Governor's Flood and Drought Preparedness Conference

What Can Colorado Do To Reduce Its Vulnerability to Flood and Drought Disasters?

December 2–3, 1999
Adam's Mark Hotel
1550 Court Place, Denver, CO

Co-sponsors:

- **Colorado Department of Natural Resources**
- **Colorado Department of Agriculture**
- **Colorado Department of Local Affairs**
- **Colorado Department of Public Health and Environment**

Thursday, December 2

9:00 **Registration and Continental Breakfast**
South Convention Lobby

10:00 **Welcome and Introductions**
Grand Ballroom II

- Governor Bill Owens
- Greg Walcher, Executive Director, Department of Natural Resources

10:30 **The State of the State: How Vulnerable Are We?**
Grand Ballroom II

Scientific Perspective

- Tom McKee, former Colorado Climatologist

Economic Perspective

- Nancy McCallin, Director, Governor's Office of State Planning and Budgeting

11:30 **Break**

11:45 **Lunch**
Grand Ballroom I

12:30 **Keynote Speech: Flood and Drought Challenges and Colorado's Water Future**
Grand Ballroom I

- Hank Brown, President, University of Northern Colorado

1:30 **Break (beverages available until 4:00)**
Grand Ballroom Foyer

Concurrent Sessions: How Prepared Are We?

	Track 1: Flood Issues *Gold Room* Moderator: Larry Lang, Floodplain Management Section Chief, Colorado Water Conservation Board	Track 2: Drought Issues *Tower Court C Room* Moderator: William P. Stanton, Conservation Planning Section Chief, Colorado Water Conservation Board	Track 3: Mitigation Issues *Spruce Room* Moderator: Marilyn S. Gally, State Hazard Mitigation Officer, Office of Emergency Management
1:45	**Rural Case Study of Flood Impacts and Recovery Activities** • Commissioner Barbara Kirkmeyer, Weld County	**Colorado's Drought History** • Connie Woodhouse, Research Scientist, University of Colorado/ National Oceanic and Atmospheric Administration	**Role of Reservoir Storage in Flood and Drought Mitigation** • John R. Fetcher, Secretary-Manager, Upper Yampa Water Conservancy District
2:15	**Urban Case Study of Flood Impacts and Recovery Activities** • Commissioner Duncan Bremer, El Paso County	**Colorado's Drought Plan** • Jack Truby, Planner, Office of Emergency Management	**Role of Reservoir Operations in Flood and Drought Mitigation** • Hal Simpson, State Engineer, Division of Water Resources
2:45	**Prevention versus Reaction: Pay Now or Pay More Later** • Ann Azari, Consultant, Ann Azari Consulting, and former Mayor, City of Fort Collins	**Risk-Based Assessment of Drought Vulnerability** • Noel Hobbs, Water Resources Consultant, Camp Dresser & McKee, Inc.	**Non-Structural Approaches to Mitigation** • Mary Fran Myers, Co-Director, Natural Hazards Research and Applications Information Center
3:15	**Buffalo Creek Case Study from the Landowner's Perspective** • Judge Donald P. Smith, Jr. (retired), Crisis Committee, Buffalo Creek	**Case Study of Denver's Drought Plan** • Dave Little, Manager of Water Resources, Denver Water	**Water Rights in Relation to Flood and Drought Mitigation Issues** • John H. McClow, Bratton & McClow, LLC, Counsel for Upper Gunnison River Water Conservancy District

4:00 **Reception (cash bar)**

Grand Ballroom I

Sponsored by:

- CH2M Hill
- Henz Meteorological Services

Friday, December 3

8:00 **Breakfast Panel Discussion: National Perspectives on Flood and Drought Mitigation**
Grand Ballroom I

Co-hosted by: Senator Dave Wattenberg and Representative Brad Young

Federal Emergency Management Agency
- Richard P. Weiland, Regional Director, Region VIII

U.S. Army Corps of Engineers
- Charles Hess, Chief of Operations

U.S. Bureau of Reclamation
- Maryanne Bach, Regional Director, Great Plains Region

National Drought Policy Commission
- Leona Dittus, Executive Director

9:45 **Mitigation Options, Issues and Case Studies**
Grand Ballroom I

Case Study: Grand Forks, North Dakota
- Kenneth A. Vein, City Engineer/Director of Public Works, City of Grand Forks

Case Study: Tulsa, Oklahoma
- Susan Savage, Mayor, City of Tulsa

Texas Drought Response Legislation
- Representative Gary L. Walker, Texas House of Representatives

11:00 **Break (pick up "saddle bag" lunch)**
Mezzanine Foyer

11:15 **Working Lunch: Interest Group Discussions**
- Environmental Interests and Others facilitated by Jo Evans, Evans Environmental Consulting
  Colorado Room
- Business Interests facilitated by J.J. Ament, Denver Chamber of Commerce
  Spruce Room
- Water Interests facilitated by Richard D. "Dick" MacRavey, Secretary and Executive Director, Colorado Water Congress
  Silver Room
- Agricultural Interests facilitated by Ray C. Christensen, Executive Vice President, Colorado Farm Bureau
  Gold Room
- County Interests facilitated by Commissioner Jake Klein, Otero County
  Denver Room
- Municipal Interests facilitated by Doug Kemper, Manager of Water Resources, City of Aurora
  Century Room

Discussion Topics:
- Define Strategies for the Governor's Action Agenda for Reducing Colorado's Vulnerability to Floods and Droughts — Infrastructure, Administrative, Statutory and Funding
- Define the Roles and Responsibilities of Federal Agencies, State Government, Local Governments, Businesses and Individuals

1:00 **Break (refreshments)**
Grand Ballroom Foyer

1:15 **Interest Group Discussion Report Summaries**
Grand Ballroom I

2:15 **Keynote Speech: Where Do We Go From Here?**
Grand Ballroom I

- Speaker of the House Russell George

2:45 **Owens Administration Response**
Grand Ballroom I

- Bob Brooks, Executive Director, Department of Local Affairs
- Jane Norton, Executive Director, Department of Public Health and Environment
- Greg Walcher, Executive Director, Department of Natural Resources

