COLORADO'S VULNERABILITY TO VERY HIGH RISK NATURAL HAZARDS REVISED 1983

Division of Disaster Emergency Services
John P. Byrne
Director

P R E F A C E

As more people occupy more land in Colorado and create improved property in settlement areas, population exposure to the damaging consequences of extreme natural phenomena increases commensurately. In the past decade or so the State has experienced disasters caused by severe winter storms, floods and tornados. However, because of the variability of Colorado's climate and topography, not all regions are exposed to the same threats.

Recent disaster events have focused increased attention at both local and state government levels on the need to mitigate such events where possible and to prepare to cope with them when unavoidable. Progress in these regards has been uneven, in part because disasters are infrequent and unpredictable. The best preparedness postures are found among jurisdictions with recent disaster experience.

The foundation of preparedness is an awareness of the hazards facing a jurisdication. This document contains information which will assist public officials in making such an analysis. The short recorded history of Colorado makes it difficult to predict accurately the frequency and severity of natural phenomena. However recent research has improved this body of knowledge and makes it possible to summarize in a regional fashion events which can be expected to occur at some time.

I strongly urge both local and state government officials to review this study carefully and to act on its implications. The shared obligation to provide for public safety demands no less.

John P. Byrne
Director

ACKNOWLEDGEMENTS

The following representatives of state and federal agencies have made significant contributions to the update of this study. The Division of Disaster Emergency Services is particularly grateful for their willing and energetic assistance.

Ellen Carroll	Division of Disaster Emergency Services
Irv Glassman	Division of Disaster Emergency Services
Dave Lawton	Division of Disaster Emergency Services
Bill Martin	Division of Disaster Emergency Services
Debby Michienzi	Division of Disaster Emergency Services
Larry Lang	Colorado Water Conservation Board
Hal Simpson	Colorado Division of Water Resources (State Engineer's Office)
Bill Stanton	Colorado Water Conservation Board
Rahe Junge	Colorado Geological Survey
Pat Rodgers	Colorado Geological Survey
Jim Soule	Colorado Geological Survey
Frank Mollner	Federal Emergency Management Agency
Sherryl Ozburn	Federal Emergency Management Agency
Richard Lin	Colorado Division of Local Government (Demographic Section)
Lee Thielan	Colorado Department of Health
Maury Pautz	National Weather Service
Larry Tunnel	National Weather Service

Revised by: Jack Truby
Len Boulas
Division of Disaster Emergency Services

TABLE OF CONTENTS

PROBLEM

In 1977 the Division of Disaster Emergency Services published a study titled Colorado's Vulnerability to Hazards which assessed the State's vulnerabilities to disaster in general terms.

Following the Big Thompson disaster it was apparent that further study was needed to identify specific localities and populations vulnerable to very high risk natural hazards. Potential dangers from flash and riverine flooding, tornados, and dam failure flooding -- Colorado's very high risk hazards -- were well known, but more precise understanding of their potential impact was essential. Additionally, new understanding has evolved about the risks which face Coloradans as a consequence of earthquakes. New questions concerning vulnerability of the people of Colorado were raised; primarily: who was seriously exposed to these hazards, what levels of vulnerability existed, and what steps could be taken to begin to reduce this vulnerability?

By 1982, with the strong support of Governor Lamm, considerable progress had been made in assisting with the improvement of the preparedness of local entities - our "first line of defense" against disaster. But the answers to the above questions are still only partial. New people come to Colorado every day and our vulnerability to the very high risk hazards discussed here is so great that much more needs to be done.

The purpose of this study, therefore, is to assess the current (1983) vulnerability of segments of the State's population to very high risk threats. This assessment includes identification of the greatest natural hazards, the populations threatened, and methods by which vulnerability might be lessened through state and local government cooperation. The ultimate goal of this and past efforts of the Division of Disaster Emergency Services is to enhance preparedness at the local level. This study is focused in a narrow sense on very high risk natural hazards. This study also more generally aims at complementing and supplementing past planning to deal with these threats to lives and property.

The authors of this study hope to advance levels of understanding of the overall preparedness problem by focusing on specialized problem areas. In the end, local leadership must assess their local hazards and make decisions which place priorities on developing the response capabilities most needed locally. These assessments and allocations of priority are variables and they fluctuate with changes in local, state, federal and even the international environment. Currently these assessments and priorities must continually reflect Colorado's growing population and the new vulnerabilities and costs which are constantly developing. To the extent this study reflects local needs, and stimulates a deeper understanding of preparedness, so its utility should be judged.

To establish meaning of the term vulnerability, it is useful to note that people become vulnerable to natural hazards when they choose (knowingly or unknowingly) to live near the areas where these extreme events occur. Vulnerability is also related to preparedness. People who prepare for the occurrence of an extreme event are less vulnerable to it than those who do not. The vulnerability of Colorado's population is rooted in a relationship between the occurrence of extreme events, the proximity of people to these occurrences, and the degree to which these people are prepared to cope with these extremes of nature.

FACTS BEARING ON THE PROBLEM

To assess Coloradan's vulnerabilities to very high risk threats, and to better understand how to reduce these vulnerabilities it is necessary to consider:

1. The occurrence of natural phenomena which are major hazards in the State.

2. Population patterns and growth in areas of the State where these extreme events occur.

3. Steps toward local preparedness and mitigation of these threats taken by concerned elements of the population, including awareness of the threat, awareness of warning signals, availability of shelters and marked evacuation routes, planned responses, and incentives to encourage people to settle away from danger areas.

Relationships between item (1) hazards, and item (2) population involved, identify patterns of risk. Relationships between patterns of risk, and item (3) steps taken toward preparedness, explain degrees of vulnerability to which various Coloradans are exposed; these steps offer insights as to the most cost effective measures which can be taken to reduce vulnerabilities.

Such relationships are not new to Colorado. The natural phenomena involved have occurred here long before people settled near them and were impacted by them. Risk grew from the increasingly close association between natural phenomena and a growing population; as disasters in increasing magnitude and frequency occurred. The need for preparedness, involving perception and response, arose out of the impact of these disasters. As vulnerability to natural hazards has grown, so has the need for preparedness -- to reduce the cost of Colorado's potential disasters.

EXTREME EVENTS WHICH ARE MAJOR HAZARDS IN COLORADO

As previously established in the Division of Disaster Emergency Services (DODES) publication, Colorado's Vulnerability to Hazards, flash floods, floods on the plains (or riverine floods), earthquakes, dam failure flooding, and tornados are considered to be Colorado's highest risks.* These major threats are often interrelated and one may compound another: (1) a flash flood may cause a dam to fail or (2) a relatively small earthquake may also lead to the same result. This identification of very high risk threats has been developed from historical analysis of the growth of Colorado's population through the mining era into modern times and the losses which have been recorded.

Flash Flooding

In most of the mountainous areas of Colorado, flash flooding usually occurs in spring and summer. In southwestern Colorado flash flooding occurs most frequently in September and October. Heavy rainfall, possibly combined with snowmelt in the intermountane canyons, threatens population living along the stream bed or near outwash areas. Very significant landslide hazards often accompany flash floods in canyons and river headwaters.

Flash flooding danger is of greatest significance along floodplains located in the mountainous areas and in particular in the Front Range where population is concentrated, where gradients are steep, where large drainage areas can focus considerable quantities of water and where very heavy rainfall can occur. Of these components of a hazardous flash flood, amounts of rainfall and the time over which rainfall extends are the most difficult to predict and prepare for. A historical analysis of rainfall patterns along the Front Range by Professor Koelzer, Colorado State University, has shown that probable maximum amounts of 20 inches of rainfall can occur in a given 24 hour period. This varies considerably from expectations held by the public as to likely amounts of rainfall.

It is significant to note that the Big Thompson flood resulted from a maximum rainfall of 12 inches. The maximum rainfall leading to the 1965 flood was 14 inches. We have only minimal data concerning frequencies and amounts of rainfall to accurately predict flash flood intensities. In another example, in 1935, Fountain Creek had rainfall amounts of 18 inches occurring in 3-4 hours. It has been documented that a large flood -- a flood greater than a 100 year flood -- has occurred on every large Colorado stream basin.

*Urban fires and wildfires, serious threats in Colorado, have not been considered here since they do not represent the degree of risk to human life that the extreme events listed above do.

The State Geologist has undertaken an analysis of Colorado's most dangerous canyons in which flash flooding can occur. Major canyons which are threatened by flash floods are shown in Annex "A".

While the bulk of these canyons exist along the Front Range, their dispersion over the State is general; many communities with significant population are closely associated with these danger areas. Flash flooding occurs annually throughout Colorado on streams and floodplains and the danger is greatest to settlements located close to the major streams identified in "Riverine Flooding".

Riverine Flooding

Large scale floods can develop from sustained or heavy rainfall from storm systems in the spring, summer and fall months in Colorado. But the most dangerous flood potential is in the spring when rivers are high during the snowmelt run off. Usually, rainfall in addition to snow melt run off is necessary before flooding occurs. These floods differ from flash floods in that the speed of onset is slower and time available for warning is greater; fewer lives are lost, but millions of dollars worth of valuable farmlands, roads, bridges, and other valuable assets, are at stake. It should be noted, however, that although riverine floods may occur over most of a river system, flash floods may simultaneously occur in headwater areas where steeper gradients exist.

The Rio Grande, South Platte, Arkansas, and the Republican Rivers have a long history of flooding onto the plains areas. In 1965, as a result of heavy rains concentrated around the Castle Rock area, widespread flooding occurred in the Denver Metro area, loss of life and very high damage was also suffered along the Front Range and on the eastern plains. As more development takes place in the Metro area, run off potential increases and extensive damage can be expected despite new flood control dams.

On the Western Slope the Colorado, Yampa, San Juan, Gunnison (N. and S. Fork), Uncompahgre, Animas, White and many other streams can be expected to flood in any given year. The most likely periods for disastrous flooding are during the spring snowmelt when rainfall occurs during peak run off periods in May and June, and when relatively heavy rainfall occurs on the Western Slope in September and October. On the Western Slope in Colorado, water volumes in the spring are normally large and gradients are relatively steep. Riverine flooding can threaten property but the distinction between flash and riverine flooding is blurred. Lives are also at stake.

Average rainfall during April, May and June on the Western Slope varies from 2 to 4 inches; on the Eastern Slope rainfall averages run as high as 6 to 8 inches during the 3 months. When this rainfall is concentrated during the run off period, flooding is likely.

Earthquakes

Earthquakes are caused by fault movements within the earth that produce a sudden motion or shaking of the earth's surface. In the 120 years that modern man has occupied Colorado, hundreds of earthquakes have been noted. In the early years there were "felt" reports, but more recently seismographic instruments have been used to detect and locate earthquakes. Geologists recognize that many of the State's mountain ranges and basins are youthful and that faults associated with them continue to move and have the potential for generating earthquakes. Analyzing both the potential for movement of these faults and past earthquake history indicates the potential for damaging earthquakes has been underestimated in the past and that a potential exists for greater damage then expected.

Large earthquakes and even moderate-sized events can damage or destroy the works of man by severe ground shaking, ground rupture, or displacement near the fault zone or by ground failure from landslides, soil settlement, soil liquefaction, and ground cracking. Additional damage and health hazards can be caused by earthquake induced dam failure, ruptured gas lines, water and sewage disposal facilities, and electrical power lines. Many critical structures (dams, hospitals, schools) have not been adequately designed for larger sized earthquakes that now appear possible in Colorado. Another area for attention is related to the fact that most local building codes continue to show a low risk seismic zonation which does not appear adequate for much of the State of Colorado in view of the emerging better understanding of our earthquake hazard (Colorado Geological Survey).

Dam Failure Flooding

Approximately 2,249 dams exist in Colorado that exceed 10 feet in height. Many of these pose considerable threat to population who live downstream from them. These dams are a particular threat when flash flooding occurs in the vicinity of the dam, causing a sudden flow of water over the spillway of the dam or over the dam. Some of the dams in question are old and are subject to failure under extreme flooding conditions. Many dams were built to store water for agriculture but now must serve to restrict flooding due to greater run off as a result of urban development. This combination of flash flooding and dam failure is precisely the situation that resulted in the Rapid City disaster in 1972. Danger is greatest where a relatively steep gradient exists between the dam and the settlement pattern.

Another hazard associated with dams in Colorado is related to seismic activity. When many of Colorado's dams were originally constructed, seismic activity was not considered to be as great a risk as it is today (for the latest analysis of seismic risk see the analysis of potential effects of intensity discussed at pages 6 and 21). As a result, structural allowances were not fully considered at the time of construction. Today, a reasonably high level of risk exists downstream from these dams. There is a possibility that an earthquake (or minor seismic activity) could shake the foundation of a dam causing the structure to weaken and fail.

At least 130 dams are known to have failed in Colorado since 1890.*

Tornados

The occurrence of tornados is confined primarily to the Eastern Slope of Colorado where they occur with considerable frequency. During the spring and summer months, tornados are likely around Denver, and contiguous metropolitan areas, the foothills of the Front Range, and in the plains counties. Because of the meteorological conditions found in Colorado, tornados often develop, move across the ground, and then rise rapidly so that they do not continue on a long, destructive storm path. Tornados therefore tend to have a relatively short duration in Colorado, despite their frequent occurrence.

When a tornado does occur, it is an immediate threat to lives and property. Since tornados occur on the eastern plains where population densities are very low, few lives have been lost and relatively little property has been damaged in recent years. But recently, it appears that many more tornados occured every year than had been previously recognized as developing on the eastern plains. They have also been observed developing over the Front Range and have impacted the growing urban areas: Manitou Springs, Thornton (this tornado also impacted portions of Denver and Lakewood) are two recent

* From the Flood Hazard Mitigation Plan for Colorado, Lawn Lake Disaster.

examples. Map 1, (page 9) shows the occurrence of tornadic events in Eastern Slope counties from 1978 through 1982 as recorded by the National Weather Service using the Limon radar. The pattern of occurrence over this 5 year period shows that Front Range foothills counties can expect a significant number of tornados every year. With better sensing systems, more have been observed in the east. Table 1, (below) shows the monthly distribution of occurrence in all counties. May, June and July are obviously a very high risk period of time; (this table was also furnished by National Weather Service using radar sensing). The destructive effects of tornados are so great that a significant threat remains to all who live on the Eastern Slope. The fact that very few people have been killed has led to some complacency among Coloradans who live east of the Continental Divide.

Table 1
COLORADO TORNADOES BY MONTH, 1975-1982

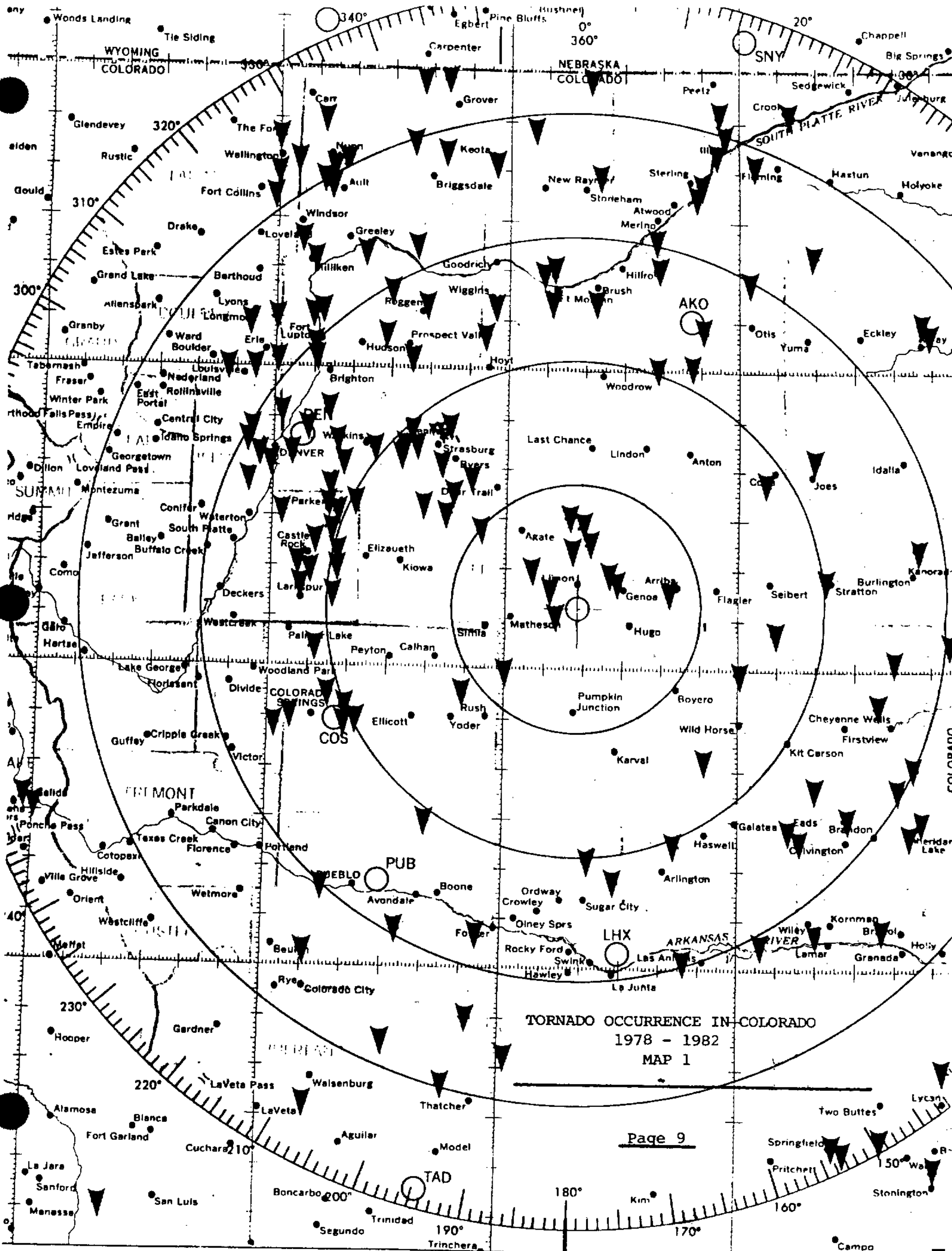
	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	TOTAL
1975	0	0	13	4	3	0	0	20
1976	0	4	11	13	1	4	4	37
1977	3	2	7	10	4	6	0	32
1978	0	0	6	4	6	2	0	18
1979	1	0	2	12	20	1	1	37
1980	1	1	7	9	2	3	0	23
1981	0	0	5	10	6	3	1	25
1982	0	0	8	30	12	6	1	57
								249

POPULATION AND POPULATION GROWTH IN COLORADO

There is a close correlation between the population settlement pattern, population growth and the cost of disasters. As population settlement grows near areas susceptible to the occurrence of natural phenomena, more people may be impacted. As growth continues, and competition for remaining land increases, there is an incentive to develop land close to areas where extreme events are likely to occur.

