consumption unit (the second level unit defined in the economic dimension on Figure 1) may simply be the sum of the losses to unit members. If the total membership of the consumption unit (perhaps all the wage earners in the family) do not have the financial resources to cope with the loss or the market cannot supply the need (Yancey et al. 1976), they may seek help from other units, often at a higher level, and the aggregation process is an expanding one. If the losses are small enough such that the members of the unit are through sharing able to bear them, the aggregation process is a damping one.

The expectation would be for the aggregation to be expanding where most of the lower level units experience major impact because too few of the others within the higher level unit would have excess capacity or resources to help. Since each higher level of aggregation has more first level units in its total membership, eventually the process will bringing in units not affected by the flood; and at this level, the aggregation will begin to become damping. At still higher levels, the damping may be sufficient for the flood not to have even been noticed. It is this damping capacity that protects society as a whole from the periodic shocks devastating to subgroups within it.

It is also important to note that flood event impacts are more likely to aggregate to the higher levels before damping out in some dimensions than in others. A flood is more likely to come to the attention of federal officials in the governmental dimension than it is to affect cultural norms.

One goal in describing the impacts of Utah floods through the empirical data in the chapters to follow is to observe the level of aggregation at which various magnitudes of losses are being absorbed in the various dimensions. As example questions of interest, how frequently do floods occur in Utah? What sizes of floods occur? How large an area is affected by a given flood? What likelihood exists for several major floods occurring simultaneously over the state? At what levels have the flood impacts of recent years been absorbed in the various dimensions? What chance is there of larger floods in the near future creating larger impacts that extend to higher levels in the various dimensions?

Flood Control Program Impacts

As outlined in Chapter I, the five principal participant groups in the Utah flood control program are 1) the federal construction agencies, 2) municipal stormwater control programs, 3) the federal flood insurance program, 4) municipal planning efforts, and 5) individual property management decisions. Decision making units within each of these groups respond to perceptions of flood impacts in ways that generate impacts in all five dimensions. From the state viewpoint, both the flood and response impacts need to be watched, lest either lead to undesirable situations from the state perspective. The perceptions (Figure 3) that guide responses to flood problems are important because of the clues they provide for targeting state actions. A general review of the perceptions and how they guide the responses thus provides background important for interpreting the empirical data of the following chapters on the de facto flood program and hazard situations in selected Utah communities.

Federal construction agencies. The federal flood control construction program seeks to maximize national economic development and environmental quality objectives within the constraint that project benefits must exceed costs (Water Resources Council 1973, 1979). Economic goals are national in that benefits are only counted if they are not offset by losses elsewhere in the nation, and environmental goals are set in large part by a national environmental perspective. Project economic benefits do not have to be perceived nationally; they only have to be shown to exist nationally through a formal evaluation procedure. Afterwards, the impacts of the alternatives in the other dimensions are discussed in a public participation process. Finally the formulated projects, if acceptable, are authorized and the money appropriated by the national congress.

From a state perspective, a different project may be preferred because 1) economic optimization from the national viewpoint differs from economic optimization from the state viewpoint insofar as costs are paid by out-of-state taxpayers or project consequences occur out-of-state, 2) the environmental values of Utahns differ from national norms, or 3) impacts in the other four dimensions are viewed differently by the people of the state than they are by the people of the nation.

The federal flood control program has the potential for significant impacts in the physical-environmental dimension as projects are built, in the economic dimension as construction money is brought into the state and, with new federal cost sharing requirements, taxes are increased, and in the social dimension as families are displaced. Cultural impacts grow out of public favor or disfavor for the program because of flood damages reduced, environmental impacts, tax payments required, etc.

Municipal stormwater programs. Even though the technical design and management of municipal stormwater drainage systems are responsibilities of local government, designs and management practices are biased toward the national, as opposed to the state, viewpoint, by national technical standards. A more important problem, however, exists in the smaller design floods used for stormwater drainage as opposed to flood control design. Drainage systems designed to contain the 10-year flood also collect water during larger storms and may actually make conditions worse during the 100-year event. Another problem from the state perspective is that community drainage systems may not be coordinated at community boundaries. Monitoring the design and management of contiguous systems may be very important for overall workability during both ordinary storms and such large events as the 100-year flood. Another monitoring consideration is that the actions of one community may also impact other communities in ways they don't like in dimensions other than the floodwater aspect of the physical-environmental dimension.

Federal flood insurance. The federal flood insurance program, like the federal construction program, imposes national choices. Furthermore, the potential for conflict is greater because the communities are required to enforce the nonstructural measures. Some communities may perceive their loss in not being able to develop a floodplain where the hazard is relatively low as far greater than any flood damage reduction benefits gained. They may also experience greater difficulty in influencing FEMA to modify their requirements to match local needs than they do when dealing with the construction agencies. Culturally, Utahns are quite willing to resist perceived unreasonable federal regulation.

Municipal planning. Municipal planning is guided by some combination of scientific explanations of the consequences of certain actions, national norms on acceptable community designs, and preferences of the residents of the municipality. The plans impact a number of people in the economic dimension (Vault 1975) and possibly in the social dimension adversely. Others gain. The resulting conflicts raise questions in the cultural dimension as to the equity of the community forcing citizens to suffer uncompensated losses, and some of these may require judicial resolution in the governmental dimension. Since few municipal planning groups have much expertise in flood related technology, the state may have an important role in providing technical support or in monitoring planning decisions for probable adverse impacts on flood problems.

Individual property management. Previous studies have shown that individual property management choices place little weight on flood risk if losses have not occurred in the last seven years (James et al. 1971). Rather, the choices are based on other factors with the probability being that social and physical-environmental factors predominate for choices relating to place of residence and economic factors predominate for choices relating to agriculture or other business properties.

Governmental groups are prone to see many private choices as placing too little weight on flood hazard (McPherson and Saarinen 1977) and leading to disasters requiring very expensive relief or structural programs. This viewpoint leads to special efforts by government to remedy the deficiency by protecting people from themselves. The effort reduces the income from floodplain use and leads to equity and judicial conflicts.

Some individuals may elect to deal with their flood problem by individual flood proofing. Such efforts can impact others by diverting flood waters (particularly on the alluvial fans typical of much of Utah) or create property development patterns or styles objectionable to neighbors. One need for empirical data is to determine what sorts of individual flood control efforts Utahns are employing and the nature and magnitude of the resulting external effects.

Another possible scenario is that individual development or property management decisions may be considered undesirable because of their environmental impacts, contribution to urban congestion, or other reasons weakly if at all related to flood problems. In some such cases, floodplain management laws may become the vehicle for achieving some other community development goal. For example, threatened increases in downstream runoff have been used as arguments against new urban development by those who prefer the aesthetics of a natural watershed. This motive raises other equity and judicial issues.

Foundations for a Utah Perspective

Current State Program

The foundations for a future state flood control program for Utah lie in the program that already exists. The Utah Department of Agriculture has been legislatively designated (Laws of Utah 1979) as the state agency responsible for coordinating structural flood control programs. This involves working with the Soil Conservation Service. The governor by executive order has designated the Division of Water Resources as the state agency with coordination responsibility with respect to the National Flood Insurance Program.

The state floodplain management effort began in Utah, as in most other states, in response to a Federal Insurance Agency mandate that each state establish a program office or coordinator to facilitate interaction between the federal program using insurance as an incentive for better floodplain management practices and the local communities responsible for those practices. This role is specifically defined in the FIA regulations (C.F.R. 24, Ch. X) as:

Section 1910.12:
The state is defined as a community for program purposes. Therefore, the state must comply with floodplain management regulations in member communities, and establish and enforce satisfactory floodplain regulations for its actions in nonmember communities. Failure to comply will result in loss of flood insurability for state properties.

Section 1925:
States may be exempt from the insurance requirement upon providing satisfactory evidence of self-insurance. Criteria for the state program are described in the regulations. As of December 1976, Maine, Georgia, and Oregon had been so exempted.

Section 1910.25:
(a) States should
1) encourage and assist community participation

2) enact necessary land use regulation enabling authority for localities
3) designate a state coordination agency
4) assist in delineation of flood hazard areas
5) establish minimum standards for floodplain regulation
6) assist localities in developing floodplain management plans
7) recommend priorities for rate making studies
8) communicate floodplain information to localities and the public
9) participate in emergency preparedness programs
10) assist communities in disseminating information on minimum elevations for structures
11) advise public and private agencies on the avoidance of activities that might aggravate flood problems
12) require floodplain uses to conform to water quality regulations to avoid pollution during floods
13) provide local communities with information on the insurance program
14) assure consistency of floodplain plans with other planning activities
15) amend state recording acts to permit recording that a parcel is in a flood zone and that a structure has been granted a variance (thereby raising insurance rates)
16) assure coordination between the state coordinating agency and any coastal zone management program
17) notify FIA of community violations
18) assist in resolving floodplain management conflicts among communities

Examination of this state role makes several points clear: 1) the role described is to facilitate the FEMA program and does not take into account state interests as determined from a state perspective, 2) the federal regulations require significant expenditure of state funds but do not provide flexibility for the state to spend those moneys in ways that seem best from the state viewpoint, 3) an effective state program needs to relate to all state interests and to the total de facto flood program in the state and not just to the flood insurance and community floodplain management components.

Basis for Long Run Objectives

An earlier section of this report proposed that one goal of the administrators of a state flood control program should be to prevent flood problems from entering the political arena as a major issue. Political processes are not very efficient for resolving complex technical issues, and the public interest is best served by a program designed to protect the public against harms required to give the issue political salience. This goal can best be served by a strategy of identifying situations likely to make flood problems salient, monitoring to detect trends toward such situations, and acting to reverse detected trends in their early stages.

The support of Senator Jake Garn of an amendment passed to require a study of special flood hazard situations in Utah to be completed by March 31, 1980 (Salt Lake City Tribune, July 16, 1979) suggests that conflicts between FEMA and several Utah communities (e.g., Springville and Payson) may already be approaching political salience. The politically motivating issue at this point does not relate to any sense of inadequate protection but rather to a feeling that the program is unnecessarily restricting new development by mapping larger areas than should be included in the floodplains and being too rigid in required regulations.

The decision making dynamics currently establishing floodplain occupancy patterns and existing Utah flood hazard situations suggest the following potential sources of politically salient problems.

1. A large flood or group of floods over the state inflicting major damage or loss of life. The salience would be even larger should the events be associated with a structural failure of measures counted on as providing protection.

2. A lack of coordination in municipal stormwater programs between adjacent municipalities causing the program of one to inflict major damages in the jurisdiction of the other.

3. Federal requirements for community participation in the flood insurance program being perceived as so stringent that the communities feel economic hardship or for other reasons consider it in their own best interest to resist.

4. Conflicts between environmental and development interests over the use of floodplain land.

Perspective for Recognizing Salient Issues

The above or other potentially salient issues are most likely to come to the attention of state officials as citizens feel adverse impacts and aggregate their concern to a high enough level to be important for state government. The most probable direction of aggregation is through lower level governments or legislative representatives within the governmental dimension. The aggregation would be reinforced should feelings develop within the other dimensions that the existing situation is too large an economic burden, too restrictive on individual rights, or threating preservation of important environmental values. The monitoring for potentially salient issues should keep an eye on how these decisions are aggregating in all these dimensions.

Perspective for Flood Program Operation

Any action on the part of Utah state government should be targeted to deal with specific emerging salient issues. The ones listed above are only suggestive. Before implementation, a contemplated action should be evaluated in terms of its technical feasibility to achieve the desired results and its economic feasibility in terms of a magnitude of achievement that justifies the effort.

The sorts of targeted action the state will be able to employ will depend on the perspective within which the state will be operating as defined by the four elements reviewed above (Larson et al. 1979):

1. Range of Action. Utah state government is currently very limited in its capability to implement either a structural or nonstructural flood control program. It is difficult to see how the state can become effective in either aspect without significant additions or shifts in manpower and budget.

2. Scope of Control. Any program would potentially be statewide in jurisdiction though it would be possible to concentrate the effort in areas of particular applicability such as the rapidly growing communities along the Wasatch Front. Expertise is available within the state and could be focused on the problem with manpower and budget reallocations.

3. Values. While state goals with respect to flood control have never been explicitly defined, several studies have produced helpful models for inferring local or state goals. For example, Larson et al. (1979) describe how a model they call PROP-DEMM was applied to determine certain state goals with respect to water and land planning in the Uintah Basin.

4. Time Frame. Except for issues relating to state construction of structural flood control works (currently rather unlikely), a time dimension of about 10 years would seem to be reasonable for watching budding salient issues.

The organization of a state program also needs to establish appropriate guidance and a forum for decision making. Practices need to be established for evaluating specific problems and presenting the findings to an appropriate group for action. Perhaps the current Board of the Division of Water Resources or some similar board could be used.

CHAPTER III

FLOOD HAZARD IN UTAH

Introduction

In terms of loss of life, the greatest flood risk in Utah is associated with flows which rise with very little warning in mountain canyons. The greatest risk to property occurs as mountain canyons discharge water, mud, and debris onto alluvial fans and other lands along the borders of valley or desert areas. Relatively less severe problems are associated with riverine flooding and with thunderstorm runoff from urban areas. In order to develop a better understanding of these problems, information will be presented on 1) the magnitude of major historical precipitation events, 2) the magnitude of major recorded runoff events, and 3) descriptions of historical floods.

Major Precipitation Events

Snow depths in the higher mountains in Utah can reach over 200 inches by April 1, and water contents of 40 or 50 inches have been recorded. A quick thaw or rain on snow can cause significant downstream flooding. Table 1 shows the largest recorded historical snowpack accumulations at Utah locations shown on Figure 5.

Intense local thunderstorms occur in both mountains and valleys. Peak intensities tend to be higher in the mountains (with some reverse trend at the highest elevations) and in the southern part of the state where warmer air masses bring more moisture into the state. More widespread storms associated with tropical disturbances occasionally enter the state in the late summer or fall from the southwest, and less severe but more general winter or spring storms associated with low pressure areas moving westward from the Pacific enter more often and from the northwest. These widespread storms seldom bring the larger rivers to flood stage (the December 1966 flood on the Virgin River was an exception) because their less intense rainfall does not generate much runoff from Utah's typically parched soils.

Peak recorded 24-hour precipitation events are shown on Table 2 for the Utah gages with more than 55 years of record. The locations of these gages are also shown on Figure 5. While few Utah gages have long term records of gaged rainfalls for periods shorter than a day, Davis (1970) tabulates values over 50-year periods of 1.78 inches for 1 hour, 2.06 inches for 6 hours, and 2.26 inches for 24 hours for Modena and of

Table 1. Record Utah snowpack accumulations (for stations with over 40 years of record).

No.	Station	Elev	Date	Water Content Inches
1	Beaver CR. RS	7,500	4/01/52	18.6
2	Bryce Canyon	8,000	4/01/37	15.3
3	Buckboard Flat	9,000	4/01/52	26.6
4	Burts-Miller Rch	7,900	3/29/50	10.1
5	Camp Altamont	7,300	3/29/52	36.2
6	Daniels-Straw	8,000	3/27/52	33.3
7	Dry Bread Pond	8,230	4/02/52	32.1
8	Duck Creek Rs.	8,700	3/28/69	34.4
9	Dutchman Rs.	7,560	4/01/52	34.6
10	East Portal	7,560	3/28/52	29.4
11	Fish Lake	8,700	3/28/52	18.8
12	Franklin Basin	8,020	3/30/71	45.8
13	GBRC Hdquarter	8,700	3/27/52	35.0
14	GBRC Meadows	10,000	3/28/52	50.4
15	Garden City Smt.	7,600	3/30/36	31.9
16	Gooseberry RS	8,400	4/23/72	19.2
17	Gooseberry Res.	8,700	3/28/52	41.3
18	Harris Flat Rs	7,700	3/28/69	24.6
19	Hewinta GS	9,500	4/23/74	15.2
20	Hobble Cr. Smt.	7,420	3/27/52	30.1
21	Hole-In-the-Rock	9,150	4/01/52	10.7
22	Huntington-H	9,800	3/28/52	51.1
23	Indian Canyon	9,100	3/31/52	25.7
24	Jones Ranch	7,600	3/29/52	17.5
25	Kimberly Mine	9,300	3/25/52	31.0
26	Kings Cabin L	8,600	3/31/32	15.7
27	Kings Cabin U	8,730	3/30/52	18.4
28	Lake Fork Mt. 1	10,200	3/26/52	21.6
29	LaSal Mtn Lwr	8,800	4/01/52	22.3
30	Long Valley Jc	7,500	2/27/69	19.4
31	Mammoth Rs-Ccr	8,800	3/28/52	43.7
32	Mill D So Fork	7,400	4/03/52	34.4
33	Monte Cristo	8,960	4/02/52	41.9
34	Mosby Mountain	9,500	4/01/52	19.2
35	Otter Lake	9,300	3/31/52	32.0
36	Panguitch Lake	8,200	3/23/37	13.0
37	Paradise Park	10,100	4/22/69	22.4
38	Parleys C Smt	7,500	3/26/52	32.3
39	Redden Mine L	8,500	3/27/52	34.2
40	Seely Creek Rs	10,000	3/27/52	41.2
41	Silver Lake	8,730	3/26/52	38.2
42	Smith Morehouse	7,600	3/29/52	24.3
43	Soapstone Rs	7,800	3/29/52	24.1
44	South Fork Rs	6,100	3/29/52	22.1
45	Strawberry Dvd	8,000	3/28/52	43.4
46	Timpanogos Cave	5,500	3/29/52	14.5
47	Timpanogos Dvd	8,140	3/28/69	44.7
48	Tony Grove RS	6,250	3/26/36	25.6
49	Trial Lake	9,800	5/20/50	42.2
50	Webster Flat	9,200	3/24/69	38.6
51	Big Flat	10,290	4/01/52	35.0

1.17 inches for 1 hour, 1.28 inches for 6 hours, and 2.72 inches for 24 hours for Salt Lake City. According to the Utah State Climatologist, record amounts for anywhere in Utah by duration include 2.1 inches for 1 hour at Blanding, August 1968; 6.0 inches for 12 hours at Bug Point, September 1970; 19.1 inches for 1 month at Buckboard Flat, October 1972; and 69.7 inches for 1 year at Alta in 1971. These Utah records are plotted on Figure 6 (beside the world records from Linsley et al. 1975) and provide a reasonable guideline as to the maximum rainfalls one could expect for various durations in Utah.

In NOAA Atlas 2, Miller et al. (1973) use frequency analyses of all Utah precipitation stations with more than 10 years of record to plot isohyetal maps for Utah of 6- and 24-hour precipitation amounts for various return periods including the 100-year. The 6-hour amounts are generally about 2.6 inches in the mountains above the Wasatch Front and

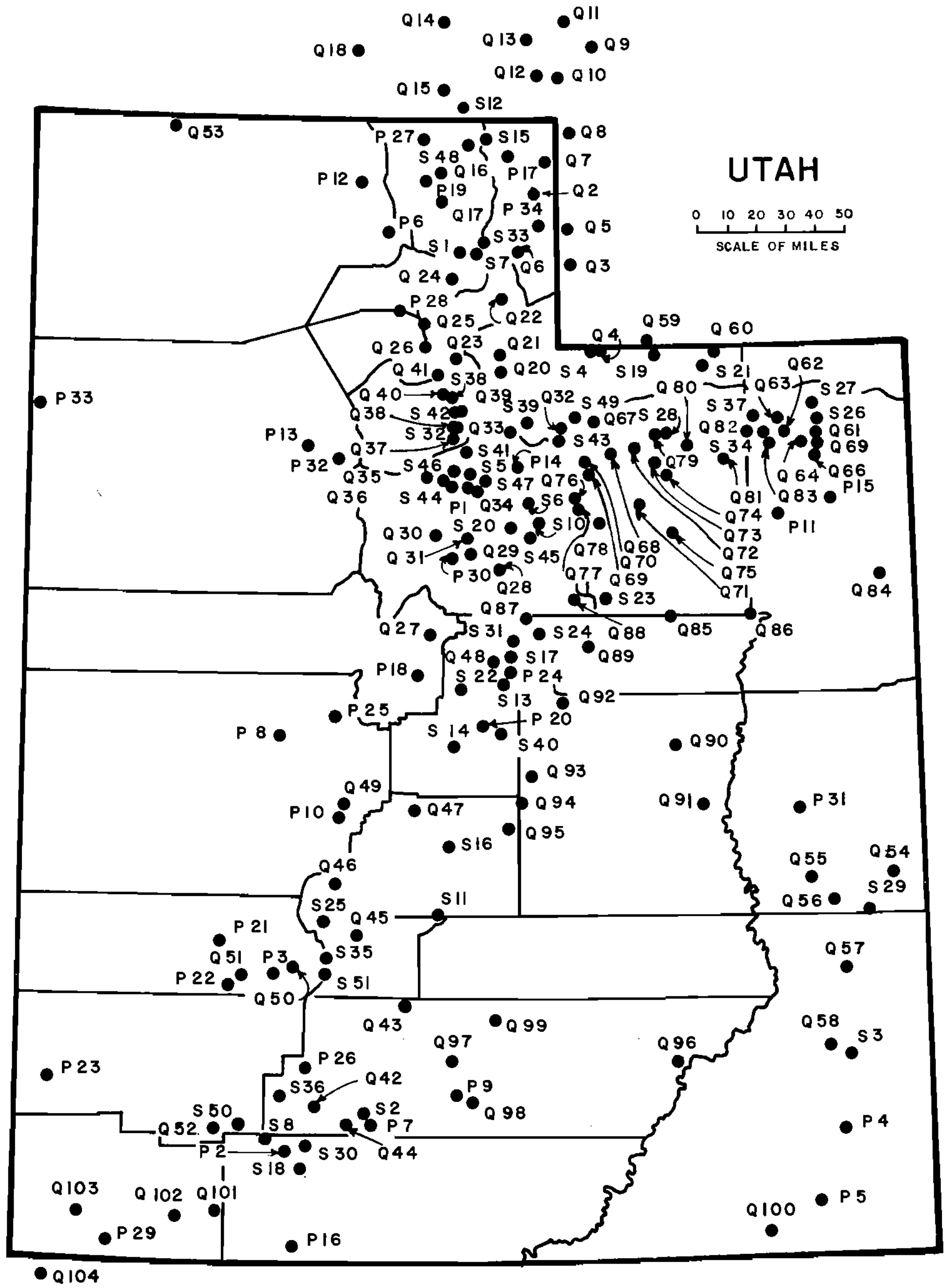


Figure 5. Location map for record snowpack accumulations (S), precipitation amounts (P), and stream flows (Q).

about 2.0 inches in the cities. Statewide extremes range from 1.7 inches in the Western Desert and around Bear Lake to 3.2 inches in the mountains above Cedar City. The 24-hour amounts range from 2.4 to 4.4 inches.

Farmer and Fletcher (1971) present magnitudes of the 10-year, 1-hour event range from 0.37 to 0.86 inches for locations in Northern Utah, 0.62 to 0.86 inches in Central Utah, and 1.11 to 1.50 inches in Southern Utah. Fletcher et al. (1977) estimated rainfalls for various Utah watersheds ranging from 1.0 to 1.4 inches in 1 hour. Their intensities for 10-minute durations ranged from 3.0 to 4.1 inches per hour.

The Corps of Engineers (1976) used a network of 14 recording gages and 40 non-recording gages over a 350-square mile area for 6 years to develop storm isohyetal maps and depth-area-duration curves for nine storms. Figure 7 provides a normalized depth-area-duration curve derived from the reported results. For comparison, the depth-area curve developed for Utah by Miller et al. (1973) is also shown.

Table 2. Record 24-hour precipitation amounts for Utah (for selected stations with 55 years or more of record).

No.	Station Name	Date	Amount (inches)[a]
1	Alpine	3/24/16	2.40
2	Alton	3/03/38	3.55
3	Beaver	9/30/11	2.17
4	Blanding	8/01/68	4.48
5	Bluff	7/29/66	3.60
6	Brigham City	4/13/72	2.19
7	Bryce Canyon Park	9/11/39	4.09
8	Deseret	2/10/15	2.00
9	Escalante	10/6/16	3.39
10	Filmore	3/11/40	2.32
11	Fort Duchesne	9/29/05	4.06
12	Garland	8/19/77	2.87
13	Grantsville	9/17/47	1.74
14	Heber	1/17/09	2.20
15	Jensen	2/26/69	1.60
16	Kanab	12/6/66	2.80
17	Laketown	8/18/77	2.47
18	Levan	4/30/95	2.85
19	Logan (USU)	3/12/46	2.17
20	Manti	6/31/43	1.75
21	Milford	10/6/16	1.92
22	Minersville	8/21/71	2.20
23	Modena	9/18/25	2.26
24	Moroni	6/01/43	2.16
25	Oak City	7/27/29	2.27
26	Panguitch	3/03/38	1.90
27	Richmond	8/18/77	3.26
28	Riverdale Pw Hs.	8/12/30	2.47
29	St. George	8/31/09	2.40
30	Sp. Fork Pw. Hs.	7/16/74	2.87
31	Thompson's	9/13/27	1.95
32	Tooele	11/15/58	2.65
33	Wendover	8/11/49	1.39
34	Woodruff	5/24/07	2.20

[a]Utah's maximum recorded 24-hour precipitation was 6.00 inches near Bug Point, September 1970.

Major Recorded Runoff Events

The U.S. Geological Survey has 105 stream gages in Utah that have more than 20 years of record. The peak recorded flows and estimated 100-year flows (based on the log-Pearson Type III distribution fitted by the method of moments and using station skewness) are shown, both as a flow rate (cfs) and as a flow rate normalized by watershed area (csm), in Table 3. The 100-year flows are plotted versus tributary drainage area in Figure 8 in order to provide a rough indication of the 100-year flood peak one may expect for various drainage areas.

From Figure 8, one can see that a number of watersheds in the Colorado River basin have recorded flood peaks several times larger than any of those in the Great Basin of comparable size. Straightline upper envelopes were drawn for both basins with the results for the Colorado River Basin of

$$Q = 5080 A^{0.225} \quad . . . . \quad (1)$$

and for the Great Basin of

$$Q = 1330 A^{0.225} \quad . . . . \quad (2)$$

where in each case Q is a flow in cubic feet per second and A is the drainage area of the tributary basin in square miles.

Also plotted on Figure 8 are an average curve for all basins in extreme south Utah derived from Berwick (1962) and an average curve for the Georgia Mountains from Golden and Price (1976). A comparison between these two curves shows the hazard to be not too different in this portion of Utah, that with the most severe flood hazard, for smaller basins but to become progressively less for basins larger than 100 sq. mi. According to Golden and Price (1976) the coefficients in the 100-year flood predicting equations for the various hydrologic regions of Georgia range from 215 to 862, a factor of 4. According to Berkwick (1962), mean annual flood peaks from Utah predicting equations vary by a factor of about 35. One would thus expect all of the Georgia data to plot in a much narrower band at the top of the Utah data. Ratios of 100-year to mean annual flood peaks in Utah basins vary from about 2 around Salt Lake City to about 7 in the southeastern part of the state. Coefficients of variation (standard deviations divided by the means of the logarithms of the annual flood peaks) trend to be inversely related to drainage areas averaging 0.09 for 9 basins larger than 500 sq. mi. and 0.34 for 11 basins smaller than 5 sq. mi. (Tooley 1980).

The exponent of 0.225 for the envelope curves on Figure 8 is extremely small. Values for the five hydrologic regions of Georgia range from 0.57 to 0.68 (Golden and Price

1976). Cummans, Collings, and Nassar (1974) report 0.86 for Western Washington. However, Berwicks (1962) curves imply values for nine hydrologic regions of Utah ranging from 0.40 all the way up to 0.98, with the highest values in steep mountain areas in the elevation ranges of 6,000 to 10,000 feet and the lowest values in more gently sloping areas. The tendency is for flood peaks to increase only slightly less than directly proportionally to drainage areas in rugged mountain terrain but increase very little, and sometimes decrease at lower altitudes.

Regional Flood Frequency Studies

Berwick (1962) used the basic data available as of that date to develop a series of curves and maps that could be used to estimate flood peaks for any frequency up to the 2 percent event for any watershed in Utah, outside the Great Salt Lake Desert and Snake River Basins, given the drainage area and mean basin elevation. He plotted curves of 50-year flood peak versus river mile for the major streams. Peak values shown include 78,000 cfs for the Colorado River at Moab, 70,000 cfs for the Green River at Green River, 15,000 cfs for the Price River at Price, 88,000 cfs for the San Juan River at Bluff, and 11,500 cfs for the Weber River at Ogden. Flood peaks from a drainage area of a given size were found largest in the southeastern portion of the state. Fletcher et al. (1977) plotted flood frequency curves for 25 Utah stations and used the resulting estimates of the 100-year flow and information on watershed characteristics to derive an equation for estimating the 100-year flood peak from the drainage area, the elevation difference between the highest and lowest points in the watershed, and a rainfall erosivity index read from a map of the state.

Flood Peaks Estimated from Precipitation

Flood control and floodplain management efforts often require estimates of peak flood flows at locations where no records are available. Rather than using regional flood frequency studies such as those described above, most flood flows are estimated from information on precipitation and watershed characteristics. For example, the Corps of

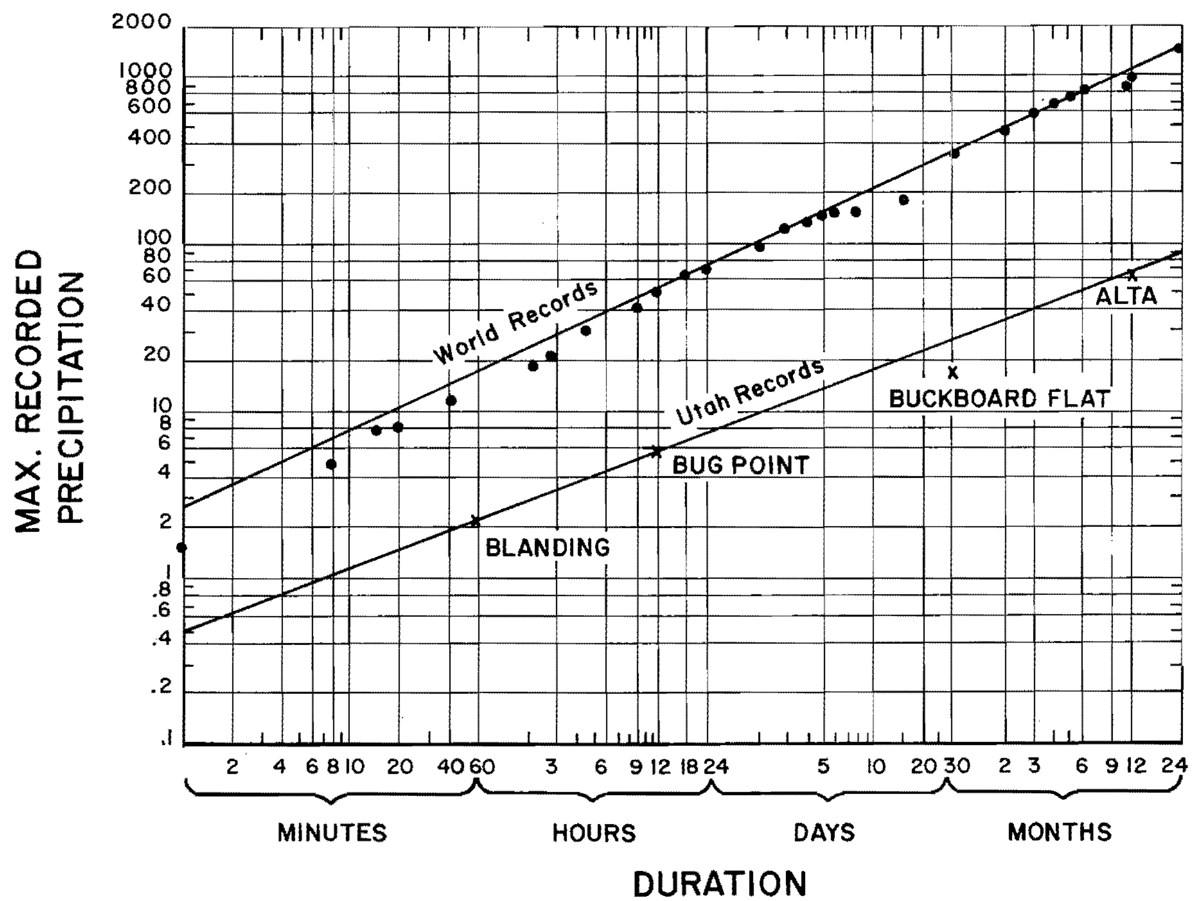


Figure 6. Maximum precipitation recorded in Utah for various durations.

Engineers' approach to estimation of 100-year flood peaks[1] uses a 100-year precipitation event estimated from rainfall records, calibration of a storm runoff model to estimate the runoff volume from such an event, and application of a unit hydrograph to the estimated volume to estimate the peak flow. The precipitation-frequency relationships are based on long-term gaged records for Utah stations and checked against regional envelope precipitation-duration curves. Regional curves expressing areal precipitation as a fraction of point amounts (such as Figure 7) are used to adjust station rainfall amounts downward to appropriate volumes over watershed areas.

The Corps' HEC-1 Model is used to estimate runoff volume from storm rainfalls. For storms where both precipitation and runoff volumes have been recorded, the optimizing feature of that model has been used to estimate the initial moisture loss (inches) and loss rate during the storm (inches per hour). Patterns observed in these losses are then used to estimate the two loss coefficients for estimating runoff volume by time interval during the storm selected to represent a desired frequency. These time-interval runoff volumes are then converted to a storm hydrograph by the unit hydrograph method. Subwatershed hydrographs are routed and combined downstream as necessary for flood-peak estimation for larger drainage areas. The flood peaks estimated for flood insurance studies for selected Utah drainage basins are shown in Table 4 and can be compared with the regional results on Figure 8. Generally the flood peaks being estimated are near or above the envelope curves obtained by frequency analysis of regional streamflow records.

[1]Interview with Herb Hereth, Hydrologist, U.S. Army Corps of Engineers, Sacramento District, June 1979.

Descriptive Information on Historical Floods

Woolley (1946), covering the period from Mormon settlement in 1847 until 1939, and

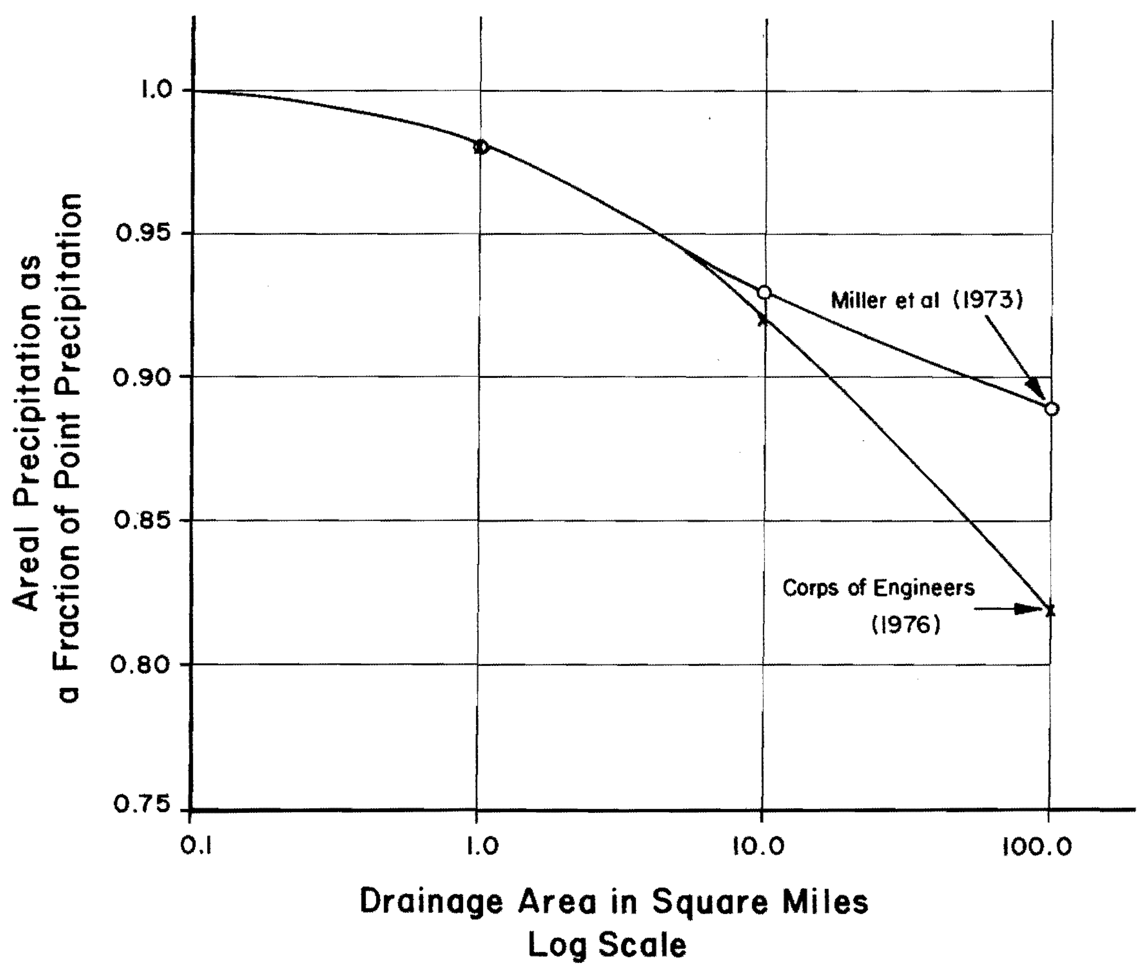


Figure 7. Normalized Depth-Area-Duration Curve derived by enveloping project cloudburst data (6-hour).

Table 3. Record gaged streamflow in Utah (flows of record at all sites with more than 20 years of gaged record).

Location	Yrs. of record	Drainage area (mi²)	Flow of Record			100-yr flow	
			Date	Flow (cfs)	CSM	Flow (cfs)	CSM
Great Basin							
Bear River near Utah-Wyoming State Line	1943-75	172	6-6-68	2980	17.3	3305.6	19.2
Big Creek near Randolph, Ut.	1940-70	52.2	7-11-57	337	7.2	351.9	6.7
Bear River near Evanston, Wyo.	1914-56	715	6-14-21	3690	5.2	4137.7	5.8
Mill Creek at Utah-Wyoming State Line	1943-62	60	6-7-57	690	11.5	908.4	15.1
Bear River near Woodruff, Ut.	1942-61	870	4-28-52	3010	3.5	3400.1	3.9
Woodruff Creek near Woodruff, Ut.	1938-75	56.8	5-25-50	528	9.3	679.4	12.0
Bear River near Randolph, Ut.	1944-75	1616	5-8-52	2660	1.6	3623.3	2.2
Bear River below Pixley Dam NR Cokeville, Wyo.	1942-75	2032	3-25-56	2300	1.1	3356.7	1.7
Smith's Fork near Border, Wyo.	1942-75	165	6-18-71	1610	9.8	1789.6	10.8
Bear River at Border, Wyo.	1930-75	2486	5-11-52	3680	1.5	4734.6	1.9
Thomas Fork near Wyom-Idaho State Line	1950-75	113	5-14-71	1040	9.2	1881.3	16.6
Bear River at Harer, Idaho	1914-75	2839	5-7-52	4440	1.6	5974.3	2.1
Montpelier Cr. at irrigators Weir in Montpelier, Idaho	1943-75	49.5	5-18-50	224	4.5	269.5	5.4
Cottonwood Creek near Cleveland, Idaho	1939-75	61.7	5-16-75	788	12.8	949.5	15.4
Cub River near Preston, Idaho	1940-75	31.6	6-16-75	753	23.8	887.7	28.1
Logan River above State Dam NR Logan, Ut.	1896-1975	218	5-24-07	2480	11.4	2268.0	10.4
Blacksmith Fork AB UPL Co.'s Dam near Hyrum, Ut.	1914-75	268	5-4-52	1400	5.2	1825.0	6.8
Devil C. AB Campbell C. NR Malad C. Idaho	1939-61	13	8-25-61	194	14.9	240.7	18.5
Weber River near Oakley, Ut.	1905-75	163	6-13-21	4170	25.6	3717.0	22.8
Weber River near Coalville, Ut.	1927-75	438	5-6-52	2190	5.0	2793.7	6.4
Chalk Creek at Coalville, Ut.	1905-75	253	4-28-52	1540	6.1	1331.7	5.3
Lost Creek near Croydon, Ut.	1921-67	133	5-10-23	770	5.8	991.1	7.5
Hardscrabble Creek near Portorville, Ut.	1942-70	28.1	8-20-45	464	16.5	541.9	19.3
South Fork Ogden River near Huntsville, Ut.	1921-75	148	5-3-52	1890	12.8	2572.2	17.4
Farmington C AB Diversions NR Farmington, Ut.	1950-75	10	6-6-75	366	36.6	527.5	52.8
Centerville Creek AB Div Near Centerville, Ut.	1950-75	3.15	5-20-75	35	11.1	54.2	17.2
Salt Creek at Nephi, Ut.	1951-75	95.5	8-1-68	832	8.7	776.9	8.1
Spanish Fork at Thistle, Ut.	1908-74	490	5-4-52	1800	3.7	1621.5	3.3
Spanish Fork at Castilla, Ut.	1890-1975	670	5-3-52	3610	5.4	2678.3	4.0
Spanish Fork near Lake Shore, Ut.	1904-73	700	4-28-52	3020	4.3	1839.1	2.6
Hobble Creek NR Springville, Ut.	1904-73	105	5-4-52	1250	11.9	1214.7	11.6

Table 3. Continued.