3:00 **Adjourn**

Special appreciation is extended to the sponsors of Friday's reception:

- CH2M Hill
- Henz Meteorological Services

Please be sure to visit conference exhibitors:

- Colorado Climate Center
- Colorado Division of Water Resources
- Colorado Office of Emergency Management
- Colorado State Forest Service
- Colorado Water Conservation Board
- Colorado Water Resources Research Institute
- Henz Meteorological Services
- National Center for Atmospheric Research
- U.S. Geological Survey
- USDA Natural Resources Conservation Service
- USDA Natural Resources Conservation Service
  Snow Survey and Water Supply Forecasting

Flood and Drought Preparedness Conference December 2, 1999

Opening Remarks
Governor Bill Owens

It was author John Steinbeck in East of Eden, who said, "And it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It has always been like that." John Steinbeck was right. It seems that, particularly in recent years, Coloradans have experienced one or the other - too much rain or not enough rain. And all too often it seems that people are not prepared for either.
There are over 65,000 homes, 15,000 businesses and a quarter of a million people who live presently within 100-year flood plains in Colorado. We need to do everything we can to prepare for the disasters that we know will happen.

We have brought together some of the foremost experts in the country to share with us the latest practices concerning flooding and drought. But no amount of lecturing or statistics can truly prepare us for those sorts of tragedies. They can't prepare a person for the loss of a business or a farm or a loved one in a flood, or the loss of a business or farm during a drought. I've seen it first hand.
I saw it when I was in Southeastern Colorado after the floods we had this spring. I have seen it in Fort Collins. I have seen not only the devastation caused by floods, I also saw the grit and determination as communities joined to pull themselves back together after these tragedies - good people getting on with their lives. Coloradans don't expect handouts, but they do expect us to plan for the future so that we can better prepare for what we know will happen.

Every year on average, Colorado sees somewhere in this state a 100-year flood. Floods have caused damage worth over $4 billion and have cost more than 300 lives. We have seen flooding severe enough to warrant a presidential disaster declaration four times in the last 20 years. Over the last two years, there have been 59 federal declarations of disaster due to flooding and draught in this country.

But it isn't just disaster relief from the federal or state government with which we should concern ourselves today. It is a question of what structural reforms we can put into place to ensure that there is a safety net in the future to help mitigate once again that which we know is on the horizon.

Everyone here knows that drought occurs when demand exceeds supply. With our highly variable climate and ever-increasing demand for water we know that a severe sustained drought will occur again. The question is not "if," but "when." The impact of drought spans economic and environmental and social factors. The tourism industry, the agricultural community, our power generators, manufacturers, miners, everyday citizens - all depend on water supplies here in the arid west.

So, although drought is less dramatic than some other disasters that we are faced with, its effects are so severe and long-lasting that it can be much more devastating than even hurricanes and earthquakes and other natural disasters. The cost of drought can also be much greater than the cost of other more dramatic natural disasters.
Floods and droughts will continue, so we must prepare for them.

The goal we've set for this conference is to help identify some potential responses that will help communities plan for and respond to breaking emergencies. In short, we need a long-term strategy that focuses not only on prevention, but also preparation. We are going to have natural disasters. We have always had them in the past and we are going to have them in the future. We must make sure that we are better prepared for these emergencies. We need to make sure that Colorado is responding in the most effective and efficient manner to the floods and droughts that lie ahead. Our community is doing this together, and I hope you all know that you have very strong advocates at the local level, within your state government and within our congressional delegation.

This conference reflects the commitment of the Department of Natural Resources, as well as our entire administration, to working to better understand the scourges of flood and drought and to put the results of our efforts to work for all Coloradans. The wraths of nature can certainly be random. They can be swift and they can be unforgiving. That's where we can provide a balance. We can work to help the victims of these disasters, as well as to plan ahead for future disasters. In government, we must act because it is our duty to act.

I look forward to continued leadership and involvement in these critical issues from the members of my Cabinet who are helping make this conference successful, Greg Walcher, Tom Norton, Jane Norton, Bob Brooks and Don Ament. This is a group of people who have put a lot of work into this conference. I want to thank you for your interest and your participation. But most of all, thank you for caring. Thanks for all you do for Colorado.

The State of the State: How Vulnerable Are We? Scientific Perspective: Physical Characteristics and Causes of Drought and Flood

Thomas B. McKee
Colorado State Climatologist (retired)
with
Nolan J. Doesken and John Kleist
Colorado Climate Center
Department of Atmospheric Science
Colorado State University

I'm delighted to be here this morning to talk a little bit about the physical characteristics of drought and flood which we have indeed been studying for the past 10 or 20 years, and I'd like to acknowledge as I begin that this is certainly not myself alone. Many of you know Nolan Doesken who's been my associate for many years in the Department of Atmospheric Science and the Colorado Climate Center and John Kleist as well.

I'm going to begin with a little bit of information and discussion about the climate of Colorado because it is the most interesting and unique climate in the United States. I know of no other place of its equal in the world, actually, in terms of the particular combination of things that we find in this state. And I'd like to remind us a little bit about that as we begin this morning. Those of you who've lived in this state for 30 years or more are probably familiar with much of it. However, as many newcomers come to Colorado I find over and over again they have no idea how the climate actually operates in the state of Colorado. So I'll begin with that.

Figure 1

The first one I'd like to of course bring to our mind is that climate is indeed a natural resource of Colorado, quite a large one in many ways. Its problem is that it is variable in time and space. Those from Central Europe, who love to ski in the Alps come to ski in Colorado, are just stunned that they can have beautiful snow and sunshine at the same time. It's not what they are accustomed to. This is one of the delights of the climate of Colorado.
The other one in terms of water is that our true water source is precipitation. We do mine water in Colorado that's been in the ground a long time and will continue to do so. The rest of the water comes from precipitation. But it's not precipitation that is actually used by anyone.