To better understand the correlation between Colorado's population and the cost of disasters from very high risk phenomena, it is useful to consider the pattern of population dispersal in the State, the concentration of population relative to high risk areas, rates of population growth and development, and the pattern of tourist recreation near risk areas.*

* Population data used in this study is taken from publications of the Demographic Section, Colorado Division of Local Government



TORNADO OCCURRENCE IN COLORADO
1978 - 1982
MAP 1

Pattern of Dispersal

Nine Front Range counties account for 80 percent of Colorado's population. These are: Denver, Jefferson, Adams, El Paso, Arapahoe, Boulder, Pueblo, Larimer and Weld.

When 11 more counties (Mesa, Fremont, La Plata, Douglas, Montrose, Otero, Garfield, Morgan, Delta, Logan and Montezuma) are added to the nine listed above, 90% of Colorado's population is accounted for.

The remaining 10 percent of the population is widely dispersed over the other 43 counties where population densities are relatively low except for a few important cities and towns. See Table 5, page 14 for 1980 county census and growth figures.

Concentration of Population and High Risk Areas

Clearly the concentration of population in Colorado is centered along the Front Range - a region where high risk phenomena frequently occur. Big Thompson, the massive 1965 flood and the Thornton Tornado are examples of recent disastrous events that have developed from the combination of population concentration and the normal occurrence of high risk events. Also, a large number of high hazard dams are located in this region as is the largest number of people threatened by relatively high intensity earthquakes. Of course, extreme events threaten other population concentrations and these have occurred in most of the rest of the State, but the threat to urban areas of the Eastern Slope is paramount.

Population Growth

Colorado's population has continued to grow in recent years despite the leveling of growth elsewhere in the U.S. Population in 1970 in Colorado was 2.21 million, and in 1980 it was 2.89 million; the percentage change per year was about 3 percent. But this population growth did not occur uniformly across the State. Growth was concentrated in the high density longitudinal strip along the Front Range, that is, the nine counties discussed above which encompassed 80 percent of the population. Also, some "islands" of growth are noticeable in Western Slope counties, and in some areas where energy or recreational development has occurred. In all, 48 counties gained population since 1970 and 15 lost population -- mostly in the rural East and Southeast.

Cities with the most significant growth are located in areas of population concentration where risks of natural disasters are greatest.

Tourism Near Risk Areas

Colorado's tourist population presents another vulnerability concern. Many areas are very appealing in winter and summer to tourists who are unfamiliar with Colorado's natural hazards or typical safety measures. For example, Manitou Springs, which has a population of about 4,400, enjoys a much larger tourist influx. As many as 10,000 tourists may be in Manitou Springs at any given time. Other areas close to or in the canyons of the Front Range and the Western Slope are also heavily impacted by tourists during peak periods. Significant Front Range and Western Slope locations near potentially hazardous canyons have a population and tourist influx as shown in Table 2, which follows.

TABLE 2

Hazardous Canyons, Their Resident Population, and Tourist Influx

Canyon	Resident	Tourist
Big Thompson	1,300	2,980
Boulder	75,600	7,000
Clear Creek	20,900	20,000
Bear Creek	7,300	Not yet significant
Fountain & Monument	191,700	11,000
Animas	15,000	1,200
Arkansas	23,000	500
San Miguel	1,200	600
St. Charles	3,900	Not yet significant
Colorado River, Grand Junction	27,500	Not yet significant
North Fork, Gunnison River	1,000	Not yet significant

Note: These figures vary considerably from day to day.

(Data obtained from local planning agencies; figures represent the maximum number of tourists in one day.)

Population Summary

In general Colorado's population distribution, growth pattern and tourist influx underlie the rapidly increasing vulnerability and cost of disasters to the State. The close relationship between population concentration and areas in which very high risk phenomena have occured for many years in Colorado is an essential element of vulnerability and cost. But vulnerability and cost can be reduced significantly by efforts at hazard mitigation and preparedness.

TABLES 3, 4 and 5

COLORADO POPULATION AND POPULATION GROWTH

1980 CENSUS

Table 3 The Twenty-Five Largest Municipalities in Colorado, 1980

Rank in 1980	Name of Municipality	1980 Pop. (Final)	1970 Pop. (Final)	Rank in 1970
1	Denver	492,365	514,678	1
2	Colorado Springs	215,150	135,517	2
3	Aurora	158,588	74,974	5
4	Lakewood	112,860	92,743	4
5	Pueblo	101,686	97,774	3
6	Arvada	34,576	49,844	7
7	Boulder	76,685	66,870	6
8	Fort Collins	65,092	43,337	8
9	Greeley	53,006	38,902	9
10	Westminster	50,211	19,512	16
11	Longmont	42,942	23,209	14
12	Thornton	40,343	13,326	19
13	Wheat Ridge	30,293	29,778	11
14	Loveland	30,244	16,220	18
15	Englewood	30,021	33,695	10
16	Northglenn	29,847	27,785	12
17	Littleton	28,631	26,466	13
18	Grand Junction	28,144	20,170	15
19	Broomfield	20,730	7,261	29
20	Commerce City	16,234	17,407	17
21	Canon City	13,307	9,206	24
22	Brighton	12,773	8,309	25
23	Golden	12,237	9,817	23
24	Durango	11,426	10,333	21
25	Sterling	11,385	10,636	20

Table 4 Twenty-five Municipalities With The Greatest Population Growth, 1970-1980

Rank by Growth	Municipality	Numerical Increase 1970-1980	Percent Increase 1970-1980
1	Aurora	83,614	111.5
2	Colorado Springs	79,633	58.8
3	Arvada	34,732	69.7
4	Westminster	30,699	157.3
5	Thornton	27,017	202.7
6	Fort Collins	21,755	50.2
7	Lakewood	20,117	21.7
8	Longmont	19,733	85.0
9	Greeley	14,104	36.3
10	Loveland	14,024	86.5
11	Broomfield	13,469	185.5
12	Boulder	9,815	14.7
13	Grand Junction	7,974	39.5
14	Federal Heights	6,344	422.4
15	Lafayette	5,487	156.9
16	Fountain	4,809	136.8
17	Brighton	4,464	53.7
18	Craig	3,928	93.4
19	Pueblo	3,912	4.0
20	Canon City	3,831	41.6
21	Louisville	3,184	132.2
22	Steamboat Springs	2,758	117.9
23	Windsor	2,713	173.5
24	Greenwood Village	2,634	85.1
25	Evans	2,493	97.0

DIVISION OF LOCAL GOVERNMENT
1313 SHERMAN - 5th FLOOR
DENVER, CO. 80203

TABLE 5
PRELIMINARY JULY 1, 1981 POPULATION ESTIMATES AND POPULATION CHANGES OF COUNTIES IN COLORADO: APRIL 1, 1980 TO JULY 1, 1981

AREA NAME	JUL '81 ESTIM.	APR '80 CENSUS	NUMBER CHANGE	PER CENT CHANGE	ANNUAL GR RATE
STATE	2965000	2889735	75265	2.6	2.1
ADAMS	252500	245944	6556	2.7	2.1
ALAMOSA	12400	11799	601	5.1	4.1
ARAPAHOE	307000	293621	13379	4.6	3.6
ARCHULETA	4000	3664	336	9.2	7.3
BACA	5400	5419	-19	-0.4	-0.3
BENT	6000	5945	55	0.9	0.7
BOULDER	195800	189625	6175	3.3	2.6
CHAFFEE	13400	13227	173	1.3	1.0
CHEYENNE	2100	2153	-53	-2.5	-2.0
CLEAR CREEK	7600	7308	292	4.0	3.2
CONEJOS	7800	7794	6	0.1	0.1
COSTILLA	3100	3071	29	0.9	0.8
CROWLEY	3100	2988	112	3.7	3.0
CUSTER	1600	1528	72	4.7	3.8
DELTA	21900	21225	675	3.2	2.5
DENVER	499000	492365	6635	1.3	1.1
DOLORES	1800	1658	142	8.6	6.8
DOUGLAS	25900	25153	747	3.0	2.4
EAGLE	14400	13320	1080	8.1	6.4
ELBERT	7100	6850	250	3.6	2.9
EL PASO	314800	309424	5376	1.7	1.4
FREMONT	29100	28676	424	1.5	1.2
GARFIELD	24900	22514	2386	10.6	8.4
GILPIN	2600	2441	159	6.5	5.2
GRAND	8400	7475	925	12.4	9.8
GUNNISON	11300	10689	611	5.7	4.5
HINSDALE	400	408	-8	-2.0	-1.6
HUERFANO	6500	6440	60	0.9	0.7
JACKSON	1800	1863	-63	-3.4	-2.7
JEFFERSON	389100	371753	17347	4.7	3.7
KIOWA	1900	1936	-36	-1.9	-1.5
KIT CARSON	7500	7599	-99	-1.3	-1.0
LAKE	9100	8830	270	3.1	2.4
LA PLATA	27900	27195	705	2.6	2.1
LARIMER	148400	149184	-784	-0.5	-0.4
LAS ANIMAS	15200	14897	303	2.0	1.6
LINCOLN	4600	4663	-63	-1.4	-1.1
LOGAN	20200	19800	400	2.0	1.6
MESA	87100	81530	5570	6.8	5.4
MINERAL	900	804	96	11.9	9.4
MOFFAT	13400	13133	267	2.0	1.6
MONTEZUMA	17200	16510	690	4.2	3.3
MONTROSE	24900	24352	548	2.3	1.8
MORGAN	22700	22513	187	0.8	0.7
OTERO	22000	22567	-567	-2.5	-2.0
OURAY	2000	1925	75	3.9	3.1
PARK	5700	5333	367	6.9	5.5
PHILLIPS	4700	4542	158	3.5	2.8
PITKIN	11300	10338	962	9.3	7.4
PROWERS	13100	13070	30	0.2	0.2
PUEBLO	124700	125972	-1272	-1.0	-0.8
RIO BLANCO	7000	6255	745	11.9	9.4
RIO GRANDE	10900	10511	389	3.7	2.9
ROUTT	13700	13404	296	2.2	1.8
SAGUACHE	4000	3935	65	1.7	1.3
SAN JUAN	900	833	67	8.0	6.4
SAN MIGUEL	3000	3192	-192	-6.0	-4.8
SEDGWICK	3200	3266	-66	-2.0	-1.6
SUMMIT	9800	8848	952	10.8	8.5
TELLER	8500	8034	466	5.8	4.6
WASHINGTON	5200	5304	-104	-2.0	-1.6
WELD	123900	123438	462	0.4	0.3
YUMA	9700	9682	18	0.2	0.1

LOCAL PREPAREDNESS AND HAZARD MITIGATION

Vulnerability and the rising cost of natural disaster in Colorado can best be reduced by limiting settlement in hazardous areas. Mitigating the costs of disaster through governmental and private processes which encourage settlement away from historically hazardous areas not only reduces the chance for future catastrophe, but also generates a net benefit to the taxpayer since he does not have to spend money periodically on relief and recovery.

When risks cannot be avoided through efforts at mitigation, preparedness to effectively respond to the onset of extreme events can also reduce disaster vulnerability and cost. Preparedness depends on the ability of a community to ensure that its citizens are aware of their local vulnerabilities; that its citizens are given and recognize adequate warning of the potential onset of extreme events; and that they know the safety measures, escape routes or shelter that can offer protection.

These preparations should be incorporated in a simple, easy to understand plan. The essence of preparedness is then to practice, publicize and test a plan based on a given hazard, so that all are confident of their operational roles and responses.

Just as there is a correlation between distribution of population, growth and the cost of disasters, there is also a correlation between population and the ability of political entities to pay for mitigation and preparedness. As population increases, additional tax revenues can be made available to deal with commensurately increasing vulnerability. A growing tax base can yield increased funding for preparedness.

The maintenance of a balance between preparedness and vulnerability as growth continues will yield large net benefits over the long term. Large savings will accrue if citizens can be adequately warned and protected. Even larger savings will accrue to the community if development is managed with disaster mitigation in mind. For example, if zoning is carried on effectively, people can be diverted or provided incentives to avoid settling in a floodplain. Thus when periodic floods occur, repeated suffering and the costs of relief and recovery will not be necessary.

Currently, efforts are underway in Colorado to mitigate and prepare for the potential impacts of natural disaster. Most flood prone communities have entered into some form of floodplain management either by zoning or involvement in the Federal Flood Insurance Program. Most high risk communities -- those populated areas near hazardous zones -- have developed or are actively working on response plans oriented on local hazards. Exercises are being conducted to test community understanding of published plans.

The processes of mitigation and preparedness are underway but large risks and high vulnerability still exist. An important problem which is a distinct obstacle to progress has become increasingly clear. Differing entities -- principally city and county governments -- have not combined concepts, leadership authority, operational techniques and resources to mutually build preparedness. Means have not been developed except in a few unusual situations to achieve the integration necessary for effective preparedness. An outstanding example of success in integration however, is the Multi Area Response System (MARS) developed in Boulder County/City.

The Division of Disaster Emergency Services (DODES) has instituted an "On-site Preparedness" program to enhance and stimulate local efforts. DODES has visited* over half of Colorado's counties with the purposes of: assisting the county to improve its preparedness posture and to meet the standards imposed by the Colorado Disaster Act of 1973, integrating city, county and state plans and informing State agencies of local problem areas. Levels of preparedness are rising but a significant gap remains.

Despite rising preparedness levels, such realities as: the 1965 flood, the Big Thompson flash flood of 1976, the Thornton tornado of 1981, the Lawn Lake dam collapse of 1982, the number of high hazard dams in Colorado and the potential impact of a severe earthquake, result in an unmistakeable realization of very high risk. This risk evolves from the proximity of natural phenomena and a growing population in Colorado. The need for each community to be aware of its own vulnerability as a consequence of local natural hazards, population patterns and its status of preparedness is of crucial importance. Each community should analyze these relationships from their own local points of view.

* By January 1983

ANALYSIS OF INTERRELATIONSHIP BETWEEN NATURAL PHENOMENA, POPULATION PATTERNS AND LOCAL PREPAREDNESS

FLASH FLOODING AND POPULATION VULNERABILITY

Flash flooding almost anywhere in Colorado represents the highest vulnerability that Coloradans have to natural disaster. Most of Colorado's population is exposed to the risks of flash flooding. Even people who live on the eastern plains are periodically impacted. But in general those elements of the population who live near the canyons of the Front Range are in the greatest danger. People who live near other canyons across the State, mainly the Western Slope, are also seriously threatened.

A more specific way to identify those elements of Colorado's population that are particularly at risk is to examine the many canyons across the State which have been identified by the State Geologist as particularly susceptible to flash flooding and other geological hazards. Then each of these canyons can be compared to existing settlement patterns to determine those in which significant elements of the population live. Of the many canyons in Colorado susceptible to flash flooding, those shown at Table 6, below have important communities located near or in them. Elements of these communities are clearly at risk. Many other communities are also at considerable risk depending on their proximity to a dangerous canyon or stream. When flood areas are ranked by order of the most population at risk, that is those that have significant elements of the population living close to the flood area, results are as shown on Table 7. These areas are listed in the order of the number of people generally exposed to flash flooding; the highest numbers of population at risk are ranked first.

