Natural Hazard Research

WHAT PEOPLE DID DURING THE BIG THOMPSON FLOOD

by

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Prepared for the
Urban Drainage and Flood Control District

August, 1977

Working Paper #32

What People Did During the Big Thompson Flood*

The Larimer County Sheriff's Department and several canyon residents estimate that more than 2500 people were in the Big Thompson Canyon the night of the flood, July 31, 1976. These included 600 full-time residents, approximately 1200 part-time residents, and many tourists. One hundred thirty-nine people died in the flood and several are still missing.

The purpose of this study is to analyze the behavior patterns which were adopted at the time of the flood, and to apply that knowledge to the improvement of warning system design for Front Range communities vulnerable to flash flooding. Comparisons are made between the actions of the survivors and non-survivors and the warned and non-warned populations. Variables which influenced the choice of action are examined. These variables include location prior to the flood, action taken, group context, location in the canyon, kind of warning received (if any), and number of people in a group. Warning characteristics such as source, mode, number and content are also discussed.

Information was obtained through informal interviews with canyon residents, county officials, relief agency personnel and out-of-state residents who were visiting the canyon at the time of the flood. Additional information was available in newspaper accounts, government agency reports and in literature on flash floods and warning systems.

The results indicate that climbing the canyon wall was the best action to have adopted, and that doing nothing different or taking no action at all were the worst in terms of survival chances. Those who were driving alone through the canyon ran the highest risk.

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* Research for this paper was funded by Denver Urban Drainage and Flood Control District. The viewpoint of this study is that of the author and does not reflect the opinion of the Urban Drainage and Flood Control District.

Recommendations for avoiding such a catastrophe in the next flash flood include the installation of signs through canyons with specific instructions for action in the event of a flash flood warning, high water or heavy rain, and improved public education for heightening awareness of flash flood potential and possible adjustments to the hazard.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

This paper is one in a series on research in progress in the field of human adjustments to natural hazards. It is intended that these papers will be used as working documents by the group of scholars directly involved in hazard research as well as inform a larger circle of interested persons. The series was started with funds granted by the U.S. National Science Foundation to the University of Colorado and Clark University but now is on a self-supporting basis. Authorship of papers is not necessarily confined to those working at these institutions.

Further information about the research program is available from the following:

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Requests for copies of these papers and correspondence relating directly thereto should be addressed to Boulder. In order to defray production costs, there is a charge of $2 per publication on a subscription basis or $3.00 per copy if ordered singly.

ACKNOWLEDGEMENTS

I would like to thank the many people who helped in this research effort.

Kenneth R. Wright, Special Assistant to Governor Lamm on the Big Thompson Recovery effort, first aroused my interest in this study when he invited me to tour the Big Thompson canyon three weeks after the flood.

During the four months I was doing fieldwork in Loveland, residents and those involved in the post-flood relief and recovery efforts were of great assistance.

The canyon residents shared their experiences with me willingly and cheerfully taught me that much strength is necessary to start again. Bob Schelling, head of Inter-Faith Task Force in Loveland, the community workers, who have been busy since the flood helping their neighbors, and Mary Kay Houston, the social worker in the Big Thompson School District, spent much time answering my questions.

Sheriff Bob Watson, Sgt. Chuck LoPresto and Lt. Gerald Becker of Larimer County Sheriff's Office shared their warning and body recovery experiences with me.

I am grateful for the assistance of two professors at Colorado State University: Michael Charney of Anthropology and chief of the body identification operation following the flood, and David McCombs, Chairman of the History Department, who taped interviews with canyon residents immediately following the flood and allowed me to listen to them.

At the University of Colorado I was fortunate enough to have the help of Risa Palm, Bob Alexander, Susan Tubbesing, Nick Helburn, and

fellow graduate students at the Institute of Behavioral Science. Tom Downing, John Sorensen, Don Rosenthal and Marvin Waterstone offered much needed constructive criticism and confidence.

The study would not have been possible without the grant from the Urban Drainage and Flood Control District in Denver, under the direction of L. Scott Tucker. Bill DeGroot of UDFCD and Les Botham of Leonard Rice Consulting Water Engineers were very helpful.

This final report incorporates insightful comments resulting from a two-day workshop. Thomas Drabek, Dennis Mileti and Janice Hutton gave special assistance. Though I have tried to include all suggestions, the viewpoint expressed and any errors are my own.

Masterful editing by Sarah Nathe enhanced the report which was typed by Holly Hollingsworth and Judith Hill.

Finally,I want to thank my advisor and the director of this project Gilbert F. White, for providing the research opportunity and offering his wisdom and encouragement throughout.

INTRODUCTION

On July 31, 1976, the Big Thompson Canyon was filled with tourists. It was the Saturday of the weekend commemorating Colorado's Centennial and the last holiday weekend before the start of school. That night a flash flood ravaged the canyon, causing the worst disaster in terms of the number of lives lost in Colorado state history.

This study analyzes behavior patterns during the Big Thompson Canyon Flood in order to assist in the design of warning systems for Front Range communities vulnerable to flash flooding. It is one of the few efforts to determine with some precision the actions taken during a flash flood, characteristics which may influence the choice of those actions, and the relationship between particular actions and survival.

The Big Thompson Canyon is one of the more scenic in the Rocky Mountain region. U.S. Route 34 runs through the canyon, adjacent to the river in many spots. It is the main link between the plains, near Loveland, and Rocky Mountain National Park. Before the flood, the full-time canyon population was 600 and the part-time residents numbered approximately twice that. There were many tourists attracted by the trout fishing, streamside motels and campgrounds.

There are three major communities in the 25-mile canyon. West from Loveland they are 1) Cedar Cove, just above the Narrows; 2) Drake, the largest community, located at the confluence of the North Fork and the Main Fork of the Big Thompson; and 3) Glen Comfort. One community on the North Fork of the Big Thompson, Glen Haven, was also affected by the flood. Figure 1 shows the relative locations of these communities.

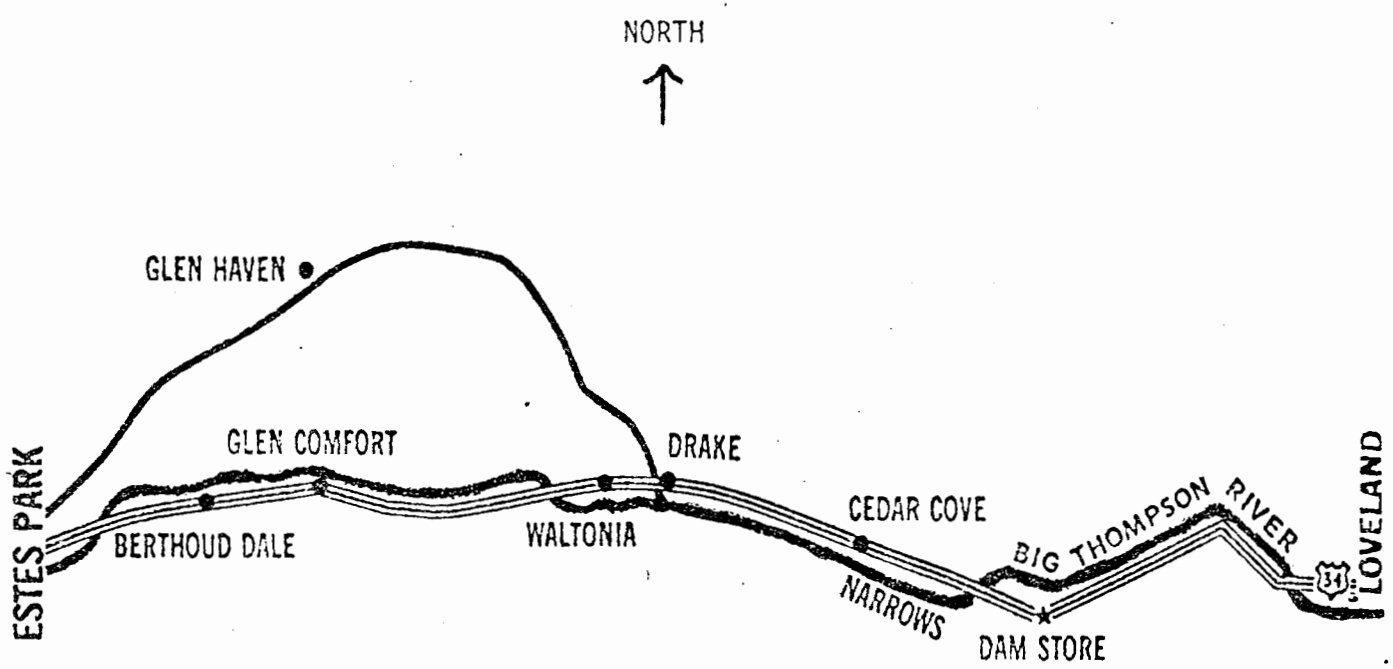

FIGURE 1

LOCATION OF COMMUNITIES IN BIG THOMPSON CANYON
(CANYON LENGTH IS 25 MILES)

According to the National Oceanic & Atmospheric Administration (NOAA) report on the Big Thompson flood (1976), heavy rain fell over a 70 square mile area in the central portion of the Big Thompson watershed between 6:30 and 11:00 PM on July 31, 1976. The most intense rainfall, over 12 inches, fell over slopes in the western end of the canyon. Figure 2 shows the distribution of rain that night in the canyon.

The impact of the flood could have been worse. The North Fork peak streamflow occurred approximately 40 minutes later than the Main Fork peak. If the two peaks had coincided, the peak streamflow would have been much greater than the 31,200 cubic feet per second (cfs) officially recorded at the mouth of the canyon (U.S. Geological Survey,1976: 5).

One hundred thirty-nine people died in the flood, eighty-eight people were injured, and six people are still missing.* According to the Geological Society of America report (1976: 4), the flood destroyed 316 homes, 45 mobile homes and 52 businesses, and 73 homes suffered major damage.