Climate of Colorado
-- is a Natural Resource
-- does vary in time and space

1) Water Source -- Precipitation

2) Precipitation -- Soil moisture
Snowpack
Streamflow
Reservoir storage
Ground water

3) Climate variability -- Wet -- highest 20%
Near average -- 20-80% probability
Dry -- lowest 20%

Flood -- type -- flash flood
-- general storm
-- snow melt
-- properties -- depth
-- area
-- duration
-- seasonality

4) Variability -- Precipitation
Water vapor available in atmosphere
Vertical motion -- storm systems
-- mountain induced

5) Forecasts -- day
-- month
-- season
-- year
-- decade
} expect progress

The precipitation makes its way in time to one of five water sources that we actually do use:

1. Soil moisture, which the precipitation affects instantly as soon as it rains or when snow melts;
2. The snowpack which we use extensively during the winter season;
3. Streamflow;
4. Reservoir storage; and
5. Groundwater.

Part of the challenge of the climate of Colorado is that it takes different time periods before the water arriving as precipitation makes its way to these other sources that we actually use. And it will turn out, when I get down to how we monitor drought in this state, that time scale becomes a critical part of how we do things.

The other issue is the climate variability. We have about three kind of states I'd like to identify as different. One is "wet" and I've tagged it as the highest 20 percent in probability. The number is arbitrary. For your use, you could use different ones. Something "near average" would occur at 20-80 percent probability levels which is 60% of the time. "Dry" is the lowest 20 percent. Any one of those states can last extended time periods.
The other one I'll mention is "flood." It is not one of the ordinary climate states. I view that much more like a set of events that occur. They are fairly short in time and they are not necessarily related to the other three states. Whether we are dry or near average or wet, floods can appear at any time and they're an event that kind of sits separately. And we have three kinds of flood in this state.

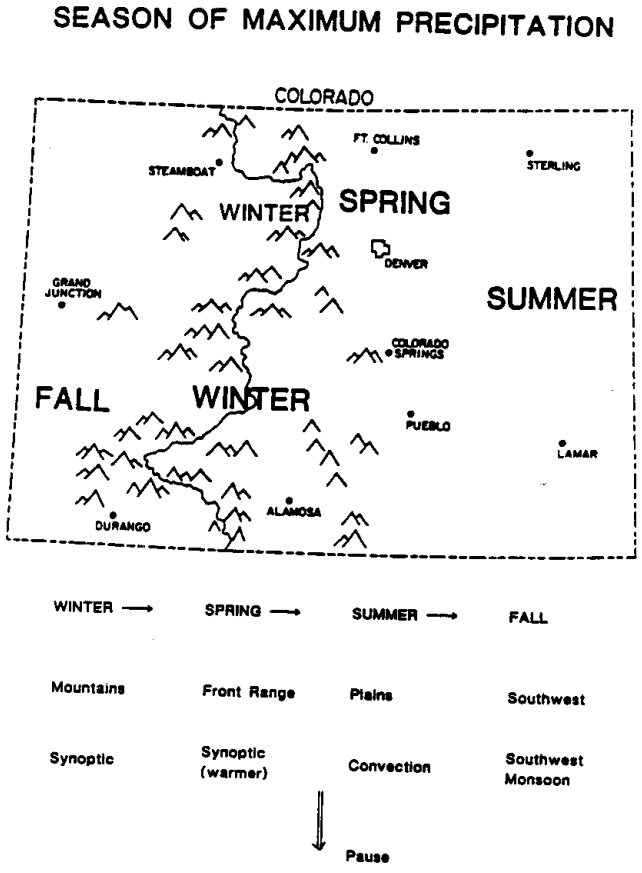
1. Flash floods, the ones we normally equate with threat of life, great disaster and damage within a few hours. The Big Thompson type, the storm in Fort Collins two years ago are examples.
2. The other ones are general storms. They take a few days, not a few hours. The rainfall could be more or less than the flash floods, and we had a tremendous example, not kindly, in the spring of this year in the Arkansas with a multi-day storm that is of this general storm type.
3. The other one of course is snowmelt that occurs more slowly and can affect people in different areas.

The other one with flood is there are actually three properties of flood that are really critical to understanding, preparing or mitigating its effects. They are the depth of precipitation, the area affected and the duration in time in which the precipitation arrives. They are all three really important features of flood events. We talk an awful lot about the rainfall amount in storms. The other two, the area affected and the duration in which they occur, are equally important, and in some storms they are probably more important. So I don't want to lose track of the fact that there are at least of these kind of characteristics that we need to worry about.

The last is seasonality and I'm going to talk about seasons in Colorado a little bit more because they are quite distinct. The variability of precipitation in our state and in our climate system is driven by two things - the availability of water vapor in the atmosphere and the vertical motion, up motion, being required for precipitation to form. The up motion comes from two categories - from storm systems and it can be mountain-induced by the terrain itself. Those two things always affect how storms arrive here.
The other one we're facing today is a great increase in forecast interest. The day-to-day forecasts are weather. It was referred to already this morning about we have a sunny day today which wasn't forecast too long in advance, but we live in a difficult place in terms some of the forecasts. The forecasts from the Weather Service in the day-to-day activities are in fact improving over the last decade or so. And the other forecasts that are now appearing more and more are longer-term forecasts for month, for season, for year. And it won't be too long before we begin to see the emergence of forecasting in longer time scales yet in the decade time scale. These are improving and I expect quite a lot of progress in the next decade in the forecasting that we see. We now have a lot interest in El Nino and La Nina; those words have become common. I think the detail with which they dealt with is going to improve in the very near future. So I look forward to that and I think it will benefit us.