People who live in or near the areas shown on Table 7, page 19, are subject to the greatest risk in the State from flash flooding. They are in immediate danger, and must continue to take steps to increase their preparedness if a high level of readiness does not now exist. A study of the "Largest Known Floods at Various Front Range Locations" (analyzed by river basin) indicates that over 350 people have died as a result of flooding since the 1800's, see Annex D*. A local warning and evacuation plan is needed because the speed of onset of a flash flood is often so short that little time is available for

*Wayne E. Graham, P.E.

TABLE 6

Major Flash Flood Canyons of Colorado*

Canyon	County	Communities Affected
Animas River Tributaries	La Plata	Durango & Upstream
Arkansas	Fremont & Chaffee	Rockvale, Portland, Canon City, Texas Creek, Park Dale, Howard, Cleora, Salida, Buena Vista, Northrop, Vicksburg, St. Elmo, Winfield, Twin Lakes, Poncha Spgs., Garfield, Monarch, Coaldale
Bear Creek	Jefferson	Morrison, Kittredge, Evergreen, Tiny Town, Fenders, Aspen Park
Big Thompson	Larimer	Cedar Cove, Drake, Glen Haven, Loveland Hgts., Waltonia, Sylvandale, Big Thompson East
Boulder	Boulder	Boulder City & Canyon
Clear Creek	Jefferson & Clear Creek	Golden, Blackhawk, Idaho Springs; Empire, Georgetown, Silver Plume (These four communities are situated in the headwaters of Clear Creek)
Colorado River Tributaries	Mesa	Grand Junction, Fuita, MacCameo
Fountain and Monument Creeks	El Paso	Manitou Springs, Monument, Colorado Springs, Green Mountain Falls
North Fork, Gunnison River	Delta & Gunnison	Oliver, Somerset, Bowie, Paonia
San Miguel	San Miguel	Placerville, Sawpit, Telluride
St. Charles	Pueblo	Beulah, Valley View, Fairview, Colorado City, Rye

*Adapted from the State Geological Survey - List of Dangerous Canyons - See Annex A for a complete list.

TABLE 7

HIGH RISK FLOOD AREAS IN COLORADO*

Canyon		County
1.	Boulder Creek	Boulder
2.	Clear Creek	Jefferson and Clear Creek
3.	Bear Creek	Jefferson
4.	Fountain and Monument Creeks	El Paso
5.	Big Thompson	Larimer
6.	Animas River Tributaries	La Plata
7.	Arkansas River Tributaries	Fremont and Chaffee
8.	San Miguel River	San Miguel
9.	St. Charles River	Pueblo
10.	Colorado River Tributaries (Grand Junction Area)	Mesa
11.	North Fork of Gunnison River	Delta and Gunnison
12.	South Boulder Creek	Boulder
13.	So. St. Vrain Creek	Boulder
14.	South Platte (North Fork)	Douglas, Jefferson, Park
15.	Cache La Poudre	Larimer
16.	Buckhorn Creek	Larimer
17.	Crystal River	Gunnison
18.	Cimarron Creek	Gunnison & Montrose
19.	Rifle Creek	Garfield
20.	Roaring Fork River	Pitkin
21.	Left Hand Creek	Boulder
22.	Four Mile Creek	Boulder
23.	Rio Grande River	Mineral, Rio Grande, Alamosa
24.	Cucharas River	Huerfano
25.	Kiowa Creek	Elbert
26.	Republican River	Yuma

*Ranked by order of most population at risk. Specific elements of the population subject to high degrees of risk have not been determined because this depends upon more precise measurement and mapping of the area.

external help. Also, the terrain is such that Limon radar may not be able to pinpoint rain cells over the foothills such as the one which caused the Big Thompson flood. In general, the Limon radar can locate massive storm systems, but specific areas of precipitation are hard to identify. Checks are needed in individual valleys through spotter networks to determine amounts of precipitation that could be dangerous. As Colorado's population grows, it is likely that most of the areas described in Table 7 and many others in the State will be under pressure for further development, thus increasing the population at risk.

Tourists represent another element of the population at risk in Colorado's flood areas. During the spring and summer periods, when flash floods are likely to occur, the population densities in these areas are significantly increased by tourists. Tourists represent a particular danger, in that they are unfamiliar with the area and the propensity for flash flooding that may exist. They probably will not be familiar with warnings or escape routes, and may be less likely to respond effectively than permanent residents. Particular efforts must be made to warn tourists with roadside signs and instructions on what to do should flash floods occur. Preparedness to reduce vulnerability in these areas in particular has developed considerably in the last two years and response means have been significantly improved with better weather warning systems; see map 3, depicting NOAA* weather warning coverage around the State. But the overall vulnerability of canyon residents remains high because of the relatively short time of onset for most flash floods.

RIVERINE FLOODS, AND POPULATION VULNERABILITY

Significant elements of Colorado's population, particularly those that live along the Front Range and many of Colorado's Western Slope streams, are vulnerable to broadscale, riverine flooding. By and large, east of the Front Range, gradients are not steep, therefore time of onset of this type of flooding is slower than with flash floods. People who live here are more susceptible to property damage than loss of life, but property damage is likely to be very high. The flood of 1965 caused damages of over 500 million (in 1965) dollars. See Annex "C" for a list of the 14 most damaging floods in Colorado's recorded history, (from: The Flood Hazard Mitigation Plan for Colorado.) Should a similar storm occur again, damages would probably be much higher (not considering inflation) since more development has occurred and water run off rates are greater. As more people move into the Denver Metro area, damages and vulnerability must be expected to continue to increase despite effective planning now underway.

*National Oceanic and Atmospheric Administration

Population growth in Colorado's western counties has not been insignificant. Population densities in recreation, mining and energy producing areas are increasing rapidly. People are settling near streams that rise rapidly. Although spring rainfall is not normally heavy on the western Slope, concentrated rainfall from an intense storm when snowmelt run off is high, would constitute a significant danger. Vulnerability remains high.

From an overall state perspective at least 212 towns and cities and all of Colorado's 63 counties have been associated with flood prone areas; that is approximately 150,000 people, 62,000 houses and 1,200 commercial and industrial business structures are located in Colorado's floodplains. (Flood Hazard Mitigation Plan For Colorado)

EARTHQUAKES AND POPULATION VULNERABILITY

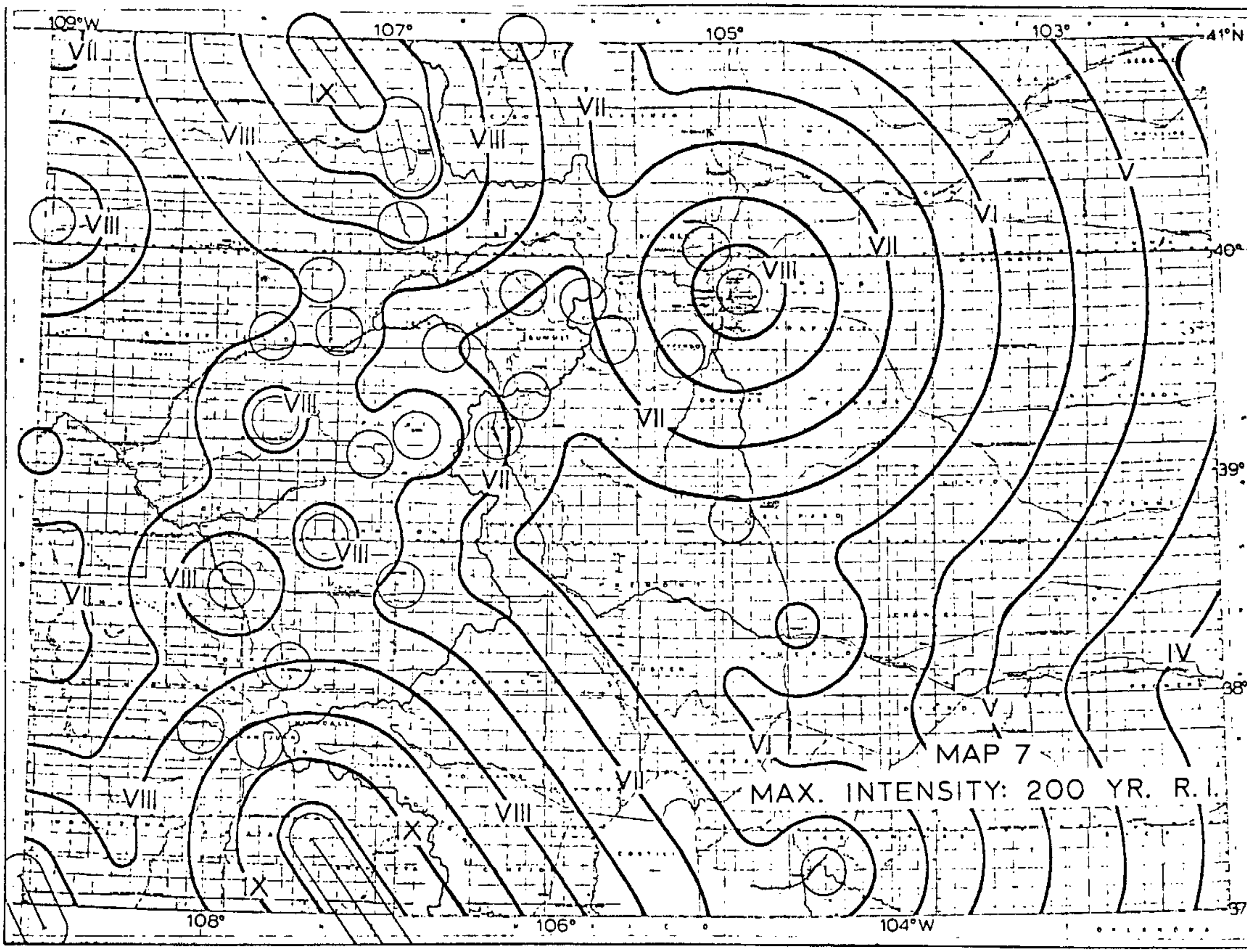
A current depiction of seismic risk to Coloradans is obtained by comparing the intensity map (map 2) on the next page to the modified Mercalli Scale on the following page. Roman numerals on the map are keyed to the scale. In other words, potential impacts described in the paragraph on earthquakes on page 5 can be expected across the State. Possibly the most dangerous of these are potential dam and other structural failures that can result near population centers. The relatively high intensities found near Denver, along the Front Range and on the Western Slope seriously increase the vulnerability of people living in these areas over that expected in the recent past.

DAM FAILURES AND POPULATION VULNERABILITY

There is some evidence that the existence of a dam tends to develop a sense of security in potential residents. Whatever the cause, settlement has frequently occurred below Colorado's dams. People settle in the potential inundation zone that would exist should catastrophic dam failure occur. More specifically, 228 dams in the State have been categorized by the State Engineer as "high hazard," that is: if the dam were to fail then there would be significant loss of life. At a lower level of risk to people and property (essentially property damage), 337 dams within the State are classified as "moderate hazard."* Only few lives have been lost in recent years from dam failure, but property damage has been

* Inundation zones for "high hazard" dams have been identified (with maps) by the State Engineer in his excellent publications which have been provided to local governments at low cost and result from the Colorado General Assembly legislation, known as "House Bill 1416."

Inundation zones for moderate hazard dams can be estimated with sufficient accuracy for local warning and evacuation planning by use of Annex F, "A Method for the Rapid Approximation of Dam Failure Floodplains in Colorado," William P. Stanton, P.E., Department of Natural Resources, Colorado Water Conservation Board.



22

MAP 2
U.S. Department of Interior
Geological Survey

Earthquake Intensity
(see next page for scale interpretation)

Modified Mercalli Intensity Scale
(from Richter, 1958)

I. Not felt. Marginal and long-period effects of large earthquakes.
II. Felt by persons at rest, on upper floors, or favorably placed.
III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.
V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D* cracked. Small bells ring. Trees, bushes shaken visibly, or heard to rustle.
VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, unbraced parapets, and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII. Steering of motor cars affected. Damage to masonry ; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.
X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslide. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI. Rails bent greatly. Underground pipelines completely out of service.
XII. Damage nearly total. Large rock masses displaced. Lines of light and level distorted. Objects thrown into the air.

* Note: Criteria for various grades of masonry construction described below.

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.
Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.
Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

Extracted from:
Earthquake Potential in Colorado
by Kirkham and Rogers

significant. The Lower Latham Dam (near Kersey in Weld County) failure in 1973 and the Prospect Dam (also in Weld County) failure in 1981 were by any standards fortunate as to loss of life. The Lawn Lake Reservoir dam failure in Larimer County (classified as a moderate hazard dam) unfortunately cost 3 (possibly 4) lives in 1982, but again Coloradans and our visitors were fortunate. National experience has shown that those who live in a potential inundation zone are doing so in some instances at very high risk. Colorado's degree of seismic activity across the State, the old age and design characteristics of many of our 2,249 dams and the high probability of flash flooding across the State intensifies this degree of risk. Of these high hazard dams, 26 are currently also identified as "unsafe." These dams are unsafe usually because spillways are too small to pass the run off from a probable maximum precipitation event. See Annex "B" for a list of unsafe, high and moderate hazard dams.

Residents who live "downstream" from a dam may be at significant risk, so that the aggregate problem for exposed communities to prepare safety measures for those at risk is urgent. National experience has shown that a significant number of lives can be saved in event of dam failure if people can be warned and evacuated. People in potential inundation zones must be made aware of the danger, local dam failure warning signals and available evacuation routes. It follows that there is a strong moral as well as legal obligation to Colorado's governments to develop and test plans which can provide adequate safety measures.

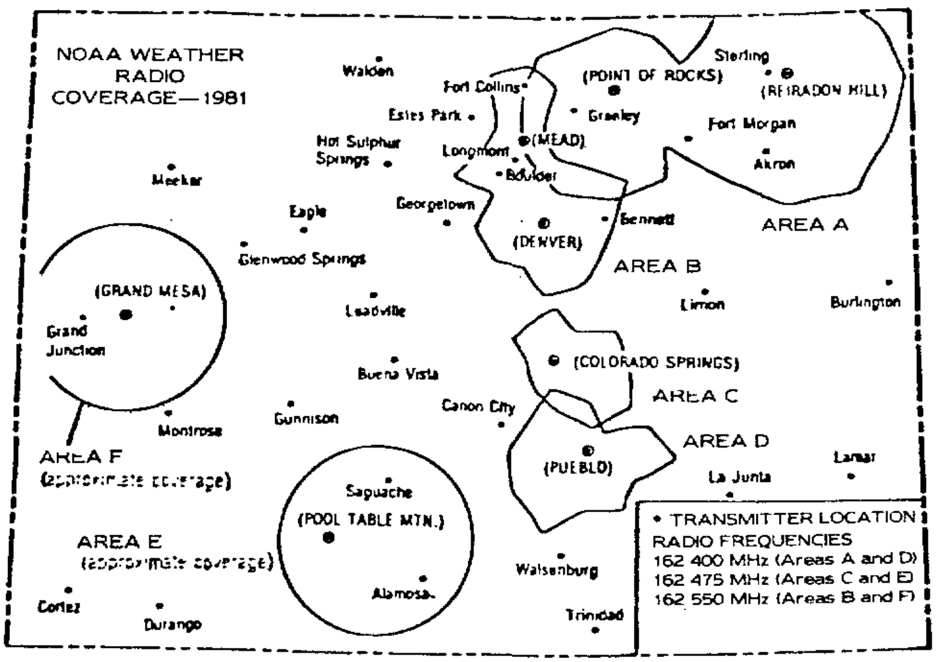
The State Engineer's list of high hazard dams has received wide publicity in Colorado. Every community exposed to possible dam failure should undertake preparedness measures with a sense of urgency. Specifically, communities should review their own situations to identify people and property at risk, then take those actions necessary to expeditiously prepare warning and evacuation plans for those determined to be at risk. Essential steps for planners are: (1) coordinate with dam owners or staff to determine failure or warning notification procedures for the dam site, (2) obtain or develop worst case estimates of flooding (or inundation maps in some cases where large numbers of people are exposed or when feasible to accomplish by dam owners with significant mapping capability) and (3) obtain flood wave travel times (assuming complete failure) to those people or communities who are in the worst case inundation zone. When these data have been determined, a plan may be formulated, publicized and tested at very low local expense.