Location	Yrs. of record	Drainage area (mi^2)	Flow of Record Date	Flow of Record Flow (cfs)	Flow of Record CSM	100-yr flow Flow (cfs)	100-yr flow CSM
Provo R. NR Kamas, Ut.	1950-69	29.6	6-6-57	825	27.9	976.2	33.0
Provo River near Hailstone, Ut.	1950-76	233	6-4-57	3880	16.7	4542.9	19.5
South Fork Provo R. at Vivian Park, Ut.	1912-63	30	2-1-63	500	16.7	201.7	6.7
Dry Creek near Alpine, Ut.	1948-73	9.82	8-25-61	597	60.8	464.0	47.3
American Fork AB Upper PP NR American Fork, Ut.	1927-75	51.1	8-3-51	645	12.6	656.9	12.9
Little Cottonwood C. NR Salt Lake City, Ut.	1912-63	27.4	6-11-21	762	27.8	812.9	29.7
Big Cottonwood C. NR Salt Lake City, Ut.	1901-63	50	6-7-12	848	17.0	847.2	17.0
Mill Creek near Salt Lake City, Ut.	1899-1963	21.7	5-20-49	152	7.0	150.2	6.9
Emigration Cr. near Salt Lake City, Ut.	1902-58	18	4-26-52	156	8.7	137.1	7.6
City Creek near Salt Lake City, Ut.	1899-1963	19.2	5-30-21	163	8.5	149.4	7.8
Sevier River at Hatch, Ut.	1912-75	340	5-26-22	1490	4.4	1723.7	5.1
Antimony Creek near Antimony, Utah	1947-75	97	8-3-59	669	6.9	1143.6	11.8
East Fork Sevier River near Kingston, Ut.	1913-75	1250	5-12-41	2030	1.6	1838.5	1.5
Sevier River Below Piute Dam NR Marysville, Ut.	1912-75	2440	5-23-22	2600	1.1	1794.1	0.7
Clear Creek at Sevier, Ut.	1912-58	169	8-7-41	487	2.9	724.5	4.3
Salina Creek at Salina, Ut.	1914-75	290	8-26-70	1800	6.2	2333.1	8.0
Pleasant Creek near Mount Pleasant, Ut.	1946-75	16.4	7-24-46	2060	125.6	1310.0	49.4
Chalk Creek near Fillmore, Ut.	1914-71	60	7-31-61	1850	30.8	1122.0	18.7
Beaver River near Beaver, Ut.	1914-65	82	7-22-36	1080	13.2	1371.3	16.7
Beaver River at Rocky Ford Dam NR Minersville	1914-75	512	6-10-21	727	1.4	831.9	1.6
Coal Creek near Cedar City, Ut.	1916-75	80.9	7-23-69 7-16-74	4620	57.1	7871.8	97.3
<u>Columbia River Basin</u>							
Clear Creek near Naf, Idaho	1910-70	19	6-15-67	386	20.3	368.8	19.4
<u>Colorado River Basin</u>							
Castle Creek above diversions near Moab, Utah	1951-75	7.58	9-19-72	69	9.1	83.1	11.0
Courthouse Wash, near Moab, Ut.	1950-75	162	8-5-57	12300	75.9	11476.2	70.8
Mill Creek near Moab, Ut.	1915-75	74.9	8-21-53	5110	68.2	11697.6	156.2
Hatch Wash near La Sal, Ut.	1950-71	378	8-20-70	4650	12.3	5403.7	14.3
Indian Cr. AB Cottonwood Cr. NR Monticello, Ut.	1950-71	31.2	8-28-71	2330	74.7	2095.6	67.1
West Fork of Smith Fork NR Robertson, Wyo.	1940-75	37.2	6-10-65	2100	56.5	1512.2	40.7
Middle Fork Beaver Creek NR Lonetree, Wyo.	1949-70	28	6-11-65	775	27.7	962.4	34.4
Ashley Creek near Vernal, Ut.	1912-75	101	6-11-65	3500	34.7	2980.2	29.5
Dry Fork above Sinks near Dry Fork, Ut.	1939-75	44.4	6-10-65	1010	22.7	1282.8	28.9
North Fork of Dry Fork near Dry Fork, Ut.	1946-75	8.62	6-5-68	169	19.6	208.8	24.2
Dry Fork BLW Springs NR Dry Fork, Ut.	1904-69	102	6-11-65	974	9.5	1363.3	13.4

Table 3. Continued.

Location	Yrs. of record	Drainage area (mi2)	Flow of Record Date	Flow of Record Flow (cfs)	Flow of Record CSM	100-yr flow Flow (cfs)	100-yr flow CSM
Dry Fork at Mouth Near Dry Fork, Ut.	1955-75	116	8-25-55	1210	10.4	1623.1	14.0
Ashley C. Sign of the Maine N Vernal, Ut.	1900-65	241	6-11-65	4110	17.1	3637.0	15.1
Duchesne R. at Provo R. Trail NR Hanna, Ut.	1930-54	39	6-13-53	1180	30.3	1262.8	32.4
Duchesne River near Hanna, Ut.	1922-63	78	6-16-63	17500	224.3	1830.3	23.5
West Fork Duchesne River near Hanna, Ut.	1923-75	61	6-5-67	758	12.4	874.4	14.3
Wolf Creek above Rhodes Canyon near Hanna, Ut.	1946-75	9	6-15-75	74	8.2	88.0	9.8
Duchesne River near Tabiona, Ut.	1919-74	352	6-16-63	5260	14.9	2602.5	7.4
South Fork Rock Creek near Hanna, Ut.	1954-75	14	6-16-75	186	13.3	230.4	16.5
Rock Creek near Hanna, Ut.	1950-75	120	6-13-65	2300	19.2	2665.3	22.2
Rock Creek near Mountain Home, Ut.	1938-75	149	6-18-71	2920	19.6	2943.0	19.8
Duchesne River at Duchesne, Ut.	1918-69	660	6-10-22	4420	6.7	4452.8	6.7
Currant C. B Red Ldge Hlw N. Fruitland, Ut.	1946-75	48	5-21-75	946	19.7	999.8	20,8
Water Hollow near Fruitland, Ut.	1946-75	14	7-18-54	133	9.5	186.3	13.3
Currant Creek near Fruitland, Ut.	1935-75	140	5-4-52	1260	9.0	1095.4	7.8
Lake Fork River above Moon Lake NR Mtn. Home	1933-75	78	6-26-44 6-17-71	2700	34.6	2959.8	37.9
Yellowstone River near Altonah, Ut.	1945-75	131	6-19-49	1880	14.4	1976.7	15.1
Uinta River near Neola, Ut.	1925-75	160	6-11-65	5000	31.3	4119.1	25.7
Farm Creek near Whiterocks, Ut.	1950-75	14.9	6-3-68	350	23.5	584.9	39.3
Whiterocks River near Whiterocks, Ut.	1902-74	113	6-20-22	2750	24.3	3067.3	27.1
White River near Watson, Ut.	1904-75	4020	7-15-29	8160	2.0	8988	2.2
Minnie Maud Creek near Myton, Ut.	1952-75	30	8-25-61	1370	45.7	2299.8	76.7
Minnie Maud C. at Nutter Ranch NR Myton, Ut.	1947-69	231	8-25-55	1370	5.9	1794.1	7.8
Fish Creek above Reservoir near Scofield, Ut.	1932-75	65	5-20-73	1160	17.8	1277.5	19.7
White River near Soldier Summit, Ut.	1940-67	53	5-5-52	1120	21.1	866.3	16.3
Price River near Heiner, Ut.	1935-69	455	9-13-40	9340	20.5	7147.5	15.7
Price River at Woodside, Ut.	1909-75	1500	9-10-61	8500	5.7	13186.4	8.8
Saleratus Wash at Green River, Ut.	1949-70	180	9-21-62	14200	78.9	13842.4	76.9
Huntington Cr. NR Huntington, Ut.	1909-75	188	8-20-30	2500	13.3	2689.1	14.3
Ferron Creek (Upper Station) NR Ferron, Ut.	1912-75	138	8-27-52 6-6-75	4180	30.3	4243.5	30.8
Muddy Creek near Emery, Ut.	1909-75	105	5-10-52	3340	31.8	3880.2	37.0
Ivie Creek above Diversions NR Emery, Ut.	1951-74	50	7-18-65	1240	24.8	1728.7	34.6
North Wash near Hite, Ut.	1950-70	140	8-7-52	8900	63.6	15440.8	110.3
Pine Creek near Escalante, Ut.	1951-75	78	8-2-67	1010	12.9	2425.9	31.1

Table 3. Continued.

Location	Yrs. of record	Drainage area (mi²)	Flow of Record Date	Flow (cfs)	CSM	100-yr flow Flow (cfs)	CSM
Escalante River near Escalante, Ut.	1910-75	310	8- -53	3450	11.1	8427.4	27.2
East Fork Boulder Cr. Near Boulder, Ut.	1951-72	21.4	5-20-64	483	22.6	646.7	30.2
San Juan River near Bluff, Ut.	1915-75	23000	9-10-27	70000	0.3	71269.9	3.1
North Fork Virgin River near Springdale, Ut.	1913-75	350	12-6-66	9150	26.1	10339.2	29.5
Virgin River at Virgin, Ut.	1910-71	934	12-6-66	22800	24.4	22825.3	24.4
Santa Clara R. ab Winsor Dam N Santa Clara, Ut.	1942-71	338	8-24-55	6190	18.3	13219.8	39.1
Virgin River at Littlefield, Ariz.	1930-75	5090	12-6-66	35200	6.9	34655.5	6.8

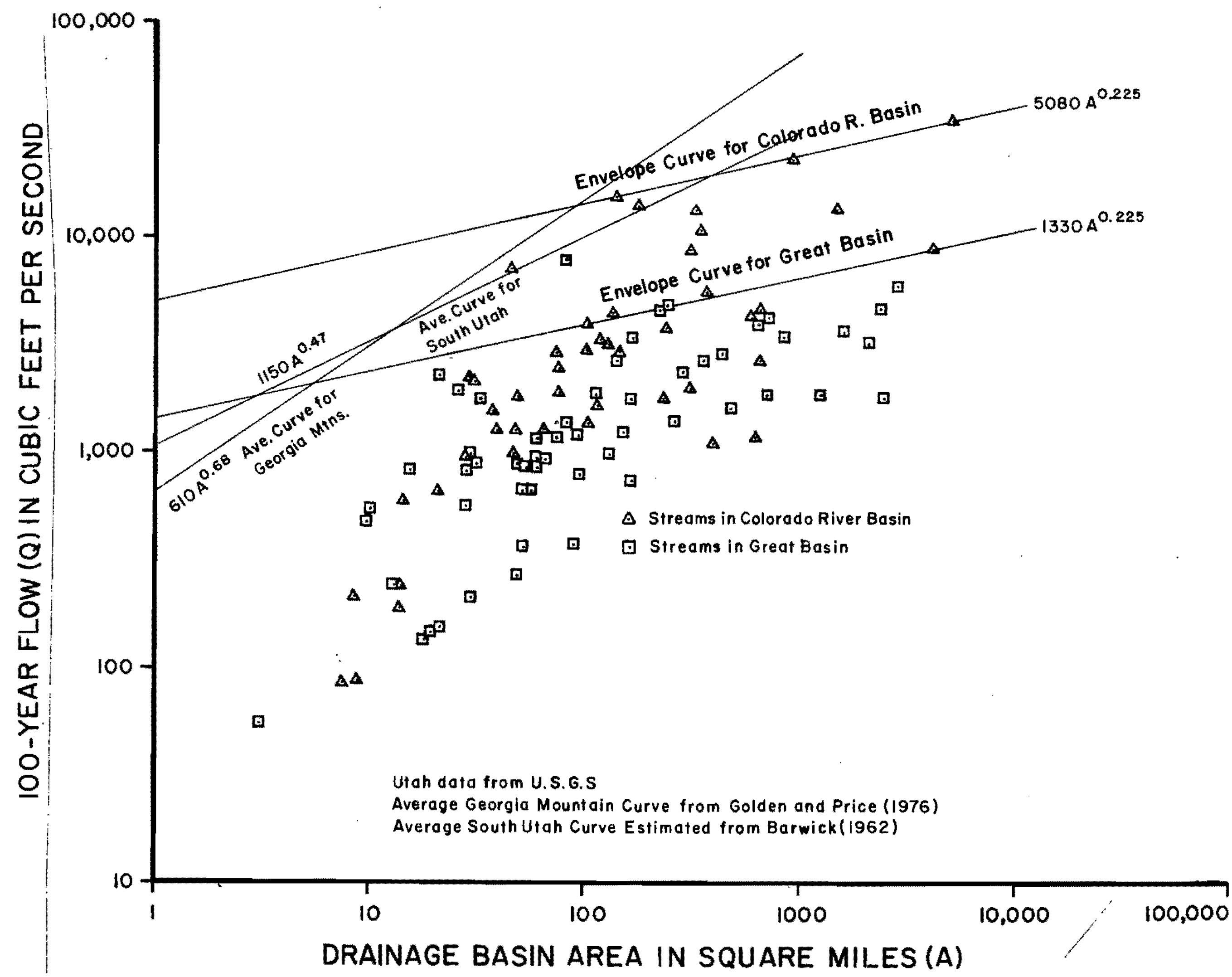


Figure 8. 100-year flows calculated for Utah drainage basins with 20 or more years of record.

Butler and Marsell (1972), extending the record to 1969, identified 1339 cloudburst floods as having occurred in Utah and compiled physical descriptions of the flood events and tabulated data on deaths and damages. The information was collected from newspaper accounts and U.S. government agency (Economic Research Service, Forest Service, Soil Conservation Service, and Geological Survey) records and tabulated them by community, county, and year.

During the 31 years covered by Butler and Marsell (1972), 836 cloudburst floods were reported. Of the 228 incorporated communities and unincorporated places of 1,000 or more population, according to the 1970 census, 131 experienced at least one cloudburst flood during the 30-year period. August accounted for 44.0 percent of the events followed by July with 29.1 and September with 12.2. A few events occurred in all the other months except February and March.

Many of the accounts describing these cloudburst floods noted large volumes of debris being carried with the water. From

Table 4. Flood insurance study flood peaks estimated for selected Utah drainage basins.

Community	Flooding Source and Location	Drainage Area ($Mile^2$)	Peak Discharges (cfs) 10 yr	50 yr	100 yr	500 yr
Moab	Mill Creek 3.5 miles upstream from the mouth of Mill Creek at confluence with Colorado River	74.8	3,800	9,980	14,000	25,500
	Pack Creek Mill Creek Drive	63.0	2,800	7,300	10,400	18,900
Helper	Price River Above confluence with Spring Glen Wash	491.0	3,736	7,804	10,208	17,827
	Above confluence with Spring Canyon Wash	465.0	3,635	7,594	9,934	17,349
	Spring Canyon Wash at mouth	24.0	887	2,879	4,378	9,744
Provo	Provo River 1 mile below mouth of Provo Canyon	680	1,800	2,600	3,200	3,800
	Rock Canyon Creek at mouth of Rock Canyon	9.4	865	1,710	2,100	3,200
	Little Rock Canyon Creek at mouth of Little Rock Canyon	0.8	305	526	637	916
Sunnyside	Grassy Trail Creek cross section A	43.6	810	2,650	3,320	6,060
	North Slope Tributary cross section B	2.5	280	650	760	1,140
Springville	Hobble Creek at canyon mouth	110	650	970	1,800	4,500
Orangeville	Cottonwood Creek Main Street Bridge	93 (area below Joe's Valley Dam)	3,230	5,290	6,240	8,800
	Northerly Tributary to Cottonwood Creek	1.3	60	244	390	960
Payson	Peteetneet Creek above Payson Canyon mouth	27.6	450	800	1,000	1,400
Bountiful	Barton Creek					
	500 West & US 89 & 91	6.6	100	230	250	260
	750 East	5.5	100	570	1,100	2,700
	Mill Creek					
	I-15	12.0	220	300	310	310
	Main Street	10.6	220	1,000	1,600	1,600
	Orchard Drive	10.5	220	1,000	2,000	4,400
	Stone Creek					
	Main Street	7.0	50	230	575	1,450
	Below confluence with North Fork Stone Creek	6.9	165	675	1,460	3,000
	Davis Boulevard	4.4	120	860	1,430	2,500

many mountain canyons, surface runoff is rare, and the floods flush accumulated plant litter and soil particles from clay to boulder size from the surface slopes into the stream channel. At constriction points, the mass is prone to snag to form temporary dams that later break to send debris plunging down the canyon. The viscous mud-rock flow maintains its depth as it flows out of the canyon onto unconfined surfaces but eventually halts as the water drains out the bottom. Because of the residual ridge, the next mud flow leaves the mouth of the canyon in a different direction, and an alluvial fan is built over a series of floods. Because of its greater depth and sediment content, this sort of flooding is much more destructive than the floods where clear water spreads quickly to shallow depths. Butler and Marsell (1972) noted Manti and Mt. Pleasant in Sanpete County as communities subject to mud-rock flows about one year in eight.

The largest flash flood flow noted by Butler and Marsell (1972) was the event of August 1, 1968, where 24-hour precipitation estimated to have reached 6.5 inches at an ungaged location near Monticello caused a peak discharge of 20,500 cfs on Cottonwood Wash near Blanding from a 205-square mile drainage area. Downstream at Bluff, the peak flow reached 42,000 cfs from a 340-square mile watershed. The flood washed out roads, inundated residences and businesses in Bluff to a depth of 3 feet, and stranded motorists.

The most damaging flood reported by Woolley (1946) occurred on August 13, 1923, when a general thunderstorm struck the Wasatch Front from Salt Lake City north to the Idaho border. The worst flooding occurred in Farmington and Centerville, where seven drowned, and in Willard where two more drowned. Damages were estimated to run into "hundreds of thousands of dollars." A similar storm struck on July 10, 1930, causing an estimated $500,000 damage statewide, with Salt Lake City, Ogden, and Farmington sustaining the heaviest losses.

Roeske et al. (1978) described a major flood in September 1970 in the Four Corners area of southeast Utah. A Bug Point rancher measured 6.00 inches in 11 hours to establish new 12- and 24-hour gaged records for Utah (previous 24-hour record was 5.08 inches near Provo). The largest flood flows were recorded on Montezuma and McElmo Creeks and the San Juan River downstream. Two persons were drowned when McElmo Creek washed out a bridge abutment near Aneth. Montezuma Creek registered a peak flow of 40,500 cfs, 27 times larger than the previous high in 12 years of record. A peak discharge of 52,000 cfs on the San Juan River near Bluff caused a levee to fail and damaged fields and irrigation facilities. The summary of flood damages that Roeske et al. (1976, p. 38) adapted from field estimates by the U.S. Army Corps of Engineers for the three river reaches all or partly in Utah (San Juan River from Navajo Reservoir to Lake Powell, McElmo Creek, and Montezuma Creek) totaled $589,000 of which $304,000 was to roads and other public facilities, $174,000 was to agriculture, $109,000 was to utility lines, and $2,000 was to commercial property. No residential damages were recorded. This damage breakdown shows that flood insurance would have been of virtually no help during one of the largest floods ever recorded in Utah because the damage did not occur to insurable property.

This situation occurs frequently. Woolley (1946) summarized that "... more than 50 percent of the floods damaged highways, bridges, irrigation structures, and railroads; about 20 percent of them damaged fields and crops; and about 18 percent flooded city streets and basements of homes with mud and debris. In a few places small areas of relatively high-priced land and comfortable homes were rendered useless" (p. 123).

The evaluation of flood hazards by the Bear River Basin USDA Cooperative River Basin Study (1977) estimated 100-year flows of 840 cfs on the Malad River flooding 1030 acres with damages to pasture land and rural roads, of 1900 cfs on the Little Bear River flooding 1600 acres damaging alfalfa fields and other croplands, and of 2500 cfs on the Logan River flooding 1260 acres damaging campsites, homes in Logan, and agricultural crops and irrigation facilities. For the Bear River Basin in Utah, average annual flood damages were estimated at $275,360 for a 50,640-acre floodplain. Of these, $4,270 were residential, $220 were commercial, and $1,130 were industrial and utilities. Again a very small portion of the damage potential is insurable under the flood insurance program.

Also, according to Butler and Marsell (1972), about 35 people have been reported as drowned by cloudburst floods in Utah, 9 of them since 1939. The worst recent event was when 5 of 26 hikers were drowned when caught by a cloudburst flood in Zion National Park in September 1961. Woolley (1946) reports 7 people drowned in the 1923 flooding.

The flood control appendix to the Water Resources Council (1971a) Comprehensive Framework Study for the Great Basin Region describes the April 1952 snowmelt flood from Parleys, Red Butte, and Emigration Creeks as inundating 75 city blocks in Salt Lake City for up to 30 days and causing $2,337,000 in damage. In terms of resulting damage, the flooding along the Wasatch Front in the spring of 1952 was the most severe in the history of the state (p. 13). Other damage amounts were Weber River $1,350,000, Spanish Fork River $1,180,000, Provo River $649,000, Hobble Creek $455,000, Bear River $404,000, Jordan River $274,000, and the Ogden River $97,000. The 1952 damage total was thus $6,746,000. The flood listed as causing the second most damage in this region was $477,000 by Bear River flooding in February

1962. The only other floods in the Great Basin portion of Utah listed as causing damages exceeding $110,000 are Farmington Creek in August 1923 ($300,000), Coal Creek in August 1921 ($218,000), and Dry Canyon (Sevier River Basin) in August 1965 ($176,000).

The flood control appendix to the framework study for the Upper Colorado Region (Water Resources Council 1971b) notes the most disastrous flood of record in this part of Utah as being caused by heavy rain on snow in June 1965 along Sheep Creek, a tributary of the Green River near Manila, Utah. That flood took seven lives and caused $802,000 in damages principally to roads, bridges, and campgrounds in this mountain recreation area. Other major events, listed in decreasing order of flood damage caused, were $380,000 by the Price River near Helper in June 1917, $297,000 by the Strawberry and nearby Rivers near Neola in June 1952, $155,000 by the Green River near Jensen in June 1957, and $120,000 by the Price River near Heiner in April 1952. Only $25,000 of all these damages were to residential and commercial property.

The flood control appendix for the Lower Colorado Region (Water Resources Council 1971c), covering the Washington County area in Utah, records the most disastrous flood in this area as occurring in December 1966. Several days of light rain followed by heavy rain on December 6 produced a discharge of 22,800 cfs on the Virgin River at Virgin, Utah, and 32,500 cfs at Littlefield, Arizona. The flow was almost twice the previous record, but the only damage was associated with flooding and erosion of about 300 acres of agricultural land, a washing away of the approaches to the State Route 64 bridges, and severe erosion of State Route 212 (U.S. Army Corps of Engineers 1973). The total damage of $962,000 was divided among $628,000 to agriculture, $335,000 to public facilities, and $5,000 to residential and commercial buildings. The appendix tabulated no other historical flood as causing more than $100,000 in damage to this part of Utah.

Hydraulic Analysis

The flood hazard at a given location is determined by the frequency with which various depths of inundation can be expected at the site and such characteristics of the flows as velocity and sediment content. Flood hazard mapping shows how the hazard varies over the floodplain. The conventional approach to riverine flood hazard mapping is to determine the water surface profile for the selected flood flow based on the principles of open channel flow hydraulics. The tool that has generally been used in Utah for this task is the HEC-2 step backwater computer program (Hydrologic Engineering Center 1973). For example, the flood insurance study for Bountiful (FIA 1978) used surveyed channel cross sections, extra cross sections near bridge locations, roughness coefficients based on previous studies extended by field inspection, and an assumption of flow conditions unobstructed by debris or sediment in the HEC-2 program to compute water surface elevations to "an accuracy of 0.5 foot." The results are generally expressed in a map showing the area subject to inundation by the 100-year flood and a flood hazard factor (FHF) expressing the difference in water surface elevation between the 10 and the 100-year floods and thereby indicating the variability of flood depth with frequency. The FHF will normally be high in mountain canyons and very low in the lowlands.

Those experienced in floodplain mapping generally recognize that the uncertainty in water surface elevation mapping exceeds a half foot even though this figure is commonly quoted in flood insurance studies. The uncertainty in estimating the FHF as the difference between two water surface elevations is somewhat greater.

Considering only those uncertainties related to the open channel flow computations, the Sacramento District of the Corps of Engineers, which includes most of Utah, has cautioned that the HEC-2 printout should be considered incomplete for flood hazard mapping until reviewed with supplemental sound engineering judgment. They emphasize that interpretation of the printout requires expertise in evaluating the reliability of the basic data, converting the basic information into the input data for computer analysis, and interpreting the output. Special attention needs to be given to the variables that affect the backwater curves and the limitations to the computer programming.

The determination of the area flooded when the flow spreads out after leaving a channel is much less precise than is the determination for confined riverine floodplains. Dawdy (1979) has developed a method quantifying how the flood hazard diminishes below the apex of an alluvial fan based on assumptions that each discharge down the fan stays in the same channel and that the channels from storm to storm are uniformly distributed along each contour crossing the fan. The FIA is beginning to use this method for true alluvial fan situations, but the two assumptions of the Dawdy method are seldom fully valid. Most situations at the mouth of Utah mountain canyons are intermediary between the assumptions of certainty as to channel location for the riverine method and complete randomness of location. Empirical data are needed. Observations of flooding in Utah show that manmade construction on alluvial fans prevents random shifts in channel location from storm to storm and causes flows in a given storm to disperse into many channels, but these effects need to be better quantified if reliable flood hazard maps are to be developed for these areas.

Generally, the mapped floodplain areas on alluvial fans have been given a flood hazard rating of AO. AO zones are defined as areas subject to shallow flooding (no more than 3 feet deep) by flows not associated with a defined channel. The maps for Utah usually indicate a maximum flood depth of one foot.

Design Ramifications

The differences between the flood hazard situations described above for Utah and typical situations nationwide suggest that flood control and floodplain management design practices used elsewhere be reviewed for effectiveness before application to Utah situations. Relevant differences include:

1. Less flood hazard for a watershed of given size.
2. A greater portion of the total flood problem associated with small watersheds.
3. Floods spreading out over alluvial fans and gradually dissipating downstream.
4. High sediment and debris content.

Before evaluating these differences in greater detail, it is helpful to also start with some ideas on their implications for effective design. These include:

1. A basic incompatibility between traditional structural flood control measures which concentrate the flow in the downstream direction and natural stream morphology on alluvial fans. Natural alluvial systems dispose of floodwater by recharge to underground aquifers whereas traditional flood control measures dispose of water by conveying it downstream as is the natural pattern in more humid climates. Structural designs to accelerate conveyance rather than recharge are thus in basic conflict with the natural system; and the more a design conflicts with nature, the more expensive it is to construct and maintain. Furthermore, a more expensive design makes little sense when flood damage per capita is less in arid than in humid climates. Designs are needed which dispose of the sediment and debris in the upper portion of the alluvial fan, spread the water among drainage channels as flows move down a fan, and recharge as much water as possible underground.

2. A major problem with traditional nonstructural designs appears likely in that they are conceived in terms of regulating development on a defined 100-year floodplain while not applying to areas outside that magic boundary differentiating danger from safety. Mapping that boundary in alluvial areas is very uncertain. The area inundated by a given flow will not be the same area inundated by the next flow of the same magnitude. Changing conditions along the stream bank cause flows to break out of the channel at different locations during different floods. The entire area subject to flooding by flows of the 100-year magnitude is a much larger area than that wherein flooding can be expected one or more years out of 100. Consequently, nonstructural protection of the full area subject to flooding by a 100-year flow requires that the measures be employed over a much larger area than would be necessary in a more humid climate, and the associated greater cost makes little sense in an area where infrequent shallow flooding causes less damage.

3. Structural and nonstructural measures specially designed to overcome the above problems need to be considered. For example, land treatment to reduce sediment and debris production in upland watersheds may be particularly important. Special channel construction to standardize locations of overtopping to reduce the area subject to inundation by a flood of a given magnitude and to maximize utilization of the carrying capacity of streets, gutters, and other smaller channels is another possibility. Perhaps, the urban storm runoff systems could be designed to convey the 10-year flood whereas a series of parallel streets could be designed to carry the 100-year flood between their curbs. As to nonstructural design, land use regulation to prevent development does not make economic sense where infrequent shallow flooding causes little damage. Flood proofing (Office of the Chief of Engineers 1972 and Owen 1977) has its greatest advantage in this sort of situation. Older buildings can be protected by short walls or levees (Johnson 1978), and new buildings can be constructed with slightly higher floor elevations (Federal Insurance Administration 1976). Minnesota (1977) uses a special manual prepared by the Corps of Engineers to promote flood proofing in that state.

4. The speed with which flood waters can rise in narrow mountain canyons (Sheep Creek 1965, Zion Canyon 1961) or mud and debris can emerge onto alluvial fans posed problems for flood prediction and warning system design. How does one detect isolated cloudbursts in the headwaters of remote mountain canyons and warn those downstream before the deluge arrives? How does one maintain an effective detection and warning system over the many years between floods?

CHAPTER IV

FLOOD CONTROL IN UTAH

Introduction

The opening chapters presented the situation in the United States wherein five principal decision making loci interact in forming the de facto situation existing in local communities with respect to lives and property in danger from floods, and the third chapter described hydrologic and hydraulic factors governing the hazard situation in Utah stimulating response by the five loci within this framework. All five loci operate in Utah. All five are influenced somewhat by national norms and somewhat by local Utah conditions. The de facto product of their interactions can be expected to vary in Utah from elsewhere because the hazard situation is different and the perspectives of the actors making the decisions at each locus are different. The de facto product can also, however, be expected to vary from what is best for Utah because of the influence of national norms.

Each locus is managed in its own way. The first encompasses three separate programs, those of the Corps of Engineers, Soil Conservation Service, and Water and Power Resources Service (formerly the Bureau of Reclamation), separately managed though partially coordinated through the Water Resources Council and the Pacific Southwest Inter-Agency Committee. The structural flood control programs run by city and county engineering departments are managed independently in every community. The third role, that of the federal flood insurance program, is the one of the five which is managed from a single locus. The community planning and zoning efforts of the fourth role are separately responsible to the 29 counties and over 100 incorporated communities. The number of individuals managing floodplain property in Utah is in the thousands. The Federal Emergency Management Agency has estimated that 26,900 structures are located on Utah floodplains (Salt Lake City Tribune, July 16, 1979), and many other properties suffer agricultural losses even though the buildings are on higher ground. The overall flood hazard situation is the integrated product of decisions at all these loci.

Federal Structural Flood Control Measures

U.S. Army Corps of Engineers

The flood control activities of the Corps of Engineers fall into three categories: 1) information and technical advice, 2) construction of single and multiple purpose flood control projects, and 3) emergency flood control work (U.S. Army Corps of Engineers 1979).

Under the Floodplain Management Services Program, established in the 1960s, the Corps (on request) studies local flood problems, provides information on methods of flood damage prevention and abatement, and assists communities in developing floodplain management programs. Fifteen floodplain information studies have been completed in Utah. These studies, listed in Table 5, describe

Table 5. U.S. Army Corps of Engineers floodplain information studies.

Stream	Community	Year
American Fork and Dry Creek	American Fork and Lehi	1969
Barton, Mill, and Stone Creeks	Bountiful, West Bountiful and Woods-Cross	1969
Blacksmith Fork and Spring Creek	Millville	1976
Burch Creek	Ogden	1970
Box Elder Creek	Brigham City	1975
Farmington Bay Tributaries	Farmington-Centerville	1974
Hobble Creek	Springville	1973
Jordan River Complex I	Salt Lake City	1969
Jordan River Complex II	Midvale-Draper	1974
Logan River	Logan	1973
Ogden River	Ogden	1971
Provo River and Rock Canyon Creek	Provo-Orem	1971
Provo River and Slate Canyon Creek	Provo	1972
Virgin River and Fort Pierce Wash	Washington County (St. George vic.)	1973
Weber River	Ogden	1976

the historical floods in the community, outline present floodplain management practices and problems, and map the boundaries and heights of possible (usually 100 yr and 500 yr) floods. The Corps is also authorized to conduct the flood insurance studies used to determine the actuarial flood insurance premium rates for the FEMA.

Since the 1936 Flood Control Act, the Corps has had responsibility for most of the structural flood control projects of the federal government. As of 1979, their civil works program in Utah (Table 6) consisted of four completed single-purpose projects (Big Wash Diversion Dam and Channel, Redmond Channel Improvement, Jordan River Channel Improvement, and Kays Creek at Layton), three proposed single-purpose projects (Lower Jordan River Floodway/Parkway, Upper Jordan River Project, and Coal Creek in Cedar City) and one authorized multiple-purpose storage project (Little Dell Lake). In addition, the Corps describes rules and regulations for flood control for six multiple-purpose storage reservoirs sponsored by the Water and Power Resources Service (Echo, Rockport, Lost Creek, East Canyon, Causey, and Pineview Reservoirs). Flood control operations are under study for Hayes and Jordanelle Reservoirs in the Central Utah Project.

Finally, the Corps has continuing authority to undertake emergency flood control work, including bank protection, snagging and clearing channels, flood fighting, rescue, and repair. The cumulative cost of emergency work in Utah is about $1.5 million. Cumulative expenditures by stream are provided in Table 7.

Water and Power Resources Service (Bureau of Reclamation)

The Bureau of Reclamation was established in 1902 (as the Reclamation Service) to reclaim arid western land through irrigation. The Bureau's programs have since expanded to include municipal water supply, hydroelectric power, recreation, water quality, fish and wildlife, and flood control; and in recognition of this wider scope, its name was changed in 1979 to the Water and Power Resources Service. The proposed, in-progress, or completed projects in Utah having flood control benefits (Table 6) achieve these benefits by regulating reservoir outflows to control snowmelt runoff following rules designed by the Corps of Engineers. Projects also provide incidental flood protection from heavy summer rains because reservoirs generally have unused storage capacity as the water surface is drawn down to supply irrigation water.

Soil Conservation Service

The Soil Conservation Service (SCS) administers a program of small watershed projects, authorized under the Watershed Protection and Flood Prevention Act of 1954, for flood and erosion control, development of agricultural and municipal water supplies, water quality, and recreation. Proposed projects are initiated and cosponsored by local agencies.

In its 1978 status report (USDA 1978) the Soil Conservation Service reports that 50 applications involving Utah watersheds have been received. Of the 50 applications, 6 were canceled, 8 were terminated in the planning stage, 18 are pending, 6 are in the planning stage, 6 are under construction, and 6 have been completed. In addition, two pilot projects (Pleasant Valley and Santaquin) were completed. Those projects being planned, under construction, or completed are listed in Table 6.

The distinctive component of the Soil Conservation Service projects is that they combine the traditional structural measures of reservoir storage and channelization or levees with land treatment programs conceived to reduce runoff rates and particularly sediment and debris movement. For example, fire protection plans are formulated for forested areas, brush management and grass seeding are used for range lands, and terracing is developed for cropland. Technical assistance is provided land owners in developing appropriate land treatment, and about 30 percent of the implementation cost is paid from program funds.

Program Assessments

The structural flood control projects of the three federal agencies in Utah have on the whole been effective. They have functioned as intended technically. Maintenance problems and adverse environmental impacts have been minor. The data on economic benefits already realized from the Corps projects (Table 6) suggests that all four will far more than pay for themselves over the project lives.

A comparison of the projects listed in Table 6 with those being built in other parts of the country would show the Utah projects to generally be small. The increasing fixed cost of the federal planning process, however, is making it more and more difficult for these smaller projects; the cost of planning is becoming disportionately large in comparison with the benefits achieved. As the federal government does less to provide structural flood control, either because of this reason or in conformance with national fiscal or environmental policy, a need for an increased state role may appear. Before activating such a program, the State of Utah should develop a policy on whether and how to obtain reimbursement from beneficiaries for project cost.

The components that seem to be needed in a structural flood control program for Utah include 1) watershed treatment to reduce the amount of mud and debris carried during cloudburst floods out of mountain canyons and

Table 6. Federally sponsored flood control measures in Utah.

Project Name	Location	Status	Total Cost $	Estimated Annual Flood Benefits
I. U.S. Army Corps of Engineers				
Big Wash Diversion Dam and Channel	Big Wash West of Milford	Completed 1961	$ 343,000	125,000
Redmond Channel Improvement	Sevier River near Richmond	Completed 1951	1,037,000	400,000
Kays Creek at Layton	Layton	Completed 1972	840,000	
Jordan River Improvements	Salt Lake City	Completed 1960	1,690,600	2,000,000
Little Dell Lake	Dell Creek, East of Salt Lake City	Planning Completed, Authorized	59,500,000	1,350,000
Lower Jordan River Parkway	Salt Lake City	Proposed, Feasibility and EIS under review		
Upper Jordan River	Salt Lake County	Study in progress		
Coal Creek	Cedar City	Feasibility studies in progress		
II. Water and Power Resources Service (Bureau of Reclamation)				
Weber River - Echo Res.	Weber River	1931	2,948,104	n.a.
Scofield - Scofield Res.	Price River	1946	925,991	n.a.
Provo River - Deer Creek Res.	Provo River	1941	37,498,116	
Weber Basin -			95,153,632	9,344,000[b]
Rockport Res.	Weber River	1957	6,687,984	n.a.
Pineview Res.[a]	Ogden River	1957	4,453,134	n.a.
Causey Res.	S. Fork Ogden River	1966	6,511,262	n.a.
East Canyon Res.	E. Canyon Creek	1966	4,772,650	n.a.
Lost Creek Res.	Lost Creek	1966	4,813,619	n.a.
Central Utah Project - Bonneville Unit	Central Utah	Authorized	753,417,000	212,000[c]
Hayes Res.	Diamond Fork	Authorized		75,000
Jordanelle Res.	Provo River	Authorized		100,000
Starvation Res.	Duchesne River	1970		1,250
Central Utah Project - Upalco Unit				
Taskeech Res.	Lake Fork River	Adv. Planning 1978		
Central Utah Project - Jensen Unit			29,736,000	n.a.
Tyzack Res.	Big Brush Creek	Under Construction	29,736,000	n.a.
Central Utah Project - Uintah Unit				
Uintah Res.	Uinta River	Adv. Planning 1978	n.a.	n.a.
Whiterocks Res.	Whiterocks River	Adv. Planning 1978	n.a.	n.a.
III. Soil Conservation Service				
Glenwood[d]				
Mill Canyon - Sage Flat (1955)	So. Central Sevier County	Under Construction (95% complete)	1,960,026[e]	4,120[e]
American Fork - Dry Creek (1958)	Alpine	Completed June 1973	6,181,929	52,825

[a]Pineview Reservoir completed under Ogden River Project in 1937 and enlarged under Weber Basin Project.

[b]Total benefits over project life.

[c]Includes estimated annual benefits of $36,000 around Utah Lake.

[d]Original application changed to a supplement of Mill Canyon-Sage Flat Watershed Project, no new flood control features.

[e]Dollars are for year following project name.

Table 6. Continued.