THE WARNING EXPERIENCE

The NOAA report following the flood (1976) discusses the warning process and the difficulties met with by Denver staff meteorologists trying to determine the situation in the vicinity of the Big Thompson Canyon prior to the flood. The meteorologists had little luck in locating information on the situation. According to several of the deputies and highway patrolmen who issued warnings, most of the people in the Big Thompson Canyon July 31, 1976 were not warned officially. The person-to-person warning concentrated on the area at the mouth of the canyon.

*Some officials estimate that there are still 25-40 bodies buried in the debris which will never be found.

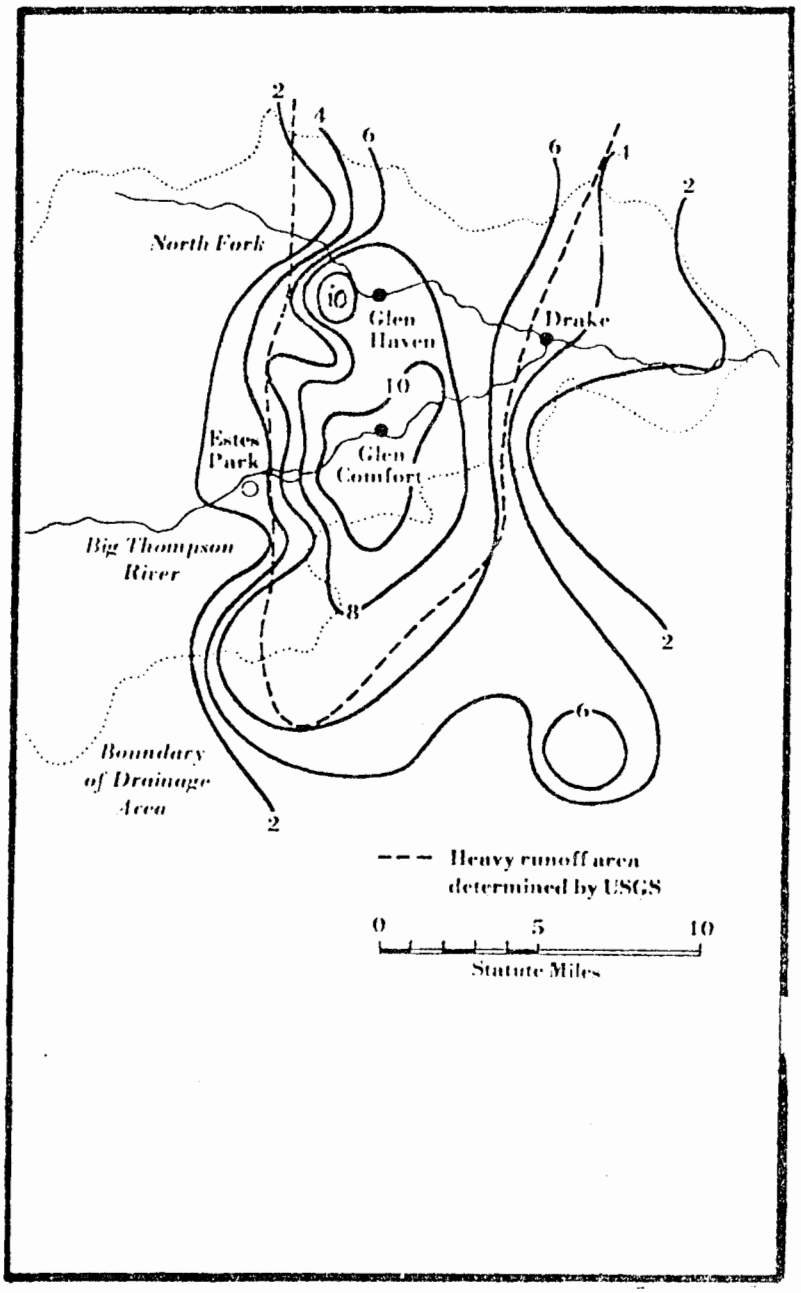

FIGURE 2

TOTAL PRECIPITATION (IN INCHES) JULY 31 - AUGUST 2, 1976
Based on Climatologic Network and
Supplemented By Unofficial Precipitation Reports
(From NOAA, 1976:3, Including Revisions of April 1, 1977)

Two patrolmen were in the vicinity of Drake trying to keep traffic from travelling up the canyon and to encourage people to climb to higher ground. Though the focus of this paper is the action taken rather than a systematic examination of the warning system, the following account of the types of warnings issued prior to the flood may shed some light on the situation prior to flood impact.

The Colorado State Patrol in Estes Park received word of traffic tie-ups in the canyon around 7:30 PM. This was not unusual for a weekend evening in the canyon. The patrolman went to check out the problem 7 1/2 miles down the canyon. He reported on the radio that there were trees, mud and rocks blocking U.S. Highway 34. Following an 8:45 PM message of flooding from the patrolman near Estes Park, the Larimer County Sheriff's Department and the State Patrol began intensive warnings of campgrounds and motorists. At that time the patrolman advised that warnings be issued down the canyon. At the lower end of the canyon, where it was not raining, it seemed hard to believe that a flood was possible. Even some of the deputies who were responsible for warning others thought the Olympus Dam near Estes Park must have broken in order to cause a flash flood situation. (It held through the flood, though the base suffered some erosion during the storm.)

Several miles up the canyon, just to the west of the Narrows, the community of Cedar Cove sits below the road and adjacent to the river. This area received warnings from a sheriff's deputy, a highway patrolman who later lost his life near Drake, a member of the Loveland police department and a private citizen.

Ten people were at the Covered Wagon Cafe just one mile west of Cedar Cove. The customers finished their meal and started up the canyon. When rockslides prevented their passage through to Drake they returned to the restaurant. One waitress had been sent home early because the bridge leading to her home across the river was notoriously low. The proprietor thought it wise for her to get home before the water rose too high. The people in the restaurant did not receive an official warning, but the water was rising in front of the restaurant. Everyone moved to the proprietor's house adjacent to the restaurant. When the waitress who left early reached her home, she called the restaurant to tell them she was safe. While she was on the phone, the proprietor's home and restaurant were washed away. All who were in the home were swept to their deaths.

At the Canyon Inn near Cedar Cove approximately 20 people,including employees and guests, were conversing about how slow business was that night. No one had an explanation for this until reports were received that landslides and rockslides had occurred west of the restaurant. At approximately 8:30 PM, a sheriff's deputy came into the restaurant to warn people of rising water and possible flooding. He instructed them to cross the river and climb up the mountainside. The people took no action in response to this warning. Twenty minutes later he returned with the message that the dam at Estes Park had broken and the people in the restaurant should cross the river and climb immediately. People did respond to this second warning. Some drove out of the canyon, and others climbed as instructed. The water was three and one half feet deep in the restaurant soon after the warning. Some perceived no danger from a flash flood warning yet responded quickly to the message that the

dam at Estes Park had broken. This adaptive action may be linked to the extensive media coverage of the Teton Dam collapse in Idaho, five weeks before the Big Thompson flood. Earlier in the evening it had been so dry in Cedar Cove that people reported having watered their lawns.

One sheriff's deputy involved in the issuance of warnings explained how patrol cars circled two or three times in one campground with loud speakers. Some people responded immediately, including a couple who remembered the Rapid City flood of 1972. Others responded following the second and third warnings. At least two people did not move from their camping spot and were among the victims.

Drake, at the confluence of the North Fork and the Big Thompson, was hit hardest by the flood. For most people there, the only warnings came from environmental cues: the river rising, the severity of the rainfall, or a change in the sound of the river. One state patrolman was was notified of the problem caused by rising water west of Drake. He advised several people at Drake to drive down the canyon rather than try to drive up. He had no idea what the eventual impact of the flood downstream would be. It is not known how many people did try to drive down or what happened to them.

One couple he warned were returning from an evening in Estes Park. They thought he was exaggerating the seriousness of the situation when he told them to get out of their car and climb. They died in the flood.

At least one couple at Waltonia had developed a personal contingency plan in the event that the dam at Estes might one day fail. They were so accustomed to the usual sound and height of the river that as soon as the sound noticeably changed, they responded to this environmental

cue and climbed the mountain. Sixteen people died in two separate motels at Waltonia. The only warning reported was an unofficial one from a motel manager. Some people managed to escape, in cars, down the canyon; others climbed up the mountainside. Details of the situation in Waltonia are difficult to ascertain since neither the motel owners nor their families survived the flood.

In the Cedarmont and 7 Pines area near Glen Comfort, no warnings were reported to have been received. At one of the four motels located in this area, a family had just taken a room. Because it was raining so hard, the proprietor invited the family inside for coffee and cookies. They accepted the invitation and left their belongings in the car, planning to move into their room when the rain let up. This family was in the Big Thompson Canyon only because they could not find a motel room in Estes Park. As they consumed the treats provided by the proprietor of the motel, the river got louder and seemed to be getting closer. After a coke machine floated by and water began seeping under the door, the father in the family decided it was time to move to higher ground. The only steps to the upstairs portion of the motel were on the outside of the building. Since he could not get outside safely, he cut a hole in the sheetrock ceiling and the wood floor above. His family, and that of the proprietor, climbed out of the motel. They spent the rest of the night on the mountainside. The motel was not washed away, but the water rose four feet and the damage to the building exceeded 50% of its total worth.

At 7 Pines Motel, six miles from Estes Park, two people from Ohio were camping. Earlier that day their tire needed fixing, and one of the campers had just returned from Loveland where he had it repaired. It was raining so hard that they moved their camping gear into the car and sat listening to the radio. When the car began floating away, they were

able to move it to higher ground with considerable effort. When they checked with a nearby motel office, the manager sent them back down toward the river to try to rescue two young women in a streamside cabin. In order to get to the cabin, they had to cross a low flat area. When they saw a wall of water rushing down the canyon, they clung to a nearby car. When it began floating away, they grabbed a shrub which also was undermined by the water. They were holding onto a pine tree when the cabin was swept away. One of the young women managed to get out of the cabin and held on to a tree downstream. The other one was crushed in the cabin. The two young men survived.

Throughout the evening, many tourists driving through the canyon met with landslides and rockfalls. Some turned back to Estes Park or Loveland, and others abandoned their cars and climbed the canyon wall. Those in the latter group had the best chance for survival.