To stress Coloradan's vulnerability to this very high risk hazard, here are some examples of the number of high hazard dams in some Front Range and Western Slope counties: Larimer - 59, Jefferson - 21, Montezuma - 7, Eagle - 5, Mesa - 4, Delta - 12, Gunnison - 8, Summit - 6, Weld - 15. In Summit and Garfield counties the Dillon and Rifle Gap Reservoir Dams threaten almost the entire cities of Silverthorne and Rifle respectively. In all, 42 counties contain 1 or more high hazard dams. Large numbers of Coloradans and tourists mainly in the Front Range counties and in developing areas of the Western Slope are exposed to this hazard. The vulnerability of these people is very high and will remain so until every community plan for response to dam failure flooding is developed, tested and kept current.

TORNADOS AND POPULATION VULNERABILITY

Tornados occur in the eastern plains every year. The relatively high frequency of occurrence in the plains counties is shown on Map 1, discussed earlier. This reflects a 5 year observation of occurrence and depicts the broad areal spread east of the Continental Divide and the incidence of tornadic events in Front Range, foothills counties. While loss of life and property has been rare, vulnerability is growing. As population spreads towards the East much greater vulnerability will develop, since this has been a low density, relatively high frequency region. To better understand community vulnerability to tornados, it is useful to compare community population densities with the incidence of tornadic activity. Where population densities and incidence of tornadic activity are highest, the greatest aggregate vulnerability exists. Note that in table 4, growth in many of Colorado's Eastern Slope cities has been significant; densities are also growing. The danger to the Front Range urban strip is great indeed. But lower density areas are faced with enough tornadic activity every year so that they can not relax. The example of the Thornton tornado will be repeated; a tornado path will intersect the settlement pattern and loss of life and significant damage will periodically occur.

Any Eastern Slope community must realistically expect and prepare for tornado impact, particularly during May, June and July. Schools are among the most vulnerable elements of our society since adequate basement shelters almost universally do not exist in Colorado. But some shelter, such as a strong interior room is better than none, and as warning systems improve, some reduction in vulnerability is possible. Map 3 shows NOAA weather warning coverage of the State. If citizens, nursing homes, schools, NOAA Weather Radio broadcasters, in all parts of the U.S., are made on one of three high band FM frequencies. The frequencies, in megahertz, and the current Colorado stations are given in the accompanying figure.



This figure shows the coverage of NOAA Weather Radio as of late 1981. The system is designed so that six different messages are transmitted in each of the areas, A through F. The irregular outlines indicating coverages of Areas A through D are relatively accurate since the effects of topography surrounding the transmitting stations have been taken into account. The coverages in Areas E and F are approximate. In Area A the same message will be transmitted at the same time on the same frequency ("simulcasting") from Point of Rocks and Reiradon Hill. This is also true for transmissions from Mead and Denver in Area B.

and businesses in the coverage area purchase relatively inexpensive (approximately $35.00), tone activated radios, vulnerability can be significantly reduced. Community warning systems are also vitally important. Money expended on these systems will eventually be repaid manyfold.

CONCLUSIONS AND RECOMMENDATIONS

Coloradan's vulnerability to the five natural events discussed in this study is very high. Flash and riverine flooding, earthquakes, dam failure flooding and tornados have such enormous impact and in all cases except riverine flooding have such speed of onset that reductions of vulnerability through preparedness is difficult.

Those people who live in or close to Colorado's major canyons and flood areas, particularly those along the Front Range, are in continuing danger. Heavy rainfall over any one of these canyons could result in a rushing torrent of water which destroys people and property in the way. Boulder, Clear, Bear, Fountain and Monument Creeks and the Big Thompson are some of the better known areas at risk. Also, sustained rainfall particularly in the spring over Colorado's major rivers can yield a predictable, large scale flood that will do great damage.

Earthquakes may occur with enough intensity to cause massive building and property destruction and loss of life in Denver and other Front Range cities. A repetition of the 1882 event would probably cause heavy loss. At the lower end of the earthquake intensity scale, many Coloradans across the State live in continual risk of a resulting dam failure flooding. Dam failure may be brought on by other events, but regardless of cause a very large number of Coloradans are at risk. Again, gradients in the State are steep enough that times of onset are likely to be very short. Governments across the State have been informed of the location of high hazard dams so that threatened elements of population have been identified in very general terms. Further identification and site specific planning by local governments concerned is a prime need.

High vulnerability from tornados affects the entire Eastern Slope region primarily in May, June and July. Vulnerability is growing as population concentrates in the foothills of the Front Range and as expansion towards the East continues. Most vulnerable are mobile homes, buildings without basements, and schools. Warning systems are improving, but speed of onset of tornados is so rapid that response times are inordinately short and unlikely to yield sufficient time for full protection.

Since a clear correlation exists between population size and density and the cost of disasters, it follows that Colorado's growth continues to intensify potential costs and vulnerability. Should the State's population grow in the next decade as rapidly as the last, that is by almost 30 percent, vulnerability will increase dramatically. Lower levels of growth will commensurately increase vulnerability. There is another acute problem additionally inherent to this growth since people are choosing to settle in many areas along the Front Range where extreme events are most likely. This is the high relief (difference in altitude), relatively high rainfall, region of the State. Fairly high intensity earthquakes have and can occur again in this area. Tornados occur in the foothills as well as across the eastern plains.

This increasingly high vulnerability along the Front Range and indeed across the State can only be reduced through better preparedness and mitigation -- mainly at the State and local levels.

COUNTY PREPAREDNESS

In general, the nine counties (Denver, Jefferson, Adams, El Paso, Arapahoe, Boulder, Pueblo, Larimer and Weld) that account for 80 percent of Colorado's population have developed plans which bear with considerable specificity on key local hazards. These county plans generally stress responses within unincorporated areas of the county, leaving incorporated entities to develop their own plans. In most cases in these counties, cities have also begun to develop their own reasonably effective plans. Also, many of these entities have held exercises to test their plans. Many have begun to develop recovery plans dealing with such issues as: damage assessment, debris clearance, and temporary housing. Some of these entities in the 80 percent population "slice" have developed effective response systems to carry out their plans and in many cases can cope with emergency situations of fairly large scale without outside help.

Counties, cities and towns which comprise the next 10 percent (up to 90 percent as described on pages 8 and 10, when counties are considered in terms of total population) of the State's population have not progressed quite so far. Many of these entities are still lacking written plans or existing plans lack sufficient specificity. The quality of these plans ranges from excellent to poor. Some have exercised their plans and have dedicated response organizations -- some have paid little attention to preparedness issues. Most of these entities would require State assistance in a large or medium scale emergency situation.

Many of the entities which comprise the last 10 percent of Colorado's population (when listed in order of total population as described on pages 8 and 10) have effective life saving plans and organizations under a sheriff, police, or fire authority that will effectively save lives when extreme events occur. Perhaps their relative isolation has generated a high degree of awareness of local threats and interest in self preservation through preparedness. But most will need rapid and effective support from the State Government to cope with damage assessment and recovery operations if not with lifesaving.

Local preparedness in recent years in general has improved significantly. A broad-scale program of emphasis, including systematic "on-site" preparedness visits and many other assistance techniques has stimulated local thought and effort. Concern with preparedness at the local level is for the most part genuine and growing. Local leadership is demanding a higher level of performance from their preparedness officials. There is a strong overall basis for optimism that the preparedness status of most counties will continue to improve.

A concern which detracts from this progress is the continuing reluctance of various political entities to integrate their plans and operational systems. The events described in this study are of such potential magnitude that no town, city or county can expect to cope with a large or moderate scale emergency without assistance. Integration of closely related entities' capabilities is the most cost efficient means of response; State assistance follows after full scale local efforts are committed.

Overall, the enormity and areal spread of the high risk events described in this study are of such a magnitude that a massive event in a populated area will still cost many lives. Possibly because of better preparedness, fewer lives may be lost today than would have been lost just a few years ago; but considering rates of growth in high risk areas, this may not be true. Certainly, if growth continues without commensurate stress on preparedness in the most hazardous areas, larger losses in lives and property will eventually occur. The priority of preparedness emphasis should be on those exposed to very high risks -- those who live in canyons, along rivers, below dams and in tornado and earthquake prone areas. Effective preparedness against disaster requires that all entities:

1. Study their own local high risk hazards and relate them to the existing settlement pattern; determine high priority vulnerabilities.

2. Develop plans with sufficient specificity to deal with high priority risks and vulnerabilities; these plans should include life and property saving measures as well as steps towards recovery.

3. Develop response systems capable of carrying out their plans; integrate plans with other potentially involved entities.

4. Test and publicize plans and safety measures; forward a copy of plans to the Division of Disaster Emergency Services so as to better integrate state-local planning.

The high risks described above only emphasize the continued need for local entities to fully adopt the above recommendations and for them to stress mitigation -- particularly zoning (or more broadly, hazard area reduction) to limit settlement in high hazard areas. Many efforts at mitigation are exposed to extreme political pressures -- for development for example. Still, over the long term mitigation is the least expensive means of reducing the costs which will evolve from the events discussed here.

STATE PREPAREDNESS

Historically, State Government has not demonstrated a deep concern for preparedness against Colorado's very high risk hazards. Prior to 1978 comprehensive Statewide written hazard assessments, plans detailing the roles of State agencies, money to train local and State preparedness officials, Statewide emergency communications or even on-site, full time management of the Division of Disaster Emergency Services were not provided for. At the time of the Big Thompson Flood only a plan oriented on nuclear attack existed in Larimer County; the State Plan was also mainly oriented on nuclear attack. The general approach by the branches of State Government was to utilize as much federal support as possible in providing preparedness for Coloradans.

Although this policy could be described as frugal, it failed to provide Coloradans with the range of support necessary to adequately mitigate, respond to and recover from extreme natural events which could occur at the local level. This area of governmental work was recognized as a developing field and its growth was largely stimulated by federal initiative. Significant state initiative emerged in 1979 when a full time management position for the Division of Disaster Emergency Services as well as funds to upgrade State emergency communications and for periodic activation of the State Emergency Operations Center were approved. The Governor also took a strong role by reviewing and strengthening DODES capabilities. He strongly supported an aggressive "on-site" program to improve local preparedness and took a variety of other measures to stimulate progress.

In recent years a number of disasters of significant magnitude have occurred in Colorado; six have received Presidential declarations since 1965. State declared disasters have also occurred in significant numbers; (see Annex "E" for federal and state disasters declared in Colorado).

The State's ability to provide assistance to local entities has grown significantly in the last two years. Better understanding, awareness, measurement of weather phenomena as well as more effective warning systems are available and being utilized. A strongly improved emergency communications capability is developing so that redundant systems can extend across the State. A computer system has been installed in DODES. Statewide exercises have improved critical response capabilities. State agencies have disaster coordinators and internal disaster plans oriented on the State Plan. Much greater emphasis is placed on inter-government coordination: local - state - federal. Increasing concern for emphasis on mitigation has been developed.

Thus far, positive changes can be identified. But overseeing the additional planning, training, operational and resource management effort across the State will require greater effort at the local and State level to match growing vulnerabilities and needs. Expenditures for preparedness in the near term will be inexpensive compared to the longer term costs to the State which will inevitably occur if the State is not fully prepared to deal with its very high risk hazards. Colorado should continue to raise its own preparedness now to save lives, property and money later.

STATE OF COLORADO

RICHARD D. LAMM
Governor

JOHN W. ROLD
Director

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
715 STATE CENTENNIAL BUILDING — 1313 SHERMAN STREET
DENVER, COLORADO 80203 PHONE (303) 892-2611

June 27, 1977

HAZARDOUS CANYONS IN COLORADO

The drainage areas and their associated tributaries and canyons listed below have been identified by the Colorado Geological Survey as containing potentially hazardous geological conditions. Intense rainfall may cause flash flooding, debris movement, rock fall, landsliding, and erosion.

These areas have been selected for the intensity and degree of potentially hazardous geological conditions and the intensity of current development coupled with projections of near-term and future development pressures. Only areas west of the mountain front are included. This list does not indicate, by omission or inclusion, all areas which may be hazardous.

For each area listed, the following information is presented.

1. The general name of the drainage area (the major drainage) for identification of the general area only. The hazardous canyons and tributaries are not all listed.

2. The county(ies) in which the potentially hazardous area lies.

3. The community(ies) affected by the hazard.

Drainage Area	County(ies)	Community(ies) Affected
Animas River (Durango)	La Plata	Durango, Animas City
Apishapa River	Las Animas	Aguilar, Gulnare
Arkansas River (near Florence)	Fremont	Florence, Rockvale, Portland, Canon City
Arkansas River (Salida to Parkdale)	Fremont, Chaffee	Parkdale, Texas Creek, Cotopaxi, Coaldale, Howard, Wellsville, Cleora, Salida
Upper Arkansas River	Chaffee, Lake	Buena Vista, Nathrop, Vicksburg, St. Elmo, Winfield, Twin Lakes
S. Arkansas River (Poncha Springs to Monarch)	Chaffee	Poncha Springs, Maysville Garfield, Monarch
Bear Creek	Jefferson	Tiny Town, Fenders, Morrison, Idledale, Kittredge, Evergreen, Rosedale, Brookvale, Aspen Park
Big Thompson River and North Fork	Larimer	Cedar Cove, Drake, Glen Haven, Waltonia, Glen Comfort, Estes Park
Lower Blue River (Dillon to Green Mountain Reservoir)	Summit	Silverthorne, Heeney

ANNEX A

Drainage Area	County(ies)	Community(ies) Affected
per Blue River	Summit	Breckenridgè
ulder Creek	Boulder	Boulder and Vicinity
Brush Creek, Eagle River	Eagle	Eagle
Buckhorn Creek	Larimer	Masonville
Cache La Poudre, North Fork	Larimer	Ted's Place, Poudre Park, Eggers, Rustic
Cimarron River	Montrose, Gunnison	Cimarron and new subdivisions
Clear Creek, Tucker Gulch	Jefferson, Clear Creek	Golden, Blackhawk, Idaho Springs, Empire, Georgetown, Silver Plume, Central City
Crystal River	Gunnison	Marble
Cucharas River	Huerfano	Walsenberg, La Veta, Three Bridges
Eagle River	Eagle	Minturn, Redcliff
Colorado River, Elk Creek, Canyon Creek	Garfield	New Castle
Colorado River (Grand Junction area)	Mesa	Grand Junction, Fruita, Mack, Cameo
Colorado River (Rulison to DeBeque)	Mesa, Garfield	Rulison, Grand Valley, DeBeque
Dolores River	Dolores	Rico
untain Creek, ument Creek	El Paso	Colorado Springs, Monument
Gore Creek	Eagle	Vail
Grape Creek	Custer, Fremont	Canon City, Westcliffe
Gunnison River, East River, Slate River, Coal Creek	Gunnison	Crested Butte, Almont
Henson Creek	Hinsdale	Lake City
Hermosa Creek	La Plata	Hermosa
La Jara Creek	Conejos	
Left-Hand Creek	Boulder	Jamestown
Little Thompson River	Larimer	No town - cabins in upper reach
Mancos River	Montezuma	Mancos
McElmo Creek	Montezuma	Cortez

Drainage Area	County(ies)	Community(ies) Affected
Michigan River	Jackson	Gould, Lindland
North Fork Gunnison River	Delta, Gunnison	Oliver, Somerset, Bowie, Paonia
Plateau Creek	Mesa	Colbran, Plateau City, Molina, Mesa
Purgatoire Creek	Las Animas	Trinidad, Jansen, Sopris, Cokedale, Tijeras, Valdez, Segundo, Weston, Vigil, Stonewall
Rifle Creek	Garfield	Rifle
Rio Grande River	Mineral	Creede
Roaring Fork River	Pitkin	Aspen and suburbs
Roaring Fork River	Garfield	Glenwood Springs and suburbs
St. Charles River	Pueblo	Beulah Valley View, Fairview, Colorado City, Rye
St. Vrain Creek	Boulder	Lyons, Raymond
San Juan River	Archuleta	Pagosa Springs
San Miguel River	San Miguel	Telluride, Saw Pit, Placerville
South Boulder Creek	Boulder, Gilpin, Jefferson	Coal Creek, Pinecliffe, Eldorado Springs, East Boulder
South Platte River and North Fork	Douglas Jefferson Park	Kassler, Deckers, Buffalo Creek, Bailey, Grant, Webster
Tenmile Creek	Summit	Frisco, Copper Mountain
Uncompahgre River	Ouray	Ouray
Vallecito Creek	La Plata	Subdivisions of Reservoir
West Plum Creek	Douglas	
White River (Meeker area)	Rio Blanco	Meeker
Yampa River, Soda Creek, Butcher Knife Creek, Fish Creek	Routt	Steamboat Springs
Yampa River, Fortification Creek	Moffat	Craig
Yampa River	Moffat	Dinosaur National Monument Campgrounds

COLORADO'S HIGH, MODERATE [illegible]RD AND UNSAFE DAMS - 1983

ANNE[illegible]