Project Name	Location	Status	Total Cost $	Estimated Annual Flood Benefits
North Fork of Ogden River (1959)	Ogden Valley	Completed Dec. 1965	807,707 (300,114)	12,835
Monroe-Annabella (1963)	So. Central Sevier County	Under Construction (94% complete)	8,377,893	23,655
Green's Lake	Iron County near Cedar City	Completed Apr. 1962	335,420	n.a.
Blue Creek - Howell (1972)	North Box Elder County	Under Construction (98% complete)	5,786,985	123,935
Miller-Bigelow (1960)	Juab County near Nephi	Completed June 1964	269,081	12,400
Minersville	Beaver County around Minersville	Completed Sept. 1968	5,311,376	33,900
Warner Draw (1968)	Washington County around St. George	Under Construction (86% complete)	9,101,189	152,780
Ferron (1962)	Emery and Sanpete Counties	Under Construction (94% complete)	10,015,749	52,045
Muddy Creek	So. West Emery County	Planning	n.a.	n.a.
Clarkston Creek	No. West Cache County	Planning	n.a.	n.a.
Vernon (1967)	So. East Tooele County	Completed Sept. 1976	1,849,762	4,430
Hansel Valley (1975)	No. Central Box Elder County	Under Construction (51% complete)	1,176,331	87,750
Martin Lateral	Duchesne County near Roosevelt	Planning	n.a.	n.a.
Hancock Cove	Duchesne County near Roosevelt	Planning	n.a.	n.a.
Class K-2	Duchesne County near Roosevelt	Planning	n.a.	n.a.
T.N. Dodd Irr. Company	Duchesne County near Neola	Planning	n.a.	n.a.
Pleasant Creek (1956)	E. Central Sanpete County	Completed	560,711	17,060
Santaquin Canyon (1954)	South Utah County around Santaquin	Completed	220,495	4,300

[f]USDA, SCS. 1978. Status of watersheds in Utah, Salt Lake City. October.

onto alluvial fans, 2) conveyance systems to transport flood waters originating in these small canyon watersheds through developed areas, 3) levees to protect low-lying areas, and 4) storage reservoirs to contain snowmelt floods on the larger streams and rivers. In the rural areas of the state, the SCS watershed protection program is well suited because 1) much of the problem is caused by mud and debris flows that are best controlled by watershed treatment, 2) the problems largely originate from small watersheds within the size limitations for the SCS program, and 3) most of the damage is to crops, irrigation systems, and rural roads. Furthermore, the SCS can combine flood control features in projects that also serve other water resources management purposes and thereby enhance the probability of project economic feasibility. Water supply and recreation benefits can, for example, be added to the flood control benefits.

The small projects' program of the Corps of Engineers focuses on urban areas where small levees or channelization are the most economic structural approach. Utah rivers in

Table 7. Emergency work--Corps of Engineers.

Basin	Stream	Costs
Great Salt Lake		$ 749,000
	Weber & Ogden Rivers	107,800
	American Fork River	65,000
	Hobble Creek	83,400
	Provo River	124,500
	Spanish Fork River	64,400
	Salt Creek	43,600
	Tributaries to Jordan River	8,700
	Jordan River	104,400
	Big and Little Cottonwood Creeks	17,200
	Logan River	52,000
	Peteetneet Creek	78,000
Sevier Lake Basin		278,000
	Sevier River and Chicken Creek	51,000
	Shoal Creek	40,400
	Pinto Creek	40,900
	Coal Creek	39,800
	Cedar Creek	67,100
	Red Creek	8,300
	Salina Creek	30,000
Green River Basin		319,000
	Duchesne River	72,000
	White River	48,000
	Ashley Creek	186,000
	Uinta & Whiterocks Rivers	13,000
Colorado-San Juan Basin (Breakdown by stream not available)		214,000

Source: U.S. Army Corps of Engineers

urban areas are relatively small, and most can easily be contained by projects of this size in areas where the SCS program is less applicable because the benefits are to urban property. Small levees are by nature single purpose flood control structures, and thus there is no opportunity to enhance their economic feasibility through multipurpose projects. One gap between the two programs is in the need for watershed treatment to reduce mud and debris flow onto purely urban floodplains. The SCS has the expertise for this sort of design but is limited financially in the role it can take in urban flood control.

Since cloudburst meteorological events cover relatively small geographical areas, they are only an important cause of flooding on smaller watersheds. For larger watersheds, half or more of the total annual precipitation can accumulate in the winter snowpack, melt in the spring, and cause major snowmelt flooding. A number of reservoirs have already been constructed to store these flows (Table 6), but the construction of additional flood control storage is clouded by the fact that most of the relatively few technically feasible sites for the purpose in the state have already been exploited and the increased concern over adverse impacts on environmental quality. Nevertheless, several points are important in assessing the future role of flood control storage in Utah.

1. The larger multiple-purpose projects provide protection on riverine floodplains but do nothing to control flooding from smaller canyons. Single-purpose structures are required to control flooding from these tributaries (only recreation offers opportunities for dual-purpose development), and this need is relatively more important for Utah because flooding from small streams causes such a large small percentage of the total damage.

2. One scenario for future water resources management in Utah is that the federal government will withdraw from its role of water development for urban and agricultural uses and that future water supply projects will be built more and more by state government. As the state undertakes water supply project construction, the opportunities for dual use for flood control should be reviewed for each new project and flood control storage should be included when justified. Nonfederal projects in other states have received Corps' financial assistance in paying for the flood control features, and this funding source should be considered.

3. Even though existing reservoirs with flood control storage have a prescribed operating procedure for joint use of the space, possibilities for increasing total benefits by using either more or less of the existing storage for flood control will develop in the future. Each situation needs to be periodically reviewed so that necessary reauthorization adjustments can be made (Holley and Kane 1974).

From the point of view of getting a problem corrected quickly, local initiative is preferable because, except in emergencies, the federal implementation process is very slow. Nevertheless, the flood hazard area may not be contained within the boundaries of a single locality, thus creating a role for a larger jurisdictional authority--state or federal--to coordinate local efforts.

The comprehensive framework studies (Water Resources Council 1971a, 1971b, 1971c) project future expansion for the federal structural flood control program. The Upper Colorado study (WRC 1971b) projected an increase in average annual flood damages in the basin from \$2.8 to \$10.5 million over the period from 1965 to 2020 and an increase in residential and commercial damages within this total from \$450,000 to \$2,740,000. This latter increase is based on assumptions of normal increases in population and economic activity and that no floodplain development will be induced by structural flood control. To cope with these increases, the study projects future needs for a number of flood control reservoirs, levees, and channels. The Soil Conservation Service projects watershed management and land treatment needs.

City and County Structural Flood Control Measures

The authority of Utah communities to deal with flood problems lies in Chapter 8, "Flood Control Projects and Drought Emergencies," of the Utah code. Section 17-8-1 provides the county commissioners authority to contract with federal agencies to construct flood control projects. Section 17-8-2 provides authority to use county funds to pay the nonfederal costs of such projects including those for maintenance and rights-of-way. Section 17-8-5 provides authority to clean natural channels and construct new or enlarged ones. Counties have eminent domain and have to conform to the pollution control standards of the health authorities and the fish and game commission.

Most of the cities and towns in the metropolitan area along the Wasatch Front have a rectangular street pattern with the north-south streets generally parallel to the contours and the east-west streets sloping downhill at gradients that are generally quite steep close to the mountains and flatten gradually toward the west. These streets are built lower than the adjacent buildings and serve as important flood-runoff conveyance facilities. The storm runoff from the streets and adjacent lots flows down the gutters. Gutter flow is sometimes diverted at drop inlets into storm sewers or open ditches and conveyed downstream.

The larger cities along the Wasatch Front--Ogden, Bountiful, Salt Lake City, and Provo--all have storm drainage programs. Buried culverts were installed beginning in the late 1800s to route streams through urban areas. Until the late 1960s, storm drainage plans were based mainly on the concept of providing pipeline capacity to carry peak flows; but because of the tremendous cost of such an approach, only a few large diameter storm drains were constructed. In 1974, the Ogden City Council passed an ordinance requiring all developers of land areas exceeding 30,000 square feet to provide holding basins to contain any increase in the runoff peaks caused by the construction. Sumps or other storage areas are now used to collect runoff peaks and thereby reduce the size requirements and hence the cost of the conveyance facilities (Hoggan and Nielson 1979).

The detention storage concept was introduced as a superior economic alternative to pipelines for controlling cloudburst runoff in this area in 1969 (Nielsen and Maxwell 1969). Temporary detention storage reduces storm runoff flows to about 10 percent of their peak values, thus greatly reducing the size required and cost of conveyance facilities. Detention basins also may serve multiple purposes, including recreation, beautification, and flood control.

The clustering of numerous cities, large and small, on the foothills and lower, flatter areas along the Wasatch Front makes it difficult, if not impossible, for individual cities to solve their urban runoff problems independently. Actions by uphill cities create problems for adjoining cities and farms downhill. For example, a new drain system constructed to the boundary of an upland city will discharge flood flows into the downhill city and may result in property damage, poor relations between the cities, and law suits. In this setting, the planning of urban runoff systems must be coordinated on at least a county-wide basis to be effective. This has been recognized by public officials, and county master plans for storm water systems have been prepared. Davis County has established a two mill levy to implement its plan by financing flood control improvements. The funds generated, currently $500,000 per year, are used primarily for constructing trunk lines to convey runoff to the Great Salt Lake.

The National Flood Insurance Program

Program History

The National Flood Insurance Act of 1968 (P.L. 90-448) made flood insurance available for the first time to property owners in coastal and riverine flood hazard areas. The idea of a national flood insurance program was proposed by President Truman in 1951, but Congress was leery of the possible federal expense and refused to support the proposal. Extensive flooding in 1955 increased public support. Early in 1956, President Eisenhower proposed a 5-year flood insurance program, which Congress passed virtually intact. The program enacted in the Flood Insurance Act of 1956, however, died a quiet death when Congress failed to appropriate funds for its implementation. A decade later, in response to continued increases in the cost of federal disaster relief, the newly formed Department of Housing and Urban Development (HUD) formulated a new version of the flood insurance idea which was passed by Congress and signed by President Johnson into law on August 1, 1968.

The main feature which the 1968 Act added to the program conceived 12 years earlier was to condition the eligibility of individuals for flood insurance on their community having an acceptable floodplain management program. While community participation in the National Flood Insurance Program was strictly voluntary, individuals could not purchase insurance unless the community (incorporated city or county for unincorporated areas) in which their property was located, joined the program. This required ordinances controlling floodplain development. The program thereby paired eligibility for flood insurance with implementation of a nonstructural flood control program to reduce future losses so that the insurance program cost could be justified by future decreases in federal expenditures for flood damage relief and structural flood control programs.

Growth in the insurance program was slow for the first several years. In the first year, only four communities became eligible nationwide and only 20 policies (Platt 1976, p. 304) were written. By 1972, these numbers had grown to 3,000 and 90,000 respectively but still covered only a small portion of the 16,000 flood-prone communities and 6.4 million residences in flood-prone areas.

Part of the problem was that the communities lacked information on flood hazard and floodplain boundaries. This information proved more costly to obtain than had previously been anticipated, and the federal budget to perform the necessary studies was not able to keep pace with the requests by communities to enter the program. To alleviate this problem, a temporary emergency phase of the program was added in 1969. Communities could join by submitting an application to HUD's Federal Insurance Administration (FIA) with evidence that a building code and floodplain regulation ordinance had been enacted. After FIA finished its study of the community's flood hazard (FIS), the community could convert from the emergency to the regular program.

The entry of new communities into the program was also slowed because so few community officials acted until their community suffered a flood event. A cut in the premium rate made possible by increased subsidization in June 1972, coupled with the damage caused by Hurricane Agnes about the same time, stimulated a jump in participation. Furthermore, the Nixon Administration decided that stronger measures were needed to prevent flood disaster relief from becoming excessively costly. The result was the Flood Disaster Protection Act of 1973 (P.L. 93-234), which provided that no federally related financial assistance would be available to help the owners of flood damaged property unless the applicant had purchased flood insurance. No loans from federally secured financial institutions could be obtained for new construction. Since individuals can buy flood insurance only if their community is a program member, community participation became a condition of individuals securing federal fiancial assistance for flood relief. The financing prohibition for individuals in non-member flood-prone communities was softened to a notification requirement by the Housing and Community Development Act of 1977 (P.L. 95-128); however, the Water Resources Council (1978) interpretation of Executive Order 11988 appears to have re-established the stronger provision. The addition of this financial "stick" to the subsidized insurance "carrot" stimulated rapid expansion in the program and marked the beginning of participation by Utah communities. By the end of 1975, two years after passage of the 1973 Act, community membership had risen to almost 13,000 nationwide (most in the emergency phase) with over 625,000 policies in force (Platt 1976, p. 305).

Community Requirements and Program Coverage

Under the 1968 Act, flood insurance would be made available in a community after a detailed study had been completed indicating flood prone areas by degree of risk and the community had enacted the necessary land use regulations to control floodplain development. Since FIA did not have the manpower or funds to conduct detailed risk studies quickly enough to respond to the communities that had otherwise fulfilled the requirements of membership, the regular program, wherein premiums are actuarial in that they are based on the degree of exposure to flood hazard, was supplemented in 1969 by an emergency program, wherein premiums are at a uniform rate. Presently, both the emergency and regular programs have two phases (Table 8), determined by the amount of flood hazard information provided the community by FIA. (C.F.R. Title 24, Ch. 10, Subchapter B, Section 1910.3.)

In the first phase of the emergency program, the FIA does not provide information defining community flood hazard areas. Instead, the community takes the initiative, identifies the hazards, and presents evidence to FIA of ordinances establishing a system of building permits and zoning controls. The ordinances should provide for the review of building permit applications and subdivision proposals to discourage the construction of new facilities in flood hazard areas or when construction occurs, encourage use of flood resistant methods and materials.

The second phase of the emergency program is entered after the FIA has identified special flood hazard areas (A zones, or the limits of the 100 year flood) by publication of a Flood Hazard Boundary Map (FHBM). Once the FHBM has been published, the community must enter the program or else proposed development in the hazard areas cannot be financed by federally secured financial institutions. The first phase of the regular program is entered once water surface levels are defined, and the second phase of the regular program also requires that a floodway be established and protected against manmade constrictions that would add to flood depths by creating backwater. The FIA requirements for the regulatory programs of the communities in each phase are given in Table 8.

In late 1979, FEMA inaugurated a special conversion and map rescission effort to

Table 8. Phases of participation in the Flood Insurance Program.

Phase		Information Provided by FIA	Community Floodplain Ordinance Requirements
Emergency	a)	No FIA defined special flood hazard area; no water surface elevation data; insufficient information to identify floodway.	Require permits for all proposed construction and development; require flood resistant materials and methods for new construction in flood prone areas; review proposed developments to assure that all required state and federal permits are obtained; review proposals for subdivisions in flood prone areas to assure that flood damage will be minimized, adequate drainage will be provided, and utilities will be constructed to minimize flood damage.
	b)	FIA designated areas of special flood hazard (FHBM); no water surface elevation data nor floodway identification	Require permits, review proposals, and establish standards, as above, in A (100-year floodplain) zones; make reasonable effort to obtain water surface elevation data and elevation of lowest habitable floor for new construction in A zones; assure that new development does not reduce flood carrying capacity; require anchoring of mobile homes, and mobile home park evacuation plan in A-zones, notify adjacent communities and the State Coordinating Officer prior to alteration of stream course.
Regular	c)	Water surface elevation data for A1-A30 zones, and appropriate A0 and A99 zones (FIRM); no regulatory floodway identified	Require permits and standards as in b) above; require elevation to base flood level of lowest habitable floor for new construction and substantial improvements (nonresidential structures may be floodproofed instead if certified), require elevation of mobile homes to base flood level; prohibit new development in A1-A30 zones that would raise flood elevations one foot or more.
	d)	Water surface elevation data for A1-A30 zones, and appropriate A0 and A99 zones (FIRM); regulatory floodway identified	All requirements of c); establish regulatory floodway and prohibit development in it that would increase flood levels; prohibit placement of mobile homes in regulatory floodway or A1-A30 zones except in existing mobile home parks.

address the problems of small communities where some floodplain management effort and the establishment of eligibility to purchase flood insurance may be justified even though the cost of a detailed study is not. The FEMA options for dealing with participating communities were 1) special conversion to the regular program based on a revised map containing only unnumbered A and C zones with residential insurance rates in the A zone of from 10 to 20 cents per $100 and in the C zone of from 1 to 15 cents (suggesting a realization that that hazard may not be much different between the zones, 2) special conversion to the regular program without a map placing the entire community on C zone rates, or 3) placing the community on a priority list for detailed study. Options for dealing with nonparticipating communities were 1) rescind the map so the community could join the program with C zone rates applicable throughout or 2) encourage the community to enroll. The criteria for conversion without a map were that the flooding 1) be confined to a floodplain less than 200-feet wide, 2) be from a source area smaller than 1.0 square mile, or 3) result solely from backwater from a manmade structure. Of the 30 Utah communities examined in November and December 1979, 15 members were recommended for special conversion with a map, 7 nonmembers were recommended for special conversion when they enroll, the maps were rescinded for 4 nonmembers, and 4 members were put on the priority list for detailed study (Karcher 1979).

The insurance covers losses due to flooding of residential and commercial structures and their contents but not damage to landscaping or any items outside the building when the flood hits. All policies carry a $200 deductible provision. Flood losses are defined to include damages sustained as a result of a general flood condition as long as the causes of flooding are not primarily located on the insured's property. Thus, damages to structures caused by flooding from dam failure, such as that in Payson in 1972, would be covered. But flooding from breaches in irrigation canals would be covered only if caused by heavy rain or snowmelt.

The amounts of flood insurance available are listed in Table 9. During the emergency phase, all those who purchase policies in a community are charged the same rate. In the regular phase, the lower subsidized rates are continued for structures built before the program came into effect but actuarial rates are charged as estimated to represent average annual damages to newer construction. Three zones are defined. The A zone encompases the entire 100-year floodplain. It is divided

Table 9. Maximum amounts of insurance available.

Type	Emergency Program		Regular Program		
	1st Layer[c]	Premium	2nd Layer[c]	Premium	Total
Structures					
Single family residential	$ 35,000[a]	$.25/$100	$150,000	actuarial	$185,000
Other residential	100,000[b]	$.25/$100	150,000	actuarial	250,000
Small business	100,000	$.40/$100	150,000	actuarial	250,000
Churches & other property	100,000	$.40/$100	100,000	actuarial	200,000
Contents					
Residential	10,000	$.35/$100	50,000	actuarial	60,000
Small business	100,000	$.75/$100	200,000	actuarial	300,000
Churches & other property	100,000	$.75/$100	100,000	actuarial	200,000

Source: FIA, Federal Register, 43 (Jan. 17, 1978):2572.

[a]$50,000 in Hawaii, Alaska, Guam, U.S. Virgin Islands.

[b]$150,000 in Hawaii, Alaska, Guam, U.S. Virgin Islands.

[c]A property owner is entitled to buy a first layer of insurance to the maximum amount indicated and for the premium shown when his community enters the emergency program. When the community enters the regular program, he can purchase additional or "second layer" insurance to the total shown by paying the actuarial rate determined by the hazard at his building site.

into subzones according to a flood hazard factor equalling the difference in elevation between the 10-year and 100-year water surfaces, a concept often hard to apply in Utah where the large floods are often not any deeper, instead they spread over a larger area. Insurance premiums are set from the A subzone number and the elevation of the main floor in the building and can go as high as $25/$100 in the areas of highest risk. The B zone encompasses areas outside the 100-year floodplain but within the 500-year floodplain, and premiums are in the range of $0.03 to $0.30 per $100. The C zone encompasses areas outside the 500-year floodplain, and property owners there can purchase insurance for between $0.01/$100 and $0.25/$100, depending on the characteristics of their structure. Property owners in the B and C zones would be purchasing protection against rarer events and security in case the flood risk areas have not been mapped correctly. Policies are written by private insurance agents for the federal government. Premiums, less a set fee for the insurance agent, are paid into a special fund created under the Act for payment of claims.

Community Floodplain Management Programs

The current (May 31, 1979) status in the National Flood Insurance Program of each of the 29 counties and 222 incorporated municipalities in Utah is shown in Table 10. Of these 251 communities, 15 are in the regular program, 147 are in the emergency program, 3 were once in the emergency program but have since been suspended, and 86 have never been in the program and hence their residents are not eligible to buy flood insurance. When a community is suspended, no new insurance can be sold nor old policies renewed, but paid policies are honored until they expire. Since policies are sold on an annual basis, no flood insurance will still be in effect a year after a community's suspension.

Statewide, 2676 policies were in force at the end of May covering almost 10 percent of the 26,900 structures estimated to be on Utah floodplains. Coverage totals $86,187,800 or an average of $32,200 per structure. At the end of July, the figures were 2714 policies for a total coverage of $89,329,000.

Of the 89 communities (81 municipalities and 8 counties) where residents are not eligible to buy flood insurance, 40 (the 3 suspended communities plus 37 others that have not joined the program even though the hazard area within them has been defined) are also subject to the provisions of the regulatory program that prevent federally supported financial institutions from making loans on floodplain property. The other 49 are not subject to these sanctions because specific flood prone areas have not been identified.

Table 11 summarizes the status of the communities by code classification. One can see from the summary that since the more populous communities have qualified for the program, 92.6 percent of the population of the state are eligible to buy flood insurance and only 0.58 percent live in communities where loan sanctions apply. Since the 86 communities where property owners are not

Table 10. Population and flood insurance participation of Utah counties and incorporated cities and towns.

Community Name	Population (1975 Est.)	Code[a]	Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
		Flood Insurance Program Participation (5/31/79)				
Counties (Unincorporated areas)						
Beaver	604	1	05/34/75		2	$ 62,000
Box Elder	5,138	1	12/17/74	02/28/78 & 01/30/79	1	17,000
Cache	2,699	4				
Carbon	4,409	1	11/27/74	06/14/77	4	60,500
Daggett	431	4				
Davis	10,740	1	04/22/75	02/07/78	5	155,800
Duchesne	5,966	4				
Emery	1,333	1	07/25/75	01/17/78	1	8,000
Garfield	284	1	07/03/75	01/10/78		
Grand	1,741	4				
Iron	1,722	1	05/08/75	04/11/78	4	204,600
Juab	481	4				
Kane	526	1	07/01/75	01/10/78	2	115,500
Millard	1,930	4				
Morgan	2,736	1	06/25/75	10/18/74 & 02/14/78	5	223,500
Piute	190	1	03/14/78	11/08/77	1	33,000
Rich	532	4				
Salt Lake	273,019	1	09/26/74	08/30/77	64	2,082,100
San Juan	7,320	1	06/39/75	01/31/78		
Sanpete	996	1	03/02/76	11/14/78		
Sevier	1,126	1	11/14/75	02/07/78		
Summit	2,423	1	06/10/75	01/03/78	4	$ 113,000
Tooele	4,247	1	06/07/76			
Uintah	12,145	1	11/30/77	02/14/75 10/18/77 08/15/78	1	35,000
Utah	15,926	1	11/12/71	01/10/75	7	158,000
Wasatch	1,616	1	04/04/75	05/31/77		70,000
				12/13/77	2	70,000
Washington	2,087	1	10/15/75	02/07/78	7	278,000
Wayne	974	4				
Weber	11,867	1	03/25/75	05/02/78	14	601,100
Cities & Towns						
Alpine	1,524	1R	02/11/76		2	67,000
Alta	226	5				
Altamont	249	5				
Alton	41	1	02/05/79			
Amalga	207	1 SC	03/03/75	09/05/75		
American Fork	10,467	1	05/23/74	12/28/73 & 02/06/76	40	$ 1,307,600
Annabella	303	1	04/14/76	01/10/75	35	1,088,800
Antimony	126	3		04/02/76		
Aurora	657	1	01/26/76	01/31/75 & 01/07/77	6	191,300
Austin	n.a.	4				
Bear River City	473	3 SC		09/05/75		
Beaver	1,750	3		06/11/74		
Bicknell	282	1	07/10/75	01/24/75	7	191,300

[a]Codes are defined in Table 11.
Two-letter designations after code are FEMA recommended actions in December 1979
SC - Special conversion to regular program (contingent on community enrollment)
DS - Detailed study RM - Rescind map

Table 10. Continued.

Community Name	Population (1975 Est.)	Code[a]	Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
		Flood Insurance Program Participation (5/31/79)				
Cities & Towns (Cont.)						
Blanding	2,768	4				
Bloomington	n.a.	4				
Boulder	148	5				
Bountiful	30,358	1R	09/29/78	10/26/73	47	1,377,800
Brian Head	118	5				
Brigham City	14,157	1	11/01/74	06/07/74 & 01/16/76	33	1,417,900
Cannonville	123	5				
Castle Dale	861	1	07/25/75	01/10/78	1	35,000
Castle Gate	n.a.	4				
Cedar City	10,349	1	03/19/75	01/23/74 & 03/05/76	32	1,024,000
Cedar Fort	241	1	01/06/76	02/07/75	2	$ 64,000
Centerfield	485	4				
Centerville	5,198	1	07/24/75	06/28/74 & 03/19/76	6	282,000
Charleston	217	1	10/22/75	09/19/75	2	60,000
Circleville	435	1	09/14/77	08/02/74 & 05/11/76		
Clarkston	471	1 SC	09/23/76	09/05/75		
Clearfield	13,416	1R	02/20/79	08/02/74 & 10/01/76	10	345,000
Cleveland	315	3		07/12/77		
Clinton	3,629	1R	07/21/78	08/02/74 & 04/30/76	17	465,000
Coalville	820	1		08/02/74 & 10/03/75	4	94,000
Corinne	486	1 SC	09/28/77	06/25/76		
Cornish	152	3 SC		04/02/76		
Delta	2,016	1	05/20/75	07/25/75	2	43,500
Deweyville	236	3		04/29/77		
Duchesne	2,198	1	11/25/74	06/21/74 & 10/24/75	37	1,158,500
East Carbon	2,168	1	03/07/75	10/29/76	1	35,000
East Layton	876	1	10/17/74	06/28/74 & 04/01/77	2	$ 70,000
Elmo	176	5				
Elsinore	431	1	09/26/75	11/14/75	19	471,900
Elwood	323	3		01/24/75		
Emery	219	1R	09/11/78	02/07/75	4	127,100
Enoch	133					
Enterprise	1,216	3		08/16/74		
Ephraim	2,380	1	01/31/75	06/28/74 & 01/16/76	7	145,000
Escalante	654	1	04/22/75	08/09/74 & 11/28/75		
Eureka	732	1	07/02/75	06/07/74 & 11/07/75	5	68,700
Fairview	800	1	06/12/75	06/28/74 & 01/09/76	12	238,400
Farmington	3,372	1	05/13/75	06/28/74 & 10/31/75	7	209,500
Fayette	85	5				
Ferron	756	1	01/20/75	05/24/74 & 12/26/75		
Fielding	301	3 RM		08/08/75		

[a]Codes are defined in Table 11.

Two-letter designations after code are FEMA recommended actions in December 1979

SC - Special conversion to regular program (contingent on community enrollment)

DS - Detailed study RM - Rescind map

Table 10. Continued.

Community Name	Population (1975 Est.)	Code[a]	Flood Insurance Program Participation (5/31/79) Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
Cities & Towns (Cont.)						
Fillmore	1,826	1	05/01/75	06/28/74 & 05/14/76	2	$ 65,800
Fountain Green	457	3		04/02/76		
Francis	328	3		07/25/75		
Fruit Heights	2,001	1	05/11/77	03/18/77	1	35,000
Garden City	149	5				
Garland	1,165	5				
Genola	542	3		02/07/75		
Glendale	257	1	05/19/77	04/02/76		
Glenwood	294	1	07/10/77	10/22/76	5	151,200
Goshen	473	3		02/07/75 & 04/15/77		
Grantsville	3,657	1	07/09/75		5	147,100
Green River	968	1		06/21/75 & 12/05/74	3	105,000
Gunlock		4				
Gunnison	1,193	1	08/27/75	08/16/74 & 08/13/76	1	30,000
Harrisville	757	1	09/29/75	08/08/75	2	70,000
Hatch	128	1	08/05/75	02/07/75 & 10/10/75		
Heber City	3,633	1	03/25/75		15	497,500
Helper	2,198	2S		01/09/74 & 01/23/76	11	$ 342,000
Henefer	446	1 SC	07/23/75	02/21/75 & 04/23/76		
Henrieville	166	1	02/07/75	02/07/75		
Hiawatha	166	5				
Hildale	729	3		06/04/76		
Hinckley	436	4				
Holden	356	1	09/28/77	06/03/77	1	35,000
Honeyville	716	1 SC	03/10/76	06/28/74 & 01/02/76		
Howell	163	5				
Huntington	1,303	1	07/09/75	05/24/74		
Huntsville	609	3 RM		06/21/74		
Hurricane	1,725	1	08/05/75	07/12/77	1	45,000
Hyde Park	1,309	1 SC	03/10/75	08/02/74 & 12/19/75	1	35,000
Hyrum	3,137	1 SC	11/07/74	05/24/74 & 04/09/76		
Ivins	240	1	10/21/74	09/12/75	7	220,000
Joseph	141	1	03/23/76	01/10/75	4	$ 91,500
Junction	158	1	01/07/75	08/08/75	1	32,500
Kamas	849	1	07/02/75	08/16/74 & 07/30/76	6	184,000
Kanab	2,088	3		10/29/76		
Kanarraville	263	1	06/06/75	12/17/76	2	48,900
Kanosh	328	1	11/25/77	04/02/76	2	60,400
Kaysville	7,553	1	04/18/75	06/28/74 & 09/03/76	9	371,100
Kenilworth						
Kingston	139	3		02/04/77		
Koosharem	127	3		12/24/76		

[a]Codes are defined in Table 11.

Two-letter designations after code are FEMA recommended actions in December 1979

SC - Special conversion to regular program (contingent on community enrollment)

DS - Detailed study RM - Rescind map

Table 10. Continued.

Community Name	Population (1975 Est.)	Flood Insurance Program Participation (5/31/79) Code[a]	Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
Cities & Towns (Cont.)						
Laketown	217	3 SC		11/12/76		
La Verkin	785	1	09/03/75	07/02/76		
Layton	15,411	1	12/13/74	08/09/74 & 05/14/76	103	3,431,600
Leamington	104	5				
Leeds	224	1	08/11/78	04/02/76		
Lehi	5,736	1	10/18/74	02/07/75	11	327,200
Levan	402	1	08/01/78	06/21/77	1	35,000
Lewiston	1,332	1 SC	06/29/76	08/16/74 & 12/19/75		
Lindon	2,083	3		06/21/77		
Loa	341	3		12/20/74		
Logan	23,810	1	11/26/74	01/16/74 & 04/08/77	24	$ 791,700
Lynndyl	105	5				
Maeser	n.a.	4				
Manila	345	5				
Manti	1,869	1	07/10/75	08/09/74 & 12/19/75	45	1,232,400
Mantua	426	1 SC	08/20/75	01/17/75		
Mapleton	2,727	1	05/07/75	06/28/74 & 03/26/76		
Marysvale	325	1	03/08/77	02/11/77	4	85,000
Mayfield	295	3		05/28/76		
Meadow	252	3		07/02/76		
Mendon	511	1 SC	08/04/76	07/18/75 & 04/01/77		
Midvale	8,310	1	12/09/76	09/26/75	2	42,300
Midway	977	1	09/11/75	06/28/74 & 10/31/75	1	11,100
Milford	1,283	1	02/24/75	08/09/74 & 12/19/75		
Millville	549	3 SC		10/22/76		
Minersville	449	4				
Moab	4,500	1	09/17/74	06/21/74 & 12/26/75	81	$ 2,787,400
Mona	450	3		06/21/77		
Monroe	1,235	1	07/08/75	06/28/74 & 10/03/75	13	362,600
Monticello	1,726	3		12/24/76		
Morgan City	1,704	1	11/26/74	06/28/74 & 04/16/76	41	1,258,700
Moroni	886	1	07/09/75	09/06/74	1	22,000
Mount Pleasant	1,743	1	02/25/75	07/11/75	31	719,000
Murray	22,595	1	12/19/74	03/29/74 & 12/19/75	20	786,100
Myton	446	3		04/02/76		
Nephi	2,882	1	05/29/75			
Newton	501 SC	1	11/15/76	07/11/75		
Nibley	419 DS	1	03/24/75	07/18/75		
North Logan	1,497 DS	1	09/26/74	06/28/74 & 11/21/75		
North Ogden	6,566	1	10/02/75	05/06/77	24	786,000
North Salt Lake	3,092	1R	08/29/78	06/28/74 & 08/13/76	6	209,000

[a]Codes are defined in Table 11.

Two-letter designations after code are FEMA recommended actions in December 1979

SC - Special conversion to regular program (contingent on community enrollment)

DS - Detailed study RM - Rescind map

Table 10. Continued.

Community Name	Population (1975 Est.)	Code[a]	Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
		Flood Insurance Program Participation (5/31/79)				
Cities & Towns (Cont.)						
Oak City	302	1	09/22/75	02/07/75	3	$ 78,000
Oakley	294	1	06/11/75	01/31/75 & 12/24/76	4	101,400
Ogden	68,978	1	12/27/74	06/21/74 & 08/16/77	35	1,165,100
Onaqui	443	4				
Ophir	85	4				
Orangeville	655	1R	03/01/79	06/07/74 & 12/12/75	1	8,500
Orderville	472	3	03/15/78	02/04/77		
Orem	35,584	1	03/15/78	10/29/76	6	173,000
Panguitch	1,314	1	03/10/75	06/28/74	1	19,400
Paradise	487	3 RM	10/04/74	11/05/76		
Paragonah	260	1	03/12/75	02/14/75	2	54,100
Park City	1,559	1	05/08/75	09/06/74 09/03/76	12	457,900
Parowan	1,764	1	06/09/75	08/16/74 & 12/19/75	5	145,800
Payson	6,500	2S		06/28/74 & 12/05/75	21	559,800
Perry	1,038	1 SC	02/07/78	07/26/74 & 11/28/75		
Pickelville	120	5				
Plain City	1,916	1	02/07/78	06/03/77	2	$ 70,000
Pleasant Grove	7,074	1	08/05/75		2	76,000
Pleasant View	2,312	1	07/23/75	09/24/76	29	1,031,000
Plymouth	187	3 RM		08/22/75		
Portage	196	5				
Price	7,391	1R	03/01/79	01/16/74 & 11/28/75	75	2,257,600
Providence	2,293	1 DS	05/02/75	08/13/76	1	35,000
Provo	55,593	1R	02/01/79	02/15/74 & 06/04/76	62	1,755,200
Randolf	507	3 SC		08/16/74		
Redmond	459	1	07/02/75			
Richfield	4,947	1	09/26/74	05/24/74 & 12/05/75	29	926,200
Richmond	1,317	1 SC	06/10/75	04/02/76		
Riverdale	4,707	1	10/04/74	06/28/74 & 11/28/75	30	958,300
River Heights	954	4				
Riverton	3,442	1	10/23/75	11/01/74 07/23/76	41	1,271,900
Rockville	n.a.	4				
Roosevelt	3,943	5				
Roy	16,781	1R	10/24/78	02/07/75	24	780,900
Rush Valley	541	3		10/25/77		
Salem	1,480	1	01/20/75	06/28/74	2	65,000
Salina	1,685	1	04/30/74	01/23/74 & 09/26/75	22	$ 612,000
Salt Lake City	169,917	1	05/28/74	12/27/74	992	33,190,200
Sandy	10,077	1	02/03/75	07/26/74 & 01/16/76	32	951,900
Santaquin	1,529	1	05/16/75			

[a]Codes are defined in Table 11.
Two-letter designations after code are FEMA recommended actions in December 1979.
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RM - Rescind map

Table 10. Continued.

Community Name	Population (1975 Est.)	Code[a]	Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
		Flood Insurance Program Participation (5/31/79)				
Cities & Towns (Cont.)						
Santa Clara	383	1	08/07/75	06/04/76		
Scipio	223	1	08/03/78	07/12/77		
Scofield	49	5				
Sigurd	358	1	09/26/75	09/19/75		
Smithfield	4,280	1	12/18/74	06/28/74 & 12/26/75	6	145,000
Snowville	170	5				
Soldier Summit	10	5				
South Jordan	4,098	1	06/10/75	07/26/74 01/30/76	6	187,000
South Ogden	10,175	1	08/02/74	04/05/74	4	98,000
South Salt Lake	9,041	1	05/23/75	09/19/75	2	47,000
South Weber	1,265	1R	09/12/78	06/28/74 & 02/13/76		
Spanish Fork	8,065	4				
Spring City	591	1	05/07/76	06/27/75	1	$ 33,000
Springdale	249	3		05/10/77		
Springville	10,206	2S		02/01/74 & 05/21/76	53	1,496,600
St. George	8,760	1	08/28/74	08/16/74 & 06/11/76 & 11/22/77	38	1,192,700
St. John-Clover	n.a.	4				
Sterling	127	5				
Stockton	403	1	03/23/76	01/24/75	1	20,000
Sunnyside	517	1R	09/29/78	04/02/76	3	63,000
Sunset	6,300	1R	11/21/78	06/28/74 & 02/13/76	4	136,600
Syracuse	2,991	1R	06/01/78	06/28/74	7	251,000
Tabiona	235	4				
Tooele	12,905	1	03/10/75	08/16/74 & 04/09/76	50	1,361,800
Toquerville	292	3		06/25/76		
Torrey	104	1	03/22/79	11/12/76		
Tremonton	2,981	3 SC		04/23/76		
Trenton	390	3 SC		06/27/75		
Tropic	359	1	09/03/75	02/07/75	1	26,000
Uintah	381	1	11/30/77	10/29/76	1	35,000
Vernal	5,492	1	04/16/75	07/03/76	8	215,200
Vernon	180	3		06/04/76		
Virgin	101	1	06/25/75	06/25/76		
Wales	121	4				
Wallsburg	265	3		07/02/76		
Washington	1,245	1	07/07/75	08/02/74 & 06/04/76	7	$ 278,000
Washington Terrace	8,078	4				
Wellington	1,146	1	02/09/77	07/26/74 & 04/09/76		
Wellsville	1,494	1 SC	07/18/75	06/21/74 & 12/26/75		
Wendover	1,001	1	07/25/75	08/15/75		

[a]Codes are defined in Table 11.
Two-letter designations after code are FEMA recommended actions in December 1979
SC - Special conversion to regular program (contingent on community enrollment)
DS - Detailed study RM - Rescind map

Table 10. Continued.

Community Name	Population (1975 Est.)	Flood Insurance Program Participation (5/31/79) Code[a]	Date of Entry	Hazard Identified	Policies in Force	Amount of Insurance
Cities & Towns (Cont.)						
Wendover	1,001	1	07/25/75	08/15/75		
West Bountiful	1,752	1	07/02/75	12/28/73 & 11/05/76	22	704,100
West Jordan	11,405	1	07/16/75	07/19/74 & 03/05/76	55	1,717,300
West Point	1,379	4				
Willard	1,117	1 DS	11/16/76	06/07/74 & 01/09/76		
Woodruff	180	1 SC	12/16/75	08/22/75	1	$ 19,800
Woods Cross	3,219	1R	08/29/78	12/28/73	1	16,000
Yost	62	4				
TOTALS	1,202,672				2,676	85,187,800

Source: Federal Insurance Administration, U.S. Bureau of Census.

[a]Codes are defined in Table 11.
Two-letter designations after code are FEMA recommended actions in December 1979
SC - Special conversion to regular program (contingent on community enrollment)
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Table 11. Number of Utah communities by code classification.

Code	Definition	Insurance Status	Sanction Status	Communities Number	Communities Population	Average Population
1R	Entered into regular program	R	N	15	146,950	9797
1	Entered into emergency program	E	N	147	967,273	6580
2	Suspended (from emergency program)	a	Y	3	18,904	6301
3	Hazard area defined, community not in program	n	Y	37	23,294	630
4	Flood prone areas known to exist but not defined	n	N	29	38,314	1321
5	No known flood prone areas	n	N	20	7,937	397
Totals				251	1,202,672	4792

Insurance Status Coding (May 1979)
- R Eligible to buy both layers of insurance.
- E Only eligible to buy first layer of insurance.
- a No new policies or renewals but old policies are good until they expire with a one year maximum.
- n Not eligible to buy any insurance.

eligible to buy insurance average a population of only 806, one can see where they might feel that they would have difficulty handling the details of complying with the federal program.

One difficulty a community may encounter is in drawing up an acceptable ordinance. The State of Illinois (1977) developed a model ordinance to help small communities in that state and distributed it in a pamphlet also containing supplemental information on its use and a reprinting of the National Flood Insurance Program rules and regulations (Federal Insurance Administration 1976b).

Figure 9 provides the floodplain ordinance for the town of Amalga as illustrative of the typical wording used in Utah. Most communities follow the wording suggested by FIA, except as to how they fill in the blanks, for convenience in adoption and in order to avoid later hassle with federal officials because of an ordinance that falls short of federal standards. Nevertheless, small communities experience continuing difficulty in changing the FIA desired wording in ways they feel necessary to fit their local situation and then having to negotiate its acceptance. From the perspective of the federal program, separate unique

RESOLUTION # ______

RESOLUTION OF THE TOWN OF AMALGA PROVIDING FOR THE REVIEW PROCEDURE OF THE BUILDING PERMIT SYSTEM ADOPTED BY THE TOWN OF AMALGA

WHEREAS, the TOWN OF AMALGA has adopted and is enforcing ordinance # ______ providing for the building code regulations and Ordinance # ______ providing for zoning regulations, and

WHEREAS, Sections ______ and ______ of the aforesaid prohibits any person, firm or corporation from erecting, constructing, enlarging, altering, repairing, improving, moving or demolishing any building or structure without first obtaining a separate building permit for each building or structure from the Town Clerk, and

WHEREAS, the TOWN BOARD must examine all plans and specifications for the proposed construction when application is made to him for a building permit.