Figure 2

I'd like to talk briefly about the annual cycle climate in Colorado. This little diagram will help. Colorado is the only place I know that has a maximum in precipitation in its annual cycle somewhere in the state in each of the four seasons. That is unlike most other places in the world and certainly in the United States where they tend to have maximum precipitation in one season. In the Great Plains, it's mid-summer. They know it. The whole area is like that and it causes quite a different level of concern of how to prepare for things or how to respond to things. Colorado is really different.



I'm going to start in the winter season. We're just entering the winter season. We have what are called synoptic storms. They are large-area storms. They are not small, 10 square miles or 50 square miles. They are much larger. They take longer to occur. And they come or don't come based on the large-scale circulation in the atmosphere at the time. They start in the mid-fall and they begin to taper off in the spring. They become the winter-dominant form of precipitation and we do have winter maximums in a lot of places in Colorado that are in the high

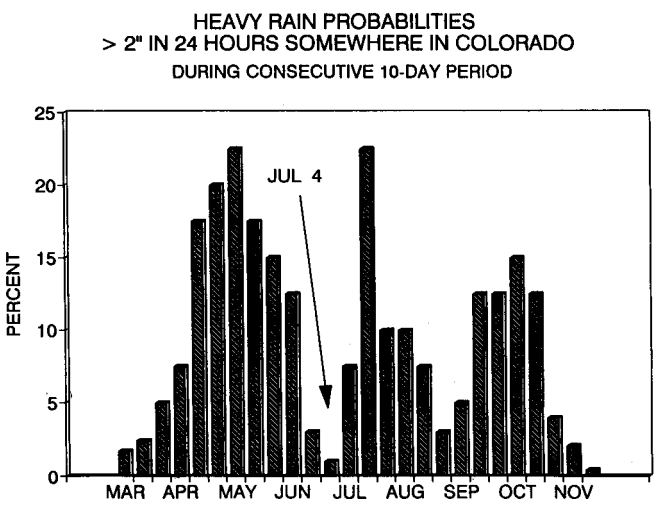
country. No place in lower elevations has a winter maximum. There are a number of places in the high elevations. It's a striking, because in Denver we have a spring precipitation maximum along the Front Range, but Berthoud Pass just 30 or 40 miles away horizontally has a mid-winter maximum - strikingly different kind of climate characteristics.

As the storms in the spring have warmer temperatures, we get more water vapor in the air, and more precipitation is likely to come. As the spring storms get wetter starting in March, the moisture increases in April and May and convection begins to appear as they get warmer. Larger rain amounts become possible, and the Front Range then becomes the one area that has the worst combination of the possibility of snowmelt flood and heavy rains on top of it. Because right at the time the snowmelt really begins in mid-May and later, along comes the season which is still heavy in rain. So that's a combination when we get in the Front Range.

Then we have a break. I should tell everybody if you really want to take a trip around Colorado and have clear weather, the one holiday to do it in is the 4th of July. The break typically appears in the third week of June. Until about the end of the second week in July, we have about a three-week period that is the sunniest time of the year throughout the state of Colorado. After that, the summer monsoon begins. The monsoon begins southwest of Colorado in Arizona and New Mexico and then migrates northward. The monsoon has a strong influence on our climate for the rest of the summer season. It gets wetter in July and early August and then it begins to taper off through the fall with a few places in the fall that have a maximum in precipitation in the southwest part of the state. The summer precipitation maximum is the norm in the eastern part of the state and in parts of Western Colorado where July is clearly the wettest month.

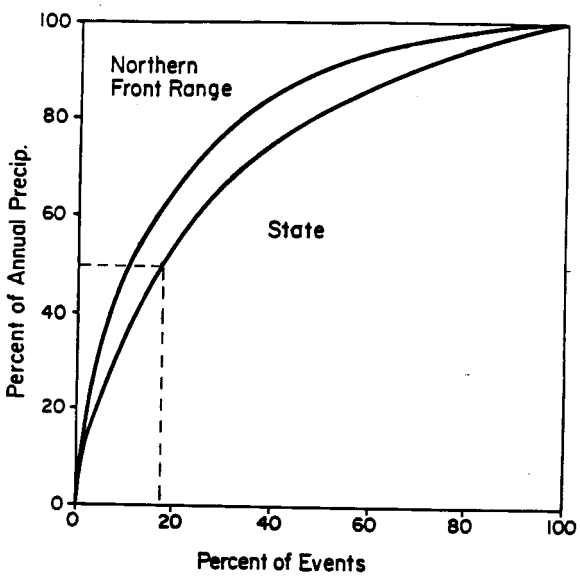
Figure 3

This whole annual cycle produces some very interesting effects. This graph is one that is really a quite dramatic way to look at it. It is the occurrence of rainfall greater than two inches in 24 hours somewhere in Colorado. In March and April it begins to increase. It goes through a maximum in early May when we still have the big synoptic storms of the winter season, but they are warmer and they are wetter. Convection is also beginning to increase. Then they diminish as the large-scale storm track, which we commonly hear referred to as something to do with the jetstream, migrates northward out of Colorado to the northern part of the United States and we get fewer of them. Then we have this lull. In July the monsoon begins from the south to the north increasing water vapor in the atmosphere. Then the rains increase. Then the precipitation decreases until the winter storms reappear in the fall, which brings the chance for heavier precipitation. The big thing about Colorado that's really important is that these various components of our annual cycle from the winter



storms to late spring to summer in the convection are not highly correlated. You can't pick one on what's going to happen the next one. It doesn't work that way. So the result is we have these independent systems operating in the state that leave us either wet or dry. Somewhere in the state one of these three kinds of precipitation-dominant processes is making somebody wet, and the next one doesn't happen and someone else gets dry. We're always in the position where we're close to flood problems through the warm season or we're close to drought. That's the way Colorado is, and it's a wonderful thing in the sense that we usually don't have the whole state dry or wet at the same time. So, we have this diversity that keeps us on our toes all the time, but we don't have as many widespread impacts over the entire state at the same time.