WHAT OTHER STUDIES HAVE SHOWN

Analyses of warning response in other situations catalogue numerous behavior patterns in situations similar to the Big Thompson flood. Hypotheses on responses and causes for them are drawn from flash flood literature, warning response literature, and the publications following the Big Thompson flood (see Table 1).

The flood experience is reviewed in White (1975) and in post-flood survey reports by Federal agencies, primarily NOAA (1970, 1972, 1973). Warning response is central to works by McLuckie (1970, 1973), Mileti (1974). Drabek (1969) and Mileti, Drabek and Haas (1976). Table 1 illustrates the hypotheses which have received attention in past research and which are appropriate to the Big Thompson study. A complete list of

hypotheses dealing with warning response is found in Appendix B.

Following the Big Thompson flood, a wide range of newspaper articles and official agency reports were issued. The Denver Post, Rocky Mountain News, Loveland Daily Herald and Fort Collins Coloradan carried many articles which dealt with actions taken by survivors and victims. State and local agencies also published reports on the flood. An annotated bibliography of reports on the Big Thompson flood by Thomas E. Downing is included as Appendix A. From these sources it was possible to draw up a set of hypotheses on how people behaved and what contributed to that behavior. These are summarized in Table 2, which charts the relationships between the possible actions and survival, and the relationships between different influential variables and specific actions taken.

METHOD

This study sought to learn about the behavior patterns of the full-time residents, the seasonal residents and the tourists who were in the canyon at the time of the flood.

Sample

The sample consists of the groups of individuals or "response units" existent during the flood. A "group" in this context indicates a person or set of persons who made a decision to take an action during the flood. This mode of analysis was seen to be the most logical in light of the research by Drabek which shows that people respond to warnings and threats not as isolated individuals but as members of groups. Thus, one person traveling alone through the canyon was considered a "group" as was a set of persons who happened to be caught on the same stretch of road and

TABLE 1

HYPOTHESES FROM PREVIOUS LITERATURE EXAMINED
IN THE BIG THOMPSON FLOOD STUDY
(from Mileti, et al., 1975:35-56)

HYPOTHESIS	RESEARCH EFFORT
Persons with recent disaster experience are more likely to take protective action on the basis of warnings than those without such experience.	Demerath (1957); Fogelman (1958); Fritz (1961); Moore, et al. (1963); Anderson (1968)
Older persons are less likely to receive warnings than younger persons.	Friedsam (1962); Hutton (1976)
Older persons are less likely to evacuate than younger persons.	Friedsam (1962)
The number of warnings received is inversely related to attempts at warning confirmation.	Drabek (1969)
Persons in peer groups are least likely to take adaptive action. Family groups are most likely to take adaptive action.	University of Oklahoma (1953); Mack and Baker (1961)
Older persons are more likely to die in disaster than are younger persons.	Friedsam (1962); Trainer and Hutton (1972); Hutton (1976)

TABLE 2

HYPOTHESIZED RELATIONSHIPS BETWEEN SURVIVAL, BEHAVIORS ADOPTED AND THE VARIABLES WHICH INFLUENCED THEIR CHOICE

BEHAVIORS	Climb canyon wall	Try to escape in car	Do nothing different	Other (climb tree, go to different part of the House)
Warning Variables				
Source	+	+	-	+-
Content	+	-	-	+-
Number	+	+	-	+-
Mode	+	+	-	+-
Confirmation	+	+	-	+-
Other Variables				
Knowledge of area	+	+	-?	+-
Age	-	+	+	+-
Environmental cues	+	+	-	+-
Access to Mobility	-	-	-?	+-
Group context	+	+	-	+
Location in canyon	-	-	+	+

SURVIVAL	Unharmed	Injured	Dead
Behaviors			
Climb canyon wall	+	+	-
Try to escape in car	-	-	+
Do nothing different	-	+-	+
Other	+-	+-	+-

\+ indicates a direct relationship

\- an inverse relationship

? relationship exists but direction uncertain

+- relationship exists but preliminary information indicates both positive and negative relationships

did not know one another until they jointly climbed the mountainside to escape the rising water. Some qualitative analysis, by individual, was completed for the people who died, as the information was readily available from published lists. Generally, however, all quantitative analysis for the victims as well as for the survivors was done using the "group."

It was originally intended that the actions of sixty groups of survivors would be examined. Thirty of these groups were to be composed of local residents and thirty groups composed of out-of-state residents who were tourists in the canyon. Due to limited information available for tourist survivors, only 27 groups of tourists are included in the study.

The sample selected is representative of both the range of familiarity with the canyon and the spatial distribution of people in the canyon that night. Half of each sample were to have received either no warning or only environmental cues prior to the flood, and half to have received an official or unofficial warning. It was only possible to identify six out-of-state groups who received any warning and twenty-one who received no warning.

The names for the thirty groups of local people included in the sample were found in newspaper articles following the flood, or on lists provided by Inter-Faith, the main relief organization. In addition, volunteers from among the residents at the Big Thompson Action Group explained their actions during the flood in casual conversations at meetings, and interviews taped with residents shortly after the flood were also used.

Tourists were selected from lists provided by Inter-Faith, newspaper articles, and state patrol records of vehicles which were destroyed during the flood. An inventory of these sources revealed an insufficient number of tourist groups. For additional information, an advertisement was placed in five college newspapers requesting persons who were in the canyon during the flood to call the researcher collect. Those who called were interviewed for the study.

The study intended to analyze actions taken by the injured. The majority of the 88 persons brought to the hospital were elderly persons who were treated for exposure and released. Most people who were in the canyon the night of the flood either survived unharmed or died. Since the number of injured was relatively small, they were excluded from the analysis.

The reported actions of those who died in the flood were taken from second-hand accounts and sources, neighbors, friends, or reports in newspaper articles. An assumption was made in cases of out-of-state non-survivors. If, according to State Police records, an out-of state car was totally destroyed during the flood and the owners were among the victims, it was assumed they were in their cars at the time of their deaths if no other information was available.

Biases

This study has certain biases which should be mentioned. First, certain variables included in the hypotheses for this study (see Table 2) were excluded from the analysis: environmental cues, warning characteristics, sex, age and access to mobility. It was difficult to assess the influence of environmental cues in the adoption of actions. Most of the survivors (56%) reported that the rising river or heavy rain were their first clues that something was wrong. However, environmental cues can

serve both as warning and as confirmation of a warning (Mileti, 1974:134). The lack of environmental cues also may have lead to a less adaptive action or to failure to adopt any action at all. Two people who received official warning in the lower end of the canyon where it was not raining were among the victims because they did not believe a flood was possible. At the lower end of the canyon, as mentioned earlier, the first warning message consisted of word of landslides and flooding. One waitress at work at the time of the warning said no one moved from the restaurant until the second warning which stated that the dam at Estes had broken. No environmental cues would precede a dam break but prior to a flood there would have to be rain in the upper reaches of the basin. The relative impact of environmental cues on the actions taken in the Big Thompson flood could not be measured in any standard form and were excluded from the findings.

The warning characteristics, source, mode, content and number were not significant when initially correlated to action or to survival and hence were not included in subsequent analysis. The reason for their lack of significance may be due to the limited sample size, especially the unavailability of data on tourists who received warnings. An additional reason to disqualify the warning characteristics from the analysis is that the data collected for non-survivors concentrated on determining actions taken and not upon warning characteristics.

However, the influence a warning had on choice of behavior and on survival is analyzed in general terms. The variable "kind of warning" was included in the discriminant analysis. This information was available for most of the survivors and the non-survivors. In cases where it was not known whether a warning was received it was assumed that environmental

cues or no warning at all preceded the flood. This was confirmed by the location of the group in the canyon. Since it was not raining at the lower end of the canyon, a group which did not receive any warning probably received no environmental cues.

Because the analysis was based upon actions taken by groups rather than by individuals, it was not possible to control for sex or age. Members of the groups were interviewed based on their willingness to participate. Due to the reliance on second-hand sources, it was difficult to get complete information on the ages of all those in a specific group, especially in cases where the group was composed of unrelated parties. For the non-survivors there was information on individuals. Some interesting facts were not examined because of the method selected; for example, this study does not explain the high percentage of women over 60 who died in the flood.

There are inconsistencies in the study which would not exist if primary sources were exclusively used. In most cases, the newspaper articles were confirmed in conversations but the data are not as carefully derived as they would be if there was control of which individual from a group was interviewed in each case. For those who died, all the information of necessity came from second-hand sources. There is a possibility that changes in perceptions of the flood, after the flood, can alter the account. For example, three different accounts were given for the last actions taken by one of the victims: 1) he was preparing to leave when he was washed away following a warning from a neighbor; 2) he was sleeping at the time of his death; and 3) he disbelieved warnings and tried to escape the water by climbing to his roof when his house was swept away.

Since those interviewed were selected on willingness to participate rather than a more objective method, there are certain biases in the sample and, therefore, in the findings. The college newspaper ads yielded response from young students rather than from another sector of the population-at-large.

Learning the last action taken by a flood victim is a difficult task. The researcher was careful not to increase stress to those families who suffered losses; therefore, no relatives of those who died were interviewed.

The research effort has been compared to gathering and sorting of clues in order to unravel a detective story. For example, a tourist would say he saw the driver of a Winnebego camper with three people in it panic and drive right into the flood and smash against a bridge. Another person would say he saw the Winnebego and noticed there were two women and one man in the camper; he thought the woman who was driving was in her sixties. With this information and the list of the victims, it was possible to tell who the victims were if none of the other victims had similar characteristics. If they did, the search would continue. Many assumptions were involved and they bias the results.

Knowing only imprecisely the population in the canyon the night of the flood prohibited the choice of a fully random sample. In addition, people who did not wish to share their experiences were not included in the study. To compensate partially for this bias, the study was designed to include all areas of the canyon and to include equally groups which received warnings and groups which did not.

Analysis

The information gathered in the study was recorded on questionnaires filled in during open-ended interviews or following conversations with

second-hand sources -- either neighbors or officials involved in the relief effort -- who knew of the actions people took during the flood.