NOW THEREFORE, BE IT RESOLVED by the TOWN BOARD OF AMALGA, UTAH as follows:

(1) That the TOWN BOARD shall review all building permit applications for new construction or substantial improvements to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a location that has a flood hazard, any proposed new construction or substantial improvement (including prefabricated and mobile homes) must (a) be designed (or modified) and anchored to prevent flotation, collapse, or lateral movement of the structure, (b) use construction materials and utility equipment that are resistant to flood damage and (c) use construction methods and practices that will minimize flood damage, and

(2) That the TOWN BOARD shall review subdivision proposals and other proposed new developments to assure that (a) all such proposals are consistent with the need to minimize flood damage, (b) all public utilities and facilities, such as sewer, gas, electrical, and water systems are located, elevated and constructed to minimize or eliminate flood damage and (c) adequate drainage is provided so as to reduce exposure to flood hazards; and

(3) That the TOWN BOARD shall require new or replacement water supply systems and/or sanitary sewage systems to be designed to minimize or eliminate infiltration of flood waters into the systems and discharges from the systems into flood waters and require on-site waste disposal systems to be located so as to avoid impairment of them or contamination from them during flooding.

PASSED and ADOPTED by the TOWN BOARD OF AMALGA, at a special meeting thereof, held on the 2nd day of January, 1975.

______________________ Mayor

Dale Rindlisbacher /s/

ATTEST:

Marilyn H. Hansen /s/
Clerk

Figure 9. Typical floodplain management ordinance.

ordinances for each community poses major difficulties because of the time required to review them for compliance with the national standards.

Floodplain Occupancy Choices

Despite the large number of cloudburst and spring snowmelt floods which have been recorded in Utah, the damage caused to private property has been remarkably small. As of 1979, the Utah Division of Water Resources estimated Utah's annual flood damage to average about $4 million of a national total that would now be about $4 billion (McCrory et al. 1976). Since Utah has about 0.5 percent of the United States population, damage rates per capita (and by implication per unit value of structure) are about 20 percent of those nationwide. Furthermore, the damage records for historical Utah floods cited above indicate that damage to privately owned structure has been a very small fraction of the total.

This fact implies that Utahns have used sufficiently good judgment in their floodplain occupancy decisions to avoid frequent flood damage. Urban development in Utah is generally on larger lots where the shallow flooding can pass between buildings, and buildings in flood prone areas have generally been built high enough off the ground to be safe. In the field surveys of Utah's flood prone communities reported in the next chapter, a few scattered homeowners (Willard) and businesses (Moab) were found to have short walls to deflect flood waters and mud flows.

The question that needs to be asked to determine the need for floodplain management is (in terms of Figure 1) whether the land use decisions being made by private individuals based on their perspective of the physical, economic, social, cultural, and governmental factors are reasonable from a higher level perspective in the governmental dimension? The two considerations most likely to make them unreasonable are that 1) floodplain occupants may be unaware of the devastation that an event as large as the 100-year flood can bring or 2) higher level perspectives may see reasons for reducing floodplain land use intensity not seen by the occupants.

With respect to the risk of devastation from rare events, the shallow-flooding on alluvial fan and valley areas is very unlikely to threaten human life or destroy buildings (except at the apex immediately below where sediment laden waters discharge from mountain canyons). It would not appear wise from the viewpoint of economics to prevent development in all areas subject to inundation by 100-year floods on alluvial fans; the areas are too large and the benefits too few. A more promising alternative is to distribute flood proofing information so that those building in these areas can do a better job of protecting themselves against shallow flooding entering buildings or basements. In many cases, deflecting levees set back from a building can divert waters during short cloudburst flood periods into drainage ways where damage will be minimized.

An additional problem frequently encountered on alluvial fans in irrigated areas is that canals cross the fans parallel to the contours and intercept flood waters coming downhill. The canals then fill, overtop away from the stream, and cause flooding in areas where no problem would otherwise occur. This problem could be greatly alleviated by canal design for flood bypass or to discharge excess waters at controlled discharge points, but a regulatory effort will be needed to make this occur. The danger of canal flooding greatly increases as an area converts from agriculture to urban, and the canal companies are slow to provide for this contingency as urbanization occurs. Each situation, of course, should be individually analyzed to determine what measures are appropriate.

An additional problem encountered in the field interviews performed in as part of this study was that some individuals living in communities enrolled in the flood insurance program were being told by their insurance agents that they could not buy insurance. The matter could be quickly resolved when the query was properly directed, but this did not occur in many cases. Better information needs to be made available to eligible floodplain occupants on the mechanics of purchasing the insurance. One wonders how much of the reason that so few policies are sold is the fault of poor information on the part of property owners and how much is the fault of poor information on the part of insurance agents.

With respect to reasons seen from a higher level perspective for reducing floodplain land use intensity, the greatest need on alluvial fans is to protect recharge areas for groundwater development. Most groundwater recharge in desert climates occurs on fans. Most of the water recharged from the ephemeral streams emerging from mountain canyons is flood water. Care needs to be exercised to make sure that the flood water control system does not unnecessarily restrict recharge and that flood waters do not become polluted and contaminate underground aquifers.

CHAPTER V

SURVEY OF FLOOD PROBLEMS

Survey Approach

Floods cause economic loss, social disruption, and environmental damage. As described in Chapter II, these primary flooding impacts induce people and institutions to respond in ways that generate waves of economic, social, and environmental effects. A survey of flood problems thus needs to identify both primary problems caused by the flooding but not being responded to appropriately and the secondary problems associated with undesirable impacts of structural and nonstructural programs to deal with flooding.

This survey considered all 251 Utah communities, whether or not they have a known primary flood problem, because of the uncertainties in determining whether a hazard exists in marginal cases and because national nonstructural programs may have secondary effects in communities with no primary problem. For example, a community exposed to very minor flooding may be forced to undertake greater nonstructural effort than is warranted by its situation, and the effort may generate undesirable economic, social, or environmental impacts. One purpose of the survey was to determine whether such consequences were actually occurring.

Available study resources, however, did not permit examination of all 251 communities. The approach was to examine a sample to identify problems for more detailed analysis in a second round reported in the next chapter. This chapter presents the sampling procedures, describes what was found in each community examined, and describes the problems found to deserve further analysis.

Sampling Procedure

Since the project budget would only permit visiting about 30 of the 251 counties, cities, and towns listed in Table 10, a sampling ratio of about one out of eight was selected. Stratified samples were used for both counties and cities or towns. Counties were classified between the densely populated areas along the Wasatch Front and the more sparsely populated rural areas. Cities or towns were classified according to the population groups of under 1,000, 1,000 to 5,000, 5,000 to 50,000, and over 50,000. A second sort of classification was according to the status of community involvement with the National Flood Insurance Program. The classifications used divided nonmember communities into the categories of 1) not mentioned and therefore presumably not having a major flood problem (Code 5, Table 10), 2) suspected as having a hazard but with the locations and degree of hazard not identified (Code 4), and 3) having a mapped floodplain area but choosing not to join (Code 3). Member communities were divided between those 1) having joined the emergency program and 2) having joined and also having a detailed study underway. The classifications used in the sampling were based on community status as of November 1977; the status of many communities has changed since then to that updated on Table 10.

Communities were classified by size as an index of both the nature and magnitude of the flood problem and of ability to cope with it. Nature relates because larger communities attract more people unaware of local conditions and hence more prone to make unwise use of floodplain lands. Magnitude relates because more people bring greater population densities and often faster growth rates, both factors making flood hazard identification and floodplain management more difficult. Ability to cope relates because larger communities have a greater tax base for financing community programs and usually greater technical expertise on staff. Classification by FEMA program status provides an index of the support of local officials for the national program for their community.

This two-way classification divided the counties, cities, and towns of Utah into the 30 groups shown on Table 12. No communities fell into the seven classifications marked "none." One out of every eight in each remaining 23 groups was selected by using a table of random numbers. A minimum of one community was chosen from each group to make sure that each was represented. The 26 cities and towns and 6 counties chosen by this process are listed on Table 12. The location of each is shown on a map of Utah in Figure 10.

Information Sought by Community

The process for gathering information on the 32 selected communities combined 1) collection of information that could be obtained about the problem from maps and other available sources in preparation for a site visit, 2) a field visit to observe selected flood problem areas on the ground, and 3) interviews with engineers, planners,

Table 12. Study sample communities.

Code (Table 11)	Flood Insurance Program Status (10/15/77): Non Members: Not Mentioned 5	Non Members: Suspected Hazard Not Mapped 4	Non Members: Mapped Floodplain 3	Program Members: Emergency 1 and 2	Program Members: Detailed Study Underway 1R
A. Counties					
Location					
Wasatch Front	None	Cache	None	Box Elder	None
Other	None	Piute[2]	Uintah[1]	Washington	Emery
B. Incorporated Cities and Towns					
Population					
> 50,000	None	None	None	Ogden	Provo[3]
5,000-50,000	Spanish Fork[4]	Washington Terrace	None	Sandy Pleasant Grove	Bountiful[5]
1,000-5,000	Garland	West Point	Beaver	Hurricane Hyde Park Parowan Richmond	Helper[6]
< 1,000	Garden City[7] Bluff[7]	Wales	Millville Kingston Koosharem	Corinne E. Layton Kamas Midway	Castle Dale[8]

[1]Entered emergency program 11/30/77.
[2]Hazard identified 11/8/77, entered emergency program.
[3]Entered regular program 2/2/79.
[4]Hazard area designation withdrawn by FIA, exempt from program.
[5]Entered regular program 9/29/78.
[6]Suspended, pending approval of revised floodplain management ordinances.
[7]Unincorporated town, membership as part of San Juan County.
[8]Detail study in review and appeals period.

and local political leaders. Since some communities had many scattered flood prone areas, a limited number had to be preselected for investigation. The preselection was based on 1) coverage of the diversity of floodplain types found within the community in terms of stream size, extent of floodplain development, and pressure for new development, 2) ease of access and proximity to one another, and 3) existence of a hazard to private property. Floodplain management for public lands was not considered within the primary focus of this study.

The preparation before the site visit included 1) obtaining available topographic and flood hazard maps (flood hazard mapping status by community is shown on Table 10), 2) inspecting maps of the upstream watershed area and the floodplain in order to understand better the source of the problem-causing flows and geomorphological conditions on the floodplain, 3) consulting Utah's flash flood history or stream gaging records to see if any floods have occurred recently, 4) discussing the community with FIA officials to obtain insights on the community's response to the federal program, and 5) obtaining descriptive information on the local economy in order to have a general idea as to the pressures for development in the hazard area.

The field visit combined observations of field conditions, taking snapshots of items of interest, and conversations with local residents. The observation schedule included 1) noting floodplain land use as residential, other urban, cropland, or natural, 2) classifying any buildings observed on the floodplain by characteristics related to their susceptibility to flood damage, 3) noting the extent of new urban construction, 4) noting any observable flood proofing, 5) noting any flood marks or signs of past damage, 6) noting any man-made constrictions that may be contributing to the flood problem, 7) noting any evidence of past efforts to increase channel conveyance, and 8) noting any obvious discrepancies between the floodplain mapping and observed ground conditions. Local residents encountered were asked if they recalled any flood experiences or local efforts to control flooding and whether they were aware of and, if so, how they felt about the FIA program.

In scheduling interviews with local officials, the goal was to include 1) an engineer familiar with the local situation, 2) a lawyer or planner familiar with local building code and zoning problems, 3) a political leader familiar with the local deliberations on the FIA program and with community prospects and feelings on growth, and 4) individuals who any of the first three suggested as having suffered severe flood damage or having strongly objected to floodplain regulations. The interview with the engineer was to pursue such topics as 1) descriptive information on historical floods, 2) descriptive information on any local structural or channel maintenance efforts, and 3) recommendations on individuals to include in the fourth group to interview. The interview with the lawyer/planner was to explore such topics as 1) description of community floodplain management efforts, 2) identification of any privately proposed development that had been

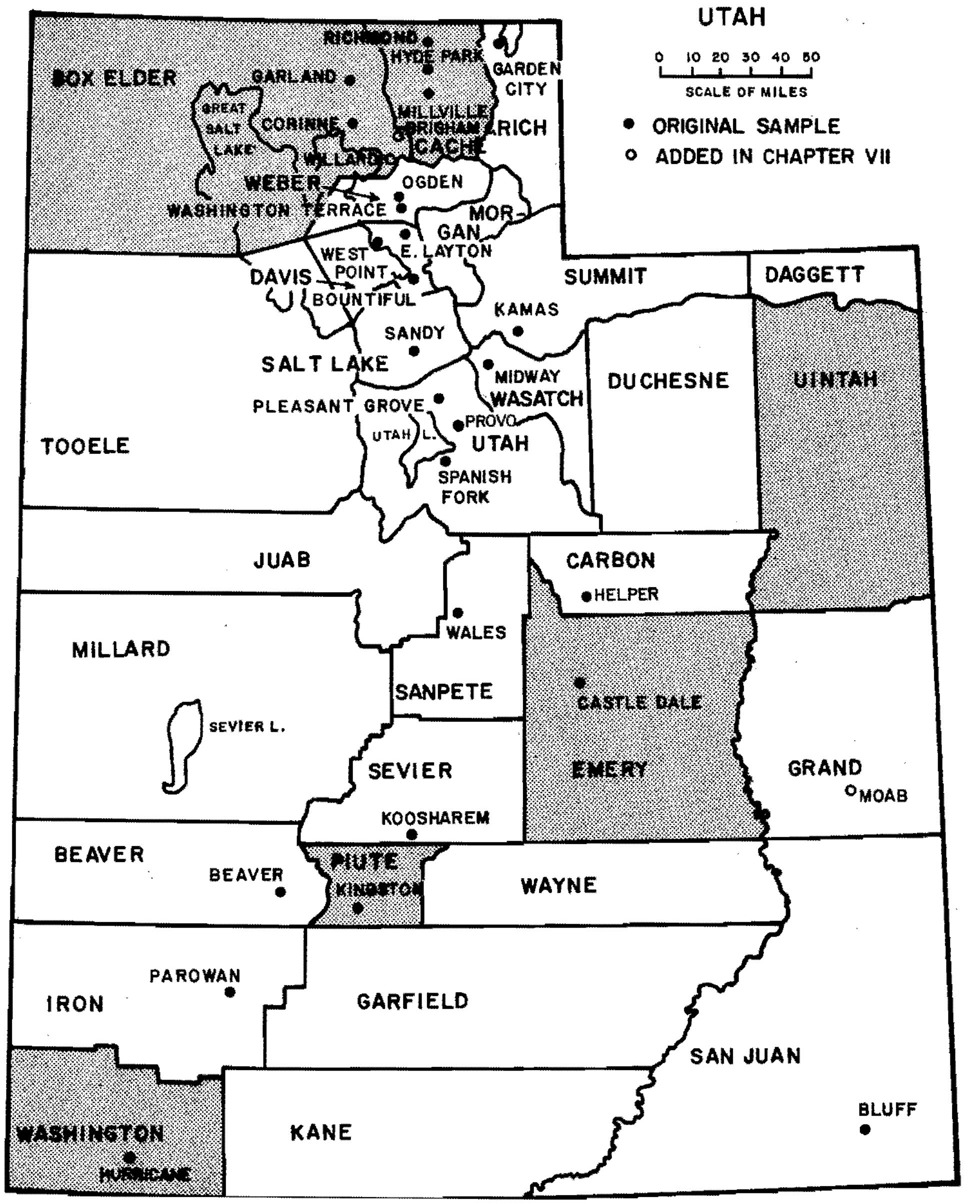

Figure 10. Location map for sample communities.

prohibited because of its floodplain location, 3) identification of any privately constructed development that was flood proofed or otherwise modified in design because of the hazard, 4) description of floodplain management program enforcement procedures and an estimate of their cost, 5) explanation of any nonconforming floodplain development that may have been observed during the site visit, and 6) assessment of the FIA program from their viewpoint and as received by the people of the community. Local politicians were to be asked about 1) remembered historical floods, 2) attitudes in the community toward the national flood insurance program, 3) memories of discussion on whether or not to join the program, 4) expectations for economic change in the community, and 5) assessment of whether the program is helping or hurting the community. Questioning on many of the above points did not produce useful information in many of the communities, and such replies are not detailed below.

Findings for Counties

Box Elder County

Box Elder County contains vast sparsely inhabited desert areas and a number of growing communities at the north end of the Wasatch Front urban area in the eastern part of the county. Flood hazard areas have been identified, and the county has entered the emergency flood insurance program permitting its 5138 residents who live outside of incorporated towns and cities to purchase insurance. As of May 1979, however, only one policy was in force (Table 10).

Although the Bear and Malad Rivers flow through the county to where they join upstream of flowing into the Great Salt Lake, flooding damages along the rivers have been small and largely agricultural. Both rivers are deeply incised in narrow canyons until they open into swampy areas near the lake, and streamside locations thus do not attract much development. According to county officials, there are three potential flood damage locations along the Bear River and none along the Malad River. As also shown on the flood hazard maps for the county, the three locations where residential property could be flooded are: 1) downriver a short distance from Corinne; 2) near Hampton's Crossing between Fielding and Collinston (Pony Express Station on historical lists); and 3) downriver a short distance from Bear River City.

Butler and Marsell (1972) describe 17 cloudburst floods as occurring in the county between 1939 and 1969 with 12 of these occurring in the incorporated areas of Brigham City (6), Willard (4), and Snowville (2). The other five occurred at Fielding, Howell, Perry, Plymouth, and Promontory. A flash flood thus has been occurring somewhere in the county about one year out of two, but most have caused only isolated damage to agricultural land and the worst during this 31-year period only damaged two or three buildings.

Box Elder Creek, which originates near the reservoir at Mantua, flows onto an alluvial fan at the base of the mountains, and passes about a mile downstream through Brigham City, poses the greatest flood damage potential in the county. South of Brigham City, Perry Creek, Willard Creek, and Three Mile Creek threaten the towns of Perry and Willard. These and other creeks flowing out of smaller mountain canyons pose danger for the unincorporated areas between Perry and Willard and south of Willard to the county line. Gravel pits in this area may be causing a significant increase in flood risk in that they may capture flood flows from the channels, impound water, and later break loose discharging stored water and gravel onto the property below.

Box Elder Creek has flooded Brigham City periodically since the city's settlement in the mid 1800s. The most serious flood occurred in February 1911 when snowmelt, possibly augmented by heavy rain, produced extremely high runoff. The clogging of bridge openings by debris diverted water into the city, bridges were washed away, and a section of railroad track was washed out. Emergency efforts were required to protect the powerhouse in Box Elder Canyon. While some flooding of basements was recorded on June 3, 1963, there has been no recent serious flooding. Nevertheless, in realization that a 100-year flood would cause extensive damage in the city, the county Department of Emergency Services conducted a flash flood exercise in 1978 in Brigham City in which 300-400 people were evacuated.

The City of Willard has experienced periodic flooding. Willard Creek basin had a flood in 1923 and another in 1936 which washed mud and debris into town and caused two deaths in the first case and substantial property damage in both cases (Woolley 1946). Following the 1936 flood, the Civilian Conservation Corps (CCC) did a substantial amount of terracing upstream from the town. The Bureau of Reclamation or the CCC also built a levy between the creek and the City of Willard shortly afterwards, and flooding from Willard Creek has not caused flood damage since. The area behind the levy is now filled with rocks and sediment. Inspection and evaluation of these old designs could provide valuable clues in developing more effective future measures for controlling floods and mud flows emerging from mountain canyons onto alluvial fans.

Recent floods occurred in Willard on August 13, 1978, and July 23, 1979. In the first case, a cloudburst on Willard Peak caused water to flow down the face of the mountain between two canyons. Mud, rocks, and debris filled the Pine View perimeter canal for one mile, causing the irrigation water to overflow the banks and add to the flooding. Basements of three homes were filled with mud and debris, causing an estimated $65,000 in damages. There were also extensive damages to lawns, orchards, and gardens to bring the total, including some wind damage, to about $250,000.

None of the three homes were insured under the FIA program even though they were eligible. Two of the homeowners received flood damage assistance under a USDA program which covers farms over 5 acres in size. The other homeowner had less than 5 acres and received no financial help. All three said that they were unaware of federal insurance even though its availability had been announced in the newspapers.

On July 23, 1979, debris and mud washed down the mountain, damaged one home, and crossed the state highway. The damaged homeowner was outside the mapped 100-year hazard area and reported that he had tried but been unable to purchase flood insurance.

In the western part of the county, there has been occasional flooding in the Grouse Creek area, but very little development is affected. There are only about 30 homes in the entire area. The main damage is from washed out roads.

The cities and unincorporated areas in the eastern part of the county have the greatest development pressures as well as the greatest flood hazards. Subdivisions and individual homes are being built at several locations along the base of the mountains from Beaver Dam on the north to the county line at the south. The area south of Willard is the fastest growing. The developments close to the base of the mountains are generally exposed to hillside flooding of the sort described for Willard. This danger, however, should not necessarily preclude hillside development. Building sites at the base of the mountains are particularly attractive because of the view they offer of the valley below, and these bench areas are usually much less productive agriculturally than are valley soils. Land use planning needs to weigh the tradeoffs, and the building construction practices used on these bench areas need to protect the structures.

Box Elder County is participating in the FIA program. It adopted the uniform building code in 1973 and became eligible for flood insurance in 1974. Out of 17 towns in the county, 13 are now eligible for insurance, but this group does not include Snowville and Howell where flash flooding has occurred. As of May 31, 1979, 33 policies had been issued in Brigham City and 1 elsewhere in the county. The detailed study is in for the county was completed late in 1979.

Three flood hazard areas were selected for field observation. Each is shown to have extensive flood hazard areas on the FIA flood hazard boundary maps, dated February 28, 1978. The three locations were: 1) Malad River east of Portage, 2) Bear River south of Fielding, and 3) a low area between the interstate highway and railroad south of Honeyville.

The first or Malad River location was found to contain low lying pasture and wasteland with no structures that would be damaged by overbank flooding and no apparent pressures for future development. Much of the area at the second or Bear River location was also pasture and wasteland, but there were also significant acreages of hay. Also a historical site (Pony Express Station, now a farm house and outbuildings) at Hampton's Crossing, with an estimated value of over $100,000, is subject to flood damage. An old steel highway bridge at Hampton's Crossing would probably obstruct large flows. Location 3 was found to contain pasture and wetlands with no structures of any kind; however, several miles to the south, the Brigham City Airport is shown within the flood hazard area on the FIA map.

In summary, Box Elder County is transversed by two rivers with defined floodplains. No significant damages have occurred to buildings in these areas historically; the only building found in the examined portion of the 100-year floodplain has been standing for over 100 years essentially undamaged. Cloudbursts causing flows out of mountain canyons or down the steep mountainsides occur, however, every few years and account for the bulk of the flood damages currently inflicted on the county, and these problem areas are not well defined on the flood hazard maps. While residents of the unincorporated portion of the county are eligible for flood insurance, the occupants of exposed areas at the base of the mountains are generally not aware of that fact and at least some have been told that they cannot obtain it. Even though Box Elder County is a program member, its citizens are taking little advantage of the program, and floodplain management efforts are minimal and doing little to reduce future flood risk. Specifically, the program does not seem to be focusing sufficiently on the hazard at the base of the mountains, and the regulatory program is not extensive enough to cause secondary problems.

Cache County

Cache County is the second of the two urbanizing Wasatch Front counties in the sample (Table 12). Flooding is known to occur in the county, but the hazard areas have not been mapped, and the county has not applied for membership in the National Flood Insurance Program. The 2699 residents of the unincorporated areas of the county are thus not eligible for the insurance.

The county covers the Utah or south half of Cache Valley with farming land on the valley floor and over 90 percent of the population living in cities and towns along the valley margins. The urban expansion is centered around Logan and occurring in the incorporated areas with significant amounts also occurring in unincorporated areas. As in Box Elder County, development has been attracted more to bench areas around the perimeter of the valley than in the relatively swampy lowlands subject to riverine flooding on the floor of the valley. Some recent shift, however, seems to be resulting from the greater escalation of land prices on the bench.

Butler and Marsell (1972) describe 13 cloudburst floods occurring in the county between 1939 and 1969. Six occurred near Logan, two each near Clarkston and Smithfield, and one each near Hyrum, Mendon, and Providence. The events large enough to cause significant damage were a gravel and mud flow out of Blacksmith Fork into Hyrum May 30, 1939, a wall of water emerging out of Cold Water Canyon at Mendon September 12, 1939, a cloudburst filling some Clarkston basements with water August 22, 1958, a cloudburst in the mountains above Providence on August 18, 1959, that flooded a dozen homes in that town and littered the bench areas in Millville with boulders and mud, a cloudburst on August 25, 1961, that inundated 1500 acres and caused $20,000 in damages at Clarkston, and the flooding of Smithfield basements by Summit Creek June 7, 1964. Significant flood damage to residences also occurred in Logan due to local runoff from heavy rains on August 22, 1977, on the bench at the mouth of Dry Creek Canyon.

Riverine flooding occurred along the Logan River in 1896, 1897, 1907, 1912, 1916, 1921, 1971, and 1972; however, information on areas flooded and flood damage is nonexistent for most of these floods. The most severe flood on the Logan River occurred in May 1907 with a discharge of 2,480 cfs. According to Table 3, this exceeded the 100-year event. The largest flow in recent years was 1,680 cfs in June 1971 (Corps of Engineers 1973). Housing along the Logan River in the City of Logan is the prime risk area subject to riverine flooding in the county. Logan and several other cities in the county are participating in the federal flood insurance program.

The Blacksmith Fork River and Spring Creek also have experienced numerous floods since the turn of the century. The last significant one occurring on the Blacksmith Fork was in May 1971. At that time, snowmelt produced a peak flow of 825 cfs (Corps of Engineers 1975). Other small rivers and creeks, such as Cub River and High Creek, occasionally flood adjacent pasture and farmlands. There has been no significant riverine flooding in the county since 1972. As was the case for Box Elder County, the damages that have occurred have been caused by flows from the smaller canyons such as the Dry Creek case cited above.

The reason the county has not made application to join the National Flood Insurance Program does not seem to be based on any opposition to mapped areas or regulatory requirements and the cost to the county of enforcing them. In August 1978, the county passed a "sensitive area ordinance" that requires, through the building permit process, new buildings in the floodplain to be designed with foundations sufficient to withstand 100-year flood flows, have no basements, and have the first floor above the 100-year flood elevation. All persons wishing to build in the floodplain must, in addition to meeting the aforementioned requirements, file a statement with the county acknowledging the flood hazard and assuming all liability for flood damage. A county map has been prepared from SCS data showing areas along rivers where flooding has occurred. The county has no flood control projects, but annually cleans river channels above and below road crossings.

The failure of Cache County to apply for program membership relates more to county staff giving higher priority to other matters and never getting around to complete necessary paper work. The experience suggests a need for FIA to minimize the paper work requirements which can be interpreted as requesting information of a sort on which the community has limited technical expertise.

In conclusion, the unincorporated areas of Cache County have experienced very little flood damage, and the county has an ordinance to reduce exposure to damage from future building in the floodplain. One caution that the county should consider is that while frequency analyses of the gaged records indicate that the 100-year flows on the Logan River and Blacksmith Fork are on the order of 2000 cfs, Figure 8 indicates that flows of around 4500 cfs have occurred from other drainage basins of similar size in the Great Basin portion of Utah. Even though such events may be much rarer than the 100-year, it would behoove the county to act to make flood insurance available to its residents before such floods occur. The county appears to already have a floodplain management program that would come close to qualifying, actuarial rates would generally be low, and the benefits of having such coverage when a major flood comes would be large.

Emery County

Emery County is in a rural part of the state with low population density but in an area where energy resource development could lead to substantial population growth in the near future. The county has entered the regular flood insurance program, but only one small policy is in force.

Butler and Marsell (1972) describe 48 cloudburst floods occurring in the county between 1939 and 1969 with 44 occurring since 1957. Most of the floods were in isolated areas where the principal damage was the closure of roads and small losses to agricultural property. Damages to scattered homes from runoff from localized intense showers were occasionally reported.

The principal hazard areas in Emery County are located along the numerous washes south of Castle Dale, near Cleveland, west of Green River, and near Ferron. The 100-year flood hazard is mapped along Ferron Creek, Cottonwood Creek running from the northwest to southwest near Castle Dale, and Huntington Creek near the City of Huntington. Some areas along the San Rafael and Green Rivers in the county are also within the 100-year floodplain.

Flooding in the county has been mainly caused by severe summer thunderstorm activity and the resulting runoff and debris washed down various washes and Cottonwood and Huntington Creeks. A boy was drowned by a flash flood near Orangeville on August 4, 1900. Severe thunderstorms in August and September of 1941 caused damage to highways and bridgework at Emery and Green River. The heavy rains of July and August of 1957 caused floods near Castle Dale, Orangeville, Green River, and Ferron. Approximately $10,000 in damage was inflicted to several homes in Orangeville. Damage to crops and to roads in the above communities was also experienced. Flooding again swelled Cottonwood Creek in 1964 destroying newly installed approaches to the new bridge near Old Mill Dam near Orangeville. In 1965, Huntington Creek flooded causing damage to Huntington City Water Works estimated at between $8,000 and $12,000.

Heavy rainstorms in 1967, 1968, and in 1969 caused flooding at Orangeville, Green River, Ferron, Cleveland, and Emery. Most of the damage from the flooding in this 3-year period was to roads, bridges, and canal structures. Several canal and irrigation structures were washed out or filled with boulders and debris near Ferron. The drugstore basement in Ferron was filled with water and debris causing damage to inventories and the furnace. Crops in the Ferron area were also damaged extensively. The most damaging historical flooding appears to have been centered near Ferron and Orangeville although some road and building damage has been experienced at Green River.

Observation of the hazard areas on the site visit indicated no buildings within the hazard areas near Castle Dale, Cleveland, Huntington, or other small communities in the county. Floodplains are used for cropping or grazing, and these activities have suffered most of the damages from the flooding that has occurred. A brief interview with a county zoning official suggested that future development will not be permitted in the unincorporated areas of Emery County and that the 1333 current residents of those areas all live on farms. Urban development does exist in the floodplain at Green River. A motel operator east of the town has invested in bank stabilization on the east bank of the Green River at a cost of $9,000 in 1972 and some terracing and rock levying in 1974 at a cost of $11,000. Other work has been done just north of town to protect properties along the west bank of the Green River. Costs of these structures were unavailable.

Emery County entered the FIA program in July 1975. However, floodplain maps were not published until January 1978, and only one policy is now in force. Interviews with officials in Green River indicated that the insurance program is little known and probably misunderstood. The officials suggested that the residents of Green River and the surrounding area have lived with the flood potential of the Green River for many years and generally assessed the potential damage to insurable assets to be low. Those who assessed the probability of damage to be relatively high had invested in flood proofing or measures such as those described above. Little proofing activity was evident, however. The unincorporated areas of the county are currently almost entirely zoned for agriculture, and the farmsteads are generally on high ground. Hence, the flood insurance program has virtually no impact. A recent ordinance which requires that a water hookup be secured before the county will issue a building permit may also reduce future flood problems.

The Ferron watershed project has been completed by the Soil Conservation Service under the P.L. 566 program. This project consists of a reservoir (Mill Site Dam) above Ferron and canals and debris basins at lower elevations. Ferron Creek and several washes drain into the reservoir. Average annual flood protection benefits were estimated in the work plan to be $27,700 (U.S. Soil Conservation Service 1965) to farming areas south and east of Ferron. The project work plan indicates that a flood in 1947 cost two lives and washed out ditches and canals as well as causing heavy damage to roads. The USGS streamgage was apparently rendered inoperable by this flood, and no peak discharge was recorded. An estimated peak discharge of 4,180 cfs was recorded during a 1952 flood (Table 3). Equation 2 suggests the possibility of a flood as large as 15,400 cfs at this location.

Emery County thus seems to be a case where the county government has pushed through the necessary applications to enroll in the program even though little insurable property is found in its unincorporated areas. Participation seems to provide several benefits for the county. It permits the purchase of low cost flood insurance against damages caused by the severe thunderstorms characteristic of the area. The floodplain management regulations provide an additional tool that can be used to implement the county planning goal of keeping any urban development associated with energy resource development within the incorporated towns.

Piute County

Piute County is very sparsely populated with little potential for immediate growth.

Flood hazard areas were mapped in November 1977, and the county joined the federal flood insurance program the following March. Unincorporated areas of the county have only 190 residents, the fewest of any county in the state. Butler and Marsell (1972) note 11 cloudburst floods in the county from 1939 through 1969, 8 in Marysvale, 2 in Kingston, and 1 in Circleville. The only damages they noted from any of these floods were from road closures in canyon areas.

As examples, heavy rainstorm floods have been recorded in Marysvale and in Kingston Canyons. In July 1955, a flash flood in the mountains northwest of Marysvale caused some $19,000 damage to the roadbed of U.S. Highway 89 and rendered some 80 acres of baled hay useless for feed. Keetch (1971) notes damage to homes in Marysvale in August 1958 from flash flooding on Cottonwood Creek, Bullion Canyon, Revenue Canyon, and Beaver Creek. Additional flash flooding occurred in July 1965 and again in August and September of 1967. Again, U.S. Highway 89 north of Marysvale was broken up by the onrush of water and boulders from the mountains, and some alfalfa fields east of Kingston were inundated by flooding of the East Fork of the Sevier River. Flash floods in July 1968 again covered the highway with debris and mud, but greater damage was caused by hail which destroyed several acres of corn. Approximately $30,000 in crop damages occurred near Marysvale during a July 1975 flash flood. In earlier storms, Highway 89 was blocked by a washout on July 11, 1936, a railroad bridge was damaged on July 24, 1925, and half of the county's hay crop was destroyed by Sevier River flooding in early August 1916 (Woolley 1946). In over 100 years of record, however, the only noted damage to buildings in either the Marysvale or Kingston areas was the relatively small amount inflicted in Marysvale in August 1958. No history of damage to buildings could be found for the unincorporated portions of the county.

Piute County and Kingston and Marysvale officials suggested that the FIA program does not suit the needs of the county since most damages occur to uninsurable crops, roads, and bridges. Marysvale officials further claim that the mapped flood hazard area, particularly along the river around where the Denver and Rio Grande Railroad right-of-way passes through town, is not correct. They instead visualize a flash flood problem wherein heavy rainstorms wash boulders and debris onto Highway 89 and onto cropland on both sides of the highway. The east fork of the Sevier River also floods over its banks at a series of bends where impediments to free flow divert the water onto alfalfa fields. The flood problem thus comes from both flows out of the mountain canyons and overflow of the rivers in the valleys.

The drainage area of the East Fork of the Sevier River near Kingston is 1250 square miles (Utah Water Research Laboratory 1968). Peak recorded discharge on the East Fork of the Sevier River near Kingston is 2030 cfs on May 12, 1941, and a frequency analysis of the recorded annual flow series indicates a 100-year flood of 1839 cfs (Table 3). Equation 1 suggests a maximum flow of 6600 cfs for a drainage area of this size, and the FIA study estimates a 100-year flow of 28,000 cfs. This thus seems to be a case where flooding much worse than any ever recorded could well occur, but the FIA flow seems unreasonably high.

Brief interviews with farmers in the area indicated that they assess the probability of flash flooding to be quite high but losses to crop and livestock enterprises to be relatively low. The small amounts of damage which occur rather frequently destroy, at most, a corn silage crop or about half of the second alfalfa harvest for the season Such losses are not considered enough to justify changing farming practices. Farmers operate as if no flood hazard exists and replant in the same pattern after losses occur. These attitudes provide empirical support for the business activity strategy in the face of flood hazard that has been outlined as theoretically optimal by Brown (1972) and Brown et al. (1972).

Even though Piute County is now in the emergency program, no specific ordinances have been passed to indicate interest in future participation in the program. Some communities within the county have been mapped but not the unincorporated areas. With almost no flood damage reported to buildings in the over 100 years since settlement and little prospect of new construction in hazard areas, Piute County has no structures with a flood problem other than that associated with events more rare than any which have occurred. Larger losses occur to crops and roads, but these do not appear large enough to justify major adjustment in farming practices or road alignments. In short, a more comprehensive floodplain management program would not seem to be justified.

Uintah County

Like Emery County, Uintah County is in a rural part of the state currently with low population density but likely soon to experience substantial growth with development of its energy resources. The county was selected from the sample of nonmember communities having an identified hazard area, but Uintah County entered the emergency program in November 1977, one month after the sample was drawn. The population of 12,145 living in unincorporated areas make Uintah County the third highest in the state in this regard.

Road damage was caused by flash flooding in August 1912, September 1927, and September 1938 (Woolley 1946). Butler and Marsell (1972) describe 20 cloudburst floods in the county, 7 in Vernal, 2 in Maeser, and 11 in unincorporated areas. Only 2 of the 11 caused reported damage to buildings. A flood on August 25, 1955, brought water 2 feet deep around a house in Dry Fork Canyon and washed boulders and silt onto the yard.

On September 1, 1909, a man was drowned while trying to drive a wagon across Ashley Creek. On July 4, 1925, an 8-year old boy was drowned when he was swept from an automobile (with nine occupants) which rolled down a wash during a flash flood. A year earlier, two boys narrowly escaped death when surprised by a 10-foot deep flash flood (Woolley 1946). On July 19, 1965, floodwaters filled the basement of a home at Ashley.

This study uncovered records of floods near Maeser, La Point, Jensen, and Randlett in 1955, 1956, 1961, 1963, and in 1965. Flooding in areas contiguous to Ashley Creek north of Maeser occurred as did flooding from the Uintah River near Randlett and flash flooding causing boulders and debris to wash from the foothill regions near La Point and Jensen. The Green River occasionally floods over its banks at a series of bends near Ouray, but dwellings are located on high ground above and to the north of the river. Several roads in the area, including portions of state highway 88, are in the 100-year flood zone and frequently under water.

A flood on October 7, 1916, was recorded as destroying bridges and buildings in Vernal (Woolley 1946). Ashley Creek flooded due to a heavy rainstorm in September 1955 causing an estimated $3,500 damage to a $15,000-home in Maeser. Some $900 damage to a dwelling near La Point was caused by flooding during the same storm. In June 1965, the heaviest rainstorm experienced in several years caused Ashley Creek to flood the basements of 11 homes. Repair costs were estimated at approximately $700-$1,000 per home. Additional damages were caused to hay crops in Jensen and Maeser and to roads and bridges near Randlett as a result of the same floods.

Uintah County entered the emergency insurance program in November 1977 after successfully negotiating changes in the boundaries of the flood hazard zone near Randlett and north of Maeser. The county's goal was to reduce the area of the mapped 100-year flood zone along Ashley Creek downstream of the point where canals had been constructed near Maeser to handle excess water from the creek. The area as originally mapped contained 525 homes and 25 businesses, and the construction of 10-15 homes a year was projected. The numbers will be somewhat smaller for the reduced area. FIA records show that one dwelling policy for $35,000 had been sold by May 31, 1979. Interviews with Uintah County officials in late 1978 indicated that seven dwelling and one commercial policy had been sold for an approximate total face amount of $167,000.

Information obtained from county officials indicated that the canal structures constructed in the Maeser area and used to justify reduction of the size of the mapped floodplain were sufficient to handle the flash floods of 1968, 1972, and 1974. Recorded channeling and canal structure costs totaled approximately $28,000, but other costs incurred in developing the canals were unavailable.

Uintah County is apparently experiencing significant pressure for urban development on its floodplains. The primary problems are along desert washes where flooding patterns are more consistent from storm to storm than they are on alluvial fans. Flooding, however, is shallow, and the appropriate nonstructural program and regulatory measures to enforce it are not well defined.

Washington County

Washington County is in an agricultural and growing resort area in the extreme southwestern corner of the state. The county entered the emergency flood insurance program in October 1975, the hazard area mapping was released in February 1978, and 7 policies for $278,000 were sold by May 1979. This is the most insurance for any county in the state outside the two most populous Wasatch Front counties. The population of the unincorporated area of the county is 2087.

Woolley (1946) lists over 15 cloudburst floods for Washington County beginning in 1863. Butler and Marsell (1972) list 36 cloudburst floods for the county. Of these 36, 12 were listed for St. George, 12 for smaller incorporated towns, and 12 for unincorporated areas including 5 in Zion National Park. An August 25, 1944, flood damaged park buildings. On September 17, 1961, 5 members of a hiking party of 26 were drowned by a flash flood on the Virgin River in the park which crested at a 14-foot depth in some narrow gorges. No other damage to buildings in the unincorporated area of the county was noted by Butler and Marsell (1972), but flooding was frequently mentioned as causing considerable damage to roads and highways and disrupting traffic. According to the earlier records compiled by Woolley (1946) buildings were damaged by flooding in 1863, 1870, 1872, 1896, and 1901. The hydraulic records note floods much larger for the size of their drainage area than elsewhere in the state. The high flows and rapid rises in narrow mountain gorges create a more severe flood problem than that found in most other areas of the state.