Figure 4



I would just like to add as I leave this part a comment about precipitation. The percent of precipitation on the vertical axis is shown as a percent of events which is the number of days of rain. I would like to leave in your mind the image of Colorado - this is true worldwide, not just here - that about 50 percent of rain or precipitation occurs

in the state of Colorado on about 18 percent of the days on which rain occurs. This means whether we are wet or dry depends on a fairly small number of events. If we miss the heavy rain events or heavy snow events, we're likely going to be dry. And so we welcome the heavier events because they are part of the lifeblood of water that we need.

Figure 5

Precipitation Monitor --
Standardized Precipitation Index (SPI)

Concept -- $\frac{P - P_{ave}}{st.dev.}$ surplus/deficit

specify time period 3, 6, 12, 24, 48 months

Definition of Drought --
must exceed -1.0
start at last zero value before -1.0
end at first zero value after -1.0

duration -- time from start to end
water deficit -- largest deficit during drought
intensity -- current value of SPI

Questions answered --
What is probability of current intensity?
What is percent of average precipitation?
What is precipitation deficit?
What is percent of last year's precipitation?
What is the probability of ending drought?

I'd next like to turn to talk about how we monitor drought. Conceptually the idea is fairly simple. We use something called the Standardized Precipitation Index. We use many variables, as many as we can find, but this one happens to work pretty well. It's the difference between the current precipitation and the average divided by the standard deviation. It's either a surplus or a deficit or near average. We monitor this as a function of time over a variety of time periods because of the fact that it takes time for water from precipitation to get into the forms of streamflow, reservoir and ground water. We typically keep something like three, six, 12, 24 and 48 months in the calculation at the same time. Thank goodness for computers. This couldn't have conceivably been done 40 years ago, not even close. Now we can monitor what's happening at all of these different time frames at the same time and get a view of where we are in different kinds of time scales, and it becomes very helpful. I'll show you a graph of this in just a minute. But we have defined drought so we can do some things with this quantitatively to say that it must exceed -1 of the Standardized Precipitation Index. That occurs about 16 percent of the time. Then we will assume that drought starts at the last zero before a -1 occurs. It ends at the first zero after a -1. This allows us to tag drought and to define them quantitatively of when they begin and when they end and how bad they were. That allows us to do several things. We get to define a duration. We can define a total water deficit. We can define a current intensity. This little index allows us to answer the following questions which are frequently asked in Colorado.

1. What is the probability of where we are right now?
2. What is the percent of average precipitation we're seeing?
3. What is the precipitation deficit we now have?
4. What is the percent of last year's precipitation?
5. What is the probability of ending a drought?

Figure 6

I'd like to show you an example of what happens as we consider dry periods. This is actually what happens at three months, six months, 12 months, 24 and 48 months of just accumulating precipitation through those time periods and letting them move month by month by month through history. You will get immediately the right depiction. The years here at the beginning of this graph are 1880 and at the end are 1940. So, this is the first half of the time periods for which we have instrumental observations. The first thing to note is that at three months the lines just move up and down rapidly. We go in and out of drought at the three-month time scale, one season, quickly and often. By this definition of drought about 90 droughts will occur within 100 years. They occur often and they come and go rapidly. The Colorado Water Availability Task Force, which executes part of the draft plan, is always looking at someplace that's either about to be dry, is dry or is just coming out of it. As the time scale gets a little longer, the drought occurrences come more slowly. Finally, when we get down to two years and four years in length, you can see that the droughts occur a lot less often, but they last a lot longer. Therein lies one of the most interesting aspects of climate - our climate and anywhere else - that is the difference between short- and long-term phenomena. Most of the people I've talked to in agriculture tell me their biggest problem is in-season, single-season drought, because it's a disaster instantly. Yet at the same time they tell me that they ask me the next question in the same breath, "I've already written off something about this year in terms of its impact on me. Tell me about next year." They have a built-in mechanism to recognize in their business a short-term timeframe they plan on and live on and at the same time the longer time scale. I'm convinced that it is this longer time frame that is the real potential problem for Colorado.

Figure 7

This next one is the last half of the period. These data also happen to be precipitation from the City of Fort Collins. But I'd like you to note in this one in particular. As we get to the longer time scales, the bottom two diagrams