Two modes of analysis were employed in this study: contingency tables and discriminant analysis.

Contingency tables were used to examine whether or not various actions taken during the flood were related to chances of survival. Because the actions cannot be ranked in any meaningful way the contingency analysis was as sophisticated as the data allowed. This mode of analysis tells whether certain actions in this particular study more frequently lead to survival than others. An example of a result of the contingency analysis is that those who took an action were more likely to live than die. The contingency tables are given as Tables 1-9 in Appendix F. The results of the contingency analysis are shown as generalizations in the first half of Table 3.

For the variables which could be ranked, discriminant analysis, a more sophisticated technique, was used. This technique is useful in classifying data into categories. It tells us which variables were most significant in predicting which class a particular case would belong. For example, in determining which factors most influenced whether a group took an action or did not take an action it was found that the number of persons in the group was most significant. It must be stressed that even though in this instance the variable "number in group" was most influential in predicting whether a group would or would not take an action, this cannot be generalized to all floods because the sample was not randomly selected. The second half of Table 3 gives generalizations from this study of the Big Thompson flood drawn from the actual data analysis found in Tables 10-13 in Appendix F.

TABLE 3
SUMMARY OF RESULTS FROM THE ANALYSIS
(Tables Detailing the Outcome of the Tests are Found in Appendix F)

FROM CONTINGENCY TABLES

Survival

1. Those who took some action were more likely to live than those who took no action.
2. Those who took no action were more likely to die in the flood.
3. Those who climbed had the best chance to survive.
4. Those who were alone were the highest at risk population.
5. Those who were with others, in groups of three to five people, were more likely to live than those alone or in other sized groups.
6. Those who were in family contexts were more likely to live than those who were alone.
7. Those who were with friends were the most likely to live.
8. Those who were in areas above Waltonia were more likely to live than those in other areas in the canyon.

Action

1. Those who drove out were most likely to have received a warning.
2. Those who climbed or took another action were more likely not to have received a warning than those who did nothing or drove.
3. Those who were with friends were most likely to climb.
4. Those who were with family groups were more likely to take no action than to climb.
5. Those who were alone were most likely to do nothing.
6. Those in groups of three to five were more likely to do something than to do nothing.
7. Those who drove were more likely to warn others than those who climbed.

FROM DISCRIMINANT ANALYSIS

1. Location in the canyon and what action the group took were most influential in statistically separating the survivors from the non-survivors.
2. Familiarity with the Big Thompson Canyon was least influential in statistically separating three of the analyzed populations: the survivors/non-survivors, the warned/non-warned, and the action/no action population.
3. The number of people in a group was most significant in characterizing the groups by whether or not an action was taken.
4. The location of the group in the canyon and their origin were most significant in separating the warned from the non-warned population.
5. In statistically distinguishing the local groups, the full-time and part-time residents from the tourist, those who visited the Big Thompson Canyon or other Rocky Mountain canyons infrequently, the number of people in the group, the origin of the group, and if the group survived were most significant.

Four separate parts of the sample are examined by discriminant analysis: 1) survivors and the non-survivors; 2) groups that took some action and those that took no action; 3) warned and non-warned groups; and 4) local and non-local groups.

The variables on which the different categories were expected to differ are those which can be measured on an ordinal scale and which are known for the entire set of groups involved in the analysis: 1) geographic location in the canyon; 2) number of people in a group; 3) origin, whether the people were indoors or out; 4) knowledge of the Big Thompson Canyon; 5) action taken; 6) whether the group survived; and 7) whether a group was warned. The last four variables listed were excluded when used as the dependent variable in the analysis. Appendix E is a listing of these variables and their range of values.

BEHAVIOR PATTERNS

A total of 112 groups were included for analysis: 58 survivor and 54 non-survivor groups of 270 persons and 129 persons, respectively. A total of 399 persons were involved in the survey. Table 4 shows the range of behavior patterns found in the canyon during the flood, and the origin and destination of those who survived and those who did not survive.

The results of the Inter-Faith survey (1976) sent to 600 flood victims following the flood showed that 33% of the full or part-time population in the canyon was 60 years old. One-fourth of those who died were over 61 years old. Thirty-five percent of those who died were full-time residents, 17% seasonal residents, 26% tourists, and 21% from parts of Colorado other than the Big Thompson Canyon and the nearby towns of

TABLE 4

BEHAVIOR PATTERNS, ORIGIN AND DESTINATION, ON THE NIGHT OF THE BIG THOMPSON FLOOD

(Numbers are numbers of groups which adopted each action. Numbers in parentheses indicate the number of individuals accounted for in the group.)

ORIGIN	DESTINATION	DEAD			TOTAL SURVIVORS	LOCAL		OUT OF STATE	
		Local	Non	Total		Warned	Non	Warned	Non
I Building	→ Building	17(53)	5(16)	22(69)	15(40)	3(5)	8(22)	0	4(13)
II Building	→ Automobile	3(9)	2(7)	5(16)	5(19)	44(15)	1(4)	0	0
III Building	→ Mountainside	0	0	0	15(54)	4(7)	2(3)	4(12)	6(32)
IV Camping Driving	→ Camping Driving	15(20)	6(14)	21(34)	9(108)	3(11)	1(4)	1(2)	4(91)
V Camping Driving	→ Mountainside	0	0	0	9(30)	0	3(11)	1(3)	5(16)
VI Other*		5(10)	0	5(10)	4(9)	2(4)	0	0	2(5)
TOTAL.....		40(92)	13(37)	53(129)	57(270)	15(42)	15(54)	6(17)	21(157)

*Other denotes those who climbed the mountainside and then went back to danger and those groups which were driving and then entered a building.

Ft. Collins, Loveland, Estes Park and Greeley. The comparatively low percentage of tourists who died indicates that the residents had no better idea of what action to take in the event of a flood than the non-residents.

Of the groups which did not modify their behavior during the flood in response to environmental cues or to warnings, 18 groups (44 people) who were driving continued to drive, and 16 groups (64 people) died in buildings, predominantly homes they were in prior to the flood.

The largest number of people to die in one location was 15 in the two motels in Waltonia. Ten people died at the Covered Wagon Cafe, and seven women with the Campus Crusade for Christ died in two separate cars while trying to get out of the canyon.

Out of 53 groups of people who died, nine groups (17 people) received an unofficial warning and five groups (14 people) received an official warning. It is difficult to tell how many people who lost their lives that night received no warning at all. This was particularly hard to assess for tourists who were not recognized by the canyon residents and may only have left the general message with their families that they were going camping in the mountains. Environmental cues may well have been of substantial influence in saving the lives of many who were in the Big Thompson Canyon the night of the flood. Among the people in the sample, ten groups (92 people) reported that they had to abandon their vehicles because they could not continue to drive through the canyon due to rockfalls, landslides and blinding rain. Others reported changing course or climbing the mountainside because of stalled cars or traffic jams. In some cases drivers did try to change direction or drive up the North Fork instead of the Main Fork, and only when the alternate route was blocked did they get out of their cars and head for higher ground. Several groups climbed the canyon wall at the last second and watched their cars go downstream.

Comparison of Findings

Certain findings from previous research can be compared with those of this study. The hypothesis, tested by Demerath (1957), Fogelman (1958), Fritz (1961), Moore, et al. (1963) and Anderson (1969), that persons with recent disaster experience are more likely to take protective action on the basis of warnings than those without recent disaster experience is supported in a qualitative analysis by three cases in this study.

One family which survived the Rapid City flood in 1972 immediately heeded the first warning they heard while camping at the lower end of the canyon. A second family noticed the river rising and, recalling their knowledge of the flooding potential of the bayous in Texas, headed for higher ground. A family familiar with tornadoes received a warning and followed the instructions of the sheriff's deputy without hesitation.

Friedsam (1962) found that older persons were less likely to receive warnings than younger persons regardless of the warning source. However, in the Big Thompson, groups of people over 70 years old were just as likely to have received a warning, as was found by Hutton (1976) in her study of the 1972 Rapid City flood. Friedsam's (1962) finding that elderly persons were less likely to evacuate than young persons is supported. Of nine groups of people over 70 years old, six took no action and three adopted an action during the flood. In agreement with findings of Friedsam (1962) and Trainer and Hutton (1972), one-fourth of those who died in the Big Thompson flood were over 60 years old, as was mentioned earlier.

The finding of Drabek (1969) that the number of warnings is directly related to evacuation is confirmed by this analysis. In the contingency table relating number of warnings and attempts at confirmation, those who received one warning were more likely to seek confirmation than those who received more than one warning; the second warning perhaps served as confirmation of the threat.

One finding which this study does not support is that examined by the University of Oklahoma (1953) and Mack and Baker (1961). They found that peer groups were most likely to take no action and family groups were most likely to take action. The opposite was true in the Big Thompson Canyon, where those in peer groups were more likely to have climbed the canyon wall than were families. Families were more likely to have done nothing adaptive. This may be due to the relatively younger ages of the peer groups than family groups.

RECOMMENDATIONS

The Big Thompson flood has heightened the concern of some officials and residents in other Front Range canyons over the tremendous hazards of living in a canyon. It would be ideal if we could count on advance prediction fron the National Weather Service disseminated over the radio and TV, as well as substantial environmental cues to lend support to a warning to evacuate in case of flood, but these are factors we cannot count on. However, the points may help other Front Range communities to plan more effective warning systems.

1. The best action to take in the event of a flash flood warning, a heavy rain or a rising river is to climb to higher ground. Cars are seen as a haven or a source of power; when threatened with a flood, people tend to get in their cars and try to escape the water by driving out of the canyon. For many people in the Big Thompson and in other flash floods this action was fatal. Had people abandoned their cars and climbed 25 feet up the canyon wall, they might still be alive today. Though some people drove out of the canyon and survived, they took an unneccessary risk; they were very lucky.

It may be raining and the canyon wall may not seem an inviting place to spend a night, but many of those who climbed the wall the night of July 31, 1976, were only cold, bruised and wet the next morning.