Also in contrast to the problems with flows emerging from mountain canyons in most other parts of the state, the principal sources of flooding in Washington County are the Virgin and Santa Clara Rivers and Fort Pierce Wash. High flows in other normally dry washes also cause occasional problems. Flooding may be caused either by general rain coupled with snowmelt or localized summer cloudbursts. The flood of December 1966, which produced 100-year flows on the Virgin

River, was caused by heavy rains that washed away the winter snowpack.

The area around St. George is rapidly developing as a retirement and vacation community. Much of this development has occurred on floodplains because the terrain is some of the most conducive to construction in the area. The pace of growth has not slowed since commencement of the federal insurance program. Thus, a flood of magnitude equal to that in 1966 would now cause far more residential damage.

Most of the construction in flood-prone areas, however, has occurred in incorporated towns and cities. As land is converted to residential use, it is usually annexed into one of the existing cities. The Bloomington Ranches subdivision is the major exception, with the lots on Sugar Les Road, between Churchill Drive on the south and Three Bars Road on the north (approximately 115 acres) within the 100-year Virgin River floodplain. Only 19 homes were located in the flood hazard zones in the unincorporated portions of the county in 1975 according to its application for the flood insurance program. County officials seem generally aware of, but somewhat indifferent towards, the flood insurance program.

The Virgin River has a drainage area of about 6,000 square miles; 3,880 square miles of the basin lie above Bloomington. According to the Corps of Engineers study (1973), the 100-year flood flow at this point would be about 46,000 cfs. Fort Pierce Wash drains 1,660 square miles, with an estimated 100-year flow of 24,000 cfs. The 545 square mile drainage of the Santa Clara River would produce a 100-year flood flow of about 26,000 cfs. These flows are somewhat higher than the 100-year flows obtained from the USGS frequency studies and reported in Table 3 as 34,660 cfs for the 5090-square mile drainage area for the Virgin River above Littlefield, Arizona, and 13,220 cfs for the 338-square mile area for the Santa Clara River above Santa Clara, Utah. Record flows at these two points are 35,200 and 6190 cfs respectively. The envelope curve of Equation 1 reads a flow of 18,800 cfs for the Santa Clara River. The December 1966 flood on the Virgin River was estimated by the USGS as a 100-year event and also falls on the envelope curve as the largest flood ever generated by a basin of that size in Utah. One would have to conclude from the magnitude of these flows that Washington County has at least one of the most severe riverine flood hazard situations in the state in terms of depth and velocity of flooding and property at risk.

Reports of flood damage in the area began shortly after the earliest white settlement. In addition to the flood of record in December 1966, winter flooding also occurred on the Virgin River in 1911, 1932, 1938, 1958, and 1969. General summer rains produced the most recent floods in September 1972 and August 1971 (Corps of Engineers 1973). These two months are the primary flood season.

Flooding on the tributaries to the Virgin River is usually caused by localized summer thunderstorms. Peak flow on Fort Pierce Wash in the August 1971 flood was estimated at 15,000 cfs, about three times the peak flow on the Virgin River for the same flood; but in December 1966, Fort Pierce Wash had a peak flow of only about 1,000 cfs.

The Ash Creek, Kolob, Upper and Lower Enterprise, Pine Valley, and Gunlock Reservoirs, all constructed with state and local funds in the mountains north of St. George, provide incidental storage for protection against snowmelt runoff, but they are not operated for flood control. The Soil Conservation Service's Warner Draw Project, authorized in 1969, contains features for flood damage reduction in southern Washington County. Structures include 11 debris basins and 6 miles of diversion channels. Proposals for additional work around St. George and on Frog Hollow Wash south of Hurricane are being reviewed. In addition, several farmers have undertaken channel stabilization measures on their own initiative to protect their fields.

The county has sought federal assistance from the Corps of Engineers and the Soil Conservation Service for structural flood control for the Virgin River, but these agencies are reluctant to sponsor structural measures in the wake of the environmentalist opposition associated with the woundfin minnow controversy that arose in debates over the Bureau of Reclamation's Dixie Project on the Virgin. Nonstructural measures, on the other hand, do not alleviate the main flood problem, which remains crop and road damage caused as much by erosion and sedimentation as by the flood water. Land use in the mapped flood hazard area is primarily range and cropland. The more serious flood severity makes flood proofing generally less effective here than elsewhere in the state.

The riverine nature of the Washington County flood problem matches the emphasis of the national program more nearly than do the situations elsewhere in Utah, but there are still important differences. For example, the high sediment content of the flood water greatly increases the damage caused by a given depth of inundation and makes actuarial rates estimated from national data too low (Grigg and Helweg 1975). It also increases the importance of land treatment for flood control and suggests differences in flood proofing design. While the county has joined the National Flood Insurance Program to make its citizens eligible for insurance, its nonstructural program has been minimal. County officials apparently do not see the danger as very great, and their assessment is supported by having experienced a 100-year flood in 1966 with minimal losses.

Findings for Towns and Cities

Beaver

Beaver was selected to represent towns with between 1000 and 5000 people that have not entered the flood insurance program even though a hazard has been identified. In June 1974 four blocks at the southern end of the town were designated as within the 100-year floodplain of the Beaver River, which flows approximately 100 yards south of the city. City officials contend that there is no flood hazard within the city, although they recognize the hazard posed by the Beaver River in the county and have refused to join the FIA program for this reason. Their appeal of the flood hazard designation succeeded in reducing the designated area to a half-block 3 feet lower than the surrounding land, and having poor drainage. City officials do not regard the periodic inundation of this half block from rainfall as a flood hazard because no damage is done by the standing water. Moreover, the fill required to raise the land high enough for highway access, should development be desired, would elevate the area above the level of the FIA designated flood. An FIA review will be conducted in the near future to determine whether the map should be rescinded.

Butler and Marsell (1972) record six cloudburst floods in the area of Beaver between 1939 and 1969. Woolley (1946) recorded six spanning the period from 1882 to 1937. All the reported damage seems to have been to roads and farms near the town (except for the distruction of a brick kiln in the South Mountains in 1882), and no mention is made of flooded buildings. The largest flood in 51 years of flow records on the Beaver River at Beaver (82-square mile drainage area) was 1080 cfs on July 22, 1936. This compares with an estimated 100-year flood of 1370 cfs. The regional flood envelope curve (Equation 2) gives a flow of 3600 cfs.

Even if FIA does not rescind the Beaver flood hazard map, the town would suffer very little cost in implementing a floodplain management program for its half-block of lowlands and make all 1750 residents eligible for flood insurance should a very extreme riverine flood occur or should localized cloudbursts send water through town in lesser washes. Expansion by incorporation to the northwest or the south would bring flood prone land into the town, and such an eventuality should cause the city to join the insurance program.

Bluff

Bluff was selected in the sample to represent towns of under 1000 population not mentioned as to status in the list of the flood insurance program. While it turned out that the reason for this omission (and omission from Table 10) was that the village had recently voted to disincorporate, the investigation was continued because of the town's interesting flood hazard situation.

Southeastern Utah has had a history of repeated flash floods over the years. The 70,000 cfs recorded on the San Juan River at Bluff in September 1927 is the largest flow ever recorded on any river in the state. Other problem areas are Comb Wash and Cottonwood Creek near Bluff and the Montezuma Creek on the Navajo Indian Reservation. In all these cases, heavy summer rains swell creeks and washes with the onrush of water, silt, and boulders. The floods of 1963, 1968, and 1970 were particularly troublesome for residents in Bluff. Peak discharges of Cottonwood Creek at the Highway 95 crossing west of Blanding and at Bluff were 20,500 cfs and 42,100 cfs, respectively, in the August 1968 flood. The peak discharge in Comb Wash near Bluff of 8,390 cfs was three times that of a 50-year flood. The flows backed water 3-feet deep into Bluff and caused over $16,000 in damages to business and residences (Butler and Marsell 1972).

Record breaking rains in early September 1970 produced flash floods which destroyed roads and bridges and damaged several ranches near Bluff, Montezuma Creek, and Aneth. Considerable damage was done to Navajo Trust Gardens. Two people were drowned when they drove their car off a washed-out bridge. New 12- and 24-hour rain measurement records for the state were set by the storm. Damages to roads, bridges, and farm buildings were estimated at $165,000.

Interviews with San Juan County officials and residents of Bluff indicated that they see the main problem as caused by high flows in Cottonwood Wash. Debris lodges against the Highway 163 bridge and backs water into town. The August 1968 flood backed water onto the school yard and a local market along Highway 163.

Since Bluff residents voted to disincorporate, property owners in the community are able to purchase insurance because San Juan County is a participant in the FIA program. However, few Bluff residents who have experienced flood damage were found to know about the subsidized insurance program or understand that San Juan County participates. To date, no insurance policies have been purchased by the 7320 residents of the county's unincorporated areas.

Bountiful

Bountiful is a community in the 5,000 to 50,000 range for which a detailed study was underway at the time the sample was taken and which is now in the regular program. The city is situated on outwash alluvial fans downstream from the mouths of Barton, Mill, and Stone Creek Canyons. These creeks flow through the city from east to west in relatively steep channels and flood narrow strips of land already fully developed with housing and other buildings.

Storm drains constructed by the city discharge local runoff into the streams at various locations. This was considered an appropriate approach to storm drainage until the early 1970s when West Bountiful began to object because flows were being increased downstream in that city. Channel capacities are less and the floods spread over a wider area when they reach West Bountiful. The damage potential is also being increased as urbanization moves westward.

Bountiful and West Bountiful have a long history of flooding. According to the Corps of Engineers (1969), "Sketchy accounts by early settlers, brief newspaper articles, and official records indicate that flooding occurred on Barton, Mill, and Stone Creeks in 1862, 1896, 1922, 1923, 1930, 1936, 1950, 1952, 1958, 1962, and 1969. No hydrographs of past floods are available." Butler and Marsell (1972) note 12 cloudburst floods in Bountiful between 1939 and 1969. Several thousand dollars in flood damage occurred to homes from flash flooding August 5, 1948. A much larger amount occurred July 27, 1951. Homes were again inundated August 4, 1954, by water and mud reaching 3-foot depths. Many homes were flooded by Stone Creek May 20, 1957. On June 24, 1969, flood water 2.5 feet deep was reported in a business establishment. The last major snowmelt flood occurred in 1975 when high spring runoff in Mill Creek caused extensive damage in West Bountiful. While no explanation was obtained for the differences in dates between these two flood histories, frequently occurring substantial flood losses to buildings are obvious from both.

Bountiful has an active structural flood control program. In the last 10 years, the city has spent over $2 million. Most of the 25-30 projects collected local storm runoff and discharged it into one ofthe three creeks. Because larger systems would be too expensive, the designs generally have been for a 10-year return period. The increased runoff caused by upstream urbanization and their new storm sewer systems are, however, contributing to the downstream problem. Bountiful was the first community examined having urbanization covering a sufficiently large portion of its total watershed area for this to occur.

To counteract the problems caused by larger flood peaks, Bountiful has constructed several small detention basins. One is on Mill Creek at Bountiful Boulevard (4 ac). Another is under construction on Mill Creek at Davis Boulevard (5-6 ac). The city also has cooperated with West Bountiful, Centerville, and Davis County in a project rerouting Stone Creek from the west boundary of Bountiful to the bay and is working to correct the flooding problems at the lower ends of Mill and Barton Creeks.

Flooding from spring runoff on Barton Creek has been aggrevated by water backed up by a culvert at 4th north and 2nd west (state highway). The 36-inch conduit is being enlarged to a 72-inch conduit by the county in cooperation with the State Highway Department.

Storm sewers were first installed under the city streets 80 to 90 years ago, and some are now inadequate. Others have collapsed and been replaced. In 1978, the city replaced two sections, one on 4th east and 6th south and one on 3rd south and 2nd east. More sections will be replaced as money becomes available. The job is estimated to cost $1,500,000, and the city expects to spend $50,000/year.

Frequently, storm sewers fill up and over flow. At other times, they are clogged from sand washed off the mountain sides. Keeping the storm drains cleaned is a major maintenance problem for the city. The city uses its street crews to clean all storm drains prior to the paving season in the spring and again after the paving season in the fall.

In 1971 a law suit was entered against Bountiful by West Bountiful in district court. The suit sought to prevent Bountiful from discharging storm water into creeks as had been the practice. The judge ruled, however, that as long as the drainage came from within the basin it could be discharged into the streams.

In total, three cities to the west are subject to flooding from runoff that originates in or goes through Bountiful. Bountiful officials feel that Davis County is headed in the right direction with its countywide flood control program. The county program uses funds from a 2-mill property tax levy to provide floodways carrying water to the Great Salt Lake. Trunk lines to the floodways are provided by the municipalities.

A detailed flood hazard study has been completed by FIA for Bountiful, and the flood insurance map and ordinance have been adopted by the city and put into effect. Actuarial insurance rates are now in effect for second layer coverage. However, the City Engineer, when interviewed, said it was his feeling that the rates are so expensive that not many people will buy the insurance. A total of 40 policies providing $1,285,000 in coverage were outstanding as of May 1979, but it is not known how much of this is second layer coverage at the actuarial rate.

The two areas in the Bountiful floodplain selected for field observation were 1) Mill Creek between 100 East and Orchard Drive, and 2) Barton Creek between 200 East and 400 East. Land use in the Mill Creek area consists of an athletic field, parking lots, and housing. Flood damage potential appears to be minor except for backyards and basements of eight houses ($75,000 class) along the south side of Mill Street.

Land use in the mapped 100-year floodplain between 2nd East and 4th East and between 2nd South and 4th South on Barton Creek (see Figure 11) is primarily residential, but existing buildings include a day care center, a medical center, and a nursing home. About 40 homes averaging $50,000 in value would suffer basement and first floor flooding in a 100-year event. The three nonresidential buildings, estimated to have a total value of several million, would also be expected to suffer basement and first floor flood damage in a 100-year flood.

Corps' hydrologic studies indicate that Barton Creek has a drainage area of 5.6 square miles and a 100-year flood of 420 cfs. The small drainage basin size explains why urbanization can have such a large effect on flood flows, and the degree of urbanization which has already occurred may cause the 100-year flood to be larger than indicated by an envelope curve based on recorded flows from natural basins.

The Bountiful situation brings out another aspect of the Utah flooding problem. Urbanization is well known to increase downstream flood peaks in humid climates, and the effect is much more severe in arid areas (James 1965). Paving over dry desert soil can increase runoff from practically nothing to nearly 100 percent. Levees that confine streams within narrow bands greatly reduce the opportunity for infiltration that quickly attenuates flows spreading out over an alluvial fan. Storm drains that convey water from throughout the urban area to the stream concentrate flows that would otherwise never add to the flows emerging from the canyons. Instead of the flood peaks emerging from the canyons being dissipated, they increase in size. Communities too far from the base of the mountains to experience flooding under natural conditions can be subjected to a severe flood problem. This may well be the most severe secondary impact of structural flood control measures in Utah.

Some entity needs to look at this problem from the viewpoint of the total storm water system. Individual communities do not have the resources for this sort of analysis and do not have the authority to solve problems outside their jurisdictions. A centralized review function to check community storm water control measures for adverse effects on those downstream may be very helpful for areas where many communities abut one another in a metropolitan area.

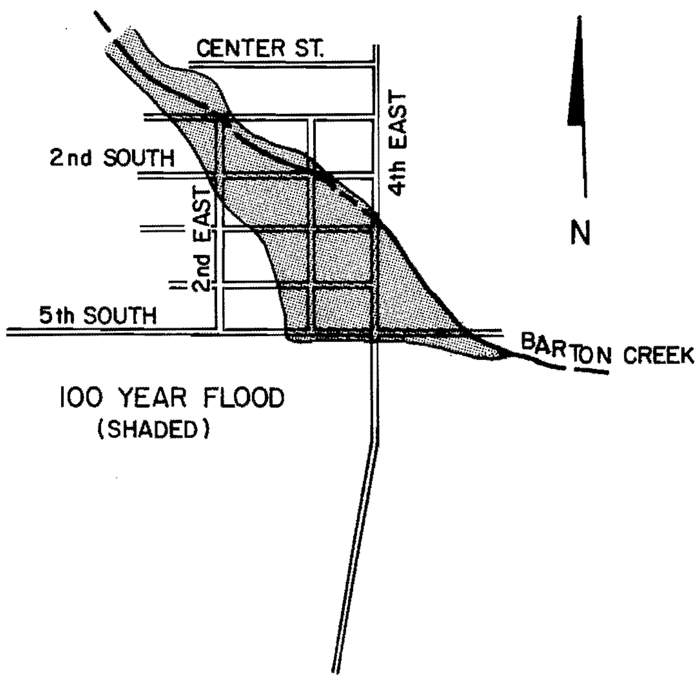

Figure 11. Flood hazard on a segment of Barton Creek in Bountiful (from FIA detailed study, 1978).

Castle Dale

This community was selected for inclusion in the sample to represent towns under 1000 that had entered the emergency program and had a detailed study underway for early entry into the regular program. The results of the detailed study have since been reported back to the community, are under review, and may possibly be appealed.

Woolley (1946) reports cloudburst floods near Castle Dale in 1913, 1930, and 1933, and Butler and Marsell (1972) report 7 cloudburst floods between 1939 and 1969. The flood of July 12, 1933, flooded gardens; however, only the storm of August 8, 1957, is reported to have flooded homes, and it is not clear from the reports whether that flooding was in town or not.

The increase in population for the town from 541 in 1970 to 861 in 1975 shows how energy resource development in the area is causing growth in a previously sparsely populated section of the state. That growth can be expected to continue and aggravate pressures for floodplain development in and near the town.

The mapped flood hazard area within Castle Dale is along the portion of Cottonwood Creek which runs along the southwest boundary of the city. Additional flooding has occurred in Buckhorn Draw and along the San Rafael River east of town. There is no development in the flood zone in the southwest portion of the town because of a high water table situation. The southeast portion cannot be developed because a sewage treatment facility is being constructed downstream, and EPA requires a certain distance separating the plant from residential development.

While Castle Dale participates in the National Flood Insurance Program and has passed a floodplain management ordinance, town officials are vague as to the city's responsibility under the program. Only one flood insurance policy is in force. The concept of floodplain management has not had much impact on planning in the community. In order to prevent continued growth from infringing on high risk areas, officials of the national program will have to do a better job of convincing local officials that it is in their interest.

Corinne

Corinne was selected from among communities of under 1000 in the emergency program. The town of 486 is located near the Bear River far enough back from the Wasatch Front not to have to worry about flood flows emerging from the mountain canyons. No flash flood problems are mentioned by Woolley (1946) nor Butler and Marsell (1972). No flood frequency analysis was made on the 90 years of gaged record on the Bear River slightly upstream at Collinston because the flows are so greatly regulated by upstream irrigation and power reservoirs, but the highest recorded flow at 11,600 cfs occurred June 7-10, 1909. That flow is fairly close to the 9,700 cfs Equation 2 gives for the 6800-square mile drainage area. The population of the community has changed little for many years.

There is no record of any flood damage being caused by the Bear River in the town in the over 100-year history of the community. The completely undeveloped wetlands along the river shown to be in the 100-year floodplain by the preliminary FIA map are generally conceded to have no development potential. None of the higher ground where the town lies is considered to have a flood hazard, and no one in the town has purchased flood insurance. Except for the very slight security being in the program could bring town residents by making them eligible to purchase insurance against very rare or local events and the insurance the floodplain management regulations provide against foolish future development of the wetlands, entry into the program has not benefited Corinne. However, since the program has also had almost no cost, the slight benefits may be sufficient to have made entry worthwhile. In December 1979, Corinne was shifted to the regular program under the special conversion provisions.

This study did not probe into why Corinne chose to enter the program when it does not have a significant flood hazard whereas other communities in the sample declined. Perhaps the reasons relate to the psychology of being a river town as opposed to being in a location more remote from a water course and where talk of flooding consequently sounds more ridiculous. A second reason could be the complete lack of interest in the community of future development of the declared floodplain.

East Layton

East Layton was also selected from among the communities under 1000 in the emergency program. There are no recorded cloudburst floods and have been no recent flooding problems other than those caused by ruptured pipelines and canals. Streams pass through the community in well-defined drainage channels. Most flood waters from the mountains to the east flow into the well-defined channels and cause no flood damage as they pass through town.

City officials were briefed on the National Flood Insurance Program by FIA personnel in April 1978 and joined after being satisfied that they will be given opportunity to review and comment on the maps that are now being prepared in the detailed flood hazard study. Some officials complained that the preliminary flood hazard maps are not sufficiently detailed and undated to be useful in considering annexation requests in this growing urban area. They state, for example, that Rainbow-Drive, which is shown as in a flood hazard area on the FIA preliminary map, does not now have a flood hazard because a large storm drain has been installed by the city. Since storm drains are customarily designed for the 10 rather than the 100-year event, this may well be an overly optimistic interpretation of the drain's effectiveness. Although housing is being developed along Mill Creek, the channel is deep and the houses are on high ground with no flood hazard.

East Layton has much more to gain than does Corinne from entry into the program because of the greater hazard and hydrologic uncertainty associated with being closer to the base of the mountains and in an urban growth situation. The community, however, does not seem to have the expertise in floodplain management necessary to realize those benefits, and this may suggest a role where the state can help.

Garden City

This community was selected as one of those having less than 1000 people and not mentioned as to flood insurance program status. Garden City is located on a relatively narrow flat strip along the shores of Bear Lake with mountain slopes rising steeply to the west in back of the town but with no drainage, except from very small hillslope areas, passing through town. Since most Utah storms move from west to east, the incidence of recorded cloudburst floods is much less for communities like Garden City on the leeward side of the mountains than it is for the Wasatch Front communities where orographic lifting augments precipitation on the windward side. Based on this topography and the fact that the town has absolutely no history of flooding (Butler and Marsell 1972), the community has not received any attention from FIA. When interviewed in the fall of 1978, the mayor was not familiar with the FIA program.

The development trend in the area does, however, threaten a significant future hazard. Large numbers of cabins and condominiums are being planned and built on hillsides above town for Bear Lake recreationists. As vegetation is removed from hillsides, more mudslides and other flooding problems are anticipated. The problem will be most intense during the construction period, but the higher runoff from paved areas being discharged down the mountain slopes can be expected to create a continuing problem. A planning and zoning board was established in 1978 by the city to deal with flood hazard and other problems related to development. Some minor problems with runoff down the mountainside are being handled by diking by individual property owners.

Thus Garden City is an example of a community with a potential threat of flood damage to residential and commercial buildings but for which the FIA program has offered no real help. The state may have an important role in helping communities too small to be effective in such situations on their own.

Garland

This community was selected to represent those in the population range from 1000 to 5000 and not mentioned in the National Flood Insurance Program. The community sets between hills rising to the west and the deeply entrenched Malad River to the east. On September 1, 1919, a cloudburst sent a "waist deep stream of water" roaring down a hillside a few miles north of town covering many acres of farmland with mud (Woolley 1946). Even though there is no current or historical evidence of flooding actually in this city since its founding in 1902, a large but undeveloped portion of the town was shown to be prone to flooding from sheet flow off the hills to the northwest by the flood hazard map FIA released to the town in October 1976. The map was rejected by the City Council, appealed, and rescinded in 1977, a decision implying that no hazard area exists in the town. The flood hazard boundary map for adjacent portions of Box Elder County released in February 1978 does not show the mapped 100-year floodplain anywhere in the city limits.

According to these maps, the community has been found free of flooding by the 100-year event; but because Garland has not joined the program, its residents are not eligible to buy flood insurance against inundation by rarer or unanticipated sources of flood water. It would be advantageous for the community to obtain a program status that would permit its residents to take advantage of the low flood hazard by becoming eligible to purchase insurance based on actuarial rates for zone C areas, particularly in light of the uncertainties in floodplain mapping in desert areas. The present situation is inequitable for property owners in that residents of the flood free area immediately outside the city limits are eligible to buy security against flooding by rare events because the county is in the program.

Helper

Helper is a town in the 1000 to 5000 population range with a detailed study completed in September 1978. The city is subject to flooding from two sources. The Price River flows from north to south through the center of town. Spring Canyon Wash enters the city on the west, curves to the north, and empties into the Price River just north of the Main Street bridge.

The population of Helper declined by 20 percent in the decade between 1960 and 1970. Since 1970, however, the city has been growing at a rate of about 2 percent per year, spurred by the increase in coal mining. Growth pressure is likely to remain high for some time. With the exception of several acres on the city's southern boundary, most of the floodplain lands within the city limits have been developed.

Hazard zone designations for Helper were made in January 1974 and revised in January 1976. The city entered the emergency program in June 1975. In 1976, FIA contracted with Nielsen, Maxwell & Wangsgard/Montgomery to carry out a flood insurance study for Helper, Price, and Carbon County. The work was completed at the end of 1977, and a review meeting was held in April 1978. Helper entered the regular program in September 1978, but was suspended after 6 months time when FIA determined the city's floodplain management ordinance to be inadequate. The problem was disagreement over the approach used by the city in restricting floodplain development rather than over objectives. A revised ordinance was submitted and received FIA approval in August 1979.

The flood insurance study indicates a drainage area of 465 square miles for the Price River above the confluence with Spring Canyon Wash. The latter has a drainage area of 24 square miles. The 10-year and 100-year flood flows estimated in that study for the Price River are 3,736 cfs and 10,208 cfs, respectively, and for Spring Canyon Wash the estimates are 887 cfs and 4,378 cfs, respectively. The USGS frequency analysis of the gaged record for the Price River near Heiner (455 square miles) indicates a 100-year flow of 7150 cfs and a record historical flow of 9340 cfs on September 13, 1940. The envelope curve for the Colorado River Basin (Equation 1) shows that flood peaks from this size drainage basin have reached 20,000 cfs.

Woolley (1946) records that eight houses in Helper were filled with mud and debris on July 29, 1921, causing $5,000 in damages. Cellars were filled with water and several buildings settled several inches from flooding in July 1927. Butler and Marsell (1972) record five flash floods affecting Helper between 1939 and 1969. They note the 1940 flood as flooding several homes in Helper and suggest that a larger event occurred in 1908 (before stream gage records begin). On August 5, 1943, a flood apparently originating from Spring Canyon "wrecked houses, railroad lines, mine properties, garages, and bridges" to an amount estimated at $75,000. On August 8, 1947, heavy rainstorms in town caused flooding from the overflow of ditches and canals. The most recent flooding on the Price River occurred on July 4, 1977, when extensive damage occurred on the Carbon County golf course south of Helper. Apparently, there was little damage in town.

The Scofield Reservoir, in the upper watershed of the Price River, controls snowmelt flooding, but does not provide much protection against cloudburst floods. No other flood control structures have been built on the Price River or Spring Canyon Wash. Flooding on Spring Canyon Wash can occur from relatively minor storms as accumulated debris obstructs flow through bridges.

Land use on the Price River floodplain in Helper is mixed commercial and residential on the north and residential towards the south. Development has proceeded southward, with newer and larger homes further south. A subdivision was proposed on the last remaining open tract on the south, but the plans have been withdrawn by the developer. The chairman of the Planning and Zoning Commission indicated that floodplain regulations were not a major consideration in the withdrawal, although approximately one-third of the tract lies in the regulatory floodway. Land use along Spring Canyon Wash is primarily residential and commercial, with several acres of idle land in the area adjacent to U.S. Highway 6 and 50. Structures in the area are at least 20 years old, and no new construction was observed. The flood insurance program provides a valuable financial resource for a community like Helper where a great deal of older development already exists on a riverine floodplain and is known to have suffered periodic damage in the past.

Hurricane

Hurricane in Washington County was selected from among the towns in the 1000 to 5000 population range with membership in the emergency program. The flood hazard is largely associated with Gould Wash on the southern boundary and another wash in the northeast part of the city.

Gould Wash, the larger of the two, presents the greater flood hazard. Flood waters from the wash filled 7 basements on July 27, 1954, and large amounts of silt were washed onto a large area 8 days later in what the Deseret News called "the worst flood in the history of Hurricane" (Butler and Marsell 1972). The bridge at Peach Avenue was washed downstream and lodged against the next bridge, forcing water to flow over the banks. No specific mention of flooding in the wash on the northeast was found.

Like other towns in southeast Utah, Hurricane is growing fairly rapidly; the annual growth rate exceeds 4 percent. Undeveloped land outside the floodplain is still extensive, and most of the floodplain land is idle or devoted to agriculture. Nevertheless, several newer homes have been built along Gould Wash, and it seems reasonable to expect the demand for further construction to continue.

Hurricane entered the emergency phase of the insurance program in June 1975, and FIA published maps of the flood zones in July 1977. No detailed study has been scheduled.

Entry into the flood insurance program has not had a significant impact on the economy of Hurricane. City officials recognize the potential flood hazards in the area, and therefore support the concepts of floodplain management and flood insurance. Residents do not view flooding as a major concern, and have been slow to purchase insurance (only one policy in effect). The newer floodplain residents have not experienced flood damages, and the older residents are content to deal with damages when they occur.

Planning studies have examined Gould Wash for sites for potential flood control structures. The structural detention of sediment and water upstream from town may be economically justified, but it would be very difficult for the federal government to implement a flood control project in the area given current planning delays and budgetary restrictions. Financial assistance to small towns in such cases may be another potential state role.

Hyde Park

This Cache Valley town was selected as a member of the emergency program in the 1000 to 5000 population range. In December 1979, Hyde Park was shifted to the regular program under the special conversion provisions. According to the mayor in August 1978 and as confirmed by Woolley (1946) and Butler and Marsell (1972), there is no history of flooding in Hyde Park. According to topographic maps of the area, the small streams emerging from the hollows and canyons onto the still steeply sloping valley floor about 2 miles east of town are intercepted by three parallel irrigation ditches. One flows about a quarter mile up the hill from town and the other two flow through the town. The entire town is built on a fairly steep slope downward to the west.

The flow from Hyde Park Canyon is directed so as to flow into the northeast corner of town, and a small area in that part of town is shown to be in the 100-year floodplain by the flood hazard boundary map. Inspection of this floodplain area revealed three dwellings in the $60,000 price range and about 40 acres of hay. One of the dwellings looked low enough to be in particular hazard.

The drainage area tributary to the mouth of Hyde Park Canyon of about 4 square miles could, according to Fletcher, generate a 100-year flow of 530 cfs. Equation 2 gives a flow of 1820 cfs. The canals are far enough back from the mouth of the canyon for much of the flow to be dissipated before reaching them, but there is danger of flood waters causing a full canal to break, perhaps at some point other than where the flows enter. While the probability of any flow reaching the canal is relatively low, the canals would largely determine the flooding pattern during the 100-year flood. Minor modifications to the canals could possibly reduce the flood risk in Hyde Park further.

Kamas

Kamas entered the sample representing towns with membership in the emergency flood insurance program and under 1000 population. No cloudburst floods are listed as having occurred in the vicinity of the town from 1939 through 1969, and the principal flood hazard is along Beaver Creek which flows through the town in a northwesterly direction. Several historical floods have overtopped the streambanks and inundated small acreages of cropland, but no documented damages have occurred to residences or other buildings.

Upon receiving their flood hazard boundary map, Kamas applied for inclusion in the emergency program but did so under a protest claiming that the 100-year floodplain is smaller than mapped. The appeal stated that even though Beaver Creek runs through the middle of town, no structures are in the floodplain. Four long-time residents filed an affidavit contending no known flood damage to structures had been experienced in over 70 years including during the heavy snowmelt runoff and rain year of 1975. When the town entered the program in 1976, the previously mapped hazard area along Beaver Creek through the town was eliminated, and the only mapped floodplain left was east of town where little development has taken place. Since then, five policies have been sold.

Two issues arise in evaluating the effectiveness of the Kamas program. These are whether the hazard area has been adequately mapped and what pressures exist to develop the remaining mapped flood hazard zone. The stopping of desirable development would be a significant cost of floodplain management for the community. The fact that five policies have been sold even though few structures are in the mapped floodplain suggests worried citizens outside the official hazard area.

Kingston

Kingston was selected to represent communities of less than 1000 people where a flood hazard area was mapped but which subsequently declined to enter the emergency program. The flood problem in the community is associated with the east fork of the Sevier River as it makes a series of bends while flowing northward from the southeast (from Kingston Canyon) along the eastern boundary of Kingston. Considerable debris and trees clog the river channel, and heavy rains flood bordering alfalfa fields. Some hay harvest loss has been experienced. The floods have apparently not reached the mobile homes on the higher east bank of the river.

Table 3 shows the 63 years of record on the east fork to suggest a 100-year flood peak of 1839 cfs from the 1250 square mile drainage area. The envelope curve value (Equation 2) is 6600 cfs. Butler and Marsell (1972) record a 4-foot wall of water moving down Kingston Canyon on August 6, 1967, closing Utah Highway 22 for 6 hours, but mention no flooding of buildings. The record flood on the river at Kingston was 2030 cfs on May 12, 1941.

The reason one official suggested for the town declining to apply for the FIA emergency program was a feeling that the sorts of damages experienced are not insurable under the program. This discounting of the riverine flood problem is also seen in that the town is unwilling to budget funds to clean the river channel of debris. The problem has been discussed between Piute County officials and the U.S. Soil Conservation Service, but no plan of action has been prepared.

Koosharem

Koosharem is a town of under 1000 that has elected not to join the program even though a flood hazard has been identified. The mapped hazard area shows a 100-year floodplain fanning out from where Koosharem Creek emerges on to the floor of Grass Valley and covering most of the town. The flow enters Otter Creek east of town. Butler and Marsell (1972) record no cloudburst floods in the area, but Keetch (1971) and Woolley (1946) record that a cloudburst caused a severe flood on Otter Creek July 12, 1896.

Koosharem is apparently a town with some risk of flooding but a long time since the last flood. Older citizens indicated that in their 70 plus years they had not witnessed a flood in Koosharem (the last recorded one was in 1896) even during the heavy rainstorms which occurred in 1965, 1967, and again in 1968. They also claim that flooding has never been a problem in the floodplain mapped along the Otter Creek. Grazing capacity is reduced by early spring excess water but dwellings near Koosharem have not received damage.

The drainage area of Koosharem Creek, which flows from the west into Koosharem and then into Otter Creek, is approximately 20 square miles as estimated from available topographic maps. Peak discharge for the 100-year flood would be less than 2600 cfs according to Equation 2.

Koosharem and Sevier County officials met to discuss the FIA participation issue at the time Sevier County made application. County officials took the necessary steps to enter the program in 1975, but Koosharem officials did not apply until April 1979. FIA has not approved the application, pending a more complete documentation.

Koosharem experiences long periods of time between floods. Hydrologically, most runoff from Koosharem Creek apparently percolates underground before flows from the canyon reach the town. Usually, any small flow remaining is intercepted by an irrigation canal. Only for events in the order of the 100-year return period does enough water come out of the canyon to flow overland through town, and by the fortunes of history no such event has occurred for more than 80 years.

Virtually the whole town is in a borderline flood hazard situation. Flows emerging from canyons onto alluvial fans spread out and percolate until they dissipate and become harmless. The rarer floods travel further down the fan before so dissipating. Koosharem is located far enough down the fan for it to be difficult to tell whether it is upstream or downstream of a line where the 100-year flood is dissipated to harmlessness. Difficulties in the determination stem from the lack of a precise definition of the characteristics of a flood reduced to harmlessness, uncertainties in estimating the 100-year flow for an ungaged stream, and inadequate ground information for routing shallow flows through areas where irregularities in the ground surface only a few inches high can have a major effect in diverting the flow.

Institutionally, FEMA considers the town to be on a floodplain. While the subsidized rates available through the emergency program would be attractive to Koosharem home owners, actuarial insurance rates would probably be higher than the expected average annual damage. Unless this can be successfully appealed (the experiences of other towns indicate good probability of success) entry into the program may unduly restrict the ability of the people to construct or replace buildings.

The situation emphasizes the need for better methods for flood routing over alluvial fans. Better methods would enable better risk assessment and provide a better basis for the design of measures to deflect flows away from buildings. This sort of design could well be the most economical approach for communities like Koosharem.

Midway

Midway represents communities of under 1000 population in the emergency program. In the only part of the town mapped in the 100-year floodplain, an area along Snake Creek near the western city boundary, there has been some flooding of cropland but no one was found who could remember any flooding of structures. Butler and Marsell (1972) record no cloudburst floods in or near the town and only one in all of Wasatch County. Woolley (1946) records flooding in the Heber City area in 1887, 1894, 1896, 1925, and 1935 but no damage to buildings.

Officials of Midway appealed the flood zone boundaries designated in 1975 on the basis that storm water ponding rather than flood prone areas were shown for the Devil's Hole drainage. A boundary revision in October 1975 deleted the disputed area. The remaining mapped 100-year zone is a 100-foot wide strip along both sides of Snake Creek. No structures were indicated as being in this area at the time the revision was made, but some sheds have apparently been built there since. One insurance policy has been issued to date.

Millville

Millville was included in the sample as a community of population under 1000 where the hazard was identified but the community elected not to join the program. The town is located in Cache Valley on the alluvial fan formed by flows out of Providence Canyon and about 1 mile west of the base of the mountains. The flow from Providence Canyon passes far enough to the north to pose little danger, and the hazard to the town now comes from two small hollows that discharge their occasional flows opposite the town and from Millville Canyon that discharges far enough to the south to almost entirely miss the town (Gingery Associates 1976). The greater problem from that source may be that the Millville-Providence irrigation canal could intercept flood flows from the canyon, carry them to the north, and break opposite the town. The west side of the town abuts against Blacksmith Fork, and lowlands along that river are subject to flooding from that source.

The only flood this century for which any damage was recorded was that of August 18, 1959, when cloudburst rains sent waves of water and debris rolling down the mountainside and littered bench areas below Millville Canyon with boulders. No damages were noted then for structures in Millville even though such nearby communities as Providence faired much worse (Butler and Marsell 1972, Gingery Associates 1976).

Blacksmith Fork drains about 268 square miles. Gingery Associates (1976) estimated a 100-year flood flow of 4535 cfs. The USGS analysis of 62 years of gaged record gave 1825 cfs. The historical flood of record was

1400 cfs on May 4, 1952. The envelope curve (Equation 2) nearly matches (4680 cfs) the Gingery Associates figure.

The area flooded by 4535 cfs is delineated in the floodplain information study. It is a low area of pasture and wasteland along the east bank of Blacksmith Fork. A small dike has been constructed along the bank to protect approximately 5 acres of pastureland. There are no structures on the floodplain. Certainly, if no Millville structures are threatened by this very conservatively estimated 100-year flood, the town is in no real danger from flooding from Blacksmith Fork. The management question on the west side of town is whether the town really needs to regulate development in an area as large as that delineated.

The more important question is whether the flood hazard mapping can be believed where it shows the town to be in no danger of flooding from the hollows and from Millville Canyon (drainage area of 6 square miles) to the east. Whether the 100-year floods from the east would reach town is, for the reasons discussed for Koosharem, difficult to determine; but, whether or not that frequency of flood would cause damage, larger events from this direction could be devastating. Prudent Millville residents might well want insurance.

The Mayor of Millville, when interviewed in August of 1978, did not seem familiar with the FIA programs, but he did indicate that the town would have been interested in joining if the whole town could have been covered by the insurance. He was incorrectly advised that the program would only cover the undeveloped land next to Blacksmith Fork and not flash flood damage associated with flows out of the canyons to the east. The city has thus taken the position that it wants no part of a program that will require it to undergo the expense of establishing floodplain management regulations to cover a portion of town in little danger while offering no insurance protection to structures that may well be in real danger. In December 1979, the town was made eligible for special conversion to the regular program should it enroll.

Since the town is primarily basing its rejection of the program on misinformation, the state could well perform an important function by facilitating communications between local governments and the National Flood Insurance Program. The problems cited in the floodplain mapping suggest a role for the state in reviewing floodplain information studies for the reasonableness of the reported results in Utah conditions.

Cases such as this, where the mapping shows as flood free areas considered to be flood prone by residents of the local community, have the effect of discouraging precautionary flood proofing practices in building construction and the purchase of insurance in areas of real risk. The FEMA concentration on riverine flood problems and failure to map flooding from small mountain hollows washing mud and debris into towns discourages participation in a town like Millville and misleads newcomers to the town as to the real danger.