Figure 6

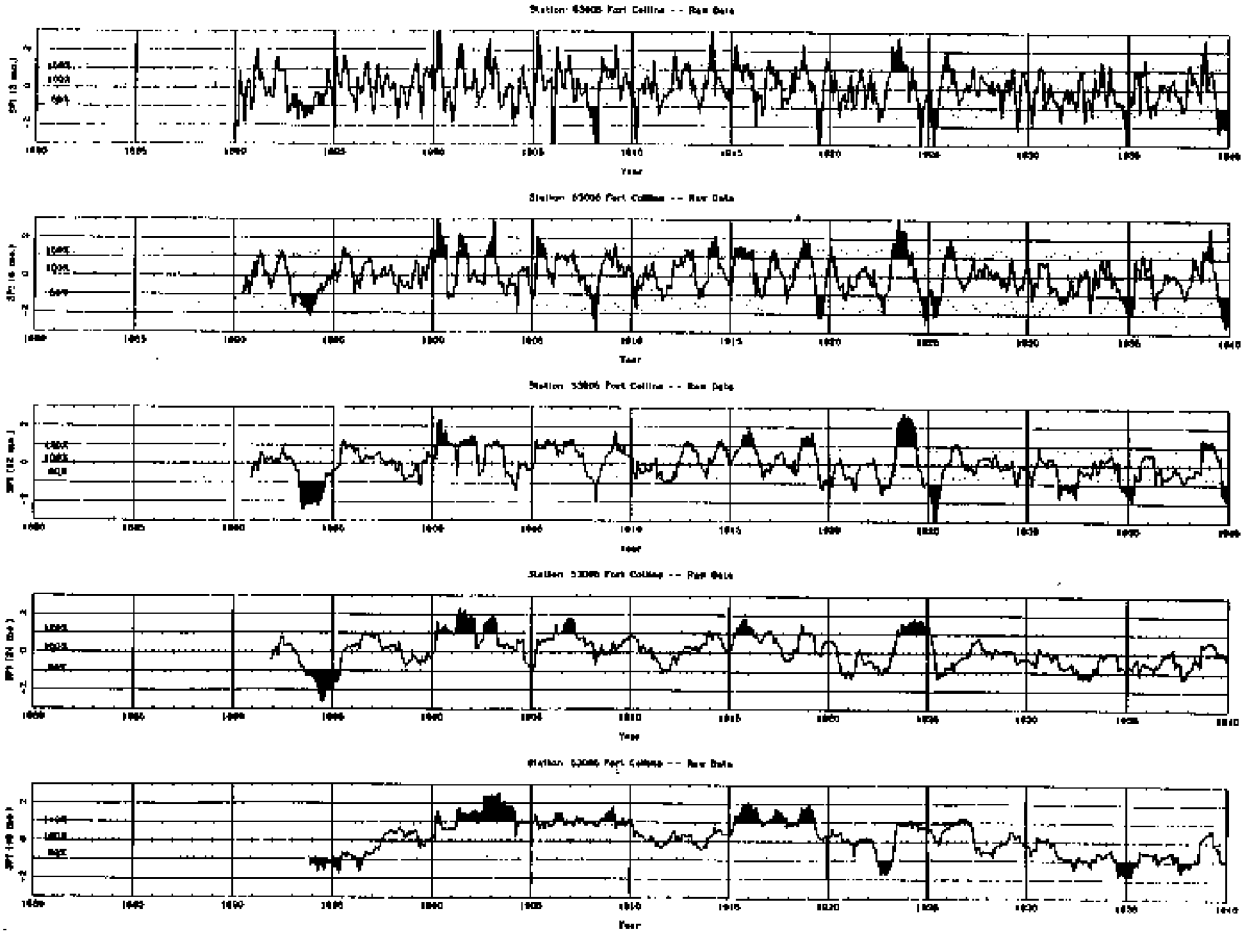


Figure 7

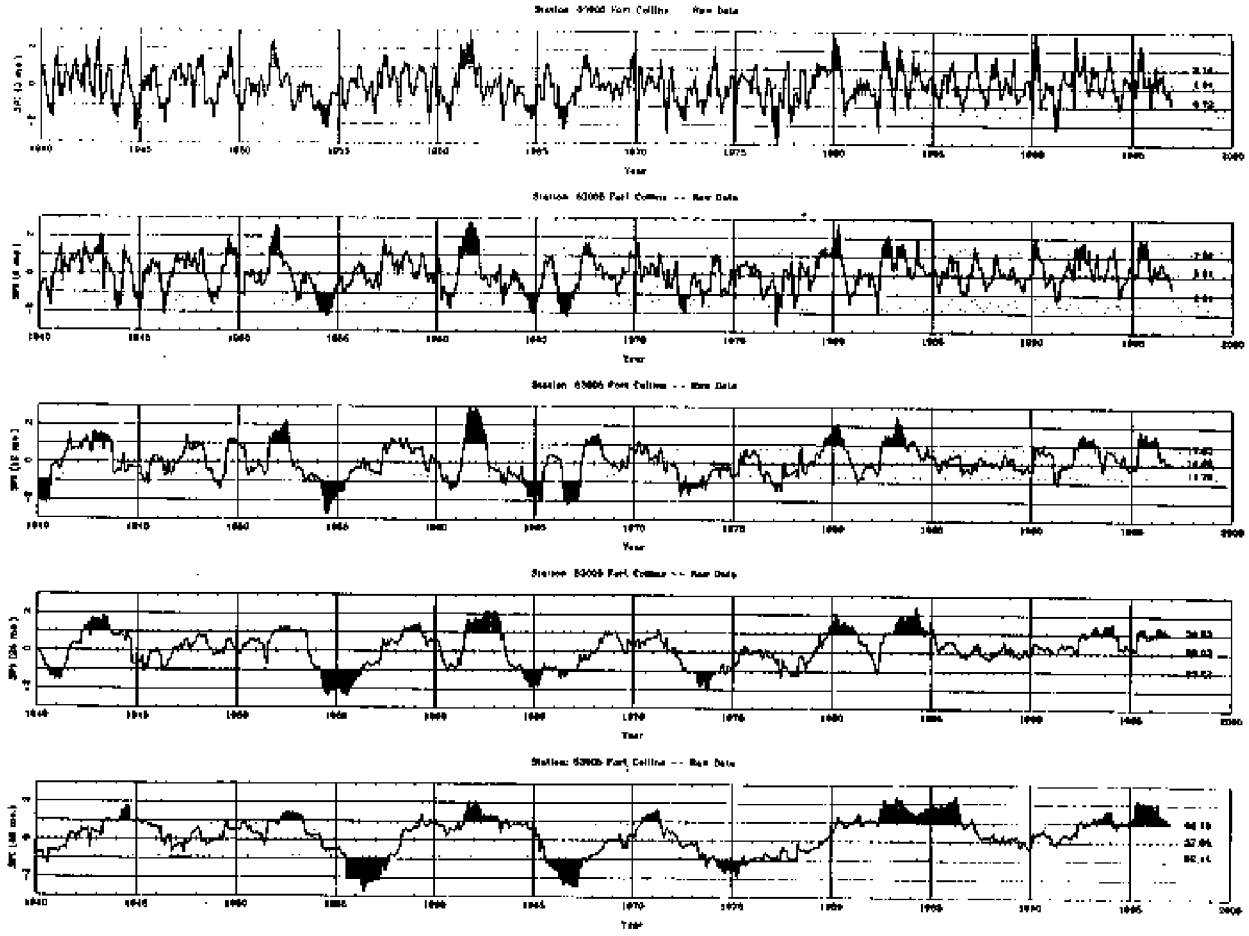