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
ADAMS	Badding (Croke)	H	24.0	44.	1/7
	Barr Lake	H	47.0	32150.	1/2
	Kalcevic	H	42.0	112.	1/7
	Lower Latham	H	23.0	6212.	1/2
	Niver Creek Det.	H	42.0	580.	1/2
	Niver Creek Det.	H	42.0	580.	1/2
	East Lake #2	M	12.0	198	1/1
	East Lake #3	M	12.0	800.	1/1
	Northglenn Terminal	M	17.0	120.	1/1
	Ottio Lake	M	16.0	112.	1/1
	Todd	M	16.0	46.	1/1
	Webster Lake East	M	14.0	54.	1/1
	Copeland	M	12.0	133.	1/6
	Croke Lake	M	22.0	43.	1/6
	Dewey #1	M	15.0	54.	1/6
	Boot Leg	M	49.0	6190.	1/1
ALAMOSA	NONE				
ARAPAHOE	Cherry Creek	H	140.0	240684.	1/8
	Englewood	H	55.0	1850.	1/8
	Holly	H	40.0	230.	1/8
	Mc Clellan	H	111.0	6000.	1/8
	Patrick Lake	H	10.0	1284.	1/8
	Quincy	H	68.0	2800.	1/2
	Windsor	H	20.0	200.	1/2
	Tule Lake Upper	M	11.0	84.	1/7
	Ward #5	M	10.0	216.	1/8
	Echo Canyon	M	68.0	2149.	6/58
	Spence	M	44.0	441.	6/58
	Town Center	M	34.5	700.	6/58
	Pargin	M	35.5	450.	7/71
	Stevens	M	30.0	635.	7/71
	Sullenburger	M	30.0	1491.	7/71
ARCHULETA	Hatcher	H	55.5	1735.	7/78
BACA	Two Buttes **	H	106.0	40918.	2/67
BENT	Adobe Creek	H	35.0	85000.	2/17
	John Martin	H	120.0	631000.	2/67
BOULDER	Barker Meadow	H	177.0	11500.	1/6
	Baseline	H	40.0	5300	1/6
	Beaver Park **	H	33.0	2161	1/5
	Boulder	H	44.0	17400.	1/6
	Button Rock	H	205.0	20100.	1/5
	Clover Basin	H	34.0	596.	1/5
	Foothills	H	52.0	4346.	1/5
	Gross	H	330.0	40987.	1/6
	Hayden	H	21.0	502.	1/6
	Lagerman	H	22.0	923.	1/5
	Lefthand Park	H	50.0	1528.	1/5
	Leggett & Hillcrest	H	67.0	11100.	1/6
	Marshall Lake	H	80.0	10462.	1/6
	Pleasant Valley	H	19.0	3076.	1/5
	Silver Lake	H	71.0	3987.	1/6
	Six Mile	H	35.0	1100.	1/6
	Valmont "A"	H	67.0	11163.	1/6
	Waneka **	H	30.0	710.	1/6
	Ish #3	M	42.0	7344	1/3
	Allen Lake	M	17.0	589.	1/4
	Bluebird	M	55.0	966.	1/4
	Clark	M	6.0	84.	1/4
	Crystal	M	11.0	140.	1/4
	Gaynor	M	15.0	614.	1/4
	Gold Lake	M	27.0	1343.	1/4
	Highland #2	M	37.0	3713	1/4
	Left Hand	M	13.0	25.	1/4

** UNSAFE DAM

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT	
BOULDER	Lefthand Valley	M	51.0	3783.	1/4	
	Margarot Spurgeon #1	M	32.0	254.	1/4	
	Mc Call	M	20.0	506.	1/4	
	Mc Intosh	M	17.0	2460.	1/4	
	Olligalchy #1	M	18.0	1737.	1/4	
	Sand Beach	M	25.0	297.	1/4	
	Albion Lake	M	44.0	1111.	1/5	
	Davis #1	M	11.0	137.	1/5	
	Erie	M	12.0	269.	1/5	
	Goose Lake	M	35.0	1036.	1/5	
	Green Lake #2	M	52.0	423	1/5	
	Jasper	M	22.0	326.	1/5	
	Louisville #1	M	20.0	187.	1/5	
	Mesa Park	M	30.0	140.	1/5	
	Panama #1	M	40.0	4989.	1/5	
	St. Joe	M	37.0	36.	1/5	
CHAFFEE	Clear Creek	H	70.0	11444.	2/11	
	Twin Lakes	H	60.0	141000.	2/11	
	Boss Lake	M	45.0	108.	2/10	
	North Fork	M	36.0	595	2/10	
CHEYENNE	NONE					
CLEAR CREEK	Clear Lake**	H	35.0	700.	1/7	
	Fall River	H	85.0	890.	1/7	
	Lower Cabin Ck. Hydele	H	66.0	1827.	1/7	
	Upper Cabin Ck. Hydele	H	174.0	1402.	1/7	
	Beaver Brook #3A	M	56.0	357.	1/6	
	Georgetown	M	24.0	292.	1/6	
	Green Lake.	M	20.0	170	1/6	
	Idaho Springs	M	33.0	215.	1/6	
	Loch Lomond	M	42.0	875.	1/6	
	Lower Urad	M	80.0	252.	1/6	
	Upper Chinns	M	28.0	110.	1/6	
	Upper Urad	M	111.0	700.	1/6	

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT	
CONEJOS	Platoro	H	165.0	60000.	3/22	
	Platoro	H	165.0	60000.	3/22	
	Terrace **	H	182.0	17416.	3/21	
	La Jara	M	40.0	14052.	3/20	
	Trujillo Meadows	M	36.0	913.	3/21	
COSTILLO	Mountain ** Home	H	125.0	18595.	3/35	
	Sanchez	H	130.0	103155.	3/24	
	Salazar H	M	25.0	133.	3/22	
	Smith	M	48.0	5808.	3/24	
CROWLEY	Lake Henry	M	18.0	11914.	2/16	
	Lake Meredith	M	30.0	26028.	2/16	
CUSTER	De Weese	M	58.0	1772.	2/12	
DELTA	Carl Smith**	H	55.0	864.	4/40	
	Cedar Mesa	H	70.0	897.	4/40	
	Crawford	H	162.0	14250.	4/40	
	Eggleston	H	31.0	2560.	4/40	
	Fruit Growers	H	55.0	5073.	4/40	
	Garnet Mesa	H	39.0	1333.	4/41	
	Kennicott Slough	H	36.0	490.	4/40	
	Marcot Park	H	39.0	448.	4/40	
	Monument	H	72.0	501.	4/40	
	Overland #1	H	60.0	5490.	4/40	
	Park	H	46.0	3400.	4/40	
	Barren	M	16.0	759.	4/28	
	Deep Slough	M	21.0	497	4/28	
	Good Enough #2	M	38.0	762.	4/28	
	Grandby #12	M	27.0	664.	4/28	
	Island Lake	M	16.5	1550	4/28	
	Kiser Slough	M	33.0	490.	4/28	
	Military Park	M	20.0	232.	4/28	
	Ward Lake	M	27.0	1710.	4/28	** UNSAFE DAM
	Weir & Johnson	M	21.0	631.	4/28	
	West #1	M	35.0	454.	4/28	

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
DELTA	Youngs Creek # 1 & #2	M	15.0	486.	4/28
	Youngs Creek #3	M	21.0	143	4/28
DENVER	Barnum Park Lake	M	20.0	51.	1/7
	Skeel	M	35.0	220.	1/7
DOLORES	Groundhog	H	125.0	21711.	7/69
	Dove Creek #1	M	24.0	95.	7/31
	Belmear Lake	M	37.0	467.	7/34
DOUGLAS	Cheesman	H	221.0	79064.	1/80
	Foothills Holding Pond	H	25.0	62.	1/8
	Allis	M	45.0	24.	1/7
	Aurora Rampart	M	48.0	1200.	1/7
	J.O. Hill	M	29.0	154.	1/7
	Waucondah	M	42.0	336.	1/7
	West Creek	M	18.0	68.	1/7
EAGLE	Climax-Mdly #4	H	143.0	2430	5/37
	Homestake Project	H	245.0	45600.	5/37
	Robinson	H	103.0	3136.	5/37
	Spring Park	H	25.0	2823.	5/38
	Benchmark Lake	M	17.0	109.	5/36
	L.E.D.E.	M	49.0	473.	5/36
	O-7	M	30.0	452	5/36
	Alicia Lake	M	13.0	600.	5/37
ELBERT	NONE				
EL PASO	Big Tooth Reservoir **	H	100.0	650.	2/10
	Crystal Creek **	H	90.0	5330.	2/10
	Fountain Valley #2	H	54.0	3950.	2/10
	Gold Camp	H	105.0	380.	2/10
	Lake Moraine	H	37.0	800.	2/10
	Manitou	H	123.0	700.	2/10
	Palmer Lake #2	H	44.0	200.	2/10

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
EL PASO	Ramah Det. Rec. **	H	48.0	5388.	2/67
	Rampart	H	230.0	38783.	2/10
	South Suburban	H	47.0	231.	2/10
	Woodmoor Lake	H	57.5	690.	2/10
	Woodland Park	M	60.0	60.	1/7
	Cheyenne Lake	M	12.0	205.	1/80
	Curr	M	31.0	310.	1/80
	Fountain Valley #3	M	30.0	700.	1/80
	Kettle Creek	M	80.0	2700.	1/80
	Monument Lake	M	54.0	310.	1/80
	Nichols	M	57.0	509.	1/80
	Northfield	M	30.0	276.	1/80
	Palmer Lake #5	M	35.0	116.	1/80
	Prospect Lake	M	11.0	368.	1/80
	R. D. Nixon	M	28.0	821.	1/80
	Spring Run #2	M	39.0	311.	1/80
	Valley No. 2	M	55.0	185.	1/80
FREMONT	Cannon Wtrsd. C-4	H	38.0	207.	2/12
	Cannon Wtrsd Det C-5	H	70.0	1141.	2/12
	Brush Hollow	M	85.0	4125	2/11
	Dry Ck. Flood Control	M	33.0	157.	2/11
	Florence #1 & #2	M	30.0	100.	2/11
	Mud Gulch Det. M6-1	M	61.0	432.	2/11
GARFIELD	Grass Valley	H	46.0	5058.	5/39
	Hughes **	H	25.0	573.	5/38
	Rifle Gap	H	100.0	12600.	5/39
	Stillwater #1	H	75.0	6088.	6/58
	Yamcolo Dam	H	97.0	9080.	6/58
	Consolidated	M	25.0	881.	5/37
	Hopkins	M	25.0	120.	5/37
	Harris	M	50.0	200.	5/38
	Meadow Creek	M	61.5	984.	5/38
	Park	M	34.0	164.	5/38
	[illegible]	M	26.0	680.	5/38

** UNSAFE DAM

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANK-MENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
GILPIN	NONE				
GRAND	Granby	H	65.0	543758.	5/51
	Matheson	H	58.0	1074.	5/50
	Meadow Creek	H	86.0	5750.	5/51
	Shadow Mtn. Grand Lake	H	40.0	18369.	5/51
	Williams Fork	H	224.0	93637.	5/51
	Willow Creek	H	125.0	10553.	5/51
	Mc Mahon	M	43.0	3500.	5/39
	Whitely Peak	M	49.0	773.	5/39
	East Ranch	M	120.0	2000.	5/50
	Monarch Lake	M	23.0	950.	5/50
	Musgrave	M	40.	500.	5/50
	Jones	M	34.0	69.	5/61
	Grimes-Brooks	M	30.0	426.	5/52
	Jones #1-	M	25.0	552.	5/52
	Sylvan	M	50.0	1300.	5/50
GUNNISON	Beaver	H	122.0	1620	4/40
	Blue Mesa	H	340.0	940800.	4/62
	Crystal	H	218.0	27240.	4/62
	Paonia	H	180.0	20900.	4/40
	Paonia	H	180.0	20900.	4/40
	Silver Jack	H	138.0	13520.	4/62
	Spring Creek*	H	50.0	1631.	4/59
	Taylor Park	H	200.0	106230.	4/56
	Fish Creek No. 2	M	24.0	300.	4/61
	Lake Arrowhead	M	27.0	334.	4/61
HINSDALE	Continental	H	92.0	22679.	3/20
	Rio Grande	H	100.0	51113.	3/20
	Road Canyon #1	M	20.0	1367.	2/67
	Trout Vale #2	M	13.0	435.	2/67
	Trout Vale #1	M	10.0	297.	2/67
	Williams Creek	M	84.0	10084.	7/71

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANK-MENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
HUERFANO	Cucharas #5 **	H	135.0	40960.	2/16
	Horse Shoe Lake	H	30.0	2760.	2/16
	Martin Lake	H	27.0	4880.	2/16
	N. Walsenburg Flood Con.	H	29.0	104.	2/16
	Waratoya Lake	H	24.0	274.	2/16
	Daigre	M	32.0	139.	2/15
	Walsenburg Water Sys.	M	22.0	430.	2/15
JACKSON	Butte	M	6.0	849.	6/44
	Lake John	M	25.0	11232.	6/44
	Lake Roslyn	M	35.0	290.	6/44
	Lower Big Creek	M	9.0	1434.	6/44
	North Michigan Ck.	M	62.0	1730.	6/44
	Pole Mountain	M	45.0	1905	6/44
	Walden	M	22.0	791	6/44
JEFFERSON	Bear Creek	H	179.5	55290.	1/9
	Bergen East	H	40.0	587.	1/9
	Blunn	H	72.0	5800.	1/7
	Chatfield	H	132.0	215000.	1/8
	East	H	17.5	175.	1/8
	Evergreen	H	34.0	669.	1/9
	Great Western	H	70.0	3253.	1/2
	Main	H	45.0	840.	1/8
	Maple Grove	H	56.0	406.	1/7
	Marston Lake	H	35.0	19795.	1/9
	Ralston	H	180.0	12750.	1/7
	Smith	H	22.0	466.	1/8
	Standley Lake	H	123.0	42380.	1/2
	Strontia Springs	H	299.0	7800.	1/8
	Tucker Lake	H	28.0	1096.	1/7
	Ward #1.	H		520.	1/9
	Wellington	H	56.0	4399.	1/80
	Ketner	M	29.0	212.	1/1

** UNSAFE DAM

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
JEFFERSON	Upper Church Lakes	M	23.2	226.	1/5
	Crown Hill Cemetery	M	9.0	291.	1/6
	Hyatt	M	29.0	1095.	1/6
	Leyden	M	40.0	1152.	1/6
	Lower Long Lake	M	8.0	257.	1/6
	Magic Mtn. #1	M	30.0	87.	1/6
	Oberon Lake #1	M	30.0	54.	1/6
	Pomona #2 & #3	M	22.0	116.	1/6
	Upper Long Lake	M	111.0	700.	1/6
	Johnson	M	16.0	821.	1/7
	Kendrick	M	20.0	332.	1/7
	Pinery	M	60.0	315.	1/7
	Bergen West	M	25.0	890.	1/8
	Bowles #1	M	15.0	2475.	1/8
	Carmody	M	11.5	22.	1/8
	Harriman	M	15.0	756.	1/8
	King Fisher Lake	M	32.0	125.	1/8
	Polly A. Deane	M	25.0	512	1/8
KIOWA	Nee Noshe	M	25.0	60618	2/19
	Queen	M	25.0	23040.	2/19
KIT CARSON	NONE				
LAKE					
	Sugar Loaf Dam	H	133.0	131054	2/11
	Evans Gulch No. 2	M	21.5	123.	2/10
	Mountain Lake	M	37.5	184.	2/10
LA PLATA	Durango Regulatory	H	40.0	227.	7/30
	Lemon	H	215.0	48700.	7/30
	Terminal	H	53.0	23254.	7/30
	Turner **	H	30.0	472.00	7/30
	Vallecito	H	162.0	129675.	7/31
	Haviland Lake	M	26.0	170.	7/29
	Johnson	M	41.0	1079.	7/29
	Keeler		43.0	488.	7/29

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
LA PLATA	Pastorius	M	26.0	295.	7/29
	Wommer #1	M	34.5	178.	7/30
	Red Mesa Ward	M.	59.0	1100.	7/32
LARIMER	Barnes Meadow	H	47.0	2349.	1/3
	Boyd Lake	H	44.0	58524	1/4
	Cache La Poudre	H	43.0	9900.	1/3
	Carter Lake No. 1	H	214.0	112000.	1/4
	Carter Lake No. 2	H	75.0	112000.	1/4
	Carter Lake No. 3	H	55.0	112000.	1/4
	Chambers Lake	H	55.0	8854.	1/3
	Cobb Lake	H	58.0	22300.	1/3
	Comanche **	H	40.0	2629.	1/3
	Dixon Canyon	H	240.0	152000.	1/3
	Douglas **	H	39.0	9364.	1/3
	Elder	H	25.0	2296.	1/3
	Fossil Creek	H	47.0	11508.	1/3
	Halligan	H	78.0	6428.	1/3
	Handy	H	31.0	4548.	1/4
	Horsetooth	H	155.0	152000.	1/3
	Hourglass	H	45.0	1694.	1/3
	Indian Creek	H	34.0	1906.	1/3
	Joe Wright	H	120.0	7200.	1/3
	Klover	H	25.0	1147.	1/3
	Lake Loveland	H	46.0	12736.	1/4
	Lily Lake	H	18.0	30.	1/4
	Lon Hagler	H	61.0	5032.	1/4
	Long Draw	H	84.0	11000.	1/3
	Long Pond	H	35.0	4040.	1/3
	Harland	H	30.0	5570.	1/4