2. Prior public education is necessary to lessen the potential losses from a flash flood. Signs should be placed at the entrances to canyons which clearly advise that in the event of a flash flood warning, heavy rains or high water, the most appropriate action to take is to abandon your car and climb to higher ground. Had signs been placed in the Big Thompson prior to the flood, it is possible that the 16 people who were driving alone in the canyon would not have continued to drive on. Not knowing what to do in the event of a flood may have influenced their decision to take no adaptive action.

Operators of motels, campgrounds and restaurants should be aware of safe places to which their customers can go in the event of a flash flood. For example, if the campground operators at the lower end of the Big Thompson Canyon had been aware of the flash flood hazard and of proper actions to take, perhaps the sheriff's deputies would have had to circle the campground only once and could have relied upon the campground operators to evacuate the campground. Gatlinburg Tennessee has an extensive network which links 3/4 of the motels in one phone call to potential flood conditions. The sheriff's deputies could have spent their time disseminating the warning to more areas, concentrating their efforts in areas heavily populated by the elderly. Had the elderly residents in Big Thompson Canyon received more advice and aid, perhaps fewer would have died.

3. The tendency is for people to disregard messages which disrupt their normal activity (Drabek, 1977) rather than to panic, as is frequently expected. By giving two, three or four warnings, the chances increase for an appropriate response. When a warning is flashed on television and the

station then returns to regular programming, it is simple for the viewer to ignore the warning on the grounds that the station would not have returned to normal broadcasting if there were real danger. People neutralize warnings because of rumors, inability to confirm a warning, lack of specific information, and ignorance of appropriate adaptive actions (Drabek, 1977). Extensive public education might lessen the tendency to ignore or neutralize a warning message.

4. Flood-prone communities should conduct emergency drills; train officials in the kinds of situations which may arise prior to, during and after a flash flood; distribute brochures to the population-at-risk; hold public discussions among officials and residents regarding the flood hazard; and require realty companies to disclose that property lies in the flood plain before it is sold.

5. If time permits, it is useful for canyon entrances to be closed off as soon as a warning message is issued. The highest risk population in the Big Thompson Flood were those driving alone. Closing a canyon is an immediate emergency action which should be taken by officials. This would insure that there is no increase in the population-at-risk from canyon entrances.

6. Though this study reveals no specific warning characteristic which would assure adaptive action, the suggestion that a warning system be adopted is one that consistently was mentioned by officials and residents throughout the Big Thompson Canyon. A warning system will not assure that no lives are lost, but it is one relatively inexpensive means of helping to lower the number of fatalities. If the warning system is properly maintained, if officials know the operations and the citizenry is educated to the hazard, more people are likely to respond quickly and effectively in the event of a flash flood. Whether the system selected is

that of an all volunteer network or an elaborate automated system, it would be better than no system at all.

POSSIBILITIES FOR FUTURE RESEARCH

This study suggests that further study is necessary in three main areas: it would be helpful to examine more comprehensively some of the findings of this study; more detailed knowledge of the actions of victims is needed; and work should be done to ascertain whether it is possible to determine a threshold time, which indicates by location whether or not an individual or group has enough time to drive out of danger or collect valuables before impact.

The results of this study are presented without in-depth examination. One of the more interesting projects to pursue in future research might be to study the increase in risk if a person is alone. From this might come a recommendation that people should group with other people if a warning is received or a threat perceived. The size of the group appeared significant in whether or not a group survived during the Big Thompson flood. Why is it that groups of three to five people survived with greater frequency than larger or smaller groups?

One of the major questions that researchers and policy makers have raised in response to an earlier draft of this paper was how many people died camping. Decision-makers are trying to decide whether camping should be allowed in the Big Thompson Canyon. An innovative approach will be required to answer this with greater precision than was possible in this study. It is not very difficult to narrow down who the campers in the canyon were at the time of the flood, but it was impossible to know in several cases whether or not the person or group was camping or whether they were in a car or restaurant. It is difficult to determine whether

a person pulled over in a Winnebego is camping or merely taking a short break in a drive. To answer questions about the actions of victims, a study focussing only on the dead will be necessary.

The third research area suggested by this study involves the time frame for response to a flash flood warning. Throughout the research and presentations of the findings, people have asked whether or not they would have time to drive out of danger rather than climb the canyon wall. In the Big Thompson some who drove lived, and it may be easier to get people to drive out of danger than to climb a slippery, cold canyon wall. How much time there is from a first warning or environmental cue to an impact is visible only after the event and, therefore, the recommendation is made that one should climb immediately following a warning. Some refinement of the time frame for specific hazardous locations would be useful in the decision of whether or not to adopt emergency flood proofing measures or to collect valuables, papers and pets, as well as to evacuate or climb.

BIBLIOGRAPHY

Dacy, D. C. and H. Kunreuther
1969 The Economics of Natural Disasters. New York: The Free Press.

Danzig, E. R., P.W. Thayer and L. R. Galanter
1958 "The Effects of a Threatening Rumor on a Disaster-Stricken Community." Disaster Study #10. Disaster Research Group. Washington: National Academy of Sciences.

Demerath, N. J.
1957 "Some General Propositions: An Interpretive Summary." Human Organization 16 (Summer): 28-29

Demerath, N. J. and A. F. C. Wallace
1957 "Human Adaptation to Disaster." Human Organization (Summer): 1-2

Diggory, M. C.
1956 "Some Consequences of Proximity ot a Disaster Threat." Sociometry XIX , #1 (March): 47-53

Downing, T. E.
1977 Warnings for Flash Floods in Boulder. Natural Hazard Working Paper 31. Boulder: University of Colorado Institute of Behavioral Science.

Drabek, T.
1977 Personal Communication to Eve Gruntfest. Denver: Denver University Department of Sociology. May.

1969 "Social Processes in Disaster: Family Evacuation." Social Problems 16 (Winter): 336-349

Drabek, T. and K. Boggs
1968 "Families in Disaster: Reactions and Relatives." Journal of Marriage and the Family 30: 443-451

Friedsam, H. J.
1962 "Older Persons in Disaster." In Baker and Chapman (Eds.) Man and Society in Disaster. New York: Basic Books: 151-184

Fritz, E. and E. S. Marks
1954 "The NORC Studies of Human Behavior in Disaster." The Journal of Social Issues X , #3: 26-41

Fritz, E. and J. H. Mathewson
1957 "Convergence Behavior in Disasters." National Research Council Disaster Study #9. Washington: National Academy of Sciences.

Hutton, J. R.
1976 "The Differential Distribution of Death in Disaster: A Test of Theoretical Propositions." Paper presented

at Joint Meeting of the Society for the Study of Social Problems and the American Sociological Association, New York. August.

Instituut Voor Sociaal Onderzoek Van Het Nederlandse Volk Amsterdam
1955 Studies in Holland Flood Disaster 1953, 4 volumes. Washington: National Academy of Sciences, National Research Council

Inter-Faith Task Force
1976 Survey of Citizen Needs. Box 706, Loveland, Colorado.

Janis, I.
1962 "Psychological Effects of Warnings." In Baker and Chapman (Eds.) Man and Society in Disaster. New York: Basic Books: 55-92.

King, L. J.
1970 "Discriminant Analysis: A review of Recent Theoretical Contributions and Applications. Economic Geography 46: 366 - 378.

Lachman, R., M. Tatsuaka, and W. Bouk
1961 "Human Behavior During the Tsunami of May 1960." Science 133 (May 5): 1405-1409.

McCombs, David
1976 Taped Interviews with canyon residents following the Big Thompson Flood. Denver: Colorado Historical Society.

McLuckie, B. F.
1970 The Warning System in Disaster Situations: A Selective Analysis. Disaster Research Center Report Series No. 9. Columbus, Ohio: Disaster Research Center, The Ohio State University, July.

1973 The Warning System: A Social Science Perspective. U. S. Department of Commerce, NOAA, National Weather Service, Southern Region.

Mileti, D. S.
1972 Behavioral Response to Short-Term Natural Hazard Warnings. A Working Paper presented to the International Seminar, Organizational and Community Responses to Disasters, Disaster Research Center, Ohio State University. Columbus, Ohio.

1974 A Normative Causal Model Analysis of Disaster Warning Response. Unpublished dissertation. Department of Sociology, U. of Colo.

1975 Natural Hazard Warning Systems in the United States: A Research Assessment. Boulder, University of Colorado Institute of Behavioral Science.

Mileti, D. S., T. Drabek and J. E. Haas
1975 Human Systems in Extreme Enviornments: A Sociological Perspective. Boulder, Colorado: University of Colorado Institute of Behavioral Science.

Moore, H. E., et al.
1963 Before the Wind: A Study of Response to Hurricane Carla. Disaster Study No. 19. Washington: National Academy of Sciences, National Research Council.

National Oceanic and Atmospheric Administration
1971 Arizona Floods of September 5-6, 1970: A Report to the Administrator. Natural Disaster Survey Report 70-2. Rockville, Maryland.

1972 Black Hills Flood of June 9, 1972: A Report to the Administrator. Natural Disaster Survey Report 72-1. Rockville, Maryland.

1973 Final Report of the Disaster Survey Team on the Events of Agnes: A Report to the Administrator. Natural Disaster Survey Report 73-1. Rockville, Maryland.

1976 Big Thompson Canyon Flash Flood of July 31-August 1, 1976: A Report to the Administrator. Natural Disaster Survey Report 76-1. Rockville, Maryland.

1977 Flash Flood Preparedness Planning Guide. By H. James Owens. (Forthcoming).

Nie, N., et al
1975 Statistical Package for the Social Sciences. New York: McGraw-Hill, Inc.

Peters, W. S. and G. W. Summers
1968 Statistical Analysis for Business Decisions. Englewood Cliffs, New Jersey: Prentice Hall: 401-415.

Quarantelli, E. L.
1954 "The Nature and Conditions of Panic." American Journal of Sociology 60: 267-275.

1957 "The Behavior of Panic Participants." Sociology and Social Research 41: 187-194.