Figure 8

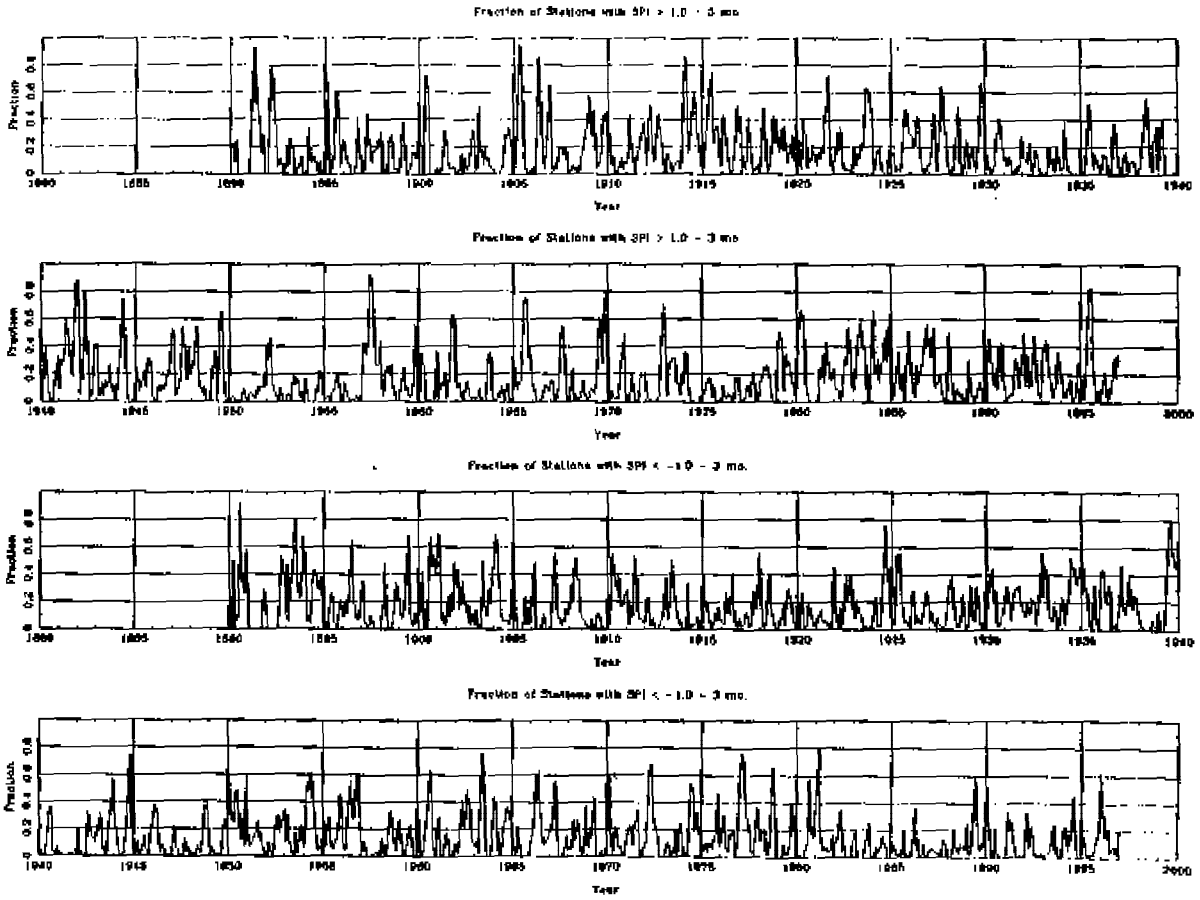
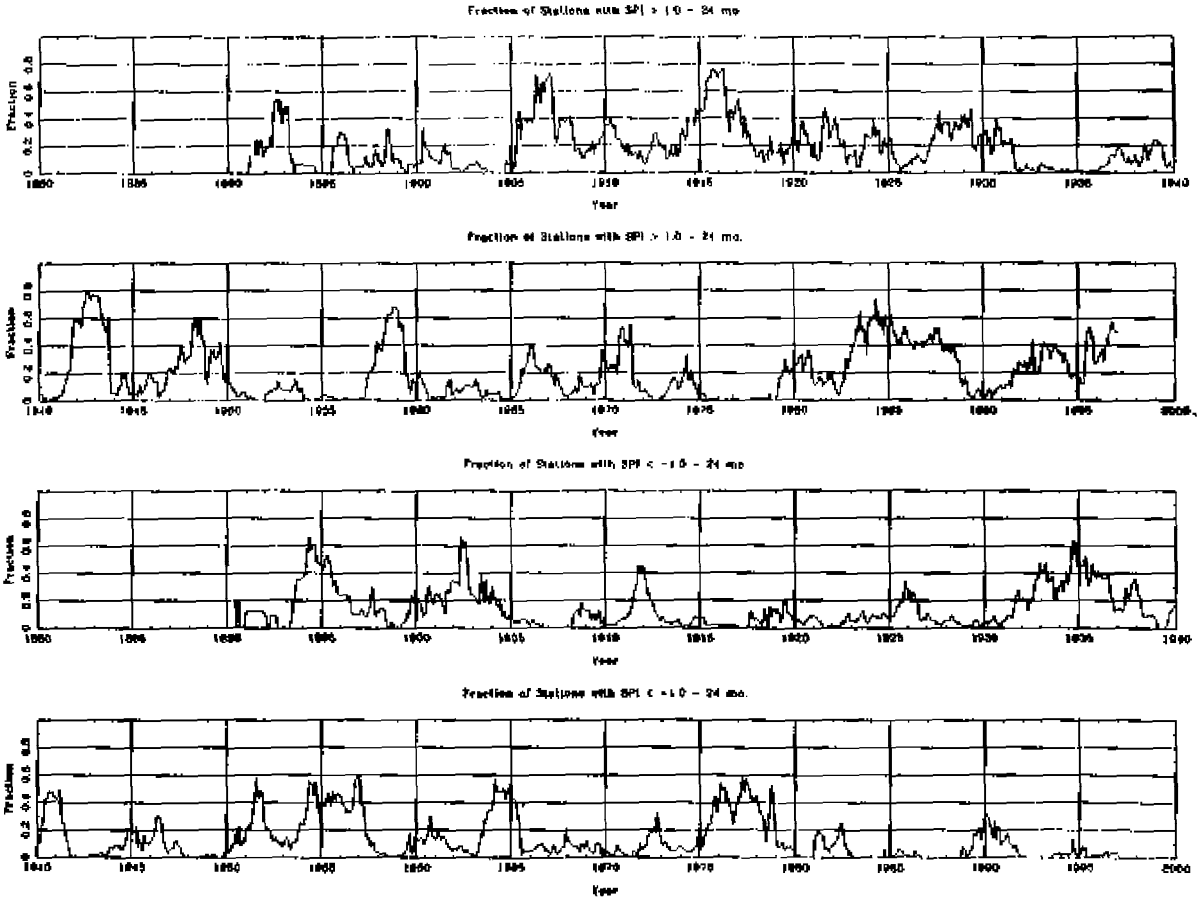