** UNSAFE DAM

COUNTY	E AM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
LARIMER	Milton Seaman	H	89.0	5008	1/3
	N Poudre #15	H	48.0	5526	1/3
	N Poudre #2	H	20.0	3910	1/3
	N Poudre #3	h	38.0	3441.	1/3
	N Poudre #5	H	33.0	8398.	1/3
	N Poudre #6	H	38.0	9968.	1/3
	Panhandle	H	47.0	2349.	1/3
	Park Creek	H	79.0	7343.	1/3
	Peterson Lake	H	62.0	1184.	1/3
	Rawhide	H	90.0	15400.	1/3
	Richards	H	21.0	726.	1/3
	Rocky Ridge	H	35.0	4479.	1/3
	Satanka Dike	H	30.0	152000.	1/3
	Soldier Canyon	H	226.0	152000.	1/3
	Spring Canyon	H	220.0	152000.	1/3
	Terry Lake	H	36.0	8145.	1/3
	Water Supply No. 3	H	41.0	4826.	1/3
	Water Supply No. 4	H	28.0	1466.	1/3
	Windsor #8	H	60.0	10291.	1/3
	Annex #8	M	52.0	3657.	1/2
	Box Elder #3	M	20.0	298.	1/2
	Clarks Lake	M	34.0	871.	1/2
	Claymore	M	20.5	1018.	1/2
	College #3	M	18.0	711.	1/2
	Curtis Lake	M	20.0	1259.	1/2
	Dixon Canyon	M	14.0	448.	1/2
	Dowdy Lake	M	25.0	900.	1/2
	Floodwater Ret. B-2	M	56.0	6470	1/2
	Floodwater Ret. B-3	M	50.0	3839.	1/2
	Floodwater Ret. B-4	M	28.0	1270.	1/2
	Floodwater Ret. B-5	M	80.0	1578.	1/2
	Floodwater Ret. B-6	M	73.5	1496	1/2
	Gray #3	M	17.0	100.	1/2
	Haviland	M	45.0	700.	1/2
	Mitchell #1	M	14.0	580	1/2
	North Grey	M	20.0	287.	1/2

CO Y	NAME OF DAM	M-Moderate	MENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
LO	Dickinson Irrigation	M	21.0	57.	1/49
MESA	Indian Wash Det	H	65.0	1615.	5/72
	Jerry Creek #1	H	56.0	1100.	5/72
	Jerry Creek #2	H	150.0	6320.	5/72
	Juniata	H	108.0	2684.	4/72
	Vega	H	162.0	33800.	5/72
	Anderson #1	M	26.0	467.	4/41
	Anderson #2	M	23.0	669	4/41
	Belen	M	25.0	818.	4/41
	Deed Creek #2	M	31.0	526	4/41
	Flowing Park	M	26.5	1359	4/41
	Fruita #1	M	47.0	143	4/41
	Fruita #2	M	40.0	168	4/41
	Gobro #1	M	33.0	227.	4/41
	Gobro #3	M	45.0	198.	4/41
	Grand Mesa #8	M	16.0	379.	4/41
	Hallenbeck #1	M	40.5	910.	4/41
	Hallenbeck #2	M	36.0	464.	4/41
	Hogchute	M	53.0	520.	4/41
	Casto	M	24.0	803.	4/62
	Craig #1	M	32.0	525	4/62
	Craig #2	M	47.0	544.	4/62
	Big Creek #1	M	22.9	788.	5/53
	Big Creek #3	M	45.0	1581.	5/53
	Bonham-Wells	M	32.0	1220.	5/53
	Bull Creek #4	M	29.5	313.	5/53
	Bull Creek #5	M	28.0	236.	5/53
	Coon Creek #1	M	13.0	769.	5/53
	Cottonwood #1	M	17.0	1578.	5/53
	Cottonwood #2	M	11.0	221.	5/53
	Cottonwood #4	M	12.0	310.	5/53
	Cottonwood #5	M	11.0	334.	5/53
	Gardner	M	24.0	32.	5/53
	Leon Lake	M	26.0	2504.	5/53
	Mesa Creek #4	M	23.0	497.	5/53
	Mesa Lake #1	M	24.0	270.	5/53
	Monument #1	M	31.0	450.	5/53
	Monument #2	M	20.0	254.	5/53

** UNSAFE DAM

COUNTY	NAME OF DAM	H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/DISTRICT
MESA	Pa[illegible] Bas[illegible]	M	19.0	166.	5/53
	Rapid Creek #1	M	24.0	1152.	5/53
	Rapid Creek #2	M	22.0	982.	5/53
	Somerville-Mc Cullah	M	42.0	862	5/53
	Upper Highland	M	80.	4340.	5/53
	Vincient #2	M	12.0	164.0	5/53
MINERAL	Big Meadows	H	55.0	2436.	3/20
	Humphreys Dam	H	85.0	842.	3/20
	Santa Maria Lake	H	102.0	45070.	3/20
	Bristol Head #2	M	20.0	804.	2/67
	Lower Homestake Trailing	M	90.0	380.	2/67
	Rito Hondo	M	40.0	561.	2/67
	Upper Homestead Trailing	M	80.0	235.	2/67
MOFFAT	Craig Raw Water	H	58.0	547.	6/44
	Craig Holding & Evap.	M	40.0	1935.	6/43
	Fortification Creek	M	27.	605.	6/43
	Elk Lake	M	39.0	398.	6/47
	Elkhead Creek **	M	75.0	13500.	6/44
MONTEZUMA	Jackson Gulch	H	180.0	9980.	7/34
	Narri-Guinepp	H	100.0	19050.	7/32
	Summit	H	30.0	5954.	7/34
	Totten	H	30.0	3495.	7/32
	A.M. Puett	M	43.0	2394.	7/31
	Cortez #1	M	37.0	55.	7/31
	Baver Lake #1	M	25.0	350.	7/33
	Baver Lake #2	M	40.0	1532.	7/33
	Big Pine	M	26.0	460.	7/69
MONTROSE	Cerro	H	53.0	775.	4/62
	Fairview	H	45.0	350.	4/41
	Morrow Point	H	465.0	117000.	4/62
	Onion Valley	H	105.0	9511.	4/40
	Buck eye H-1	M	38.0	2200	4/42
MORGAN	Empire	H	40.0	37700.	1/1
MORGAN	Empire	H	40.0	37700.	1/1
	Jackson Lake	H	38.0	35629.	1/1
	Williams-McCreery	H	50.0	17616.	1/1
	Bijou #2	M	25.0	9183.	1/1
	Pawnee Raw Water	M	38.0	2867	1/1
OTERO	Crooked Arroyo Det. CA-1	M	60.0	2468.	2/16
	CA-3	M	33.0	446.	2/16
	CA-4	M	36.8	325.	2/16
	CA-2	M	40.0	6998.	2/16
	Dye	M	40.0	7986.	2/16
	Holbrook	M	23.0	4600	2/16
	Horse Creek	M	15.0	28000	2/16
OURAY	Ridgeway	H	233.0	125000.	4/68
PARK	Antero	H	46.0	85564.	1/23
	Eleven Mile Canyon **	H	128.0	97800.	1/23
	Montgomery	H	108.0	5088.	1/23
	Spinney Mountain	H	90.0	54500.	1/23
	Tarpyall	H	37.0	2617.	1/23
	Jefferson Lake	M	24.0	1720.	1/9
	Lake George	M	18.0	270.	1/9
	Estates #1	M	30.0	207.	1/65
PHILLIPS	NONE				
PITKIN	Ruedi	H	330.0	98000.	5/38
	Grizzly	M	56.0	600.	5/37
	Ivanhoe	M	16.0	800.	5/37
	Lake Ann	M	40.0	212.	5/37
	Wildcat	M	86.0	1250.	5/37
PROWERS	NONE				
PUEBLO	Pueblo	H	200.0	357000.	2/14
	St. Charles #2	H	35.0	2700.	2/15
	St. Charles #2	H	35.0	2700.	2/15
	St. Charles				

** UNSAFE DAM

COUNTY	NAME OF DAM	H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
PUEBLO	St. Charles	53.0	8638	2/15	
	St. Charles Mesa	M	16.0	91	2/13
	Teller	M	88.0	900.	2/13
	Beckwith	M	60.0	763.	2/14
	Lake Isabel	M	93.0	760.	2/14
	Hardesty	M	25.0	1565.	2/16
RIO BLANCO	Sheriff **	H	58.0	987.	6/57
	Big Beaver**	M	98.0	7658.	5/72
	D D & E Wise	M	41.0	1007	6/43
	Allen Basin	M	52.0	2250.	6/57
	Chapman	M	34.0	246.	6/57
RIO GRANDE	Beaver Park	H	96.0	4739.	3/20
	Fuchs	M	20.0	153.	2/67
ROUTT	Fish Creek	H	58.0	1850.	6/58
	Lake Catamount	H	52.0	1422	6/58
	Lester Creek	H	91.0	5657	6/58
	Willow Creek	H	100.0	23064.	6/58
	Sage Creek	M	41.0	1718.	6/54
	Gardner Park	M	33.0	1155.	6/57
	Lake Creek	M	38.0	261.	6/57
	Trull Creek #1	M	34.0	185.	6/57
	Whiteley Nelson	M	32.0	426	6/57
	Grimes Brooks	M	30.0	426.	5/52
SANGUACHE	Vouga	M	59.0	920.	3/35
SAN JUAN	NONE				
SAN MIGUEL	Gurley	H	66.0	10039.	4/60
	Miramonte	H	87.0	6851.	4/60
	Trout Lake	H	43.0	3422.	4/60
SEDWICH	Julesburg	M	65.0	28178.0	1/49
SUMMIT	Clinton Gulch Dam	H	170.0	4320	5/36
	[illegible]on	H	231.0	252678.	5/36
	[illegible]e ** Pasture	H	64.0	912.	5/36

COUNTY	NAME OF DAM	H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
SUMMIT					
	Green Pasture	H	64.0	912.	5/36
	Upper Blue	H	75.0	2140.	5/36
	Reynolds	M	29.0	157.	4/63
	Sawmill	M	26.0	90.	4/63
TELLER	Mason	H	50.0	2653.	2/12
	Mc Reynolds	H	33.0	2050.	2/12
	North Catamount	H	200.0	12300.	2/10
	South ** Catamount	H	100.0	3934.	2/10
	Burgess #1	M	32.0	268.	1/7
	Manitou Park	M	27.0	93.	1/7
	Wildhorn	M	24.0	17.	1/65
	Bison Park	M	27.0	1148	2/11
	Cripple Creek #2	M	50.5	280.	2/11
	Mount Pisgah	M	80.0	2471.	2/11
	Penrose Rosemont	m	90.0	2538.	2/11
	Pringtine	M	44.0	300.	2/11
	Skagway	M	76.0	3078.	2/11
	Victor #2	M	40.0	259.	2/11
	Wilson	M	20.0	669.	2/11
WASHINGTON	Prewitt	M	30.0	28840.	1/49
WELD	Black Hollow	H	42.0	8058.	1/3
	Bull Canal	H	47.0	4000.	1/2
	Empire	H	40.0	37700.	1/1
	Horse Creek	H	64.0	29356.	1/1
	Hilton Lake	H	50.0	6970.	1/2
	Hilton Lake	H	50.0	6970	1/2
	Riverside	H	41.0	65000.	1/1
	Windsor	H	43.0	17689.	1/3
	Windsor Lake	H	14.0	1464	1/3
	Carlin	M	20.0	86.	1/1
	Coal Ridge	M	28.0	653.	1/1
	Sullivan	M	10.0	60.	1/1

** UNSAFE DAM

ADDITIONAL HIGH AND MODERATE HAZARD DAMS

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
WELD	Eaton-law	M	14.0	528.	1/2
	Greeley Lake West	M	22.0	69.	1/2
	Lake Canal #1	M	18.0	327.	1/2
	John Law	M	14.0	250.	1/2
	Loup Lake	M	24.0	459.0	1/2
	Wood	M	31.0	3106.	1/2
	Koenig	M	9.0	100.0	1/3
	Little Thompson	M	35.0	452.	1/3
	Oklahoma Lake	M	22.0	493.0	1/3
	South Side	M	39.0	355.	1/3
	Akers and Tarr	M	38.0	171.	1/4
	Clennon	M	14.0	120.	1/4
	Highland #1	M	15.0	1064.	1/4
	Highland # 3	M	20.0	1670.	1/4
	Ide & Starbird #1	M	12.0	122.	1/4
	Union	M	33.0	12739.	1/4
	Frederick	M	19.0	330.	1/5
	Mc Grew	M	20.8	8725.	1/1
	Owl Creek	M	16.4	1750	1/1
	Prospect	M	44.0	6300.	1/1
YUMA	Bonny	M	158.0	170100.	1/23
	Duck	M	18.0	25.	1/64
	Wray Water-Shed # 5	M	27.0	27.	1/64
	Wray Water-shed #1	M	31.9	63.	1/64
	Wray Water-shed #3	M	37.0	39.	1/64
	Wray Water-shed #6	M	35.0	190.	1/64

COUNTY	NAME OF DAM	HAZARD H-High M-Moderate	EMBANKMENT HEIGHT	NORMAL CAPACITY	DIVISION/ DISTRICT
LARIMER	N Poudre #1	M	16.0	674.	1/2
	N Poudre #17	M	32.0	932.	1/2
	N Poudre #4	M	24.0	1669.	1/2
	Pennock Creek	M	20.0	278.	1/2
	Sherwood	M	13.5	250.	1/2
	South Gray	M	29.0	885.	1/2
	Warren Lake	M	23.0	2100.	1/2
	Worster	M	67.0	3750.	1/2
	Berthoud	M	25.0	516	1/3
	Cemetary Lake	M	20.0	378.	1/3
	Chapman	M	20.0	595.	1/3
	Dunath Lake	M	24.0	1148.	1/3
	East Portal	M	65.0		1/3
	Flatiron	M	86.0	1000.	1/3
	Horseshoe #2	M	14.5	8051.	1/3
	Idlywilde	M	38.0	83.	1/3
	Lawn	M	24.0	817.	1/3
	Lone Tree	M	26.0	9268.	1/3
	Loveland	M	26.0	2150.	1/3
	Loveland Water Storage	M	48.0	805.	1/3
	Pinewood	M	130.0	2000.	1/3
	Rist-Benson	M	19.0	491.	1/3
	Rist, George	M	17.0	444.	1/3
	Ryan Gulch	M	30.0	915.	1/3
	Sunny Slope	M	15.5	480.	1/3
LAKE	Apishapa	M	41.0	460	2/17
LINCOLN	Limon WTRSD. L-2	M	27.7	315.	2/19
	Limon WTRSD. L-3	M	26.5	344.	2/19
MESA	Monument #2	M	20.0	254.	5/53
	Palisade Cabin	M	50.0	154.	5/53
MONTROSE	Roatcap Wash	M	48.0	790	4/40
WELD	Lower Latham	H	23.0	6212	1/2
	Todd	M	16.0	46	1/1

** Unsafe Dam

RICHARD D. LAMM
Governor

JERIS A. DANIELSON
State Engineer

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES

1313 Sherman Street-Room 818
Denver, Colorado 80203
(303) 866-3581

December 9, 1981

UNSAFE DAMS

as of 12/1/81

ARMY #	NAME	DIV. & DIST.	COUNTY
130	Comanche	1 - 3	Larimer
148	Spring Creek	4 - 59	Gunnison
259	Waneka	1 - 6	Boulder
359	Eleven Mile Canyon	1 - 23	Park
384	North Sterling (Point of Rock)	1 - 64	Logan
408	S. Catamount	2 - 10	Teller
410	Crystal Creek	2 - 10	El Paso
445	Big Tooth	2 - 10	El Paso
629	Carl Smith	4 - 40	Delta
663	Goose Pasture	5 - 36,	Summit
681	Hughes	5 - 38	Garfield
759	Two Buttes	2 - 67	Baca
763	Beaver Park	3 - 20	Rio Grande
805	Rio Grande	3 - 20	Hinsdale
815	Terrace	3 - 21	Conejos
818	Mountain Home	3 - 35	Costilla
854	Windsor Lake	1 - 3	Weld
901	Lake Moraine	2 - 10	El Paso
976	Elkhead	6 - 44	Rio Blanco
1015	Sheriff	6 - 57	Routt
1066	Turner	7 - 30	La Plata
1143	Clear Creek	2 - 11	Clear Creek
1146	Cucharas #5	2 - 16	Huerfano
1163	Douglas	1 - 3	Larimer
1200	Beaver Park	1 - 5	Boulder
1347	Ramah Det.	2 - 67	El Paso