1964 "The Behavior of Panic Participants." In D. P. Schultz (Ed.) Panic Behavior. New York: Random House: 69-81

Scanlon, J. and B. Taylor
1975 The Warning Smell of Gas. Emergency Planning Canada, Field Report 75-2. Ottawa, Canada.

Scanlon, J. et al.
1976 The Port Alice Slide. Emergency Planning Canada, Field Report 76-1. Ottawa, Canada.

Susquehanna River Basin Commission
1976 Neighborhood Flash Flood Warning Program Manual. Prepared by Stewart K. Wright. Publication No. 45. Mechanicsburg, Pennsylvania.

1976a Planning Guide, Self help Flood Forecast and Warning System, Swatara Creek Watershed, Pennsylvania. Prepared by Stewart K. Wright. Publication No. 42. Mechanicsburg, Pennsylvania.

Trainer, P. B. and J. R. Hutton
1972 "An Approach to the Differential Distribution of Deaths from Disaster." Paper presented at meetings of the Midwest Council on Social Research on Aging. Kansas City, Missouri.

White, G. F.
1964 Choice of Adjustment to Floods. Department of Geography Research Paper #93. Chicago: University of Chicago.

1975 Flood Hazard in the United States: A Research Assessment. Program on Technology, Environment and Man Monograph Series. Boulder: University of Colorado Institute of Behavioral Science.

William, J. B.
1964 "Human Factors in Warning and Response Systems." In Henry Wechsler and Milton Greenblat (Eds.) Disaster. Cambridge, Massachusetts: MIT Press.

Wilkinson, K. and P. Ross
1970 Citizen's Response to Warnings of Hurricane Camille. Social Science Research Center, Report No. 35, Jackson, Mississippi: Mississippi State University.

Young, M.
1954 "The Role of the Extended Family in Disaster." Human Relations 7: 383-391

APPENDICES

APPENDIX A

ANNOTATED BIBLIOGRAPHY ON THE BIG THOMPSON FLOOD

Private

*The Big Thompson Flood, July 31, 1976. Don Cotten, Editor, C. F. Boone, Publisher: P. O. Box 10411, Lubbock, Texas 79408. $3.00 + 50¢ postage.

Fifty plus pages of black and white photos and articles. Coverage is broad but somewhat brief. A statement on page 26 incorrectly proposes that such a flood won't happen again for another 100 years. (Its probability of occurrence is the same in any year.) Includes a 127-name list of victims.

*The Big Thompson Disaster. Lithographic Press: P. O. Box 455, Loveland, Colorado 80537. Fall 1976. Contact Loveland Chamber of Commerce for orders. $2.00 each.

"A collection of editorial and pictorial material concerning Colorado's tragic flash flood of July 31, 1976." Mostly newspaper reprints, but generally accurate. Photos are black and white. Proceeds from sales go into the relief fund.

*Geological Society of America, The Big Thompson Flood of 1976. A field trip guidebook prepared for the Annual Meeting of the Geological Society of America, 1976.

The 37 pages include photos and summaries of meteorological aspects of the flood, hydrological aspects and geological hazards, and flood hazard estimation for land use planning.

University

*Colorado State University, Aftermath. By Dan Hilleman, CSU professor and several graduate students (phone 491-5143). First edition, December 1976.

An occassional newsletter, primarily for residents of the canyon. Although it is helpful, informative and entertaining, if published faster (i.e. mimeographed) it could be a more useful tool for communicating the most current arguments, issues and progress. Comments on the newsletter (format and content) are welcomed, especially those from the residents. Dan has videotaped a number of the Big Thompson Action Group meetings.

APPENDIX A (continued)

*Colorado State University, untitled. By Daryl Simon (Engineering Research Center), Elmar Reiter (Department of Atmospheric Sciences) and John Nelson (Department of Civil Engineering), publication March, 1977.

In process of preparing a report on the storm for the National Academy of Sciences, Academy of Engineering. It will include meteorological and hydrological aspects of the storm--its frequency, characteristics and possible adjustments. Dr. Simon has also done some general consulting concerning flood frequency, flow lines, sedimentation and design of highway bridges in the Narrows.

*Colorado State University, collection of papers on the Big Thompson flood. By Hal Cochrane,CSU professor of Economics and graduate students of Econ 540 (phone 491-1101). January,1977.

Analysis of several aspects of the Big Thompson flood. Data on sales revenues from Loveland and Estes Park reveal a 6% gain in revenues for the first 9 months of 1976. The impact of the flood on sales appears quite small and localized. Other topics include land use and ownership patterns in the canyon, alternative futures for the canyon, and the establishment of a park within the canyon.

*Ohio State University, Disaster Research Center, Emergency Medical Services. Delivery of mental health services to rural areas. Unpublished. Director of the DRC is Verta Taylor (phone 614-422-5916).

An in-house field report was prepared on emergency medical services following the flood, including the identification of dead, A monograph may be published later in the year. The two studies are part of larger studies funded by the Department of Health, Education and Welfare.

*University of Colorado Institute of Behavioral Science, Response to Flash Flood Warnings: The Big Thompson Canyon Flood and a Hypothetical Boulder Flood. By Gilbert F. White, Eve C. Gruntfest and Thomas E. Downing (phone 492-8147). Natural Hazard Working Papers # 31 and # 32, 1977.

The first part of the study will analyze what people did in the Big Thompson flood, and relate the behavior patterns to survival, social variables, and characteristics of the warning (if one was received). The second part of the study will attempt to estimate the response to a flash flood warning for Boulder, based on previous research and the findings of the Big Thompson study. Lessons learned in the July 31 flood may help other communities avoid disaster.

APPENDIX A (continued)

*University of Denver, Search and Rescue Operations in the Big Thompson Flood. By Thomas Drabek, Department of Sociology (phone 753-3459). Due to be completed in summer, 1977

Description of the activities of the various groups (about 35) involved in search and rescue operations during and after the flood.

*University of Colorado, Big Thompson Tributaries: Geomorphic Activity and Its Controlling Factors During the 1976 Storm. By Jim Balog, INSTAAR, Boulder 1977.

Field surveys of selected tributaries have given the distribution of erosional features and sediment yields from them. Vegetation communities are being mapped from remote sensing imagery. Precipitation distribution and topographic parameters will be combined with these data to delineate controlling factors on geomorphic activity.

Federal

*Federal Insurance Administration and Colorado Water Conservation Board, Special Flood Plain Information Report, Big Thompson and Tributaries, Larimer County, Colorado. By Gingery Associates, Inc.. Preliminary draft, December 22, 1976.

Detailed description of history of flooding and hydrology of the Big Thompson. Includes an index to the flood plain maps. Gingery and Associates did the hydrology, Kucera did the actual mapping on this project funded by the FIA, CWCB and the Colorado Department of Highways. Reproducible maps of the flood plain (1% probability flood fringe and floodway) will be available January 12, 1977. This report provides the basis for the county's flood plain management regulations in the canyon. The FIA plans to prepare a flood insurance rate map of the entire county in 1978 based on the engineering done by Gingery and Associates.

*National Weather Service, Big Thompson River, Colorado, Total Precipitation for July 31 to August 2, 1976. By Elroy C. Balke, Regional Hydrologist. September 13, 1976.

Map of precipitation levels, indicates storm centers of over 10 inches rainfall below Estes Park, near Glen Haven and over the Rist Canyon. Includes a rainfall and flood crest time sequence and a list of data sources (bucket survey).

*U. S. Geological Survey, Storm and Flood of July 31 of the Big Thompson. By W. Hansen, Editor, USGS Professional Paper. Expected in the Summer, 1977. (phone 234-3495).

APPENDIX A (continued)

Will include discussions of geologic processes and relationships to damages, post-disaster relief and long-range planning for geologic hazards in other parts of the state, and various aspects of the event's hydrology, meteorology and geology and geomorphic effects.

*U. S. Geological Survey, Floods in Colorado. By Robert Follansbee, Leon R. Sawyer, USGS, DOI Water-Supply Paper 997, 1948.

Description of flooding on the Big Thompson.

*U. S. Army Corps of Engineers, Flood Plain Information, Big Thompson River, Loveland, Colorado. Omaha, Nebraska. December, 1971.

Description of past flooding of the Big Thompson, and of the estimated Intermediate Regional Flood and the Standard Project Flood. Report includes a rough map of the flood hazard areas.

*U. S. Army Corps of Engineers, Economic Impact of the Big Thompson Flood. By W. Noordam, Planning Division, Omaha, NB (phone 402-221-4435 or for messages, toll free, 800-228-9477). November, 1976.

Data were collected at the end of September. Covers early estimates of the costs of government cleanup, emergency efforts, transportation damages, land erosion, building damage, private property damage and indirect damages. The Colorado Division of Economic Development is scheduled to publish data on indirect losses in January, 1977.

*U. S. Forest Service, Private Ownership in the Big Thompson Canyon and Roosevelt National Forest, Mount Olympus, Colorado, (6th P.M.) N4015-W 10515/15, 68NW. Prepared by Region 2, Denver, Colorado, 1971.

A report on land ownership in the Big Thompson region was prepared a year ago to assess the feasibility of Forest Service acquisitions in the area. The map shows the Forest Service holdings.

*U. S. Geological Survey, Colorado Water Conservation Board, The Big Thompson River Flood of July 31, August 1, Larimer County, Colorado: Flood Information Report. October, 1976.

Covers general description of the flood and estimates of flood discharges at various points in the canyon. Includes 51 air photos of the canyon after the 1976 flood. High water lines are drawn on the photos.

APPENDIX A (continued)

*U. S. Soil Conservation Service, Conservation in the Big Thompson. With the U. S. Forest Service and the Colorado Division of Wildlife.

$920,000 have been allocated the Soil Conservation Service under the Department of Agriculture's 216 program for work in Larimer County. A team will survey the work to be done, including conservation in the upper tributaries and maybe in the Big Thompson itself. A work plan should be ready in February.

State

*Colorado Geological Survey, Geologic Hazards in the Big Thompson Canyon Area, Larimer County, Colorado. By J. M. Soule and W. P. Rogers, CGS, 1313 Sherman, Denver, Colorado (phone 892-2611) 1977.