Ogden

The second largest city in the state was selected to explore flood hazard situations and responses to them in a city of 50,000 in the emergency program. Ogden's problem of flood waters and associated sediment and debris moving out of the mountains and needing to be transported through the city to lowlands to the west is typical of Wasatch Front communities. The problems, however, are intensified by a larger city with greater population density spreading over a larger area. The greater degree of urbanization increases the contribution to flooding from local runoff from impervious areas, reduces percolation of water moving over the alluvial areas and hence causes flooding to extend farther down the hill, and results in more damage as flows pass through a more congested area.

For many years, Ogden residents have suffered recurring damage from both snowmelt and cloudburst floods. Snowmelt flows originating in Taylor Canyon east of the city have on occasion turned one of the east-west streets, 27th Street, into a river and carried large rocks and debris into residential and business areas. Yards and basements have been flooded and sometimes buried in mud when these waters have not been contained within the street curbs. Cloudburst floods have been more damaging and difficult to control. Heavy storms occurring randomly at locations in and above the city have caused considerable damage and inconvenience through flooded basements, land erosion, and sediment deposition. Woolley (1946) lists a number of floods beginning with a storm in August 1901 that filled basements, gashed streets, and brought business downtown to a standstill. Butler and Marsell (1972) report 30 cloudburst floods or an average of one a year between 1939 and 1969. The smaller events blocked streets and snarled traffic while the ten or so largest ones washed debris into the city and flooded basements. Depths up to 5 feet have been reported over yards and around buildings.

Ogden has recently been making an extensive effort to improve its storm drainage system (Hoggan and Nielsen 1979). New detention facilities and pipelines are designed to handle a 10-year, 2-hour storm. The city officials consider this level of control to be financially feasible. In the event of a more severe storm, the system's capacity will be exceeded and the city's east-west (downhill) streets will have to carry the excess.

The city has dealt with the problem of continuing development further increasing runoff by passing an ordinance in 1974 that requires all commercial development over 30,000 sq ft and new subdivisions to provide detention to contain runoff from a 10-year 2-hour storm in excess of natural runoff. In Ogden, such a storm is considered to produce 0.7 to 1.0 inch per hour of rainfall. The natural or preconstruction runoff rate is estimated from site conditions with a typical value of about 30 percent. Buildings and pavement are considered to increase the rate to 95 percent.

Although the city has not dictated specific designs or standards for developers to use in complying with this ordinance, two basic approaches have been used: 1) sumps to inject the water into the ground and 2) small detention basins to hold the runoff for gradual release after the storm. Centralized detention basins (up to 20 acres in size) are added by the city to reduce the size of trunk lines. The designs of systems that inject water underground need to be checked to make sure that the recharge won't flow underground into basements or other problem-causing locations.

In October 1977, the city was awarded a Local Public Works Capital Development and Investment Program grant of $7.6 million from the Economic Development Administration of the U.S. Department of Commerce. The major conditions of the grant, which was awarded because of depressed economic conditions then existing in Ogden, were that the construction of projects funded by the grant be 1) initiated within 90 days and 2) completed within one year. Since many unimplemented plans for storm drainage were "on the shelf" in the City Engineer's Office, compliance with these provisions was feasible. Of the total amount awarded, $4.1 million was allocated to storm drainage, and this was sufficient to implement every plan the city had ready.

The project, to construct a new drainage system for the entire downtown business district and provide a variety of significant improvements at other locations, was started in December 1977 and completed on schedule one year later. Centralized detention basins were utilized to the greatest extent practical. However, in the downtown area there was no available space for detention basins so it was necessary to construct larger storm drains.

Scattered areas in the north part of the city and about 100 acres in the south end are developing rapidly. There is also continuing pressure for urban development and recreational use further up the mountainside above town.

Ogden officials were briefed on the FIA program in April 1978. Preliminary flood hazard maps prepared by FIA are obsolete because of the extensive improvements to the storm drainage system in 1978. A detailed flood hazard study is currently being conducted by FIA for Weber and Davis Counties. This sort of change in the hazard situation suggests a need for updating hazard mapping and adjusting actuarial rates with changing watershed conditions and with expansions to the storm drainage system. Setting priorities for needed updating may be another role appropriate for state government.

Four locations identified as having a zone A flood hazard on the FIA maps dated August 16, 1977, were selected for field observation. These were located near: 1) Sullivan Road at Quincy, 2) 1100 North Street west on Washington Blvd., 3) 2nd Street at Washington Blvd., and 4) Ogden River in the vicinity of Washington Blvd.

The flooding potential in Sullivan Hollow (adjacent to Sullivan Road) between Gramercy Avenue and Van Buren Avenue has been eliminated for events smaller than the 10-year with construction of a new interceptor drain along Van Buren in 1978. A greater hazard remains on the north side of Sullivan Road between Quincy and Van Buren. Approximately 20 homes ($50,000 class) there are subject to basement flooding.

The flood hazard area near Washington Boulevard in the vicinity of 1100 North is a low weeded area surrounded by residences. Several old rundown buildings are located on the southwest fringe of the mapped floodplain. Potential damage from the ponding of storm runoff is currently negligible; however, future pressure can be expected for development of the weeded area.

The flood hazard along 2nd Street in the vicinity of Washington Boulevard is aggravated by inadequate drainage facilities for storm runoff. A shopping center, supermarket, and several shops are located adjacent to the intersection. On the south side of 2nd Street between Washington Boulevard and the railroad approximately a mile to the west, there are several low priced homes and a few business buildings fronting on the street. A low area along the east side of the railroad tracks north of 2nd Street is pastureland. Damage potential appears slight because the flood hazard is concentrated in the pastureland. The recently installed storm drain on Washington Boulevard will alleviate the hazard, and the city is currently expanding the drainage system to contain the 10-year event. An evaluation to determine what would happen during the 100-year event would be worthwhile. The flood hazard identified by FIA along Washington Boulevard itself is largely to indicate that flood waters will flow down the street, and it does not necessarily indicate much potential damage to the numerous stores and other businesses located along both sides of the street.

At the fourth location inspected, Ogden River flows in a deep channel through Ogden business and residential districts. The bridge at Washington Boulevard appears to be adequate to handle flood flows. Pineview and Causey Reservoirs, Bureau of Reclamation projects located on the mainstem of the Ogden River and South Fork Ogden River, respectively, provide considerable flood protection from rain and snowmelt floods originating above the reservoirs. Approximately 23 square miles of drainage tributary to the river is uncontrolled. The Corps estimates a 100-year flood on the Ogden River in downtown Ogden to be 1690 cfs (Corps of Engineers 1971). All in all, the flood risk along the Ogden River appears to be fairly low.

In contrast, along the base of the mountains, on August 18, 1979, 7 Ogden homes suffered extensive damage and about 23 more suffered lesser damage. A total loss amounting to about $1,000,000 was triggered when a cloudburst washed mud and debris down the mountainside. According to an analysis by the Utah Geological and Mineral Survey, the mountain slopes had been extensively used by off-road vehicles to the point that much of the protective vegetative cover had been worn away. The rainstorm then washed sediment and debris down the hill to fill an irrigation canal at about 2:00 a.m. on a Saturday morning. The canal consequently overtopped, the irrigation water flowed down the steep slope below the canal eroding a great deal of soil, and this eroded sediment caused the principal damage to the homes below (Salt Lake Tribune, August 21, 1979). The area inundated was not in a mapped floodplain, and none of the residents had purchased flood insurance.

Damagewise, this was a major flood for Utah. Only one other flood in the history of the state has caused greater economic loss. Some doubt exists as to whether the losses would have been covered had these homeowners had flood insurance because most of the flood water was from an irrigation ditch even though the event was triggered by rainfall. The episode shows the need for residents living at the base of mountain slopes to purchase insurance, and Utah should do its best to make sure that coverage for this sort of problem is available through the National Flood Insurance Program.

Insurance, however, does not prevent damage from occurring. Several preventative measures are plausible. One would be to convey irrigation water on steep hillsides above highly damageable property in pipes rather than ditches. This is done at some locations where water and debris flow down natural depressions, but in this case the ruts from the recreation vehicles caused the flow to come down the mountainside at a location where it wouldn't normally be expected. Certainly standards for construction (or structural improvement) of irrigation facilities on hillsides above urban areas and of new urban development immediately below hillside ditches deserve review, and the state may have an important role formulating criteria for that review, just as it does now in reviews for dam safety. The risk in areas below irrigation canals may in many cases significantly exceed the criterion of one event in 100 years used to define floodplains.

A second plausible preventive measure would be tighter controls on recreation vehicles and other uses that devegetate or otherwise rut and erode mountain slopes. Since the uses that caused the problem are already illegal, this approach requires greater effort in patrol and enforcement. Discovered rutted or eroded areas could be treated by erosion control measures similar to those used when slopes are laid bare by construction activity. The CCC and other agencies were very active in doing this sort of work in the 1930s, but high labor costs have almost eliminated such efforts in recent decades. The alternatives for cost effective erosion control using modern technology deserve further exploration. Even with use control and land treatment, however, one can still expect rare natural events to erode enough soil to fill an irrigation ditch below. Furthermore, a regulatory and land treatment approach may require state assistance for coordination among town governments and between towns and the counties having jurisdiction over the unincorporated areas above them.

A third approach would be through flood fighting. In the 1979 Ogden flood, the efforts of a group of members diverted the flow of mud and debris away from a church building that accordingly escaped essentially undamaged. The short warning times make this approach very difficult at the base of the steep slope, but the flow moves more slowly on the flatter land to allow time for some protective effort. Building locations and designs are thus particularly critical at the immediate base of the slope; flood fighting becomes more practical at greater distances.

Parowan

This Iron County community is a member of the emergency program with a population between 1000 and 5000. The city lies on the distinct alluvial fan northwest of where Parowan Creek discharges from the mouth of Parowan Canyon. The chief channel flows westward from the mouth of the canyon along the base of the Hurricane Cliffs. A second channel carries water diagonally through the town from southeast to northwest, and an unused irrigation ditch runs northward from the mouth of the canyon along the east edge of town. The latter two channels present the worst flood problems as they collect flood waters and carry them into town.

There is no stream gage on Parowan Creek. The USGS topographic map shows a drainage area of 68 square miles above the mouth of the canyon. Based on Equation 2, a 100-year flow should be no larger than 3440 cfs. Flooding could be caused by cloudburst or snowmelt, but the former is the more likely. Woolley (1946) records floods coming down the canyon and washing debris into town in 1857, 1874, and 1906. Butler and Marsell (1972) record eight flash floods near Parowan over the 30 years covered in their report. On August 1, 1955, flows from Parowan Canyon damaged roads, homes, and gardens. On August 2, 1963, the creek overflowed its banks to wash thick red silt over several hundred acres of farm land and to a depth of nearly 10 inches around one farm home. About $600 in damage, including $100 to buildings, was reported after a cloudburst caused a flow of 500 cfs from Parowan Creek. The last flooding in the city occurred in 1976 when cloudburst-washed debris clogged the culvert under the canyon highway, causing shallow flow along the eastern edge of town but little damage. One can summarize this hazard situation by noting that major damages have not occurred to buildings and most losses have been in the agricultural areas beyond the city limits.

No flood control structures have been built on Parowan Creek. A gravel pit at the mouth of the canyon provides an incidental holding basin but little protection against the larger flood flows.

Parowan has experienced an annual population growth of almost 5 percent in recent years, partially due to its convenient location with respect to winter and summer recreation areas. Portions of the floodplain have been and are being developed.

FIA first issued flood hazard maps for Parowan in August 1974 showing the entire city in a floodplain. An appeal of the boundaries led to a revised map in December 1975, with a reduction in the designated hazard area from the whole town to the three strips described below. Parowan entered the emergency program in June 1975. No detailed study has been announced.

The designated hazard areas consist of three narrow strips. These run along the south (Highway 9) and east (3rd East) edges of town and on a diagonal southeast to northwest from 3rd South 1st West to 4th North 6th West. The south strip follows the creek channel from a gravel pit at the mouth of the canyon to the west edge of town. Several homes are exposed to flood damage in this zone between 1st East and 2nd West on 3rd South. A diversion structure at 2nd West channels low flows into the diagonal hazard zone, where the water is used for watering lawns and gardens. Downstream from the diversion, the main stream channel is used only to carry excess runoff. Little development is present along the main stream channel below the diversion point, and proposals for development are discouraged by the city.

The east hazard zone follows the course of a now unused ditch. A few homes lie within this area, and several new ones are to be constructed. Thus, the damage potential is increasing in this area subject to shallow flooding.

A third flood hazard zone begins at the diversion point mentioned and runs diagonally through the city. A number of homes are in this zone. City officials feel flooding is very unlikely in the area because during high flows the diversion gate is closed to force water down the main channel. If the diversion gate were left open or overtopped, basement flooding would occur along the diagonal zone.

Enforcing the requirements of the flood insurance program does not appear to have created problems for the city. They have successfully kept new development out of the more hazardous areas. A problem may exist, however, in that the community does not consider the entire area subject to flooding by the 100-year event as hazardous.

One of the main differences between the Parowan flood hazard and that at the Cache Valley towns of Millville and Hyde Park is that the community is located immediately below the mouth of the canyon before the emerging flow has opportunity to disperse or percolate underground. This factor together with the larger drainage area tributary to the canyon and the greater hazard of intense rainfall as one moves southward in the state, make Parowan's risk somewhat greater than that in the other two communities. The Cache Valley communities have the alternative of intercepting the flood water, but a structural flood control program for Parowan needs to explore what can be done to make sure that the gutters and streets disperse and harmlessly convey away rare flood flows.

Pleasant Grove

This city is a Utah County member of the emergency program having a population in the 5,000 to 50,000 range. Pleasant Grove lies on the alluvial fans formed by Grove Creek and Battle Creek. The mouths of both canyons are on the eastern border of the city. Neither stream has a well defined channel below the mouth of its canyon. Under normal conditions, both empty into the Provo Reservoir Canal which runs parallel to the mountains about a half mile below the canyon mouths. The older parts of town are below the canal, but much new development is occurring above it.

The city has been growing in recent years at an annual rate of almost 7 percent. Bench lands between the town and the canyon mouths are prime development areas with new subdivisions on both. The pressure to develop was probably increased by the construction of detention basins at the mouth of both canyons, although benchland real estate in general in the Utah Valley has experienced high growth pressure.

There are records of localized flooding in Pleasant Grove. Butler and Marsell (1972) record cloudburst floods creating local drainage problems on June 9, 1958, and flooding from Battle Creek on August 19, 1959. In February 1979, rain on frozen ground caused some basement flooding. In the 1960s, a debris basin was constructed at the mouth of each canyon, and land treatment has been applied to the watersheds as part of the Soil Conservation Service's American Fork-Dry Creek Watershed Project. Both debris basins are designed to reduce the 100-year flood flows (655 cfs on Grove Creek and 411 cfs on Battle Creek) to 32 cfs. According to a recent report, however, residual flooding at that frequency is still possible because of poorly maintained channels below the detention basins (Utah County Council of Governments 1974). A problem could also occur should the basins be allowed to accumulate debris.

FIA notified Pleasant Grove of an unmapped flood hazard in 1975. The city judged its regulations to be in conformance with FIA requirements and decided that joining the insurance program would not impose any new requirements on the city and its residents. Thus, the city joined the program in August 1975, but contested the mapped flood prone areas on the basis that the flood hazard should be reevaluated now that the detention basins are installed. FIA subsequently withdrew the flood prone designation, and Pleasant Grove elected to remain in the program. A detailed study begun in December 1978 is not yet completed.

The floodplain management program in Pleasant Grove includes ordinances in conformance with the emergency phase of the federal insurance program. Specific enforcement has included prohibiting fill or construction from infringing on the Grove and Battle Creek channels and requiring new subdivisions to be designed so that peak runoff will not be increased. In contrast to the smaller communities, the local officials seem to have formulated their floodplain management program independently of FIA.

The major doubt as to the adequacy of the Pleasant Grove program relates to uncertainties as to whether the debris basins, as constructed and maintained, can contain the 100-year flood. When they are overtopped, whether by that event or a larger one, the city should provide a floodway for the resulting flows to pass downstream. The state may need to take a role in establishing standards and checking debris basin and downstream conveyance design to prevent unacceptable safety problems.

Provo

Provo, a city of over 50,000, entered the regular program in February 1979. The city is subject to flooding from three sources. On the bench areas on the eastern side of the city, flood waters periodically discharge from the mouths of Slate Canyon, Rock Canyon, and Little Rock Canyon and spread out over their respective alluvial fans, depositing considerable debris. On the lowlands to the west of the city, periodic rises in the level of Utah Lake inundate nearby property. Third, snowmelt, heavy rains, or both in combination can increase flows in the Provo River to the point of inundating nearby lands and damaging property along its route across the city to Utah Lake.

The population of Provo has been growing at a rate of about 1 percent annually since 1970, somewhat less rapidly than in the previous decade. Considerable population and economic pressure to develop floodplain lands has led to occupancy of a substantial portion of the alluvial fans and the floodplain along the Provo River. Development on the bench is likely to continue as long as suitable undeveloped terrain is available. Residential development is also occurring along Utah Lake.

FIA designated flood hazard areas in Provo in February 1974, and revised their map in 1976, reducing the designated flood prone area somewhat. Provo entered the emergency program in January 1975. FIA contracted with the Bureau of Reclamation in August 1976 to complete a flood insurance study to define the hazard area more carefully. The resulting FIS entered its review period in August 1978. After a three month extension, granted to enable the resolution of some disagreements over the contents of the required floodplain management ordinance, Provo entered the regular program in February 1979.

According to the flood insurance study, the three canyons, Little Rock, Rock, and Slate, drain watersheds of approximately 0.8, 9.4, and 6.0 square miles, respectively. The Provo River has a drainage area of 680 square miles, of which 107 are below Deer Creek Reservoir. The estimated 10, 50, and 100-year flood flows are listed in Table 13. The amounts for the three smaller basins are considerably more than ever recorded from any watershed in Utah of similar area (Figure 8).

Incidental snowmelt flood protection is provided by Deer Creek Reservoir, approximately 12 miles upstream from the mouth of Provo Canyon. If funding is provided for the Jordanelle Reservoir through the Bureau of Reclamation's Central Utah Project, further snowmelt protection on the Provo River will be provided. River flows can be somewhat reduced by diversions into the Timpanogos and Murdock Diversion Canals at the mouth of Provo Canyon. A discontinuous system of levees contains flood flows from the Provo River over most of the reach within the Provo City boundaries. Localized flooding may occur through gaps in the levees, and as the river nears Utah Lake. Provo City and Utah County share responsibility for annually clearing the river channel of debris. The most recent flooding from the Provo River occurred in 1957, and the largest flood of record was in May 1952, when the flow rate reached 2,520 cfs (a 50-year event) and caused considerable damage. Butler and

Table 14. Summary of flood flows in Provo.

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet Per Second)			
		10-year	50-year	100-year	Eq. 2
Provo River, 1 mile below canyon mouth	680	1800	2600	3200	5770
Rock Canyon Creek, at mouth of canyon	9.4	865	1710	2100	2200
Slate Canyon Creek, at mouth of canyon	0.8	305	526	637	1260
Little Rock Canyon Creek, at mouth of canyon	6.0	538	1120	1600	1990

Source: Provo FIS.

Marsell (1972) record eight cloudburst storms. Most caused local storm drainage problems and none resulted in flooding in the city by river or canyon flows. Earlier, a cloudburst on August 31, 1913, caused flooding from Rock Canyon that filled streets with mud and debris and flooded homes (Woolley 1946).

Land use in the mapped 100-year floodplain of the Provo River is largely recreational (a golf course) on the north, residential in the middle reach, and residential, commercial, and agricultural near the lake. The worse problems have occurred in the Provo River Canyon above town. On July 13, 1938, a mudslide, 400-feet wide and 20-feet deep, dammed the river inundating resorts and summer homes (Woolley 1946).

High levels in Utah Lake are caused by high volumes of total spring runoff. Basement flooding is caused by temporary rises in the relatively shallow water table near the lake. The flood insurance study calculated the surface elevation of the 100-year flood to be 4494.5 feet above sea level, about 4.5 feet above the normal elevation.

The main nonagricultural land uses in the 4-square mile lake flood zone are the Provo Municipal Airport and the Utah Lake State Park. The airport is bordered by a system of levees, but it does not provide protection from the 100-year flood. Several homes and commercial structures are located in the mapped flood hazard area. Most of the new development on Provo's west and south sides have been located outside of areas subject to lake flooding. On the south, the flood zone joins the natural marshland of Provo Bay.

Flooding along the small mountain front canyons is caused by summer cloudbursts and characterized by rapid concentration, high velocity, and high sediment loads, but with short durations and shallow depths. Steep slopes and impermeable soils make the peak flows from the canyons on Provo's east boundary higher than in similar canyons elsewhere in the region. However, the U.S. Forest Service has applied land treatment to all three watersheds, and all three have detention basins at the canyon mouths. None of the basins provide protection against the 50-year event.

Land use in the 0.5 square mile flood zone below Slate Canyon is primarily residential, except for a few acres of orchard, the Utah State Hospital on the north, and a gravel pit on the south. Residential development has generally proceeded up the alluvial fan. Homes in the lower reach are generally older, smaller, and of frame construction; and homes in the higher areas are larger, newer, and of brick.

Land use in the 0.75-square mile flood zones of Rock Creek and Little Rock Creek is residential. Homes are fairly large and new. The price of lots average over $20,000, and it is unlikely that any of the homes would sell for less than $75,000. Under the ordinance enacted pursuant to the regular phase of the flood insurance program, homes in the flood zone begun after February 1, 1979, must elevate the lowest floor to the altitude of the crown of the nearest street, a requirement that precludes most basements. This requirement has created some financial hardships and has generated considerable controversy, not only in Provo but in other areas of shallow flooding such as Springville and Payson. The controversy has apparently been sufficient to persuade FIA officials to change the AO designation to a B zone below Rock and Little Rock Canyons.

One may suspect that the quickly passing flood flows in these areas could be deflected away from buildings and passed downstream in gutters or ditches in a manner that would not threaten basements. On the other hand, basements filled with water and debris constitute the preponderance of the historical flood damages to structures on alluvial fans in Utah and continuing to build them invites continuing trouble.

Richmond

Richmond is a Cache Valley member of the emergency program in the 1000 to 5000 population range. The town is built on the north side of an alluvial fan below where City Creek enters the east side of the valley. Cherry Creek, about 2 miles further north, crosses an undeveloped corner of the town. Two southward flowing irrigation canals are shown on the topographic map to end at and thus presumably discharge unused water into City Creek upstream from town. In contrast to the typical alluvial fan situation where the creek soon dissipates into a very small and perhaps undefined channel and perhaps because of the irrigation water discharged into it, City Creek passes through Richmond in a large deeply eroded channel.

Cherry Creek is also deeply incised. The only record of flooding that could be found was a cloudburst that washed out roads and inundated farmland on July 24, 1923 (Woolley 1946). No record was found of flooding in town, and no flooding is mentioned by Butler and Marsell (1972).

Field observation of City Creek revealed that there are about a dozen homes in the $50,000 class along the creek within city limits and in the area designated on the FIA maps as having a flood hazard. The creek bed was overgrown with brush and appeared to have other debris and obstructions that would contribute to flooding in the event of high runoff.

When the FIA program was presented to the city, the administration talked to numerous "old timers" about any history of floods and found no record of any flooding. The city decided to go along with the FIA program since it was offered by the federal government although they could uncover no potentional problems. Since enrolling in the flood insurance program, the city has made people that build in the mapped floodplain aware of the availability of flood insurance, but none have purchased any insurance. No mandatory floodplain management practices have influenced building decisions. In December 1979, FIA shifted Richmond to the regular program through the special conversion provisions.

Sandy

Sandy is a member of the emergency program in the 5000 to 50,000 population range located on the east side of the Jordan Valley in a rapidly developing area south of Salt Lake City. The community has been annexing a great deal of territory in recent years, and the city limits are very irregular as they bypass unincorporated territory to include more distant subdivisions.

The main natural drainages are the Jordan River flowing north on the west side of the city and Dry Creek flowing westward on the south side. Several smaller canyons emerge from the mountains to the west. Willow Creek passes through the southeast corner near Willow Creek Drive. In addition, the area is crossed by several canals and ditches which may overtop their banks as a result of runoff collected from summer thunderstorms. The Galena, Jordan and Salt Lake, East Jordan, and Sandy Irrigation Canals run from south to north through the west half of the city. Sandy Ditch and Dry Creek flow generally east to west through the city. Flooding along the Jordan River is caused by rapid snowmelt, occasionally augmented by general rain, in the watershed tributary to Utah Lake. For the other watercourses, flooding is caused by intense summer thunderstorms.

A 100-year floodplain was mapped for Sandy by the Sacramento District of the U.S. Army Corps of Engineers as part of the larger set of floodplain information studies which cover the Jordan River drainage between the Jordan Narrows on the south and Cadahy Lane on the north (1969 and 1974). These studies delineate the floodplains of the natural stream channels, but do not identify the area of flood hazard from canals. FIA designated the flood hazard areas in Sandy in July 1974 as those described by the Corps of Engineers. A revised map, issued in January 1976, adds areas along the canals and reduces the size of the designated floodplains along natural drainage ways. This sort of revision makes a great deal of sense, not only for Sandy, but also for the many other Utah communities wherein irrigation ditches can be blocked by sediment or filled to overflowing by water during cloudbursts.

After these changes, Sandy joined the emergency program in February 1975. A detaied study is underway, part of a group of studies covering Salt Lake County, but findings are not yet available. Accurate mapping of the floodplain in this sort of situation involving ungaged mountain watersheds, dispersed flow over valley areas, and interception of flows by ditches only to have them break out at some other location is an extremely difficult assignment. Since the city is in an area of rapid urbanization, a great deal can be done in the design of streets and gutters and urban development patterns to minimize the problem.

Flooding along the natural streams and irrigation canals has occurred in the Sandy vicinity, but records and accounts of damage have not been kept. For example, Butler and Marsell (1972) do not mention a single flash flood in the area. This should not be taken to mean that there were none but rather that the community has not been recognized as a separate entity long enough to receive recognition in the press for nearby flooding. Perhaps more important, growth has changed both the socio-demographic character of the community and many aspects of the physical hazard. Both changes increase the probability of flooding catching the population unaware.

Sandy has grown at a rate between 3 and 4 percent for the past several years. The irregular city boundaries are evidence of substantial growth through annexation. In general, land use passes from commercial and older residential, to newer residential, to agricultural or idle as one travels from the city's center in any direction except north. Development in flood hazard areas has been occurring at a steady, though not rapid, rate for some time. The flood zones along the Jordan River, Dry Creek, and East Jordan Canal were selected as representative of Sandy's flood hazard and examined in more detail.

The Jordan River follows the city's west boundary from 98th South to about 92nd South, with an average floodplain width of 500 feet. Much of this area would be inundated by the proposed Lampton Reservoir, an element of the Bureau of Reclamation's Central Utah Project, Bonneville Unit, and will not be developed for this reason. The city has, in addition, reserved for open space the land immediately below the proposed dam. One request for development has already been denied. Further development in the Sandy segment of the Jordan River floodplain is thus being prevented.

Dry Creek has a drainage area of 14 square miles, 5 of which are below the canyon mouth, and empties into the Jordan River near 94th South. Most of the stream below the canyon mouth is within Sandy. The Corps of Engineers (1974) has calculated that the 100-year flood flow would reach 1,200 cfs at the canyon mouth and diminish to 600 cfs by the confluence with the Jordan River. Flows approaching this magnitude have not been observed, and even the Corps estimates are considerably less than the 2180 cfs indicated for 9 square miles by Equation 2. Five bridges (those at the Glena Canal, State Street, 10200 South Street, 700 East Street, and 1300 East Street) particularly obstruct flow, increase the damage potential to the canal and roads, and broaden the upstream flood area slightly. No buildings were observed in the floodplain. A detention dam at about 300 East significantly reduces lesser flood flows but would pass flows greater than downstream channel capacity during the more extreme floods. All in all, Dry Creek does not seem to pose a serious flood hazard.

The East Jordan Canal enters the city limits at 10600 South and about 200 East, flowing in a generally northerly direction, and exits at about 8400 South and 300 East. Little hazard from the canal exists through the southern half of this stretch. To the north, the canal passes through the center of the city. Although development has generally been kept back from the channel, a few homes are exposed to basement flooding.

The City of Sandy regulated development in flood prone areas prior to entering the federal insurance program. Regulation in the recently annexed areas was previously provided by Salt Lake County's floodplain management program. To this time, membership in the insurance program does not appear to have caused significant enforcement costs for the city nor caused developers to go to much expense in changing locations or methods of development.

Spanish Fork

This Utah County town was selected as a city in the 5,000 to 50,000 population range not mentioned in the FIA list of Utah communities by program status and thus for which no floodplain has been identified. The town is located on the slope of East Bench several miles west of the base of the mountains and about half a mile away from and about 10 to 15 feet higher than the Spanish Fork River to the southwest. One irrigation canal flows for about a block through the southern end of town but is not a possible source of flooding for the town above. The three cloudburst floods mentioned by Butler and Marsell (1972) for the town occurred in canyons some distance to the east. The flood of July 25, 1911, on the Spanish Fork River crested after a 4-foot rise (Woolley 1946) and was thus nowhere near entering town.

The FIA identified the Spanish Fork River as a source of flood hazard in 1974. City officials appealed the designation, arguing that the area within the city limits was well above any flood hazard from the river. The appeal was sustained, and FIA withdrew its flood hazard designation. Occasional backup of local runoff in the urban storm drainage system was the only flood problem identified, and it was not considered to be serious.

The city is in as flood free a location as one could expect to find. One could note that the FIA program put the community to a needless expense in designating a flood hazard that had to be removed by appeal, but such hassle was not unreasonable for a national program floundering in its early stages.

Wales

This Sanpete County town of under 1000 was selected as one considered by FIA to have a flood problem but where no hazard area had been mapped. The site for the town of about 100 people is located at the foot of an alluvial fan at the mouth of Wales Canyon to the west.

The base flow emerging from the canyon has its source in springs about 2 miles up the canyon. The springs sometimes go dry in late summer but generally flow enough to maintain the stream. Heavy rains or rapid snowmelt in the mountain watershed have caused the flooding of cropland south of town. The only event recorded by Butler and Marsell (1972) occurred July 31, 1965, and caused $10,000 in damage to Wales Canyon road and lesser damage to the culinary water system and to agriculture. Woolley (1946) noted four floods in August 1909 as causing considerable damage but did not specify the type. No damage to dwellings has been documented. Some washing from a gravel pit at the mouth of the canyon has spread gravel onto marginal foothill cropland west of Wales.

Residents of Wales and the surrounding area do not appear to be concerned about whatever potential flood hazard exists, and the community has made no effort to participate in the National Flood Insurance Program. This seems to be another case of a small town that may, but there is some doubt, suffer significant damage during a 100-year flood and where the danger during even rarer events is from shallow dispersed flooding.

Washington Terrace

This community just south of Ogden was selected as a city in the 5,000 to 50,000 population range considered to have a flood problem but where no hazard area has been mapped. The town lies on high ground separated from the Wasatch Front by Burch Creek which intercepts any flow coming down the canyons. The only possible sources of flooding are storm runoff originating within the town and whatever flooding Burch Creek may cause to low lying property in its deeply incised canyon. The latter possibility is ruled out by the flood insurance study prepared for that creek by the Sacramento District, U.S. Army Corps of Engineers, November 1970, where the lowest corner of the town is shown to be some 50 feet above standard project flood stage.

The town has constructed detention basins and storm drains to protect new subdivisions. The city has declined entry in the National Flood Insurance Program because its officials felt that they did not have a riverine flooding problem. The evidence substantiates this judgment, but some residents may benefit from C zone rates to insure themselves against damage from local storm runoff.

West Point

This low density subdivision in Davis County was selected as a town in the 1000 to 5000 population range considered to have a flood problem but where no hazard has been mapped. The town is located on land gently sloping toward the Great Salt Lake some miles below the base of the Wasatch Front and away from any natural water course. The only conceivable source of flooding from flows originating outside the community would be for communities above to discharge storm water runoff where it would flow down the slope into West Point. Such a problem would be best handled through county or state efforts to coordinate the drainage programs of the individual communities as urban development in the area continues its rapid pace.

This study found that under current conditions Bountiful has a flood problem and West Point has none because of its distance from the base of the Wasatch Front. Continued urbanization may reverse the situation and the policy followed by the National Flood Insurance Program can do nothing to help West Point prevent development of a future problem because flood hazards for that program are defined on the basis of existing conditions.

West Point has constructed a storm water storage and drainage system to protect new subdivisions. The absence of a natural flood hazard is a plausibly sound reason to decline entry into the National Flood Insurance Program. A counter argument would be that complying with the program now would make West Point citizens eligible to buy insurance later should continued upstream development aggravate their problem.

Summary of Survey Findings

The descriptive information obtained in surveying the floodplains in the 32 sampled communities were not verified or analyzed in detail. That was not the intent. The goal was rather to get an overview of primary and secondary problem situations, and that was what was accomplished. Because the survey focused on an overview of ways the statewide program might be strengthened rather than recommending specific actions to correct the flood problems of specific communities, none of the 32 community problem descriptions in this chapter should be considered as a thorough analysis of that community's problem. Each should instead be read as what a review of that community's situation contributes to identification of needs to revise and strengthen the state and national programs. For example, many times a problem already encountered in one community was not redescribed when encountered in a second community. The findings are presented in two parts. The first relates to problem differences among the 23 categories in the stratified sample (Table 12). The second is a listing of principal identified problems.

Differences Among Community Types

Since all Utah areas as big as a county recognize some flood prone locations, all the Utah counties sampled were making efforts to join the flood insurance program. The rural counties tend to have only scattered farmhouses outside their incorporated areas, and these are largely on high ground. New development largely occurs within the town. Accordingly, rural counties can provide an opportunity for their citizens to buy some security against the uncertainty of unexpected flooding for very minimal nonstructural program activity. The rural counties thus consider membership as worth their while, but it does little to solve their real flood problem of damages to roads, utilities, and agricultural. That problem can only be expected to grow worse as federal agencies become less active in structural flood control. Only in a few Utah cases, however, is that problem sufficiently severe for the benefits to correct it to justify the cost.

The urban counties are experiencing rapid population growth that is changing lowland storm runoff hydrology, expanding the population and increasing building density on floodplain areas subject to shallow flooding, and causing more people to move closer to the base of the mountains where mud slides occur. These counties are moving ahead with entry into the National Flood Insurance Program and implementation of the nonstructural regulations it requires. The greatest problems these communities face are the needs for more effective methods for dealing with floods and mud flows immediately below the base of the mountains and for better coordination among the activities of the various cities and towns and for the construction of drains that serve several and none can afford alone. These counties would be especially well served by technical improvements in flood hazard mapping on alluvial fans and in flood proofing techniques against water and mud flows.

The incorporated cities and towns which were not entering the National Flood Insurance Program were found to have no riverine flood problem. Many, however, have some problem with occasional flows from hollows and canyons from adjacent mountainsides, but they were not entering because of an impression that this situation could not be covered by insurance. Better communications are needed to resolve this misunderstanding, and many of the communities in this group could serve their citizens better by acting to make it possible for them to obtain insurance against this sort of event.

The communities entering the program were divided between those which recognize a primary flood problem and saw flood insurance as one way to deal with it and those which did not think they had a problem but decided to enter because it was easy to do and could potentially help some of their citizens. Many of these reduced their floodplain management requirements and insurance cost to residents by successfully appealing overly conservative mapping.

None of the communities have become active enough in nonstructural flood control efforts to have encountered significant costs. Nor have their programs been strong enough to have created incidents of developers feeling that they were seriously handicapped by program requirements. Recently, however, such smaller communities as Helper and Castle Dale are beginning to send signals that the cost of satisfying the regular program requirements may be more than they want to pay. Others may be following suit, and FEMA should consider the appropriateness of modifying its required regulations for situations where they must be inforced in small towns to protect against infrequent, shallow flooding.

<u>Principal Identified Problems</u>

1. Utah communities do not have an effective technology nor an effective coordinative structure for dealing with flooding at the mouth of small mountain canyons and which may be aggravated by mingling with irrigation water. They do not have effective methods for problem quantification, and they are not formulating effective controls. The problem is compounded since areas with this hazard are not recognized by most flood insurance studies, and people relying on these studies for guidance to avoid flood risk are mislead to believe that the problem does not exist.

2. The larger Utah communities, which are installing storm drainage systems and basing their designs on containing the 10-year flood, are not analyzing the effects of their installations on the 100-year or larger floods, both inside their jurisdiction and for those downstream. Future flood events where serious downstream damages will be caused by upstream storm drainage facilities are inevitable.

3. Designed and de facto (behind culverts, in irrigation ditches, etc.) storm pondage and debris basins are being increasingly used despite the fact that they are maintenance intensive and improper operation and maintenance can lead to failures with serious downstream consequences. These valuable structures need to be examined for performance should they be improperly maintained or experience larger than design events. Pondage which induces seepage should be evaluated to determine where the water goes. Downstream floodways should be provided.

4. Upstream urbanization, recreation developments, and recreation vehicle use are causing runoff, sediment, and debris problems for those below. Land treatment is particularly important as a flood damage reduction measure in arid climates where so much of the damage is caused by the sediment content of the flood water, and yet the technology for cost effective land treatment does not seem to be being significantly advanced and financial programs are lacking to help communities protect watersheds above completely urban areas.

5. The hazards delineated in the various communities are not being defined on an equal basis. Some, for example, have flood areas defined along irrigation canals while others do not. Some have been able to remove flood hazard designations through the appeals process for areas of no less risk than are still mapped as flood prone in other communities.

6. Generally speaking, floodplain mapping in Utah is too conservative in delineating areas at hazard from larger drainages and overlooks hazards from local flooding. The history of flood damage in the state shows the latter situation to be a major damage source.

7. Many areas in the state have either never or not for many years experienced a major flood. For small, arid basins, no runoff at all may occur for decades. The effects of a single large event on unsuspecting residents can then be devastating. It is much more difficult for the people in this sort of community to understand their hazard than it is for the inhabitants of more humid climates where smaller floods are more visible.

CHAPTER VI

ANALYSIS OF FLOOD PROBLEMS

Introduction

The survey of 32 communities accumulated general descriptive information on Utah flood hazards, primary problems caused by the hazards, structural and nonstructural efforts to mitigate them, and secondary problems associated with the efforts. From the results as described in Chapter V, one has to conclude that 1) flooding causing about $4 million dollars in damage annually and about one drowning every three years is a significant problem for Utah and 2) the efforts to deal with the problem are often poorly directed or at least inefficient. In order to move from this negative conclusion toward constructive recommendations, the next step was to explore problems revealed in the survey in greater depth.

Classification of Flood Program Problem Types

Some conceptual order was given to the diversity of problems encountered by classifying them by a taxonomy based on the theory of economic optimality. Flood control requires multiple measures to achieve multiple goals, and four situations can keep a multiple-input, multiple-output process from being nonoptimal (James and Lee 1971, p. 61-90). Specifically:

1. Marginal costs in excess of marginal benefits: A community may have (either as a site in which a federal program is being implemented or through its own efforts) a flood control or floodplain management program more extensive and expensive than justified by its flood problem. Such a case might, for example, occur if a community were following federal guidelines in implementing a regulatory program too elaborate for the local situation as evidenced by the costs of enforcement to the local government and of conforming to the public. In this case, the program needs to be curtailed.

2. Marginal benefits in excess of marginal cost: A community may not be making sufficient effort in its flood control program as evidenced by the existence of unimplemented economically justified alternatives. Such a case might occur if a community, because of the long period that has elapsed since it last experienced flooding, does not recognize the extent of the hazard or if institutional barriers have prevented preferred alternatives from being implemented. In this case the program needs to be augmented.

3. Nonequal marginal rates of substitution: The community may be relying on one measure when in fact some other measure might do the job more effectively or at less cost. Over emphasis on either the structural or nonstructural approach at the expense of the other is an example. In this case, shifts are needed from the overemphasized to the underemphasized program components.

4. Nonequal marginal rates of transformation: The community may be adequately dealing (or even devoting marginal costs in excess of marginal benefits) with some flood problems while neglecting others. Such would be the case if a community had an effective program to deal with riverine flooding but was ignoring problems caused by hillside runoff.

Selection of Communities for Analysis

Review of the information reported in the last chapter led to selection of seven communities as having significant flood program problems of sorts that cover the classifications in the above taxonomy and that need to be understood better to improve the effectiveness of Utah's flood control efforts statewide. Generally, rural areas were not found to have much problem. The greater difficulties were encountered along the rapidly growing Wasatch Front where newcomers are more apt to expose themselves to risk or cause hydrologic change that increases risk for others.