FOURTEEN MOST DAMAGING FLOODS
IN
COLORADO´S RECORDED HISTORY

DATE	MAJOR STREAM AND LOCATION	LOSS OF LIFE	DAMAGES (in $ of date shown)
Jul 1896	Bear Creek at Morrison	27	$
Oct 1911	San Juan River near Pagosa Springs	2	100,000
Jul 1912	Cherry Creek at Denver	2	1,000,000
Jun 1921	Arkansas River at Pueblo	78	19,000,000
May 1935	Monument Creek at Colo. Springs	18	1,760,000
May 1935	Kiowa Creek near Kiowa	9	
May 1955	Purgatore River at Trinidad	2	4,000,000
Jun 1965	South Platte River at Denver	8	500,000,000
Jun 1965	Arkansas River	16	46,700,000
May 1969	Bear Creek in Boulder	0	5,000,000
Sep 1970	Southwest Colorado	0	4,000,000
May 1973	South Platte River at Denver	10	121,500,000
Jul 1976	Big Thompson River in Canyon	139	35,500,000
Jul 1982	Fall River at Estes Park	3	30,680,000
		314	$769,240,000

Extracted From: "Flood Hazard Mitigation Plan For Colorado

ANNEX C

10a20

A[illegible] D

LARGEST KNOWN FLOODS AT VARIOUS COLORADO FRONT RANGE LOCATIONS
Study by Wayne E. Graham, P.E.
(extract)

Stream and Location of Discharge Measurement	Date	Cause	Deaths	cfs Peak Discharge	Comments
CACHE LA POUDRE RIVER at bottom of canyon, upstream from Ft. Collins	Jun 9, 1981	Failure of Chambers Lake Dam		21,000	
	May 21,1901	Not Known		12,000	
	May 20, 1904	Heavy Rains of cloudburst intensity		more than 21,000	
	Jun 15, 1923	Mountain cloud-bursts & heavy rain		8,500	
	May 31, 1930	Heavy rains		10,200	
3IG THOMPSON RIVER between Drake & bottom of canyon	Jul 31, 1919	Cloudburst		8,000	
	Jul 31, 1976	Intense rainfall	139	31,200	Death occurred throughout the length of the Big Thompson Canyon
	Apr 30, 1980	Heavy rains		6,150	
IG THOMPSON RIVER bove Olympus Dam	Jul 15, 1982	Failure of Lawn Lake Dam	3		Deaths occurred in Rocky Mtn. National Park
IG THOMPSON RIVER ear Loveland	Aug 3, 1951	Failure of dam on Buckhorn Creek	4	22,000	
T. VRAIN CREEK t Lyons	Aug 31, 1894	General storm		9,800	
	Jul 30, 1919	Series of cloudburst		9,400	
	Jun 22, 1941	Extremely localized cloudburst		10,500	
SOUTH PLATTE RIVER at Denver	Sep 10, 1933	Heavy rain		22,000	
	Jun 17, 1965	Heavy rain	8	40,300	Deaths are: entire Sout Platte Rive Basin
	May 7, 1969	Heavy rain		21,000	
	May 7, 1973	Steady rain of long duration below elevation 7,000 ft. Rain above this level retarded runoff.		17,600	
MONUMENT CREEK at Colorado Springs	May 30, 1935	Cloudbursts	4*	50,000	*Deaths in Colorado Spgs area -- 15 deaths occur other parts of state
FOUNTAIN CREEK at Pueblo	Jun 4, 1921	General Storm		34,000	
	May 30, 1935	loudbursts		35,000	
	Jun 17, 1965	Torrential & tremendous rainfall		47,000	
ARKANSAS RIVER at Pueblo	May 30, 1894	All-day rain	5	Not known	
	Aug 5, 1902	Not known		30,000	
	jun 3, 1921	Cloudbursts between Canon City & Pueblo	78	103,000	78 bodies recovered -- many were downstream & never recovered
ARKANSAS RIVER BASIN	Jun 16-19, 1965	Torrential & tremendous rainfall	16		Deaths are: the entire Arkansas River Basin

Stream and Location of Discharge Measurement	Date	Cause	Deaths	cfs Peak Discharge	Comments
BOULDER CREEK near Orodell & Boulder	Jun 1, 1894	Heavy rain		11,000	
	Jun 2, 1914	Rainfall hastened the melting of snow		5,000	
	Jun 6, 1921	Heavy rains		2,500	
	May 7, 1969	Heavy rains	1	1,220	Death occurred on Boulder Ck.
SOUTH BOULDER CREEK	Sep 2, 1938	Cloudbursts		7,390	
CLEAR CREEK near Golden	Aug 1, 1888	Not known		8,700	
	Jul 24, 1896	Cloudbursts	3		Deaths occurred on Golden Gate Gulch
	Sep 9, 1933	Rain		5,890	
	Jun 4, 1956	Failure of Georgetown Dam		5,250	
CLEAR CREEK at mouth near Derby	Jul 24, 1965	Heavy rain		5,070	
	May 6, 1973	Steady rain of long duration below elevation 7,000 ft. Heavy snow above this level retarded runoff.		4,700	
BEAR CREEK at Morrison	Jul 24, 1896	Cloudburst on Cub Creek, washed-out dam dam on that stream	27	8,600	Deaths occurred on Bear Creek & tributaries upstream from Bear Ck. Dam

Stream and Location of Discharge Measurement	Date	Cause	Deaths	cfs Discharge	Comments
BEAR CREEK at mouth at Sheridan	May 7, 1969	Heavy Rains		8,150	
CHERRY CREEK at Denver	May 19 & 20, 1664	Heavy fall of alternating hail & rain over upper basin	19	not known	Deaths occurred along the South Platte River & Cherry Creek at Denver
	May 22, 1878	Heavy rains of cloudburst intensity	2	not known	
	Jul 26, 1885	Heavy rains		20,000	
	Jul 124, 1912	Heavy rains	2	11,000	
	Jul 28, 1922	Heavy rains		6,000	
	Aub 3, 1933	Heavy rains caused failure of Castlewood Dam	2	15,000	1 death in Denver, the other near Parker
	Jun 16, 1965	Intense Rain		less than 1,000	Maximum inflow to Cherry Creek Reservoir was 59,900
LITTLE DRY CREEK	Jun 12, 1927	Not known	2	Not Known	Englewood Dam constructed in the mid 30's
TOLL GATE CREEK at 5th Ave.	May 9, 1957	Intense Rain	3	10,500	Deaths occurred in Toll Gate Creek Basin
	Jun 16, 1965	Heavy to torrential rainfall		17,000	
SAND CREEK	May 30, 1948	Localized thunderstorm		10,500	Discharge measured at mouth
	May 9, 1957	Intense rains		25,500	Discharge measured at Yosemite St
	Jun 16, 1965	Heavy to torrential rainfall		18,900	Discharge measured downstream from Toll Gate Creek

RECENT PRESIDENTIAL MAJOR DISASTER DECLARATIONS

NOTE: Six disasters have received Presidential Declarations in Colorado over the period 1965 - 1982. Most of these disasters were caused by precipitation but two were caused by dam failure. A summary of these presidentially declared disasters is shown in the following table. On the next page is a summary of the 15 state declared disasters that have occured over the period 1979 - 1982. Again, precipitation (flooding and snowstorms) is a dominant cause.

YEAR	LOCATION	CAUSE
1965	Front Range 33 counties	Sustained Rainfall
1969	Front Range 15 counties	Sustained Rainfall
1970	Southwest	Sustained Rainfall
1973	(1) Kersey	Dam Failure
	(2) Front Range 13 counties	Sustained Rainfall
	(3) Southwest 13 counties	Sustained Rainfall
1976	Big Thompson Front Range 2 counties	Flash Flooding, Heavy Rainfall over short duration
1982	Lawn Lake Front Range 1 county	Dam Failure

RECENT STATE DECLARED DISASTER EMERGENCIES

YEAR	LOCATION	CAUSE
1979	Southeast Colorado (Baca, Las Animas, Bent and Prowers counties)	Snowstorm
1979	Northeast Colorado (Logan County)	Snowstorm
1979	Northeast Colorado (Weld County)	Snowstorm
1980	Northeast Colorado (Weld County)	Dam Failure Prospect Dam)
1980	Eastern Colorado (Yuma, Kit Carson, Cheyenne counties)	Snowstorms
1980	Eastern Colorado (Larimer, Boulder, Weld, Logan, Morgan Sedgwick and Washington counties)	Flooding
1980	Northeastern Colorado (Larimer County)	Wildfire (Bear Trap)
1980	City of Trinidad	Flooding -- water supply system
1981	Statewide counties as designated by Colorado Department of Agriculture	Grasshopper Infestation
1981	Metro Area (Adams, Denver, Jefferson, Weld counties)	Tornadoes (Thornton)
1981	Adams-Weld Counties	Heavy rains weaken dam structure (Horse Creek Dam)
1982	Statewide	Cattle Scabies
1982	Montrose County	Flooding
1982	City/County of Ouray	Flooding
1982	Front Range (Denver, Arapahoe, Adams, Jefferson, Boulder, El Paso and Weld counties)	Snowstorm

A METHOD FOR THE RAPID APPROXIMATION OF DAM FAILURE FLOODPLAINS IN COLORADO

July 1983

By
William P. Stanton, P. E.
Supervising Water Resource Specialist
Flood Control and Floodplain Management Section
Colorado Water Conservation Board

CONTENTS

Preface

Since 1890 there have been at least 130 known dam failures in Colorado. Following the failure of Lawn Lake dam and subsequent flooding through the town of Estes Park, Colorado on July 15, 1982, considerable attention has been focused on reducing damages from potential dam failure floods.

In January 1983, state agenices prepared a Flood Hazard Mitigation Plan for Colorado which included recommendations to improve state programs in dam safety, floodplain management and emergency preparedness. One of the ideas was a recommendation that the Colorado Water Conservation Board (CWCB) develop a technique for mapping approximate dam failure floodplains below all dams in Colorado. Because no state agency had a program to map dam failure inundation zones, the idea was to develop a manual which would outline a simple, cost effective procedure which would allow dam owners and local officials to determine an approximate inundation zone themselves.

On June 1, 1983, Governor Lamm signed House Bill 1416 which, among other things, directed the Division of Water Resources (State Engineer) to prepare a report on approximately 238 dams in the state formerly classified as "high hazard." The hazard rating is determined by the potential for loss of human life or property damage in the area downstream for a dam and does not pertain to the safty of the structure.

Each report included a map indicating the possible extent of flooding in the event of failure to a point where such floodwaters would no longer exceed the boundaries of the 100-year floodplain. The dam failure floodplain for approximately 337 "moderate hazard", 1,680 "low hazard" dams, and thousands of highway embankments and stock ponds which were not included in H.B. 1416 remain to be mapped.

Knowing where the water might go from a dam failure flood may help to reduce development in areas which effect the hazard rating of the dam. It may also help local officials plan for emergency response activities which could reduce flood damages and save lives.

1.0 Purpose

The purpose of this document is to provide dam owners, floodplain managers, emergency planners and citizens with a quick and simple method to find out where the water from a dam failure might be reasonably be expected to go. The suggested level of detail is intended to be consistent with readily available base map information. The approximate flood boundaries developed with this method are for planning purposes only and should be conservative, that is, the flooded area should be slightly overestimated.

2.0 Tools You Will Need

A. Best available topographic base map(s) for the stream below the dam. The 7.5 minute, 1: 24,000 scale (1 inch = 2,000 feet) quadrangle maps published for sale by the U.S. Geological Survey cover approximately 95 percent of the state and are recommended. Contour intervals for these maps are typically 10, 20, or 40 feet. Individual structures in the floodplain are often shown on these maps. They may be purchased for $2.00 each from the Denver Distribution Section, U.S. Geological Survey, Denver Federal Center, Building 41, Denver, Colorado 80225. A free index map is also available.

B. Engineer's scale (but you don't have to be an engineer).

C. Colored pencils and a heavy black felt tip pen.

D. Information about the dam including:

a. Location
b. Height or Drainage Area

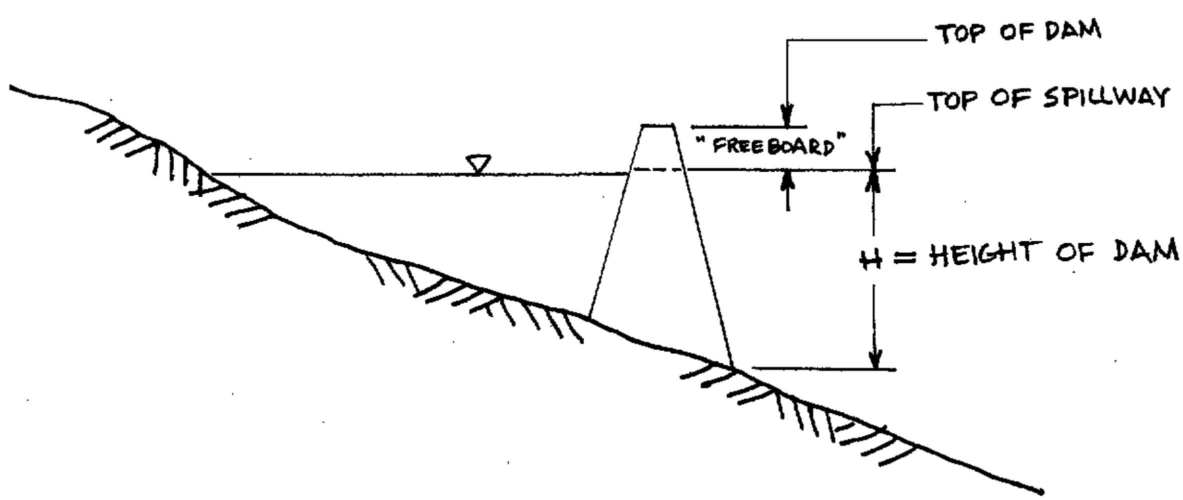
3.0 **Dam Failure Floodplain Boundary**

PROCEDURE TO DELINEATE APPROIMATE
DAM FAILURE FLOODPLAIN BOUNDARIES

1. Starting at the top of the dam and working downstream to the end of the study reach, draw a reference line down the center of the channel and mark each mile post. Making this center line and marking regular intervals is called "stationing."

2. Find where the topographic map contours cross the river and mark each point on the reference line.

3. Find the height of the dam in feet measured from the top of the spillway to the lowest point in the channel just below the dam.



4. From the height of the dam, estimate the depth of the dam failure floodplain at intervals below the dam based on the assumed rate of attenuation given below.

Miles downstream from dam	Assumed Flood depth as a percent of dam height
0 - 1	100
1 - 2	70
2 - 10	60
10 - 20	50
20 - 30	40
30 - 40	30
40 - 80	20
80 +	10

5. Using the contour interval on the topographic base map (typically 10, 20, 40, or 80 feet), compute the horizontal scaling ratios for each stream interval to be applied in the downstream direction from where the topographic map contours cross the river.

6. Locate the flood contours on the channel and extend them perpendicular to the direction of flow until they meet the corresponding ground contour.

7. Connect the endpoints of the flood contours, looking out for islands and an even spacing of flood contours. Flood boundaries should cross ground contours on a tangent.

8. At major obstructions, such as highway or railroad bridges, an adjustment in the flood depths may be appropriate to reflect water backed up just upstream of the obstruction and shallower depths just downstream of the obstruction. By advancing or bending flood contours slightly downstream, a greater depth will be apparent, and vice versa.

The procedure to estimate flood boundaries may be conservative for the following reasons:

1. The topographic map contours show top of the water and not the true thalweg (lowest point in the channel). The depth of flow that was in the river at the time of mapping will be added to the assumed depth.

2. A conservative stair step approximation of the assumed attenuation curve was used to interpret flood depths.

3. The flood boundary is shown as a heavy line which, on a scale of 1 inch equals 2,000 feet, may be as much as 200 feet wide.

EXAMPLE 1

Given:

Consider a hypothetical 25 foot high dam on the Yampa River in Routt County. A U.S.G.S. topographic base map with 40 foot contour intervals and 20 foot supplemental contours in the vicinity of the channel is available.