Maps geologic hazards such as rockfalls, mud flows and debris fans on a 1:12,000 scale. A large portion of the damage in the canyon was caused by geologic processes, other than flooding, triggered by the heavy rains and the floods. These data will also be mapped on a 1" to 200' scale for planning purposes, available for local officials and public inspection as an open file report.

*Colorado Geological Survey, Geomorphic Features Formed by Flooding in the Big Thompson Canyon, Larimer County, Colorado. By D. Shelton, CGS, 1313 Sherman, Denver, Colorado (phone 892-2611). Fall, 1976.

Surveys the geological formations left by the flood waters between the mouth of the canyon and the town of Loveland.

*Governor's Special Assistance for Flood Recovery, Recommendations for Goals, Big Thompson Restoration Committee. By Kenneth Wright, Wright-McLaughlin Engineers, 2420 Alcott, Denver, Colorado (phone 458-6201). August, 1976.

A preliminary outline (not approved by the Governor) of recovery efforts needed. Sets goals and objectives for highway, flood plain management, channel work, canyon occupancy, administration, canyon residents welfare, economic base and financial concerns. The anticipated role of the governor's office is included.

County

*Larimer County Assessor's Office, Computer printout of pre and post-flood assessed valuations. By Dick Green, County Assessor, Fort Collins (phone 221-2100, X206). September 16, 1976.

The county assessor re-evaluated all property (buildings and land) in the disaster area. Property was devaluated on the basis

APPENDIX A (continued)

of actual damage, and availability of access. The original computer printouts included owner, parcel number, pre-flood assessed value, and post-flood assessed value. The county computer system can also access property description and damage to land and buildings as a percent of pre-flood value. The county planning department has a number of these printouts. The assessor will reassess property damage in January, for 1977 tax purposes.

*Larimer County Planning Department, Maps of the Big Thompson Canyon. Property Ownership, 1976 Flood Damage (Drake and Cedar Cove completed, rest of canyon is in progress), Land Use. Fall, 1976.

The planning department has compiled a lot of information on the canyon, including these maps.

*Larimer County Planning Department, A Summary of Present and Anticipated Land Use Regulations Dealing with Redevelopment of the Big Thompson Canyon. By Rex Burns, Senior Planner, LCPD, Fort Collins, Colorado 80522, P. O. Box 1458 (phone 221-2100). October 25, 1976.

Reviews the history of flood plain regulation in Larimer County and its application to the Big Thompson. Explains floodway (FW) and flood fringe (FF) designations.

*Larimer County Planning Department, Bridge Inventory, Big Thompson Canyon, Colorado. By Rex Burns. January, 1977.

Surveys new bridges (private) and accessroads needed in the Big Thompson, not including the North Fork. Also lists property owners and locations to be served by each bridge. Twenty three new bridges are needed, two bridges survived the flood, and two were rebuilt illegally.

Other

*Inter-Faith Task Force, Survey of Citizen Needs. Box 706, Loveland, Colorado 80537 (phone 669-4205).

The Inter-Faith Task Force was organized after the flood by personnel from the Christian Reformed Church World Committee experienced in handling the aftermath of a disaster. The Task Force brought together many of the local churches to form a center for organizing volunteer help and meeting the needs of canyon residents. Activities have included a general survey of citizens' needs, a more detailed survey of damage and personal economic impact, a construction survey to assess material needs for rebuilding houses, various citizen advocacy activities and fund raising and distribution (coordinated with the Chamber of Commerce).

APPENDIX B

HYPOTHESES FROM PREVIOUS RESEARCH RELATED TO THIS REPORT

Hypotheses relative to actual warning characteristics

Evacuation is no more likely to occur when the source of warning is official than when it is unofficial (Danzig, et al., 1958).

Persons warned by authorities are more likely to evacuate immediately than those warned by unofficial sources (Drabek and Boggs, 1968).

As warning messages increase in accuracy and/or information of survival choices, and/or consistency with other warnings, and/or clarity about nature of threat there is a greater probability of adaptive behavior being adopted (Demerath, 1957; Fritz, 1957; Fritz and Williams, 1957; Crane, 1960; Schatzman, 1960; Moore, et al., 1963).

Variations in the channel through which the threat message is delivered accounts for differences in response to warning (Drabek, 1969; Moore, et al., 1963) accounts for no perceptible differences (Danzig, et al., 1968).

Persons do not readily evacuate on the basis of first warning received (Fritz and Marx, 1954).

The number of warnings is directly related to evacuation (Fritz and Matthewson, 1957; Drabek, 1969).

Hypotheses relative to human warning response

When warning recipients perceive a high degree of certainty in a warning the probability of their making a confirmation attempt increases (Danzig, et al., 1968).

Those with previous disaster experience are more likely to go through organizational channels for information and verification than those without such experience (Mack and Baker, 1961).

The closer a person is to a target area of a warning the higher the incidence of word of mouth communication and the larger the number of information sources used for obtaining additional information (Diggory, 1956).

Income is inversely related to evacuation probability (Young, 1954; Moore, et al., 1963).

High school graduates are more likely to take adaptive action than persons with less or more education (Mack and Baker, 1961).

APPENDIX B (continued)

Lower socio-economic status persons are more likely to go to public shelters than to relatives' house or other evacuation sites (Moore, et al., 1963; opposite found to be true in Drabek and Boggs, 1963).

Women are more likely to engage at both ends of adaptive/non-adaptive continuum. They are more anxious to leave than men (Mack and Baker, 1961; Moore, et al., 1963).

People define potential impact in terms of prior experience with that disaster agent Instituut Nederlandse , 1955; Demerath, 1957; Drabek and Boggs, 1968).

Small town urban dwellers with small town backgrounds are less likely to interpret warnings as valid than are urbanites (Mack and Baker, 1961).

Panic is not typical behavior. It exists only when imminent danger is perceived whenever there is limited number of escape routes, when escape routes are closing and escape must be made quickly or when there is a lack of communication and people feel uniformed (Quarantelli, 1954, 1957, 1964; Fritz, 1954).

Perceived time before impact is inversely related to the probability of taking adaptive behavior (Demarath, 1957; Fritz, 1957; Williams, 1957).

Strongly established patterns of centralized decision making may delay action prior to impact (McLuckie, 1970).

Drawn from Mileti, Drabek and Haas, 1975: 35-57.

APPENDIX C

USE OF VARIABLES AND LEVELS OF ANALYSIS

List of Variables	Groups in Sample	Level of Analysis	
		Chi Squares	Discriminant
Occupation	Most groups, All survivors	yes	yes
Starting point	All groups	yes	yes
Action taken	All groups	yes	yes
Area of canyon	Most groups, All survivors	yes	yes
Number of people In group	All groups	yes	yes
Kind of group	All groups	yes	yes
Kind of warning	Most groups, All survivors	yes	no
Warning received?	All groups	yes	yes
Knowledge of Big Thompson Canyon	All groups	yes	yes
Warning source	Survivors, Few non-survivors	yes	no
Warning mode	All survivors, Few non-survivors	yes	no
Warning content	All survivors, Few non-survivors	yes	no
Confirmation	All survivors, Few non-survivors	yes	no
First indication Something wrong	All survivors	yes	no
Warn others	All survivors	yes	no
Access to mobility	All survivors	no	no
Age	All non-survivors, Some survivors	no	no
Sex	All non-survivors, Most survivors	no	no

APPENDIX D

DESCRIPTION OF VARIABLES AND FREQUENCY OF RESPONSE BY GROUPS

1. Knowledge of Big Thompson Canyon (N=112 where N is the total number of groups)

Full-time resident	37%
Part-time resident/many visits to canyon	42%
Tourist/few visits to Rocky Mountains	21%

2. Group Context (N=110)

Family	79%
Friends	11%
Strangers	2%
Alone	6%

3. First Indication Something Wrong (N=51)

None	4%
Heavy rain	19%
Rising river	37%
Warning	27%
Sound of river	11%

4. Warning received? (N=51)

Yes	39%
No	60%

5. Warning Received from Source (N=20)

Stranger	20%
Friend	20%
Sheriff's Rep	45%
Loveland Police Dispatcher	15%

6. How Warning was Received (N=20)

Telephone	52%
Bullhorn/loudspeaker	4%
Face to Face	21%
Siren	5%

7. Content of Message (N=20)

Flood danger	10%
Flood danger/get out	42%
Flood danger/go to higher ground	26%
Flood danger/warn others	21%

APPENDIX D (continued)

8. Number of Warnings Received (N=20)

1	61%
2 or more	38%

9. Aid in Dissemination Process (N=39)

Yes	36%
No	64%

10. Attempt at Confirmation (N=36)

Yes	88%
No	11%

11. Access to Mobility (N=43)

Yes	90%
No	9%

12. Age (N=111 where 111 is the total number of groups)

1-15	0
16-30	17%
31-45	16%
46-60	15%
61-75	26%
76-90	6%

13. Area of Canyon (N=111)

Out either end	4%
Cedar Cove and below	30%
North Fork	5%
Drake and Waltonia	28%
Above Waltonia	22%
Unknown	11%

14. Number of People in Group (N=111)

1	12%
2	43%
3-5	30%
6-10	9%
11+	5%

15. Occupation (N=111)

Worker	80%
Retired	13%
Student	7%

APPENDIX D (continued)

16. Origin, Starting Point (N=111)

Car	28%
Building (including private, commercial & trailors)	61%
Camping, outside	10%

17. Kind of Warning (N=111)

Environmental Cue, none	70%
Official, unofficial	30%

18. Action Taken (N=111)

Something	58%
Nothing	41%

(N=65)

Climb	40%
Drive	26%
Other, another part of the house, safety, then danger	33%

APPENDIX E

VARIABLES USED IN THE DISCRIMINANT ANALYSIS

Location in the Canyon (measured by distance to Estes Park)

1. Outside Estes Park
2. Above Waltonia and Glen Haven
3. Drake, Waltonia
4. Outside Loveland and west through Cedar Cove

Warning Received

1. Yes
2. No

Starting Point

1. Any building
2. Car
3. Outside

Know Big Thompson Canyon

1. Well, full-time resdient
2. Part-time resident, many visits
3. Tourist

Did

1. Action taken, yes
2. No action taken

People

1. 1
2. 2
3. 3-5
4. 6-10
5. 11+

Survived

1. yes
2. no

APPENDIX F

TABLES FROM CONTINGENCY AND DISCRIMINANT ANALYSIS*

*The chi square and the Cramers V are both relative indicators of the strength of the relationship which may exist. It must be remembered that these are relevant only in this particular sample of those in the canyon during the flood.