The seven communities were not limited to those surveyed in the last chapter because discussions with various public officials during the survey suggested some other situations as even more informative to analyze. The analyses of the selected communities were not to encompass their total flood problem but only those aspects that would add to better understanding the statewide situation. The seven communities selected were 1) Bountiful (including the relationship of its problem to that in adjacent West Bountiful), 2) Brigham City, 3) Helper, 4) Moab, 5) Ogden, 6) Provo, and 7) Willard. All are located on Figure 10 and are discussed below in alphabetical order.

Bountiful

Three creeks, Stone, Barton, and Mill (Figure 12), carry runoff from the Wasatch Front to the east through Bountiful toward the Great Salt Lake to the west. Under natural conditions in this arid climate, not very much runoff entered these creeks as they passed through the present townsite. Urbanization, however, increased runoff and caused local drainage problems because of the lack of natural channels to convey storm water to the nearest creek.

Over the past 10 years, Bountiful has been correcting this problem by constructing collector sewers to convey storm runoff to the three creeks. Small (1 to 6 acre) detention basins are designed into the system to hold back the flood hydrograph to reduce size requirements for the storm sewers. Altogether, 25 to 30 projects costing over $2 million have been constructed.

Because the financial cost of providing greater protection was considered excessive, the facilities have been designed for a 10-year return period. City policy according to the city engineer is that for anything larger "we just have to take our knocks," but the problem this storm drainage policy poses for dealing with the hazard from the 100-year event is that hydraulic analyses have not been performed to estimate those knocks. Consequently, the flood insurance program does not have the information needed to establish actuarial rates for providing flood insurance coverage. More important, the measures that prevent flooding during the 10-year event may aggravate the hazard during the 100-year event.

It is not easy to obtain these needed estimates. The problems of estimating urban runoff and natural stream hydrographs and combining them are complicated. The single factor doing the most to complicate risk assessment, however, is the sedimentation problem. Basins are filled and sewers are clogged by sand and debris washed from the mountain sides or open land within the urban area. Material washed into the system can reduce the capacity for subsequent storms. Material carried into the system at the start of a larger storm can clog the facilities for runoff to follow. Urban drainageways, with more crossings and covered sections, are much more susceptible to clog-

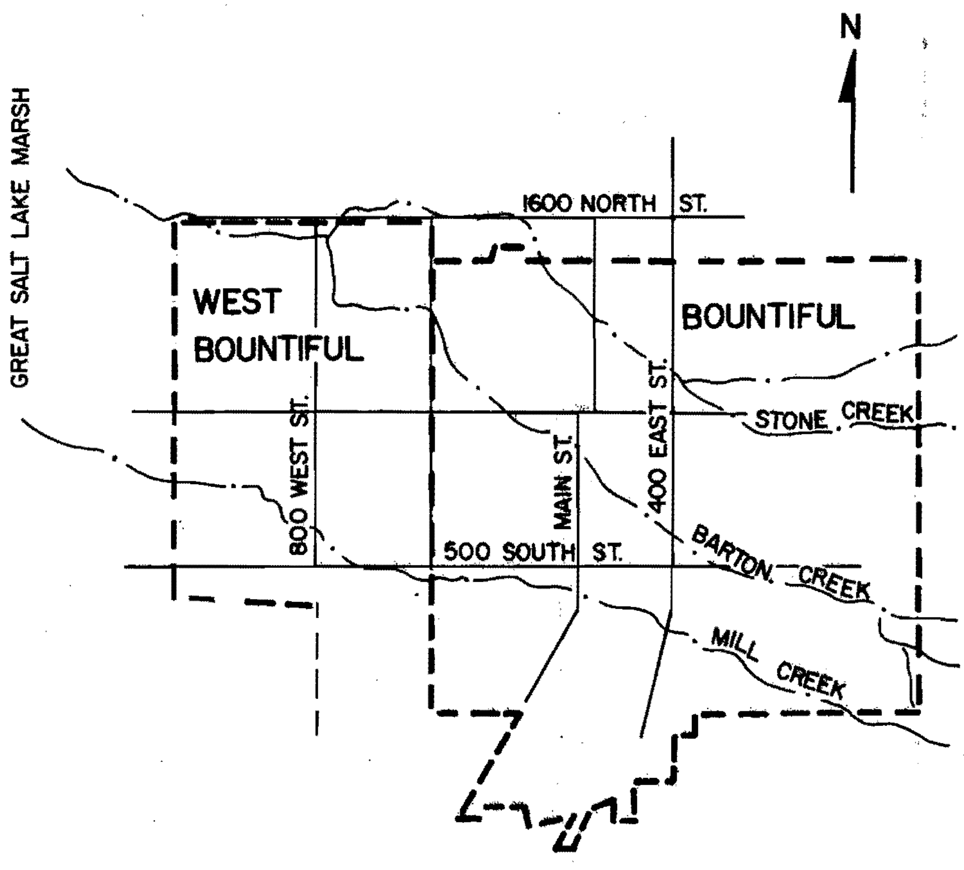

Figure 12. Map of Bountiful and West Bountiful.

ging than are natural channels. Keeping the storm drains cleaned is a major maintenance problem.

The deposition of silt in the streambeds also causes a continuing problem as the silt deposited in the streambeds by mountain runoff causes the water to overflow the banks and flood adjacent property. Those flooded feel that it is the city's responsibility to keep the streambeds clean, however, the city doesn't always agree. Its response depends on whether encroachment by those harmed into the floodway contributed to the problem. In 1977 the city wrote to several citizens experiencing flooding caused by clogged streambeds advising them that the city did not feel responsibility for their damage because they had encroached on the streambed by building walls, planting trees, etc. In other circumstances, the city rechanneled Mill Creek and built a retaining wall to correct a flooding problem due to silt deposition after repeated complaints by some of the residents along the creek who were experiencing recurring flooding.

In spite of the effort spent on its storm drainage system, cloudburst events fill basements nearly every summer. The city recognizes that the problem cannot be entirely corrected with storm drains designed to handle the 10-year event and, consequently, complements its storm drains with the nonstructural approach of requiring new development to provide grading for drainage on a slope from the buildings back to the street and streets designed to carry the flow. An ordinance requires developers to have their designs inspected and approved before construction begins.

Although this storm drainage program has done much to alleviate Bountiful's problem, problems as well as water have been conveyed downstream to West Bountiful. In 1971 West Bountiful sued in district court to stop its uphill neighbor from building collector lines to discharge urban runoff into the natural creek channels. The judge ruled against West Bountiful with a decision that as long as the drainage comes from within the basin it could be discharged into the streams. Nevertheless, Bountiful cooperated with West Bountiful, Centerville, and Davis County in a project rerouting Stone Creek from the west boundary of Bountiful to the lake (Figure 12). In 1979 West Bountiful joined with the County and Phillips Petroleum Company in installing a 6-foot diameter drain line to carry excess flows in Mill Creek through the city to its west boundary. Finally, the city has plans for diverting Barton Creek flood flows to Stone Creek (which has excess capacity) on the east side of the city, but difficult financing and right-of-way problems must be solved before the plans can be implemented. The city doesn't have enough money to do the project on its own; and according to city officials, county funds are not readily available either.

Bountiful individually and by interacting with its downstream neighbors has gone a long way toward correcting common storm drainage and flooding problems. Others remain unsolved or are being made worse:

1. Sediment deposits in manmade and natural drainageways and sediment laden flood water are increasing flood damages. The three principal alternatives for dealing with this problem are a) regular maintenance to keep basins and channels clean, b) system design incorporating constrictions to accelerate flow and move the sediment downstream and debris basins at locations just above where flattening gradients or widening channels would cause deposition (concentrating deposition makes removal less expensive and the filling of a debris basin is less damaging than the blocking of a bridge opening), c) land treatment to reduce erosion from primary sediment source areas. All three have their place. For an existing system, one can reduce maintenance cost and damage during overflows by land treatment. When system improvement is an option, the design should seek an optimal balance among construction cost, reducing maintenance costs, and damages. The maintenance program should be based on the contribution of the cleaning effort to damage reduction.

2. Community flood control efforts and decisions by individuals in the private sector for dealing with their problem are handicapped by the lack of information on the hazard. The technical difficulties in providing this information stem from the hydrologic uncertainties in estimating flows from small ungaged watersheds and how the flows are affected by land treatment and sedimentation, the stochastic variability of storms occurring during various states of tributary watershed conditions, antecedent moisture, and antecedent system situation with respect to opportunity to clean out sediment and debris from the last storm. All of these difficulties are increasingly severe as one draws nearer to the base of the mountains and as more human activity (construction, recreation, etc.) occurs on small watersheds draining into urban areas below. Methods for defining the extent of these floodplains and the degree of hazard within them are essential to an informed public and private flood damage mitigation efforts and the establishment of actuarial insurance rates. A major discrepancy between the degree of hazard and the insurance rates, one way or the other, is going to cause long run problems for the insurance concept. This point, however, does not preclude the wisdom of in some cases using single low rates over large areas because the benefits of being more precise are just not worth the trouble.

3. Local storm drainage system designs based on controlling the 10-year event need to be better coordinated with the national program to minimize damages caused by the 100-year event. Bountiful and West Bountiful are cooperating to keep uphill storm drainage

systems from increasing downstream damages during the 10-year storm, but neither community is reckoning with what the system will do during the 100-year storm. The grading to keep water out of basements and from ponding in yards and the facilities to speed drainage out of Bountiful are doubtless going to reduce (albeit not to zero) damages during the 100 as well as during the design 10-year event. Downstream in West Bountiful, however, it is doubtful that the increased channel sizes will be sufficient to handle the amount by which flows are increased during these large events. Analysis is needed for floodplain mapping in these downstream areas and for more equitable resolution of the total problem.

4. The total flood hazard also depends on land use and facilities construction within the unincorporated areas uphill from Bountiful. Downstream designs need to be coordinated with upstream watershed conditions. Land use planning for the future needs to be coordinated with budgeting for future storm runoff facilities. Allocations for equitable distribution of required costs among communities need to be consummated in binding cost sharing agreements covering maintenance as well as construction.

Brigham City

While Brigham City is potentially threatened by flooding from both Box Elder Creek and smaller hollows at the base of the Wellsville Mountains, only the former problem is discussed here. That emphasis, however, should not be taken as dismissing potential problems at the mouth of the small canyons, even though no record was found of damage from that source. It is only that for the purposes of this study, flooding from runoff from mountain hollows is covered by the other examples.

Box Elder Creek has flooded Brigham City periodically since settlement in the mid 1800s. The most serious flooding occurred in February 1911 when snowmelt, possibly augmented by heavy rain, resulted in record runoff. Obstructive bridges diverted water into the city, bridges were washed away, and a section of railroad track was washed out. There is no recent history of such serious flooding.

The area identified as having a flood hazard (zone A) on the FIS Flood Hazard Boundary Map (June 12, 1979) follows Box Elder Creek (Figure 13). This area is completely developed except for a few scattered vacant lots. The Corps of Engineers' study of flood hazard in Brigham City (Corps of Engineers 1975) shows roughly the same floodplain, but the mapping distinguishes the flooding problem along the creek from that back from the creek and associated with sheet flow. According to the Corps' study, a total of 170 acres would be inundated in Brigham City by a 100-year flood. Of the total, 45 acres would be urban (most of the floodplain shown on Figure 13), 25 acres would be streamway, and 100 acres would be open or agricultural land (mostly downstream from the area shown in Figure 13).

It is anticipated that flooding would deposit silt, sand, and rocks on streets, lawns, gardens, and pasture. Residential losses would include damage to foundations, basements, heating systems, floors, furnishings, and lawns and gardens. Commercial losses would include damage to structures and equipment, loss of business and inventories, and costs of clean up and repair. Agricultural losses would include erosion, deposition of silt and debris, damage to farm improvements, and costs of clean up.

Examination of the flood hazard area between 300 North and 600 North and between 100 East and 400 East discovered approximately 50 homes located in an area where the principal damage would be basement flooding by sheet flow. West of 100 East the floodplain is very narrow, and only homes located next to the creek would be affected. East of 400 East, the creek goes through a park in a fairly well-defined channel. Some homes located on the creek east of the park are subject to minor flooding.

The flood hazard is aggravated by various obstructions to the channel flow. Natural obstructions include trees, brush, and other vegetation growing in and along the streamways. Manmade obstructions include virtually all the bridges and culverts in the city (Table 14).

City officials expressed the opinion that the Corps of Engineers' analysis of the flood hazard in Brigham City exaggerated the flood threat. According to the officials interviewed, the city has not passed any ordinances restricting development on the floodplain, but the building inspector did indicate that it has been a customary practice to require new houses to be constructed with the first floor above the 100-year flood level.

Despite the negativeness of these expressions, the city is participating in the FIA insurance program, and several people living in the floodplain have purchased flood insurance. It was the opinion of the Public Works Director that this insurance had been purchased primarily to satisfy restrictions imposed on lending institutions by the flood insurance program.

The County Office of Emergency Services feels that there is a significant flood hazard in Brigham City from Box Elder Creek. In 1978 it conducted a flash flood exercise within the area mapped as being subject to inundation by the 100-year flood in which 300-400 people were evacuated from their homes.

The Corps estimates that a 100-year flood flow would be 1100 cfs at the mouth of

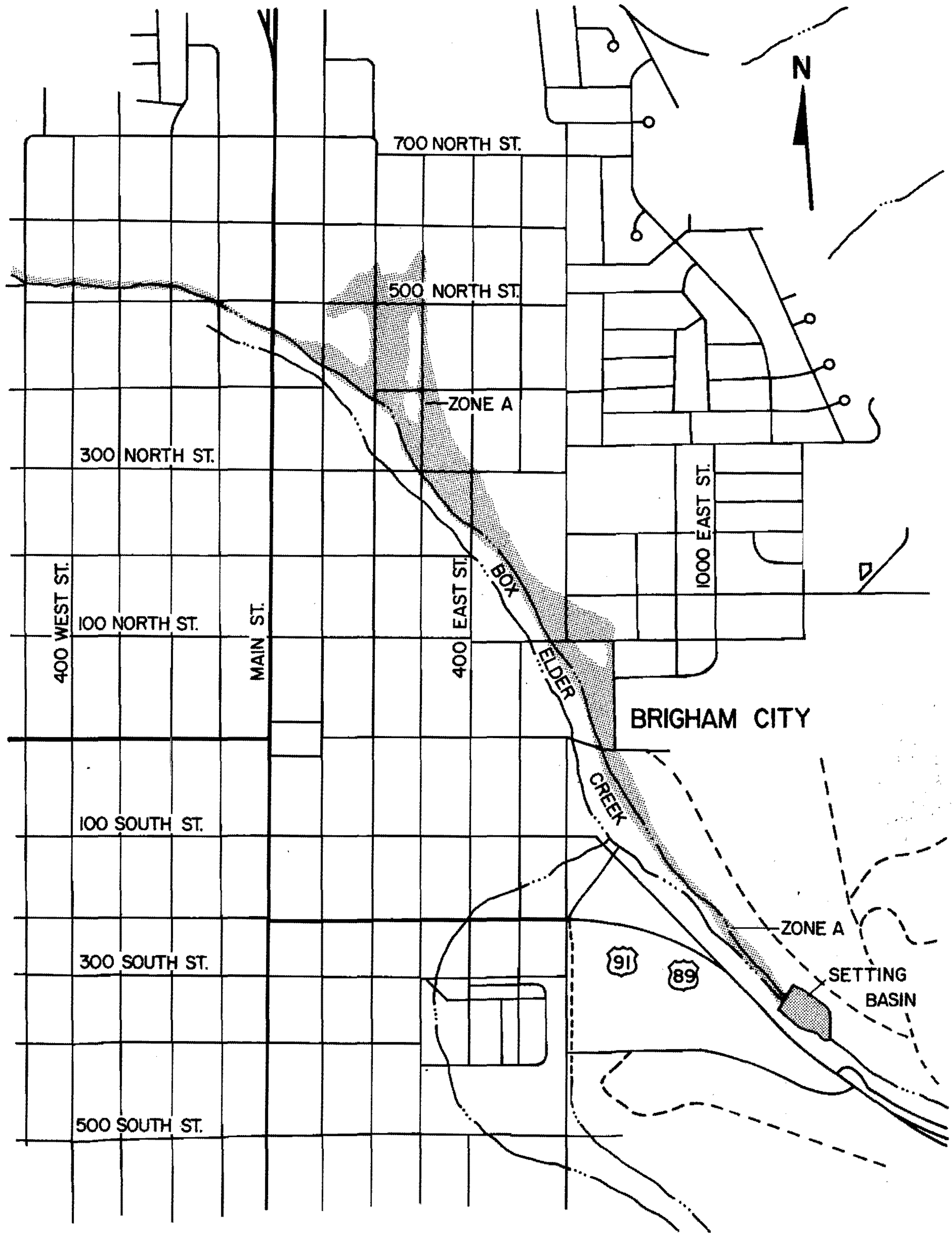

Figure 13. Brigham City flood hazard area.

Table 14. Obstructive bridges and culverts.

Identification	Location b	Elevation[a] Stream-bed	Top of Under-clearance c	Road-way c	100-yr Flood
Interstate Highway 15[d]	0.82	4217	4220	4230	4221
1800 West Street	6.37	4228	4231	4232	4232
Union Pacific RR	10.73	4276	4278	4282	4280
5th West Street	12.38	4304	4308	4310	4307
3rd West Street	13.27	4320	4324	4326	4326
2nd West Street	13.62	4327	4332	4333	4332
1st West & 5th North Streets	14.15	4337	4341	4343	4341
Main Street	14.72	4348	4355	4356	4352
1st East Street	15.23	4358	4363	4364	4362
4th North Street	15.44	4365	4369	4371	4370
2nd East Street	15.73	4369	4376	4378	4375
3rd East & 3rd North Streets	16.44	4388	4391	4393	4393
4th East Street	17.17	4400	4405	4407	4406
1st North Street	18.34	4430	4436	4439	4436
6th East Street	18.61	4434	4440	4442	4440
Forest Street[d]	19.37	4454	4459	4468	4466

[a]All elevations are rounded to the nearest foot, mean sea level datum.
[b]Distance in thousands of feet upstream from Black Slough.
[c]Average elevation.
[d]Culvert.

Source: Corps of Engineers, Sacramento District, Floodplain Information, Box Elder Creek, Brigham City, Utah, June 1975, p. 16. 41 p.

the canyon and 400 cfs at Main Street in Brigham City. Box Elder Creek drains an area of 33 square miles of which 15 square miles drain into Mantua Reservoir. Excluding the controlled area, Equation 2 gives that the 18-square mile drainage could produce a flood flow of up to 2550 cfs at the canyon mouth. The maximum recorded peak flow in Brigham City is 159 cfs, recorded on February 1, 1911. The period of record was 1909-1912, but local sources say that a flood of that magnitude has not occurred since.

The above information suggests that the primary flooding problem along Box Elder Creek has several distinctive characteristics relative to hydrologic analysis, damage estimation, and measure design for Utah's flood problems:

1. The presence of a defined channel that has remained at a fixed location for at least 100 years makes the type of flood risk analysis proposed by Dawdy (1979) inappropriate for Brigham City. Nevertheless, the flows that overtop the channel banks are unconfined and spread at fairly shallow depths over a large area. Delineation of the hazard area is handicapped by difficulty in estimating what volume of water will escape, which way it will flow, and how far the flow will go before it will be rendered harmless through containment in gutters and ditches. The development of methods for delineating the hazard area, and defining the hazard within it, in these circumstances would provide a much sounder basis for floodplain management. More important, it would define parameters which flood control and floodplain management efforts should be addressing to be effective. One important application would be in the design of measures that work to convert the flooded area from a random to a constant pattern.

2. Most of the bridges crossing Box Elder Creek cannot pass the 100-year flow without significant backwater, and the smallest bridges determine the points where the banks are overtopped. Vegetation growing within the channel reduces its capacity further, becomes a source of debris that clogs bridge openings, and adds randomness to the flooding patterns by causing bridges that would otherwise have no problem to be the ones that back water onto adjoining property during a particular storm. Cleaning vegetation from the channel would thus have the benefit of improving flood pattern consistency, but the benefit should be weighed against cost, environmental effects, and downstream effects. The vegetation contributes to the natural process of spreading flood flows at the canyon mouth so that the flooding problem does not extend very far downstream. The net effects of enlarging bridge openings depend on the balance between the damage caused in the locations where water spreads after being diverted at the bridge and the damage caused if the water is instead spread by another smaller bridge

downstream. One can visualize sizing bridge openings to spread the water where property will be damaged least. Certainly, the series of bridges must be viewed as a system, and the enlargement of individual bridges should not be undertaken in disregard for downstream effects.

3. The flood hydrology prepared for Box Elder Creek shows 100-year peak flow estimates of 1100 to 1600 cfs at the canyon mouth to decrease to about one third of this amount 1.5 miles downstream at Main Street. A detailed hydraulic analysis could determine how much of this decrease is caused by percolation to groundwater; how much by detention storage in the stream channel, settling basin, and adjacent lowlands; and how much by water being diverted from the stream into overland sheet flow through town. Since the entire floodplain area mapped as subject to sheet-flow flooding is upstream from Main Street, one would expect this last cause to be considerable. From the results, one could obtain some valuable insights on the hydraulics of flood hydrograph dissipation after emerging from mountain canyons and on designs that would be effective in dissipating the flooding for much less cost than that of a large channel to convey the peak through town. The potential for cost reduction can particularly be seen in the fact that a structural solution of bridge enlargements and channel cleaning for Box Elder Creek through Brigham City would require a 1600-cfs channel all the way to Black Slough.

Helper

Analysis of the Helper situation concentrated on program administrative costs and on difficulties associated with significant growth restraints or location shifts that would result from the more comprehensive floodplain management effort required of communities entering into the regular phase of the flood insurance program. Helper only has a population of 2200, but it is located in an area where coming fossil fuel development is expected to trigger major economic and population growth.

While a city map shows large tract of undeveloped land (Figure 14), much of this open space is rough terrain relatively unattractive for development. The exception is the open space along the Price River at the south end of the city. At the time the study began, a subdivision had been proposed on the tract. Plans have since been withdrawn, though apparently not because of floodplain regulations.

The connection with this situation is uncertain, but Helper is showing increasing reluctance to continue with a floodplain management program of the sort expected by FEMA. Helper was suspended from the insurance program when FIA rejected its flood control ordinance on nine counts. The issue of general concern for the smaller cities and towns in Utah entering the regular phase of the federal insurance program is the cost and personnel necessary to comply with the inspection requirements for new development and substantial improvements to older buildings. The work, as described in Chapter III, includes such efforts as checking buildings for compliance with respect to lowest floor elevations and the use of flood resistant materials. Cities with significant flood prone areas and part time building inspectors worry that the required ordinance may impose an unwelcome and perhaps financially untenable extra burden on inspectors. They also worry that the requirements will impose an unfairly large cost burden on land development activities and cause their community to lose out in kinds of economic growth that they consider important. As the side in such controversies having much greater resources, it would behoove FIA to either develop facts and figures that can be presented to alleviate these fears or to relax requirements where the facts and figures cannot justify a larger program.

An additional problem has surfaced as some question the legal status of the flood hazard zones designated by FIA. Utah law requires that zoning changes be made only after public hearing. Since data limitations and hydrologic uncertainties make precise delineation of the 100-year floodplain impossible, legal boundaries are based on rough information. As better information becomes available or physical conditions change (through upstream urbanization for example), more accurate or new boundaries can be delineated. Perhaps the requirement for a public hearing can be satisfied by presentation and discussion of the technical facts. The legal status of the revised maps, should the reaction of the public at the hearing be unfavorable, is unresolved.

At this time, a revised ordinance submitted to FIA by Helper appears to be acceptable to both for resolving the immediate situation. If approved, Helper would automatically be reinstated into the insurance program.

Whether or not this case is successfully resolved, the compatibility of FEMA floodplain management requirements with the technical and financial capacity and with the long run economic goals of small towns is going to continue to be an issue. Perhaps requirements should be relaxed for small towns where the benefits from a more demanding floodplain management program would be meager, and the state should take a leadership role in promoting this change. Perhaps, the communities should have technical and financial help in meeting the requirements, and the state should provide supporting services needed to make this possible. The more appropriate course is now unclear.

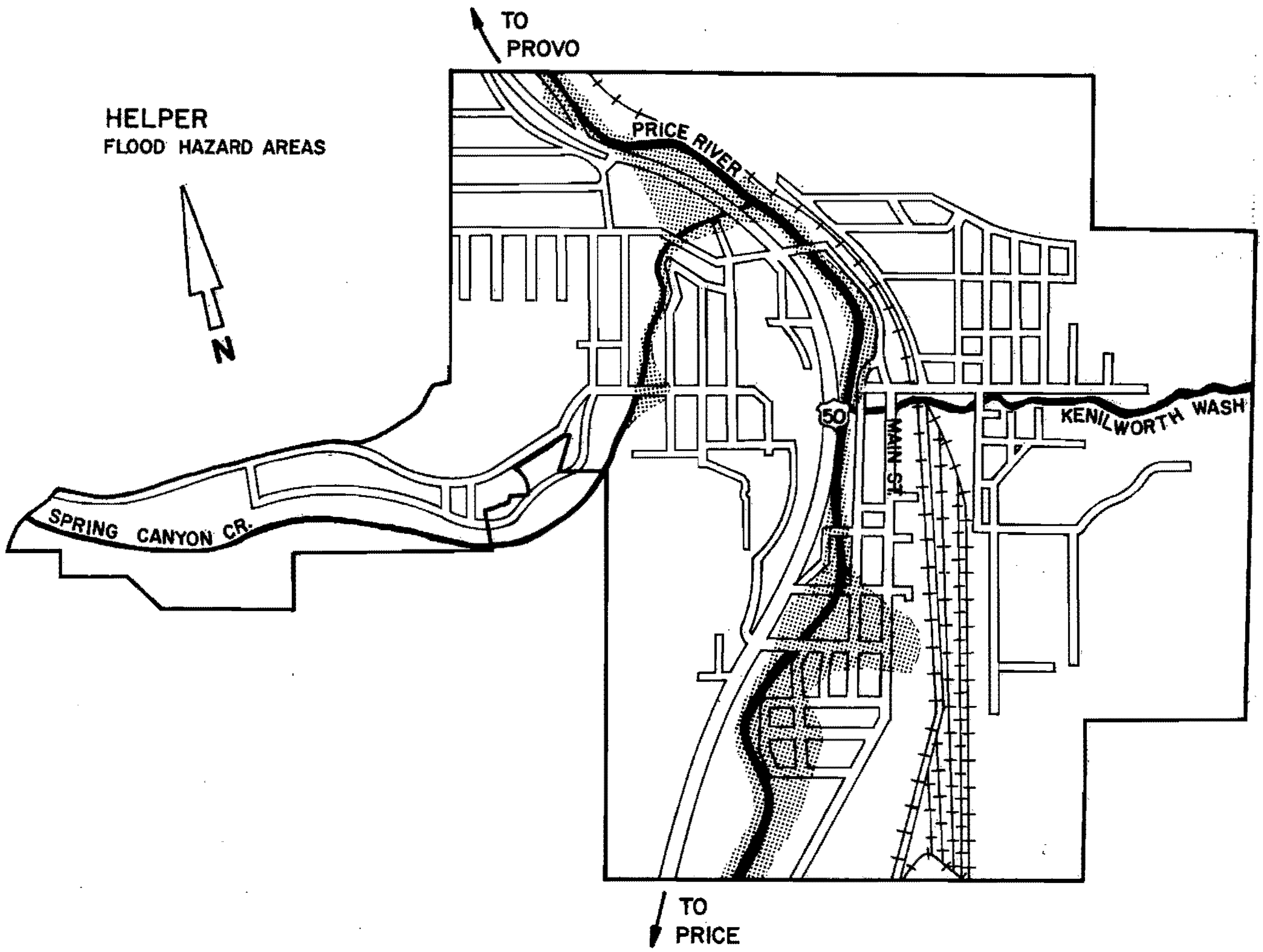

Figure 14. Helper flood hazard area.

Moab

Moab was selected as a town with a substantial flood problem for which a number of structural and nonstructural solutions had been proposed but where very little has been done. The town lies in a valley (Spanish Valley) approximately 12 miles long and 1 mile wide. The valley is bounded on the east and west by sandstone cliffs locally called "slick rock." The Colorado River flows from the east, goes around a bend 2 miles north of Moab, and then flows to the southwest. Mill and Pack Creeks, which originate in the La Sal Mountains to the southeast of Moab, flow parallel to each other into the center of the city and converge. Then Mill Creek flows into the Colorado River approximately 1 mile west of town (Figure 15).

The Mill Creek watershed has diverse characteristics. Slopes vary from moderate in the La Sal Mountains to flat in the plateaus of the north and south mesas and then to almost vertical sandstone canyons below the mesa area. Infiltration is almost zero on the "slick rock" cliffs of these canyons but is moderately good on the alluvium of the mesa. Both snowmelt and cloudburst flooding occur with the cloudburst flood being the more severe and less predictable.

There are written records of flooding in and near Moab as early as 1881 (Woolley 1946). Severe damage to dwellings, businesses, roads, bridges, and farmland has been documented over the years. According to U.S. Geological Survey records, five cloudburst floods were recorded during 1881-1900, 23 during 1901-1920, 31 during 1921-1940, 23 during 1941-1960, and 19 during 1961-1969, for a total of 101 for the period 1881-1969. Since that time, floods occurred in 1970, 1974, 1976, and 1978.

The Soil Conservation Service (1975) completed a flood hazard analysis for Moab and the surrounding area as a step in planning for structural flood control. Their estimates for instantaneous peak discharges on Mill Creek and Pack Creek for various frequencies are given in Table 15. The Corps of Engineers estimate a standard project flood peak in excess of 23,000 cfs. The maximum probable flood peak has been estimated to exceed 74,000 cfs (Utah Division of Water Resources 1976). Moab is thus obviously in much more hazardous position than is Brigham City where the 100-year flood at Main Street was estimated at only 400 cfs.

The Soil Conservation Service (1975) reports that flooding from Mill and Park Creeks increased with agricultural development of the upper watershed. A report in the local newspaper, The Times Independent, dated August 23, 1901, suggested that the Pack Creek channel had increased from a 16-foot to a 100-foot width in 5 years. Interviews with two engineers in Moab also suggested that the flooding became more frequent with increased use of the upper watershed.

Flooding in Moab is not solely caused by the two streams running through town. Bliss and Tusher Canyons drain "slick rock" areas east of the city and discharge onto developed areas below. The resulting damage was sufficient to qualify the problem for remedial action under the CCC program during the 1930s. Debris basins were constructed in Bliss Canyon and at the mouth of Tusher Canyon.

Table 15. Estimates of the instantaneous peak discharge for Mill and Pack Creeks near Moab, Utah.

Flood Frequency (year)	Mill Creek (cfs)	Pack Creek (cfs)
100	14,000	10,400
10	3,800	2,800
2	800	500

Source: U.S. Soil Conservation Service (1975).

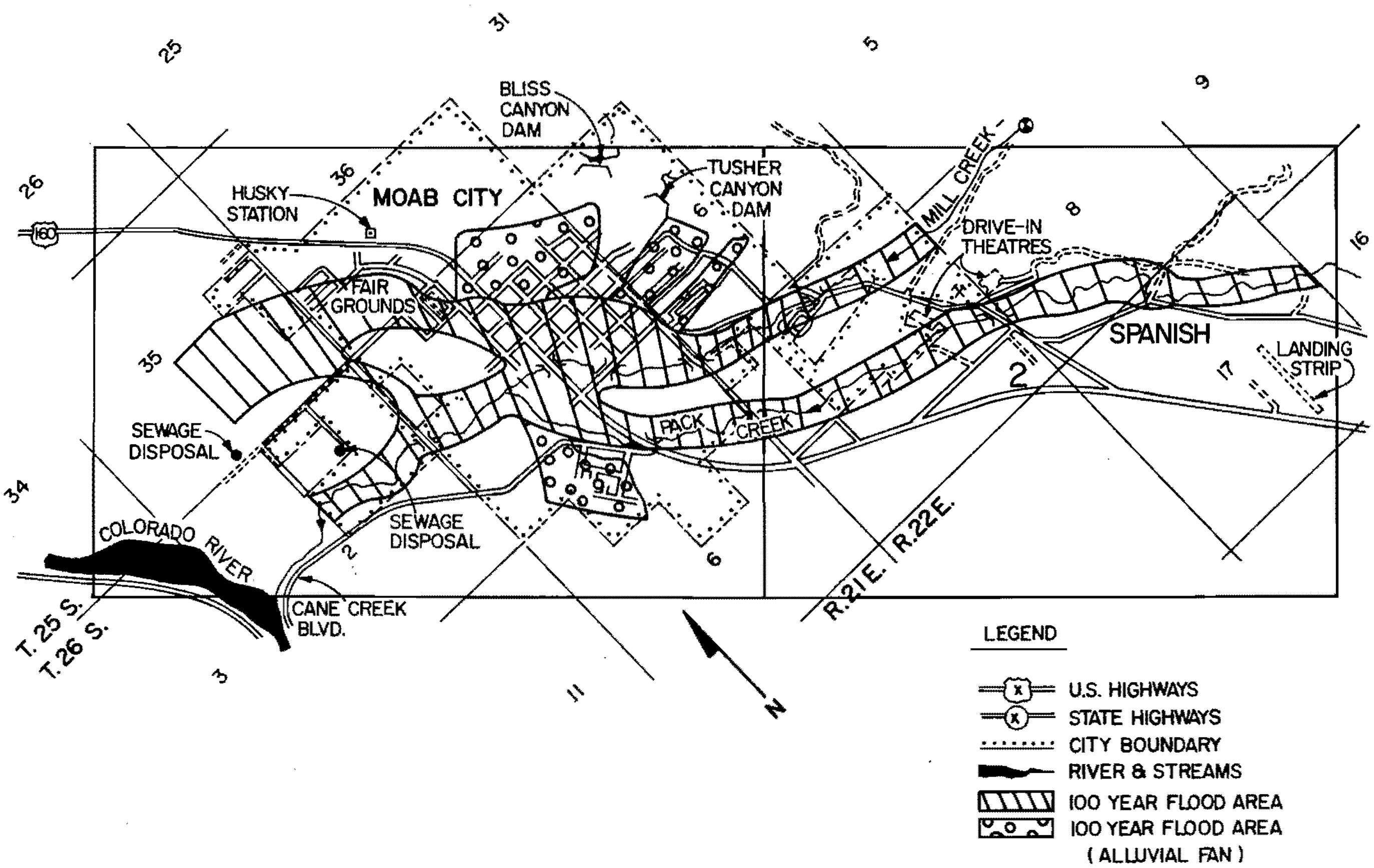

Figure 15. Moab flood hazard area.

Structural efforts to control flooding from Mill and Pack Creeks were begun by the Civilian Conservation Corps (CCC) in 1936. Mapping of the potential dam sites on Mill Creek was initiated by the Utah State Engineer in 1938. The Bureau of Reclamation (1959) listed a small structure on Mill Creek in its Pack Creek Project Report. The reservoir would have been sized at approximately 2,500 acre feet to be used primarily for irrigation but with some storage reserved for flood protection. The Corps of Engineers' study of the area in 1963 recommended channeling Mill Creek through Moab. In 1969, the Bureau of Reclamation recommended an arch dam on Mill Creek to serve for flood protection, irrigation, and recreational use at a cost of approximately $10 million. The Utah Division of Water Resources was asked to join with the Corps of Engineers in a joint effort to determine the needs of the Moab area in 1970 and recommended an earth and rock fill dam on Mill Creek. The U.S. Soil Conservation Service completed a report in 1975 on the flood hazard in response to a request of the Moab City Council for a more detailed analysis of the flood problems on Mill and Pack Creeks. The last three reports have been issued by the Utah Division of Water Resources (1976, 1977) and the Army Corps of Engineers (1979). The benefit-cost ratio estimated for the most favored project was 1.29.

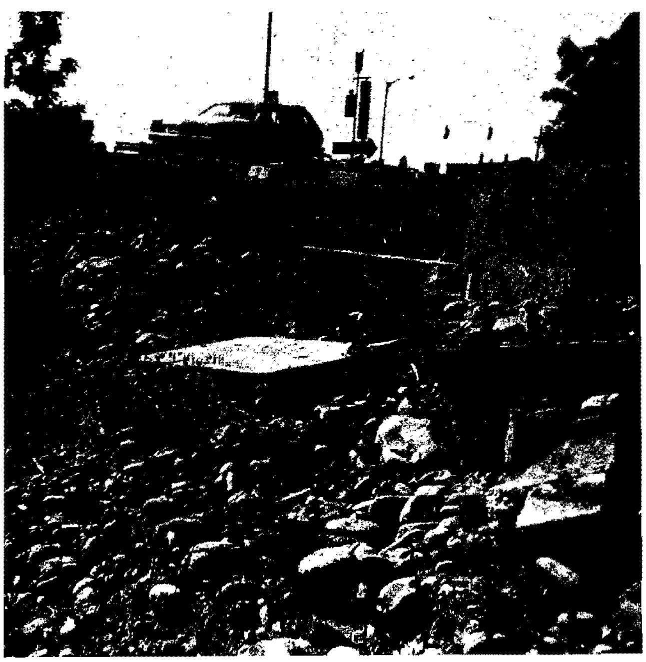

Figure 16. Flood damage in downtown Moab.

The preliminary FIS has been completed (Federal Insurance Administration 1979). The 100-year floodplain as delineated in Figure 15 can be seen to cover much of the central city as well as residential subdivisions to the east and southeast. Most of the benefits from flood control are in the areas outlined in Figure 15 although some occur in Spanish Valley to the south.

Considerable flooding has occurred in downtown Moab between first and second South on Main Street with the most recent event in the Spring of 1979. Figure 16 illustrates damage in the area just east of the Main Street Bridge. Other illustrations are found in Soil Conservation Service (1975) and Corps of Engineers (1979) reports.

Despite this history of efforts to analyze, report, and recommend remedial structures, floods still cause considerable damage. With the exception of the catch basins constructed in Bliss and Tusher Canyons, the studies have produced only recommendations. Local officials indicated their frustrations in not getting projects financed and underway. They were also concerned as to how to restrain growth on the upper Mill Creek watershed that is increasing runoff through town.

It is interesting to point out that although city officials have urged floodplain residents to obtain insurance coverage on all buildings and mobile homes and their contents, the response has been scattered, even in the face of continued flooding and delay in constructing flood control structures. Only 81 policies for a population of 4500 are shown in Table 10. Residents in Walker subdivision, businessmen in central city locations, and residents in the southeast areas of the city were interviewed briefly to determine their attitudes and concerns about the flooding problem and the damages they have experienced during recent floods. All those interviewed were located within the 100-year flood zone. None could assess the probability of damage nor its extent for their particular area of the city. Some had flood insurance, but more did not. Those who had experienced damage could estimate losses in terms of replacement costs for carpets, pipes, lawn, and household articles, but could not state a subjective probability of that same damage recurring.

Several of those interviewed were confused about the FIA insurance program, and some had not heard of the program at all. Some knew the program existed but did not know that the City of Moab was a participant. A relatively small number had strong complaints including such specifics as a lack of communication between city officials and the citizens, delays in getting flood protection, and continual damage to their property. However, none of these complaining residents and businessmen carried flood insurance.

While quantitative delineation of attitude patterns is unreliable without a more carefully controlled sampling procedure, residents and businessmen obviously lack information on the probability and extent of damage (Kunreuther et al. 1978). Residents and business managers located on the 100-year floodplain do not perceive the low probability-high loss decision process outlined in the insurance and economic literature (Arrow 1953, Hirshleifer 1970, and Kihlstrom and Pauly 1971). They lack the necessary information about risk and loss to select the optimal insurance coverage by weighing the expected cost of insurance against the benefits of coverage should a disaster occur. They are unclear about the probability of flooding in their area and the extent of the loss. A primary role of the insurance agent is to provide this information, but the agents are not informed either. The agents obviously need help so that they can do a better job of marketing flood insurance.

Property owners may also believe that forgiveness grants or low interest loans may be forthcoming from the federal government to cover uninsured losses or that flood damage may open an opportunity to refinance at a lower interest cost. Such opinions, however, are in conflict with recent legislation (PL 93-234, PL 93-288, and PL 94-68) that has moved away from such disaster relief programs as forgiveness grants, essentially zero interest loans, etc., to more loss reduction-contingent insurance programs and higher interest loans.

Some losses were estimated from the interviews. Some $63,000 in clean up costs, excluding new carpet and furniture costs, were estimated at the time of clean up after the June 1962 flood. Some residents who experienced loss from that flood offered costs ranging from $1,500 to $8,500 to replace household items and clean up the debris and silt. During and after the 1974 flood (a 10-year event), one motel in the downtown area had to evacuate for 2 weeks. Its 45 units normally bring an average rental of $26/unit/day for a total loss of business of $16,380. The 1976 flood forced evacuation of the lower units of another motel in the same area. Its 33 units for 2 days normally bring an average rental of $25.50/unit/day for a $1,683 loss plus s $3,600 clean up bill. Neither motel carried insurance. Two mobile homes were flooded in the upper Mill Creek watershed during the 1974 flood causing uninsured losses of $7,500 and $8,900. In the June 1967 flood, an inventory of $9,000 worth of automobile parts was washed away from a service station supply shed. Repair costs for roads and bridges (the latter damages ranging from $40,000 to $200,000) were much higher.