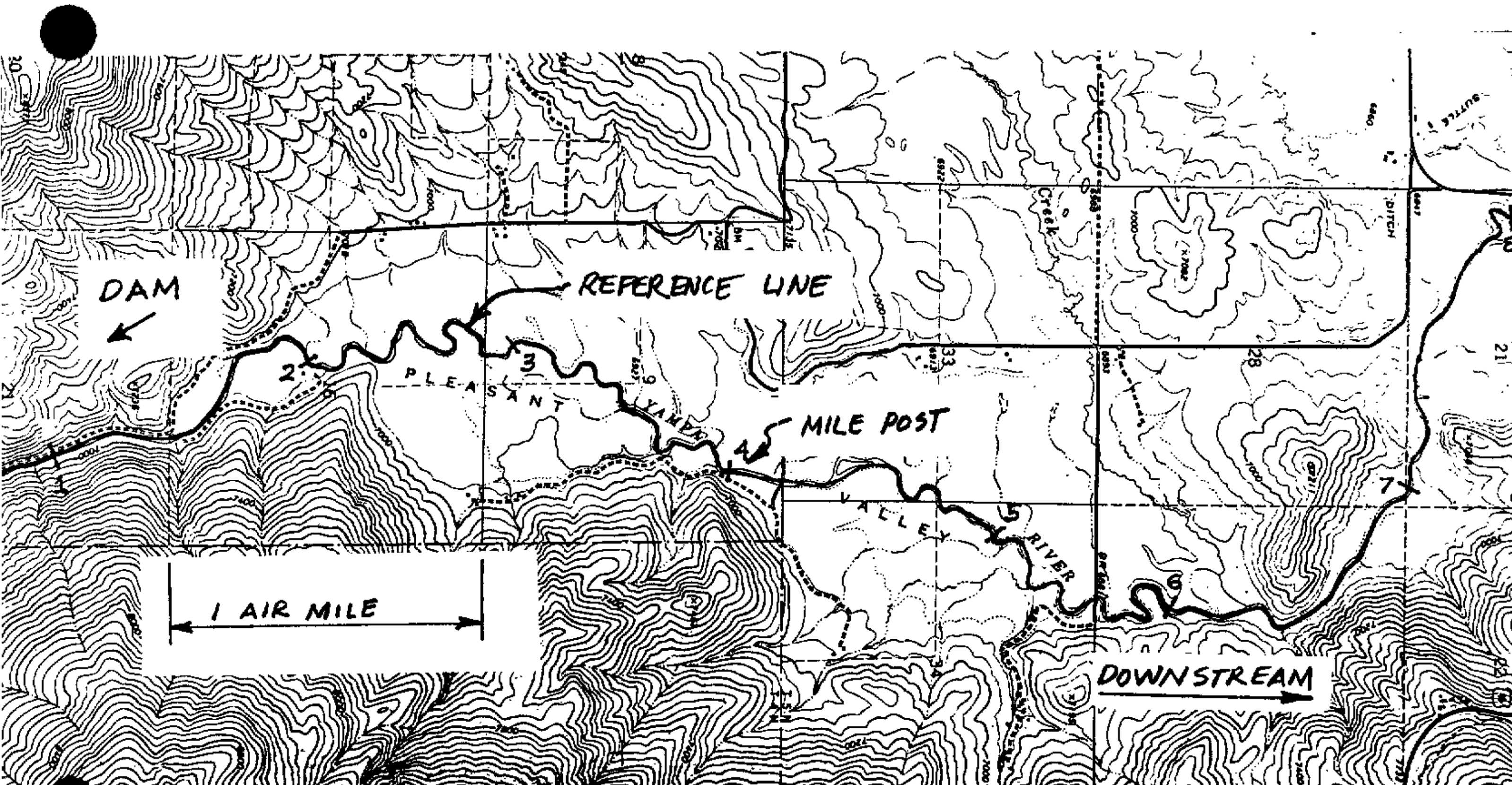
Find:

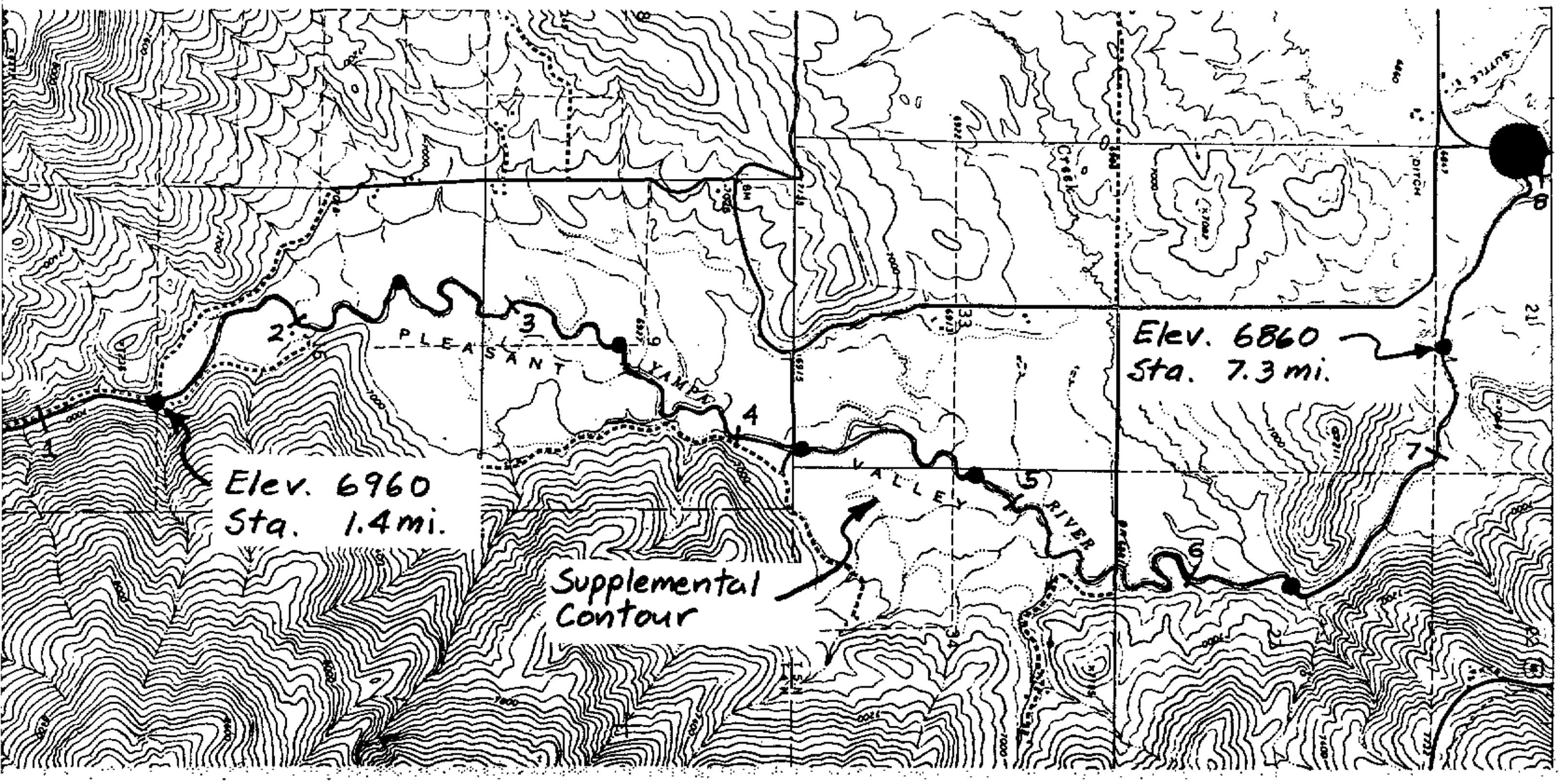
Approximate flood depths and draw the dam failure flood boundaries for the interval from 2 to 8 miles below the dam.

Solution:

Step 1: Draw a Reference line down the middle of the channel and mark each mile post starting at the crest of the dam.

Note that channel stationing considers bends in the river and is different than straight line distances. For example, channel mile post 4 is actually about 3 air miles below the dam.





<u>Step 2:</u> Mark where the ground contours cross the stream centerline. Note that while the contour interval for the map is 40 feet, supplemental contours have been shown in the vicinity of the river as dashed lines so the actual available continterval is 20 feet for this reach.

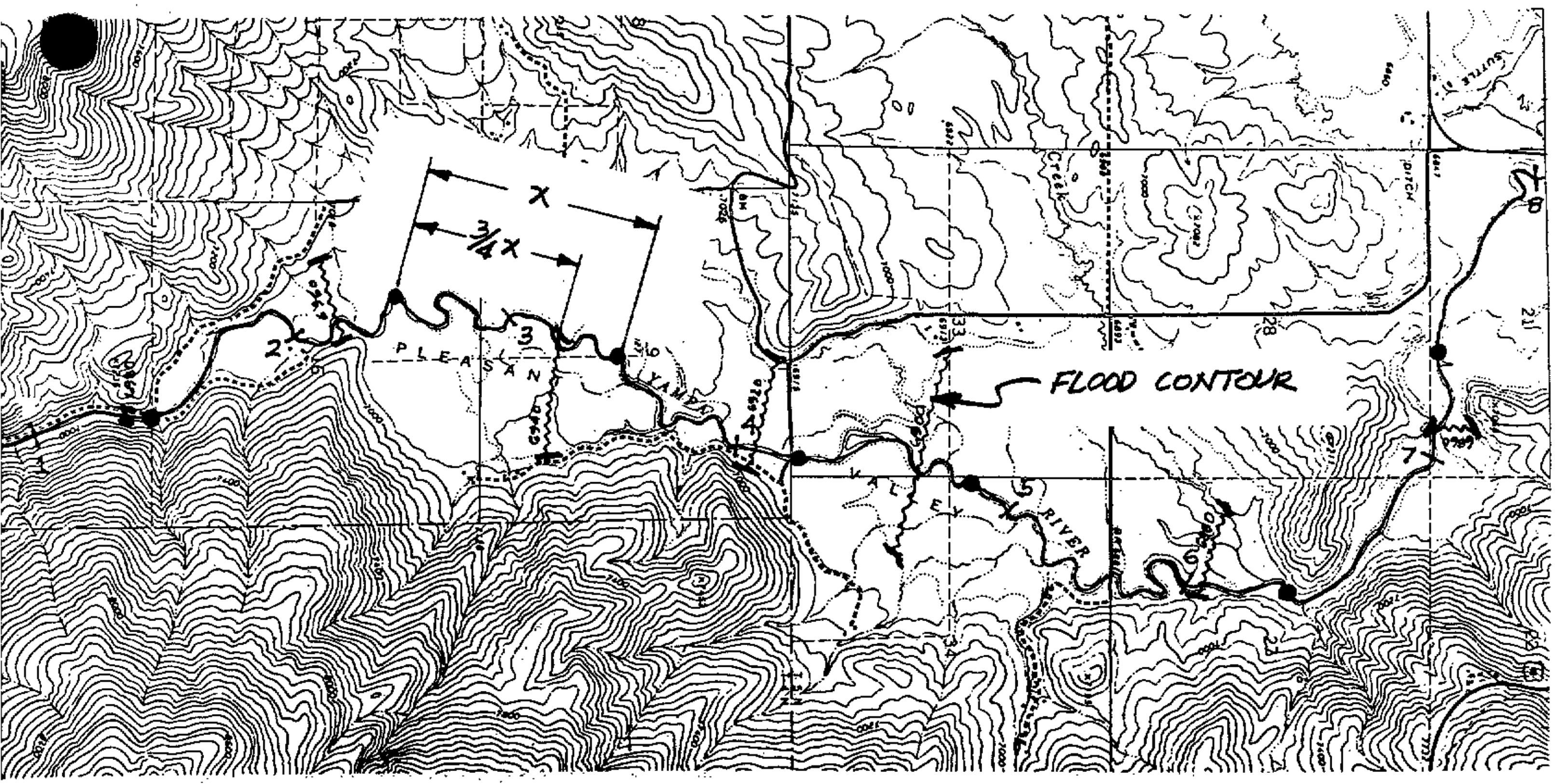
Note the average streambed slope may be computed as follows:

$$\text{Slope} = \frac{\text{rise}}{\text{run}} = \frac{(6960 - 6860)}{(7.3 - 1.4)} = \frac{110}{5.9} = 19 \ \frac{\text{feet}}{\text{mile}}$$

<u>Step 3:</u> The height of the dam was given as 25 feet.

<u>Step 4 and Step 5:</u>

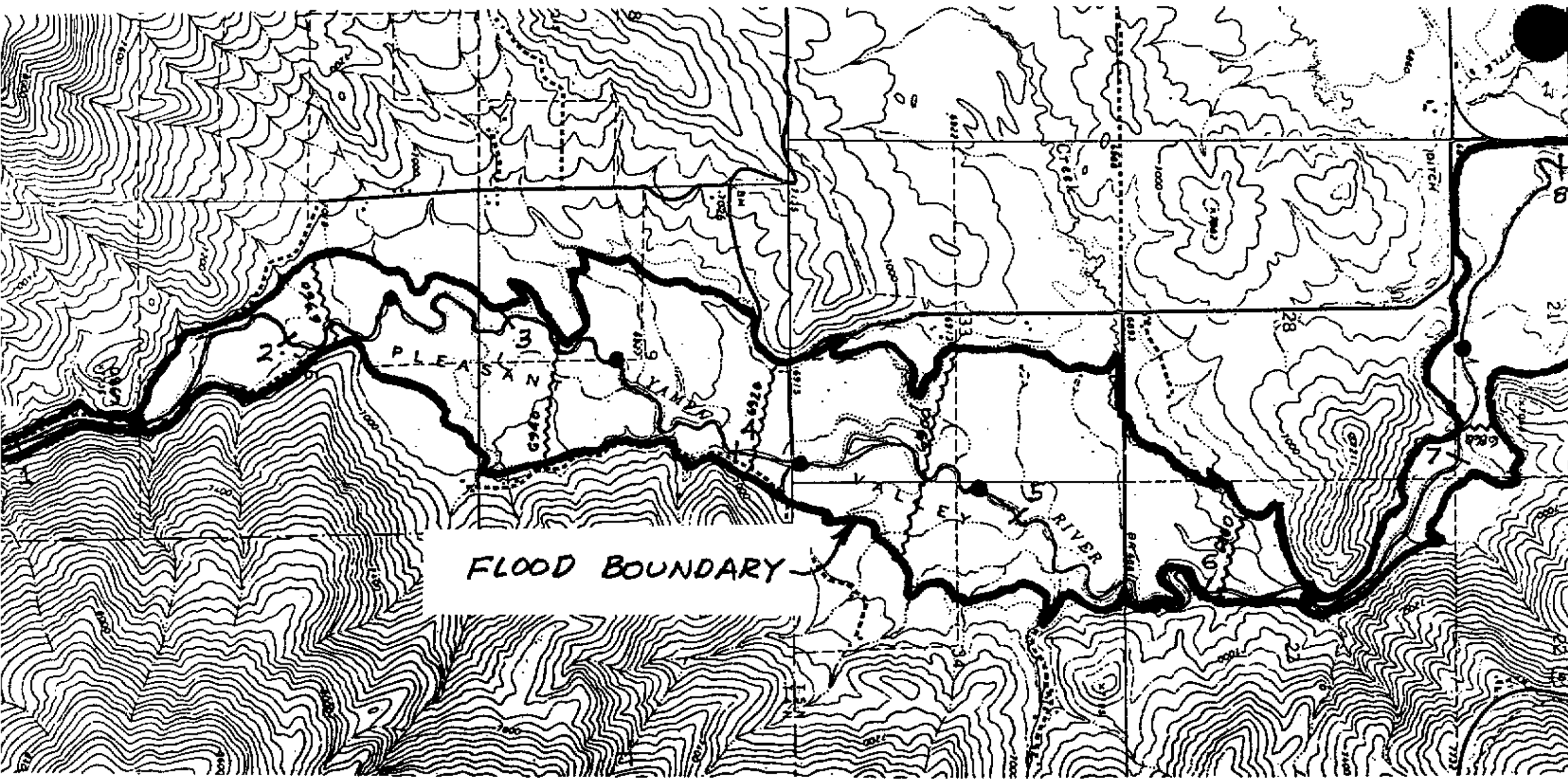
Interval Below Dam, miles	(Step 4) Approximate Flood Depth, feet	(Step 5) Horizontal Scaling Ratio, (Approximate Flood Depth/ Contour Interval)
0-1	25	25/20 = 1 1/4
1-2	18	18/20 = 9/10
→ 2-10	15	15/20 = 3/4 ←
10-20	13	13/20 = 7/10
20-30	10	10/20 = 1/2
30-40	8	8/20 = 1/3



Step 6: For the desired depth (15 feet in this example), interpolate horizontally between points where the ground contours cross the stream (horizontal scaling ratio = 15/20 = 3/4 of horizontal distance between ground contours) and mark the location of flood contours in the channel. In this example, if "x" is the distance between points where ground contours cross the channel then the flood contours shall cross the channel at about 3/4 of the distance "x" from the upstream point.

Flood contours should be extended as wiggly lines from the channel perpendicular to the direction of flow until they meet the corresponding ground contour.

Label flood contours with the appropriate elevation as a check and for documentation.



Step 7: Draw flood boundaries with a pencil line by connecting the end points of the flood contours. Flood boundaries should approach ground contours at a tangent and can only cross them at the ends of a flood contour.

Step 8: Since there are no major obstructions, no adustments are necessary.