TABLE 1

RELATIONSHIP BETWEEN AN ACTION TAKEN AND SURVIVAL

COUNT ROW PCT	DID SOMETHING	DID NOTHING	ROW TOTAL
Lived	43 74.1	15 25.9	58 52.3
Died	22 41.5	31 58.5	53 47.7
Column total	65 58.6	46 41	

CORRECTED CHI SQUARE 10.84192 with 1 degree of freedom
SIGNIFICANCE .0010
CRAMERS V .33084
CONTINGENCY COEFFICIENT .31409

Results

Those who did something, (i.e., took some action), were more likely to live than those who took no action. Those who did nothing different were even more likely to die in the flood.

TABLE 2

	CLIMBED	DROVE	NOTHING	OTHER	BACK INTO DANGER	
Lived	24 41.4	10 17.2	15 25.9	8 13.8	1 1.7	58 52.3
Died	2 3.8	7 13.2	31 58.5	7 13.2	6 11.3	53 47.7
Column total	26	17	46	15	7	111

RAW CHI SQUARE 28.1806 with 4 degrees of freedom
SIGNIFICANCE .0000
CRAMERS V .50386
CONTINGENCY COEFFICIENT .44997

Results

Those who climbed were most likely to survive. Those who did nothing were most likely to have not survived. (Other actions include climbing a tree, going outside, or going into another part of a building.)

TABLE 3

RELATIONSHIP BETWEEN NUMBER OF PEOPLE IN GROUP AND SURVIVAL

COUNT ROW PCT	1	2	3-5	6-10	11+	ROW TOTAL
Lived	2 3.4	24 40.7	22 37.3	6 10.2	5 8.5	59 52.7
Died	12 22.6	24 45.3	12 22.6	4 7.5	1 1.9	53 47.3
Column total	14 12.5	48 42.9	34 30.4	10 8.9	6 5.4	112 100.0

RAW CHI SQUARE 12.86620 with 4 degrees of freedom
SIGNIFICANCE .01
CRAMERS V .33893

Results

Those who were alone were much more likely to die than those who were with others. Those who were with others, especially in groups of 3-5, were more likely to live than those alone or in other sized groups.

TABLE 4

RELATIONSHIP BETWEEN GROUP CONTEXT AND SURVIVAL

COUNT ROW PCT	Groups 1 FAMILY	2 FRIENDS	3 STRANGERS	4 ALONE	ROW TOTAL
Lived	46 78.0	9 15.3	2 3.4	2 3.4	59 53.3
Died	31 59.6	4 7.7	1 1.9	16 30.8	52 46.8
Column Total	77 69.4	13 11.7	3 2.7	18 16.2	111 100.0

RAW CHI SQUARE 15.68833 with 3 degrees of freedom
SIGNIFICANCE .00
CRAMERS V .37595

Results

Those who were in family groups were more likely to live than those in other groups. Those who were with friends were most likely to live.

TABLE 5

RELATIONSHIP BETWEEN AREA OF THE CANYON AND SURVIVAL

COUNT ROW PCT	LIVING	DEAD	ROW TOTAL
Out via Loveland	4 80	1 20	5 4.5
Cedar Cove	17 51.5	16 48.5	33 29.5
Glen Haven	5 83.3	1 16.7	6 5.4
Drake and Waltonia	14 45.2	17 54.8	31 27.7
Above Waltonia	19 76.0	6 24	25 22.3
Unknown	0 0	12 100	12 10.7

RAW CHI SQUARE 23.29271 with 5 degrees of freedom SIGNIFICANCE .001
CRAMERS V .45504 CONTINGENCY COEFFICIENT .49493

TABLE 5 (continued)

Results

Those who were above Waltonia were more likely to live than those in other areas. (The number of unknowns makes assessment of this table's significance difficult.)

TABLE 6

RELATIONSHIP BETWEEN WARNING RECEIVED AND ACTION TAKEN
FOR SURVIVOR GROUPS ONLY

ACTION	CLIMBED	DROVE	NOTHING	ROW TOTAL
Warned Survivors				
Yes	9 42.9	8 38.1	4 19.0	21
No	24 64.9	2 5.4	11 29.9	37
Column totals	33	10	15	58

RAW CHI SQUARE 10.034
SIGNIFICANCE .0066
CRAMERS V .41595

Results

Those who drove out were most likely to have received a warning. Those who climbed or did something else were more likely to have received no warning. (Warning here refers only to official or non-official warnings. It does not include environmental cues. These could potentially be quite important in the analysis but limited information excluded them.)

TABLE 7

RELATIONSHIP BETWEEN GROUP CONTEXT AND WHAT THE GROUP DID

ACTION	CLIMBED OR SOMETHING ELSE	DROVE	NOTHING	ROW TOTAL
Group Context				
Family	32 41.6	15 19.5	30 39.9	77
Friends	8 66.7	1 8.3	3 25	12
Strangers	3 100	0 0	0 0	3
Alone	4 22.2	1 5.6	13 72.2	18
Column Totals	47	17	46	110

RAW CHI SQUARE 14.710 SIGNIFICANCE .0226
CRAMERS V .23413 CHI SQUARE 25.858

TABLE 7 (continued)

Results

Those who were with friends were most likely to climb. Those who were with family were more likely to do nothing than to climb. Those who were alone were most likely to do nothing.

TABLE 8

RELATIONSHIP BETWEEN NUMBER OF PEOPLE IN A GROUP AND ACTION TAKEN

COUNT ROW PCT	NUMBER OF PEOPLE IN GROUP 1	2	3-5	6-10	11+	ROW TOTAL
Did something	4 6.2	21 32.3	27 41.5	8 12.3	5 7.7	65 58.6
Did nothing	10 21.7	27 58.7	7 15.2	2 4.3	0 0	46 41.4
Column totals	14 12.6	48 43.2	34 30.6	10 9.0	5 4.5	111 100.0

RAW CHI SQUARE 21.05066 with 4 degrees of freedom
SIGNIFICANCE .0003
CRAMERS V .43548
CONTINGENCY COEFFICIENT .39927

Results

Those who were alone were more likely to do nothing than those who were with others. Those in groups of 3-5 were more likely to do something than do nothing.

TABLE 9

RELATIONSHIP BETWEEN SPECIFIC ACTION AND WARNING OTHERS

COUNT ROW PCT	CLIMBED	DROVE	NOTHING	ROW TOTAL
Warned Others				
Yes	5 35.7	6 42.9	3 21.4	14 33.3
No	19 67.9	2 7.1	7 25.0	28 66.7
Column totals	24 57.1	8 19.0	10 23.8	42 100.0

RAW CHI SQUARE 7.98750 with 2 degress of freedom
SIGNIFICANCE .0184
CRAMERS V .43609
CONTINGENCY COEFFICIENT .39974

Results

Those who drove were more likely to have warned others than those who climbed. Those who did nothing and climbed were more likely not to have warned others than those who drove.

TABLE 10

SIGNIFICANT VARIABLES AND RELATIVE WEIGHTS WITHIN
THE ACTION/NO ACTION DISCRIMINANT EQUATION

Variables significant to the equation	Standardized function coefficients
Number in group	-0.868
Survival	-0.531
Warning received	0.303
Origin	0.253
Familiarity with Big Thompson Canyon	-0.127
Location in the canyon	-0.056

CHI SQUARE 29.383 with 6 degrees of freedom
SIGNIFICANCE .000
WILKS LAMBDA .75987

Results

The number of people in a group was most significant in characterizing the groups by whether or not any action was taken. Familiarity with the Big Thompson Canyon was least influential in statistically differentiating those who took an action from those who took no action.

TABLE 11

SIGNIFICANT VARIABLES AND RELATIVE WEIGHTS WITHIN
SURVIVED/DIED DISCRIMINANT FUNCTION

Variables significant to the equation	Standardized function coefficients
Location in the canyon	0.839
Action taken	0.641
Warning received	0.294
Number in group	-0.230
Familiarity with Big Thompson Canyon	-0.140

CHI SQUARE 35.84304 with 5 degrees of freedom
SIGNIFICANCE .000
WILKS LAMBDA .718

Results

The area of the canyon and what action was taken were most influential in statistically discriminating between those who survived and those who died.

TABLE 12

SIGNIFICANT VARIABLES AND RELATIVE WEIGHTS WITHIN THE WARNED/NON-WARNED DISCRIMINANT EQUATION

Variables significant to the equation	Standardized function coefficients
Location in the canyon	-0.883
Origin in the canyon	-0.704
Action taken	-0.444
Survival	-0.426
Number in group	-0.363
Familiarity with Big Thompson Canyon	-0.167

CHI SQUARE 18.603 with 6 degrees of freedom
SIGNIFICANCE .005
WILKS LAMBDA .84177

Results

The location of the group in the canyon and their origin are most influential in statistically separating the warned from the non-warned population. The familiarity with the Big Thompson Canyon was least influential in statistically separating the warned from the non-warned.

TABLE 13

SIGNIFICANT VARIABLES AND RELATIVE WEIGHTS WITHIN
THE LOCAL/TOURIST DISCRIMINANT EQUATION

Variables significant to the equation	Standardized function coefficients
Number in Group	0.564
Origin	0.424
Survival	-0.401
Warning received	-0.305
Action taken	-0.300
Location in the canyon	-0.199

CHI SQUARE 13.598 with 7 degrees of freedom
SIGNIFICANCE .059
WILKS LAMBDA .881

Results

The number of people in a group, their origin and whether or not they survived were most significant in distinguishing between the locals and the tourist populations.