Considerable investment has been made in flood proofing in downtown Moab by business firms and motels, some of whom have flood insurance and others of whom do not have coverage. A motel owner, who apparently does not have coverage, spent $34,500 for walls along the bank of the Mill Creek to contain the flood water. Part of the wall was washed out in the 1976 flood. Another motel owner in the same area has spent $22,000 on walls and rock work since 1972 to direct the Mill Creek channel away from the motel. Another business built a 4-foot concrete wall and gutter to contain and direct the flood waters. The approximate cost of the structure was $9,300.

Despite a long history of recurring flood damage, recognition at the community level of a serious problem, and recognition at the national level that structural measures are justified, no structural program has been implemented to protect Moab. Furthermore, the goals of the National Flood Insurance Program of covering losses to existing property through insurance and of using the availability of that coverage as an incentive to promote floodplain management practices are not being achieved either. The following factors can be hypothesized as contributing to this situation:

1. A belief within the community that the flooding is caused by upstream land use development and hence they rather than the floodplain occupants should pay for the losses.

2. A belief within the community that structural measures are coming or that other forms of financial relief will be available to make insurance on floodplain management less necessary.

3. A feeling that the floodplain mapping overestimates the hazard and thus that there is really no need to buy insurance in much of the mapped area. A community in this situation often appeals to FEMA to have the designated floodplain area reduced, but a community with good prospects of obtaining structural relief could through such action reduce benefit estimates to the point where a project would no longer be feasible.

4. Ineffective salesmanship for flood insurance in the community.

Ogden

This city provides a good example of innovative designs in an active storm drainage program at the community level. The increased runoff and resulting storm water problems brought by urban growth gradually became serious enough for the people to demand action, and city government began to respond about 1969. In that year the city adopted the Weber County master drainage plan and prepared to act within the framework of the proposed county system. However, most of those storm drainage plans had to be shelved because sufficient funds were not appropriated to do the work.

The experience of this financial limitation led to a planning philosophy followed by the city during the last decade of building a system 1) at minimum cost and 2) with maximum utilization of existing conveyance facilities. The high cost of building large-diameter storm drains to convey water long distances was apparent. Detention storage provides a way to reduce them and thus becomes a basic component of the city's urban runoff control systems. (See page 72.)

One of the projects constructed by the city with its Economic Development Administration grant in 1977 is the debris basin and drain line on 27th Street (Figure 17). Runoff washes large rocks, trees, and other debris down Taylor Canyon at the head of 27th Street. To intercept the flows and separate the rocks and debris from the water, a debris basin was constructed at the mouth of the canyon. This basin is essentially a small earth-fill dam with an outlet box and pipe for draining water from the basin. Debris and rocks are caught and held behind the dam, thus preventing this material from being washed into streets and yards. The basin is cleaned and reshaped after each storm and periodically, as required. The estimated benefits from reducing cleanup costs and damages to yards and basements on 27th Street significantly exceed the cost of constructing and periodically cleaning the basin. The debris basin of Figure 17 provides a model of one of the most effective methods for controlling cloudburst runoff and debris from mountain canyons.

One issue deserving further examination is what happens when a very large storm occurs. Specifically, are there cases when storm drainage facilities actually make flooding worse as debris dams are washed out, sumps recharge aquifers with polluted water, storms fill basins with sediment and flood peaks from following storms are higher than ever before because the compensating damping storage is lost, or grading changes urban watershed boundaries to concentrate flows differently. Since state government has responsibility for dam safety and pollution control, need for reviews of storm drainage system designs to protect the public interest need to be determined.

Provo

As one of the first Utah cities to join the regular flood insurance program, Provo has committed itself to a strong nonstructural flood control effort. The question to be analyzed was thus one of what effect

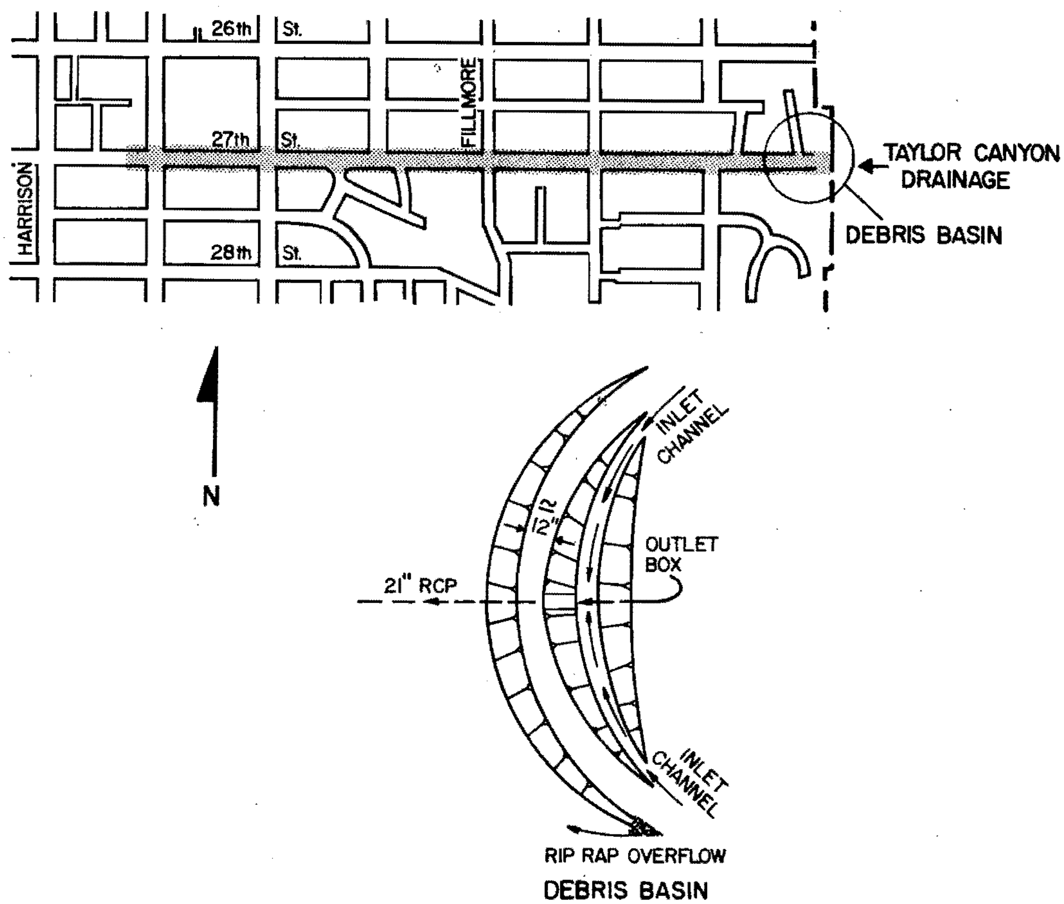

Figure 17. Debris basin on 27th Street, Ogden, Utah.

is this membership having on administrative cost within city government and on municipal growth in the context of one of Utah's larger cities in a rapidly growing area. The flood hazard area on the eastern bench was the focus of the examination.

The floodplains mapped on the alluvial fans at the mouths of State, Rock, and Little Rock Canyons (Figure 18) are classified AO because of their shallow flooding. Flood depths are estimated to be 1 foot or less during the 100-year flood. The risk to property on the floodplain is low because the flooding is shallow. Furthermore, flood hazard zone delineation and classification are known to be uncertain because of the difficulty of predicting the paths floodwater takes down the fan. In fact, the uncertainty of the floodplain boundary may be so great that there is really little difference in hazard between bench areas within and outside the boundary. This is in fact the assumption made by Dawdy (1979).

The regulation setting development restrictions in AO zones is one of the most controversial elements of the flood insurance program in Utah. With certain exceptions, the construction of new buildings with basements is not permitted in AO zones once the community enters the regular insurance program. This provision has been enforced in Provo since February 1, 1979. The first effect of passing the regulation was to create a rush to obtain building permits and begin construction on flood prone lots prior to the February deadline. Real estate developers who failed to beat the deadline then found that their lots in mapped flood zones decreased substantially in value. One real estate developer reported that even with a $5,000 reduction in the pre-February price, lots in the mapped flood zone were not selling. Part of the difficulty, however, must be attributed to high interest rates.

The shallow flood flows in AO zones often make feasible fairly simple, small scale flood control structures. In Provo, three designs are common. Holding basins can be constructed at the mouths of canyons to contain peak flows, sediment, and debris. As mentioned in Chapter V, structures, similar to that shown on Figure 17, have been built at the mouth of each of the three canyons. These basins would have to be approximately doubled in size to accommodate the 100-year flood, but there are no plans to do so at this time. Future analysis may show that the reduction in flood insurance premiums to home owners in the floodplain resulting from enlarging the basins more than offset the costs.

The design of subdivision curb and gutter systems to carry shallow flood flows is another possibility. One developer drew plans for such a system and submitted them to FIA, seeking to obtain an exemption of the restriction against basements. FIA had the plans for 6 months and then declined to consider removing the restriction until after the system is actually in place. The developer was dissatisfied with the delay and the continuing uncertainty as to FIA's ultimate decision. Thus, indecision and inflexibility at the federal level has worked to discourage use of curb and gutter systems in urban flood control even though such designs could substantially reduce damage.

A third sort of design is to use protective barriers to channel flood flows around homes or to flood proof the portion of any structure below the base flood elevation. This alternative might be implemented either for an entire subdivision, probably during the period of initial development, or by individual home owners. Originally, protective barriers and flood proofing to reduce basement flooding were allowed under FIA regulations as a way to avoid the no-basement restriction. A fairly recent change has foreclosed this option for residential structures, although the policy is not yet firm. The technical issue that needs to be resolved is whether or not the proposed practices can actually be counted on to prevent basement flooding, and this determination requires analysis of subsurface conditions on the bench area.

The inflexibility in FIA's regulations covering AO zones has thus restricted the range of alternative responses to the flood hazard in Provo and may well be directing the community toward nonoptimal solutions. Some relief is in sight however, as the FIA is giving consideration to revising some of the AO zones to B zones where the restrictions mentioned above do not apply.

The issue of regulation in AO zones has also surfaced in Springville and Payson, both currently suspended from the insurance program, and generated enough concern that Senator Garn has proposed an amendment to pending legislation that would require a special study of Utah's AO zones by FIA. Here the State of Utah may find a role in pressing for regulations that allow flexibility so that the most economical combination of floodplain management alternatives can be implemented. The basic problem is that national standards may not be optimal or even reasonable for the uncertain shallow-flooding alluvial fan situation and that forcing similarly if not identically worded ordinances for communities throughout the nation is creating uniform national standards.

With respect to the effects of the regular program on administrative costs and municipal growth as found from the Provo data, the 6-month old program is too new for precise assessment but they are likely to be large. So far, the major administrative cost has been associated with the paperwork of resolving differences with FIA. The decline in lot price suggests a preference to shift development elsewhere, a trend which

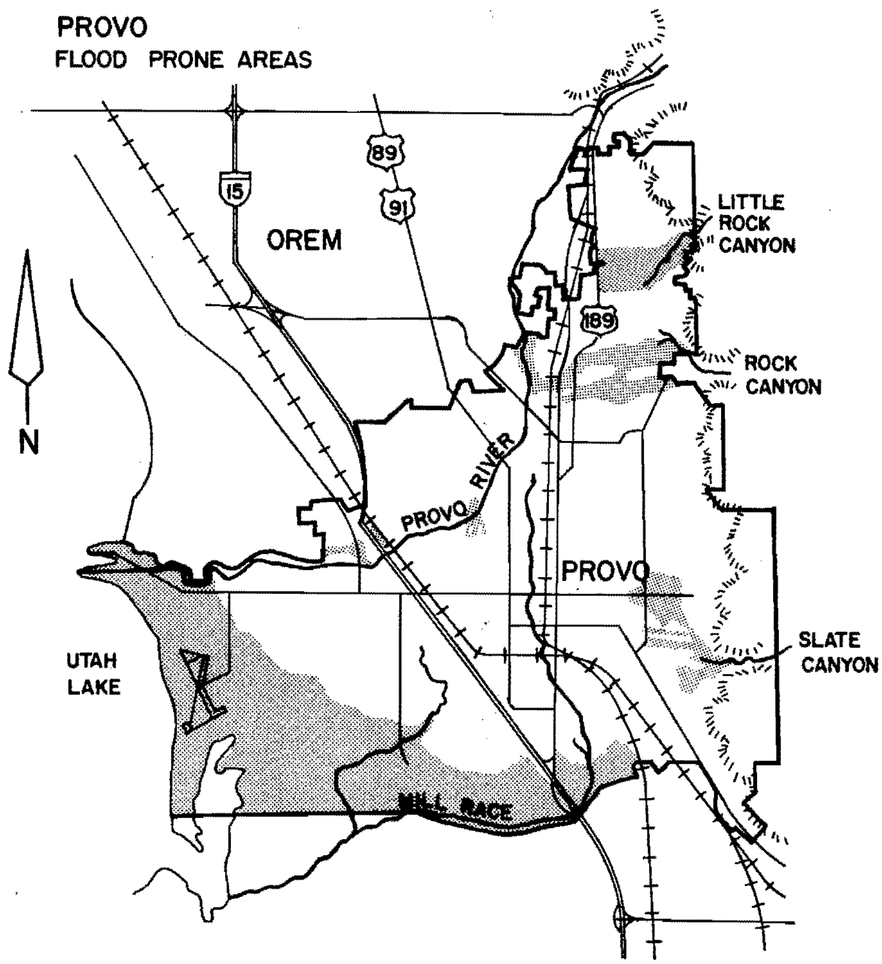

Figure 18. Map of Provo.

furthers the objectives of floodplain management and shifts growth to other communities. Objective analysis of the desirability of the shift is handicapped because little information is available on the performance of protective barriers and flood proofing during actual flood events.

Willard

The City of Willard sits at the base of the Wasatch Front immediately below a point where Willard Peak rises very steeply to an elevation of 9764 feet above the flat lands adjacent to the Great Salt Lake. The very steep rise of 5300 feet in less than 3 miles creates an orographic uplift which intensifies precipitation on the mountainside above town. Some of the runoff runs directly down the face of the mountain largely bare of vegetation at velociies fast enough to wash a great deal of debris onto the valley floor. Much more collects in Willard Canyon and drains out in Willard Creek passing just north of town. An irrigation canal runs along a contour on the mountainside a short distance above town (Figure 19).

Flooding from the creek caused a great deal of damage on August 13, 1923 (2 women drowned when their house was demolished) and again on July 31, 1936 (Woolley 1946). Following the 1936 flood, the CCC did a substantial amount of upstream terracing, and the Bureau of Reclamation or the CCC built a levee northeast of town between the creek and the town. Field observation of the area revealed that although there is considerable sediment deposition and growth of underbrush back of the levee, a sizable flood flow could be contained. Confirmation can be found in the facts that floodwaters from the creek have not entered town since 1933 and the flood hazard mapping indicates that the levee could contain the 100-year flood. In short, except for the area on the creek side of the

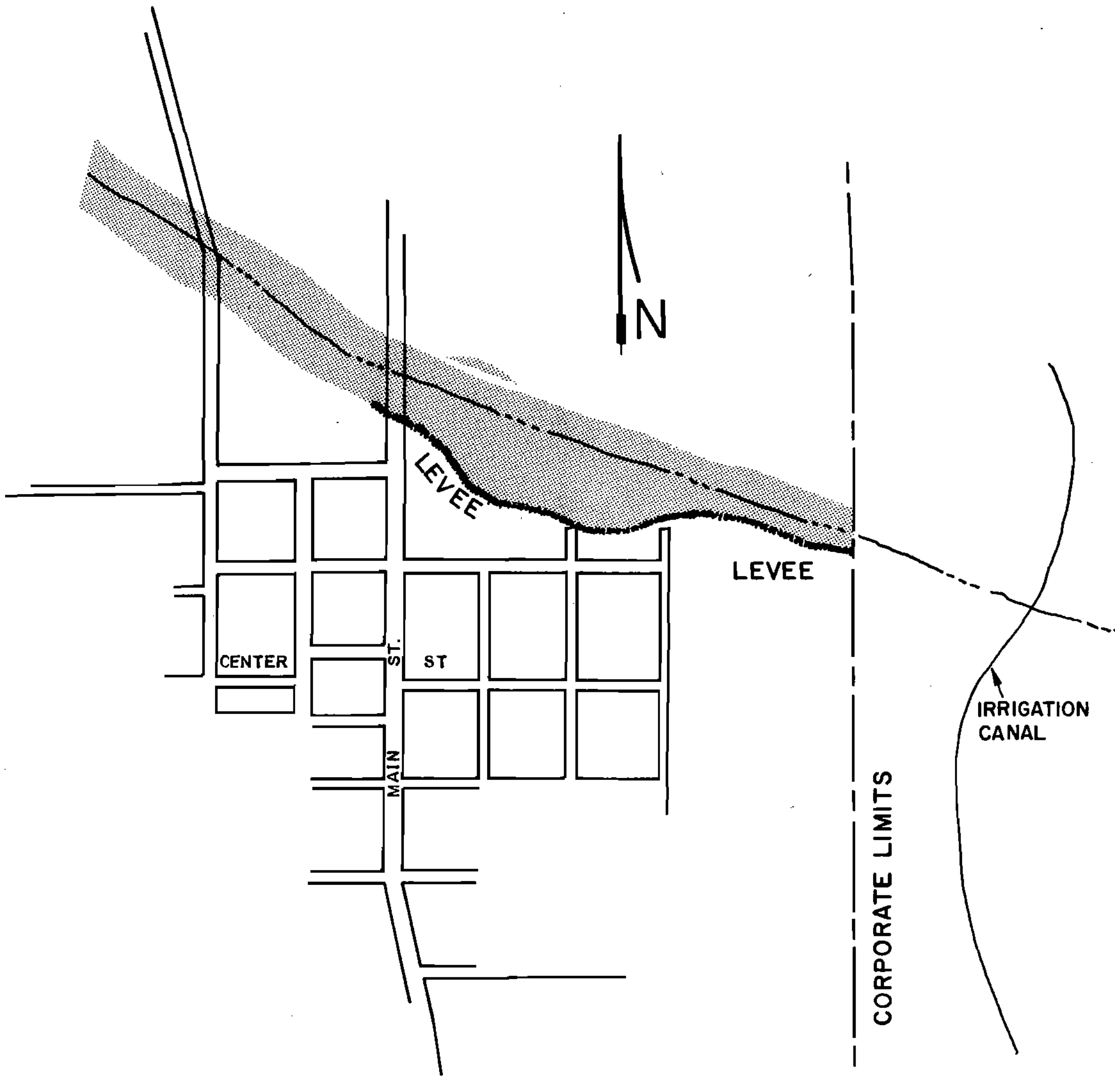

Figure 19. Map of Willard.

levee, the town has less than one chance in a 100 of being flooded.

Nevertheless, damaging floods occurred in Willard in both 1978 and 1979. On August 13, 1978, a cloudburst on Willard Peak sent flood flows down the face of the mountain south of Willard Canyon. Mud, rocks, and debris from the flood filled in the Pine View perimeter canal for a distance of 1 mile, causing the canal water to overflow the banks and add to the flood discharge. Damages to three homes whose basements were filled with mud and debris, lawns, orchards, and gardens amounted to about $250,000. A similar event caused a lesser amount of damage at another point along the base of the mountain in July 1979.

In November 1979, the Box Elder County Commission pledged to assist Willard in organizing a flood drainage district covering the town and the area south to the Weber County line. The first step was to apply to FEMA to study the hazard in the area, principally from three small canyons east of town and four larger canyons to the south (Figure 20). FEMA responded that their backlog of work would delay the study for two years (Salt Lake Tribune, November 13, 1979). The situation relates to an important state role in priorizing studies.

Willard is obviously a community with a flood problem, and that problem obviously extends beyond the mapped floodplain area. The consequence is rather that a floodplain management and insurance program focused on the mapped hazard area does nothing to correct the problem of runoff bringing debris down the face of the mountain, blocking the irrigation canal, and causing waters from both sources to comingle, erode the hillside, and carry mud and debris into town. In fact

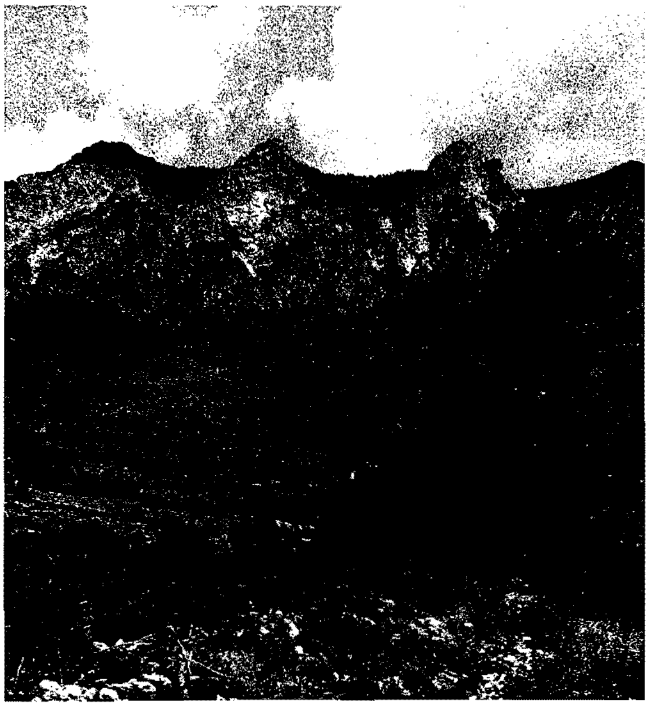

Figure 20. Small canyon watersheds above Willard.

the existing program may be making matters worse by conveying the impression that property outside the mapped floodplain is safe and that owners do not need to buy flood insurance.

Statement of Problems Identified

Streamflow drains excess precipitation toward the sea. Sometimes the runoff rate exceeds the capacity of the natural drainage way and damages property or even takes lives. This physical problem of flooding becomes an economic problem as well when the response to flood events misses cost effective opportunities for reducing the damage or costs much more than the damages prevented. These departures from economic optimality can, as described at the beginning of the chapter, be classified into four groups.

The examination of the seven communities showed that the greatest problem in Utah does not fall in any one of these categories but in all four. The major Utah problem is one of inappropriate response caused by uncertainty. Decision makers at all levels (Figure 1) do not know the magnitude of the floods to expect, the locations to expect to flood, the regulations on floodplain use, how changes in the upstream watershed will affect the hazard, etc. The flood information studies completed for Utah locations have contributed to a better informed public as to flood hazards; but in a number of situations, the information they provide is not sufficient to establish wise floodplain land use. The reasons for the large degree of uncertainty are in large part technical, and hence research to overcome these technical deficiencies would be of great help.

A second pervading problem was one of flood control and floodplain management programs directing their efforts toward lesser hazards while ignoring larger ones (a marginal rate of transformation problem). The effort spent on riverine flood hazards was often extensive even though flood damages were minor, but major damages caused by local runoff from small mountain canyons were ignored, except of course by the individuals left to recover from the loss as best they could. This nonequitable division of flood control effort is aggravated by the technical difficulty in defining this sort of hazard and the understandable tendency of the national FIS program to concentrate on the more familiar riverine hazard.

Other lesser problems, not necessarily in order of importance, include:

1. The marginal rate of transformation problems of putting too much effort on controlling flood waters and neglecting needed preventive (land treatment) efforts to reduce erosion and sedimentation.

2. Expenditures for flood control exceeding marginal benefits received in cases of an overestimated riverine flood hazard or where small communities with minor flood risk would be expected to inaugurate a major floodplain management effort. A community floodplain management program has certain fixed costs (for example for floodplain mapping) which far exceed any possible benefit in small communities with minor flood hazards.

3. The marginal rate of substitution problem of federal requirements forcing Utah communities into a floodplain management program of a type matching national norms when in fact special designs (for example to deflect and disperse shallow flooding) would be more effective for Utah conditions.

4. The externality problem of the flood control or floodplain management efforts of one community increasing risk in another.

The six problems enumerated above relate to urban flooding. In reality, the larger share of the flood damages in Utah are to roads and highways and to agriculture. The agricultural damages are probably not in most cases large enough to justify structural flood control programs and nonstructural measures do not apply. On the other hand, opportunities for improvements in road design standards whose marginal benefits exceed their costs may exist and should be examined.

CHAPTER VII

EVALUATION OF PROGRAMS AND RECOMMENDATIONS

Introduction

Chapter II presented a framework of the dynamically interactive feedback processes through which people at various levels and from various perspectives seek benefits from floodplain occupancy, experience sequences of flood events, and respond by modifying their occupancy or by attempting to modify the pattern of flooding. Through these processes, society balances benefits against risks. Efforts made by government to alter this balance generate additional impacts, some beneficial (increasing benefits or reducing risk) and others detrimental (implementation cost or adverse environmental or social impacts). That chapter ended with generalized presentations of how the balance between benefits and risk and government efforts to change this balance might be weighed from the Utah perspective.

Chapter III moved from this general framework to empirical data describing flood risk in Utah. Chapter IV outlined efforts at the national, local, and individual levels to reduce flood risks or enjoy the benefits of floodplain occupancy. Chapter V inventoried and Chapter VI probed situations in selected Utah communities. The purpose in this chapter is to analyze the information presented in these chapters through the framework of Chapter II in order to identify needs for program improvement. Some of the needs can reasonably be met by action at the level of state government. Others cannot. The final goal is to make recommendations on what the State of Utah should do.

Evaluation of Adequacy of Flood Hazard Information

Flood risk in Utah was found to be relatively low compared with the rest of the country, but considerable danger exists from flash flooding caused by cloudburst storms that cause the water to rise rapidly in mountain canyons and discharge sediment and debris at the points where the canyons emerge onto alluvial fans at the edges of desert valleys. Waters rise quickly to dangerous depths in the canyons, a situation accounting for most flood drownings in Utah, and the silt and debris which emerge onto the heads of the alluvial fans can do considerably more damage than can flooding by water alone.

As the flood travels downhill over the alluvial fan, the mud and debris settle out, and the water spreads out over a larger area and infiltrates underground. Where infiltration is hindered in urban areas, the flow eventually disperses to the point it can be collected in gutters or ditches. The issue of how far down the alluvial fan to regulate floodplain use (let alone how to vary the distance with the type of use) has never been objectively resolved, and arbitrary decisions in bounding the downstream edges of these "AO" floodplains create major disagreements between communities and the administrators of federal programs. In an arid climate the alluvial fans are also crossed by numerous small irrigation canals that can intercept and convey flood waters to other locations where they break and cause damage where flooding would otherwise not be a problem.

Flood risk assessment is compounded by the fact that many Utah communities seldom experience flooding and yet could be subjected to considerable damage should a major flood occur. Residents of these areas subject to a major disaster, should a large and rare flood occur, have less appreciation of the risk than one typically finds in more humid climates because lesser events are not occurring periodically as reminders of potential danger. Furthermore, expert hydrologists are less able to help them with reliable information on flood risk because of the statistical difficulties in predicting the magnitudes of rare flood events from sparse data.

The hydraulic assessment to map floodplains and define flood risks are even more limited by a lack of practical methodology. Mudflows (Woolley 1946, p. 75-84) are a particular problem. These flows are particularly likely from canyons where weathering between storms produces large amounts of loose rock, unstable side slopes are likely to slide into the drainageway, and the perennial flow is insufficient to keep the channel relatively clean. From a given canyon, mudflows are more likely to be associated with larger storms and after long periods in which loose detritus has accumulated. According to Hooke (1967), a water flow becomes a mud or debris flow when it passes the point of irreversible sediment entrainment. Water flows freely deposit excess sediment load, but a debris flow cannot selectively deposit sediments. The entire load is deposited simultaneously when enough water has drained out the bottom for the flow to become too viscous to continue.

Mudflows may emerge either into a river flowing in a larger canyon or onto an alluvial fan. The former situation frequently blocks highways and railroads and may dam the river to back water onto upstream property and intensify flooding downstream when the temporary blockage gives way. The event of July 13, 1938 (p. 76) illustrates just one of many such events that have occurred in Provo Canyon.

The distance a mudflow will travel down an alluvial fan is determined by how long before sufficient water drains out to stabilize the flow. The two major parameters seem to be the size of the flow (the amount of water) and the freedom of the water to drain. As soon as the flow enters an area where the canyon opens out to the point where water can laterally leave the flow, the drainage begins.

Different flows move onto the fan in random directions (Price 1974). Dawdy's (1979) assumption of equal hazard at all points on a given contour crossing the fan is reasonable for mudflows because the very ridges left by one flow deflect the next flow in a different direction and because the small manmade levees and gutters which direct water flow into consistent patterns are relatively less effective. The greatest need is for a method to predict how far mudflows of various frequencies will travel before stabilizing. The ideal mudflow hazard mapping would show the risk of inundation at various distances below the canyon mouth. Because mudflows are so much more devastating than shallow water flooding, a regulatory criterion much more stringent than the 100-year may be reasonable. Prohibition of all residential development may be in order.

The above description of mudflow characteristics suggests that one possibly effective structural approach would be to develop a long basin somewhat wider than the upstream canyon near or just below its mouth. The mudflow wold then stabilize in the basin which could then be cleaned and reshaped before the next event.

Downstream from where the mudflows stabilize, the risk is from shallow water (often with a high sediment content) flooding. Since floodplain mapping is primarily to provide risk information to urban areas and urban areas have fixed locations and designs for gutters and ditches, the danger will not be uniformly distributed along a given contour on the alluvial fan but will rather be concentrated at locations determined by gutter and ditch geometry. Hence these need to be measured and analyzed to determine risk, or even better, they should be designed to reduce risk. Other important factors in determining risk are the locations of natural channels, the effort made to clean these channels between floods, bridge openings, and irrigation canals. The ideal shallow water flood hazard mapping would show the risk of flooding at various locations over the fan. The mapping should be performed with a secondary goal of searching for cost effective ways to constrain the hazard area.

In conclusion, specific needs exist for reducing flood impacts through:

1. Identification of areas at mouths of mountain canyons where mudflows or shallow water flooding would be severe enough, as measured by depths and velocities, to cause major damage and loss of life.

2. Identification of flood risk in mountain canyons for use in siting highways, campgrounds, and recreation areas and in formulating warning and evacuation procedures for use during flash flood events. State water resources planners could work with state park officials in reducing the risk of major loss of life from flooding in Utah.

3. Review of plans to construct transportation and irrigation facilities crossing alluvial fans to make sure that they will not unduly pond nor concentrate flood waters and create significant hazards in formerly flood free areas.

4. Review of plans to construct storm drainage facilities designed for less than the 100-year event to make sure that they are not unduly intensifying downstream risk during major storms nor extending flood problems into new areas.

Evaluation of Effectiveness of Flood Control Activity

The uncertainty as to flood risk and the duration between flood events work to reduce the effectiveness with which individuals and institutions respond to flood problems. The risk from the 100-year flood as seen by the public is severely underestimated by the people of a community which has experienced no flooding since the 1890s and seen water in their wash only during a few rare events. A public that has not worried about flood problems is not going to know much about government programs for dealing with them. Communities whose officials remain in their jobs for only a few years must regularly have federal and state programs reexplained if they are not to be forgotten.

In this context of poor information and uncertainty, many Utah communities have entered into the federal flood insurance program as a means of making flood insurance available to interested citizens. It is easy to pass the required ordinances without recognizing the potential cost to the community of enforcing them and, more important, conforming to program requirements after the community enters the regular program. The program has not yet advanced to the point where one can assess the problems that may be caused as federal program requirements attempt to acheive less than the economically optimal floodplain use from other viewpoints. (See discussion on differences in acceptable risk on page 11.)

Uncertainties as to the real flood risk have aggravated the difficulties for Utah communities attempting to establish a reasonable floodplain management program and meet FEMA requirements. Flood hazard maps have been difficult to read in areas where buildings were not shown and stream channels were often poorly defined. New information or changing conditions have required map changes, and delays often occurred in spreading the information. Perhaps more important, optimal floodplain management practices have not been defined, and probing questions are raised as to the reasonableness of those required.

Utah flood damage experience also suggests a special need for coordination between transportation and water resources planning. The debris plugging culverts as alluvial channels aggrade or during sediment-laden storm runoff have added greatly to inundation problems to say nothing of exposing highways to a very large share of the total average annual flood damage. Highways through the canyons are also exposed to the cloudburst torrents, and travelers may become trapped during the storms if there are not periodic points of road access to higher ground. Such situations deserve careful consideration in highway alignment and culvert and bridge design decisions.

In terms of the framework of Figure 1, the two primary impacting actions in recent years in Utah have been localized cloudburst flood events and the National Flood Insurance Program. The localized events have not sent impact waves past the second or third level in any of the five dimensions; and, consequently, the actions that are being taken are at the individual and, in the governmental dimension, at no higher than the county level. For the most part these are reasonably effective against smaller storms, but untried as to performance against major events.

The National Flood Insurance Program has caught the attention of most of Utah's 251 communities (162 having 92.6 percent of the population), about 10 percent of the floodplain occupants, and state government. The national structural flood control program is becoming increasingly less active. The overall biggest current problem is that the national programs are not making progress in addressing the types of flood problems Utahns have experienced in the last few years, even though a structural solution for Moab has been studied and found feasible since the 1930s and one recent event was the second most damaging flood of record in the state. The situation is probably adding to a general disillusion toward federal programs in the social and cultural dimensions.

Dingman and Platt (1977) concluded that floodplain management practices are being unnecessarily delayed by widespread misunderstanding as to the degree of precision hydrologically possible and legally necessary in delineating flood hazards. The Utah experience is that the problem is compounded when the methods used consistently miss major flood problems. Walesh (1979) described one of four critical negative features of the National Flood Insurance Program as being its limited scope with respect to using the costly inventory and analyses being made in defining flood hazards to finding solutions to flood problems. The Utah experience shows that advances in floodplain mapping methodology may hold the key to finding solutions in that current techniques are not providing information that is really contributing to solving problems.

In summary, the situations where the greatest opportunity exists for situation-improving action include:

1. Programs to a) augment awareness of citizens and public officials of federal programs to help them solve their flood problems and of the requirements to qualify for those programs and b) to train community engineers and planners to deal effectively with their situations.

2. Assistance to communities dealing with federal agencies on flood control, floodplain management, and transportation programs. Federal officials may not be thinking of Utah situations as they promote their programs, and communities may need technical help in explaining local conditions and in expressing their perceptions and desires to federal officials.

Impact Evaluation from a Utah Perspective

In considering the above flood and response-decision impacts, one sees a number of reasons for flood control and floodplain management practice in Utah varying from that elsewhere. This variance emphasizes the potential importance of a role for state government in reminding federal officials that Utah situations are different and of providing technical help to communities and individuals who need to deal with their own problems. Specific needs for variations from national programs in order to better match the Utah perspective include:

1. Most Utah flood problems are not effectively solved by large scale structural flood control measures but rather by some combination of land treatment to control sediment and debris sources and small scale storage and channelization systems designed to disperse flood flows rather than concentrate them at downstream discharge points. The Soil Conservation Service program is the best focused on these sorts of designs, but that program is not institutionally oriented toward the primary Utah hazard areas found in

the highly urbanized Wasatch Front communities and in isolated mountain recreation areas.

2. Only a few of Utah's larger communities have municipal stormwater control programs and these largely protect against the 10-year event. The programs of the individual communities are not always coordinated with one another nor with the problems in containing larger floods. For example, a stormwater conveyance system that quickly discharges the 10-year flow at the downstream boundary of a community may also greatly speed the flow of the 100-year event and cause significantly larger downstream flows for that event than occurred previously.

3. The federal floodplain management and flood insurance programs of FEMA have not proved adaptable to the Utah variations from the more typical national situations. Representative issues relate to flood hazard mapping on alluvial fans, land use regulatory practice in areas subject to dispersed shallow flooding, and reasonable program expenditure for small rural communities.

4. Community floodplain management programs are hampered by having to be implemented from poor hazard information in communities whose priorities are quite different from flood concerns and by requiring response from a population which generally believes the federal officials to have greatly exaggerated the problem. Many Utah communities have floodplain management ordinances on the books, but none have achieved fully operational programs.

5. Individual flood control efforts have generally been effective in Utah as can be seen from the low rate of damage occurring to private buildings despite the fact that Utah communities are generally located in the most hazardous areas along the base of the mountains (Woolley 1946, p. 57). Much of this success can be attributed to an urban design with large lot sizes allowing plenty of space between buildings for dispersed shallow floodwater flow. As population pressures increase urban residential density, the flooding problem will be aggravated unless suitable flood proofing techniques for Utah conditions are devised and employed.

Recommendations on Potential State Actions

Based on the above information and analysis, the seven areas where Utah state government would be best advised to consider action targeted to improve flood control practice within the state are:

1. Provide a continuing functional forum for keeping communities aware of what they need to know to meet the requirements of the federal flood insurance program and for facilitating the exchange of experiences among community engineers and planners. The state can sponsor workshops as needed and facilitate information exchange on a routine basis.

2. Promote dissemination of information on the risk of major flooding in areas where the danger is not recognized by the public. This sort of effort could do a great deal to prevent a major disaster when inevitable truly large floods occur.

3. Provide technical support for community flood control programs. The support could be limited to a role of doing no more than responding to queries of a technical nature or could be integrated into an active program of reviewing and approving community-proposed structural flood control measures. Flood control dams are already reviewed to make sure that they will function safely during flood events, and many channel or levee failures can be just as disastrous as the failure of the small dam. Regular review would also help prevent flood control measures in upstream communities from worsening downstream damages. The pros and cons of a review program should be carefully evaluated before deciding to go forward and before selecting the sorts of review to require should a program be found desirable.

4. Since effective designs of distributary flood control channels on alluvial fans and of flood proofing for buildings in the path of shallow surface water flooding and underground flow through gravel lenses are not available, a potential state role exists in developing appropriate designs and standards. Communities cannot effectively do this individually, and the federal government is too oriented toward problems of greater national interest to devote the needed effort.

5. As the federal government withdraws more from structural water resources programs, the states are going to come under increasing pressure to share or perhaps wholly provide financing for structural flood control. Many communities have needs that they are financially unable to supply alone. Furthermore, remaining federal programs are moving toward requiring state cost sharing. Certainly, the state should review both federal and local flood control projects from the Utah perspective before state funds are committed. In certain cases, one can expect the economically optimal flood control program to require land treatment, storage, or channelization outside the area of the protected community's jurisdiction. In other cases, communities can by cooperation accomplish mutual flood control objectives at much less cost than they can by acting individually. Most of the projects required in either of these cases, however, are small compared to what is viable for a federal program involving the large fixed cost of planning as prescribed by the Principles and Standards of the Water Resources Council and the National Environmental

Protection Act. Utah may be forced to act, perhaps in conjunction with a requirement of community cost sharing or payback according to local benefit, if economical flood control programs are to be established in these situations. Some use of state water project revolving funds for flood control may be appropriate.

6. Individual communities often do not have sufficient technical expertise or political clout to interact in a way that effectively represents the interests of their citizens when dealing with the federal government on flood control matters. The state government can establish expertise at a position of sufficient political strength to become an important advocate. A state flood problems office may also have a role in helping the community deal with other state agencies on certain flood related problems.

7. Certain additional state legislation may be helpful. State legislation to create special flood control districts may be a reasonable alternative for direct state action to solve flood problems crossing community boundaries. State legislation could also clarify the situation when FEMA changes flood hazard boundary maps and hence the area regulated by floodplain zoning without the public hearings that are now required.

Research Recommendations

The primary need for research is to develop better methods for delineating hazard areas from mudflows and shallow water flooding on alluvial fans and in other valley lands below where small drainages emerge from the mountains. Problems include estimating how flows disperse, how dispersal affects downstream flood hazard, how land grading and storm drainage practices are counteracting dispersal, and what urban design alternatives can improve the Utah situation.

Other needs should be emphasized from the 42 listed by Howells (1977) in his nationwide review. These (by his numbers) are:

2. Development of standards of performance through which the effectiveness of alternative flood control programs can be assessed.

5. Establishment of reasonable and legally sound standards for accuracy and reliability of flood hazard information.

10. Exploration of alternative institutional arrangements for coordination of local flood control and floodplain management programs.

14. Development of guidelines to assist local governments establish optimal flood control and floodplain management programs.

30. Development of improved methods for estimating the effects of land grading, retention storage basins, and channel improvements in urban areas on downstream flooding.

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