Figure 9



which is four-year running periods for the late 1970s to about 1980 through the present time, it's been nothing but wet for about the last 19 years. There was a wet period just like this early in the century, which lasted from about 1905 till about 1929 or 1930. You can also see very clearly here there was a brief dry period in the mid-1960s and a drier period in the 50s.

As an example of one drought, let us look at the period in the mid-1950s in the bottom panel, which is the 48 month time scale. The center of the drought period is solid black indicating that the SPI is below -1. According to this diagram the drought actually begin in 1954 when the SPI went below zero. The SPI didn't go below -1 until sometime in 1955 and the drought ended according to the definition we've been using when the SPI went above zero sometime in 1958.

Figure 8

This diagram is a view of history now, and it is the fraction of weather stations in the state of Colorado that are either in a very wet state, values greater than 1 of the index, or in a very dry state. This is at the three-month time scale. I think you get the idea right away the bottom two panels are dry; we're in drought. Starting again in the late 1800s and the last part of the panels at the bottom, this is wet, above plus 1 to the same index. You get the idea that it comes and goes rapidly and changes quickly.

Figure 9

I'd like to show you the same diagram at a longer time scale and let you get an instant idea of the history of Colorado this century. This one I think is easier to grasp. In the bottom panel now will be the drought. We started out with very few weather stations at the turn of the century and they were dry. It was quite a lot, we had 50 or 60 percent of the weather stations were in drought. About 1905 it disappeared, but there were so few weather stations at that time that my confidence of how widespread it was is not high. Starting about 1905, though, we had a good number of stations in the state. You'll notice from 1905 up to about 1930, this entire period was free of dry conditions in the state of Colorado. In the 1930s drought appears. It was nearly a decade-long phenomenon, and we were not nearly as negatively affected in the State of Colorado as was the Great Plains to our east. The 1940s we reappeared very wet early in the decade. As this diminishes we come back to the 50s and drought reappeared again for quite a consistent time period. Drought reappeared briefly in the 60s and again a little bit in the 70s. After the late 1970s, except for a brief period at the very end of the 1980s and early 1990s in part of the state, we have not seen large dry conditions. The top graph is wet, and you can see again before 1930, this period was very wet. This was followed by a wet period in the 40s and then in the 50s it vanished. It had been a little intermittent until we get into the late 70s and once again this wet period that we're still in has appeared.

Figure 10

Summary of Dry and Wet Periods for Colorado from the Fraction of Observing Sites. Precipitation for 24 month SPI.

Date	Dry	Duration	Date	Wet	Duration
1893-1905	X	12			
			1905-1931	X	26
1931-1941	X	10			
			1941-1951	X	10
1951-1957	X	6			
			1957-1959	X	2
1963-1965	X	2			
			1965-1975	X	10
1975-1978	X	3			
			1979-1996	X	17

If I take previous diagrams and put them in numerical form, then this little table would show us that we have had two wet periods in the last century, 1905 to 1931 and 1979 to 1996 which is still present in 1999. We had two dominant dry periods. They were the decade of the 30s and they appeared again in the period in the 50s. So, we have seen in the history of the last century we can get dry and wet for sustained periods. It turns out that in this century the two wet periods have been longer than any dry periods. We can get dry for things that approach a decade. We have not seen them since the 1950s.

Figure 11

Correlation of summer precipitation to (April - September SPI) with previous winter snow (April 1 SSI).

	Yampa Y	White W	Colorado CO	Gunnison GU	San Juan Animas Dolores SA	Rio Grande RG	North Platte NP	Cache La Poudre CLP	Big Thompson BT	South Platte SP	Arkansas AR
YW	-0.05	0.05	-0.06	0.14	0.09	0.09	0.00	-0.11	-0.12	0.14	0.09
CO	0.03	0.09	-0.01	0.17	0.09	0.11	0.08	-0.02	-0.08	0.15	0.10
GU	0.09	0.14	0.01	0.10	0.05	0.08	0.09	0.03	-0.02	0.07	0.06
SA	0.12	0.09	-0.09	-0.03	-0.14	-0.05	0.04	-0.09	-0.08	0.01	-0.06
RG	-0.02	0.14	-0.06	0.04	0.00	-0.01	0.01	-0.05	-0.16	-0.07	0.03
USP	0.17	0.21	0.13	0.34	0.36	0.26	0.14	0.11	-0.03	0.30	0.29
LSP	-0.03	0.09	-0.05	0.12	0.14	0.21	0.03	-0.05	-0.08	0.06	0.09
UAR	0.02	0.15	-0.01	0.12	0.07	0.02	0.02	-0.08	-0.13	0.13	0.00
LAR	0.11	0.20	-0.01	0.17	0.20	0.18	0.06	0.00	-0.09	0.12	0.11

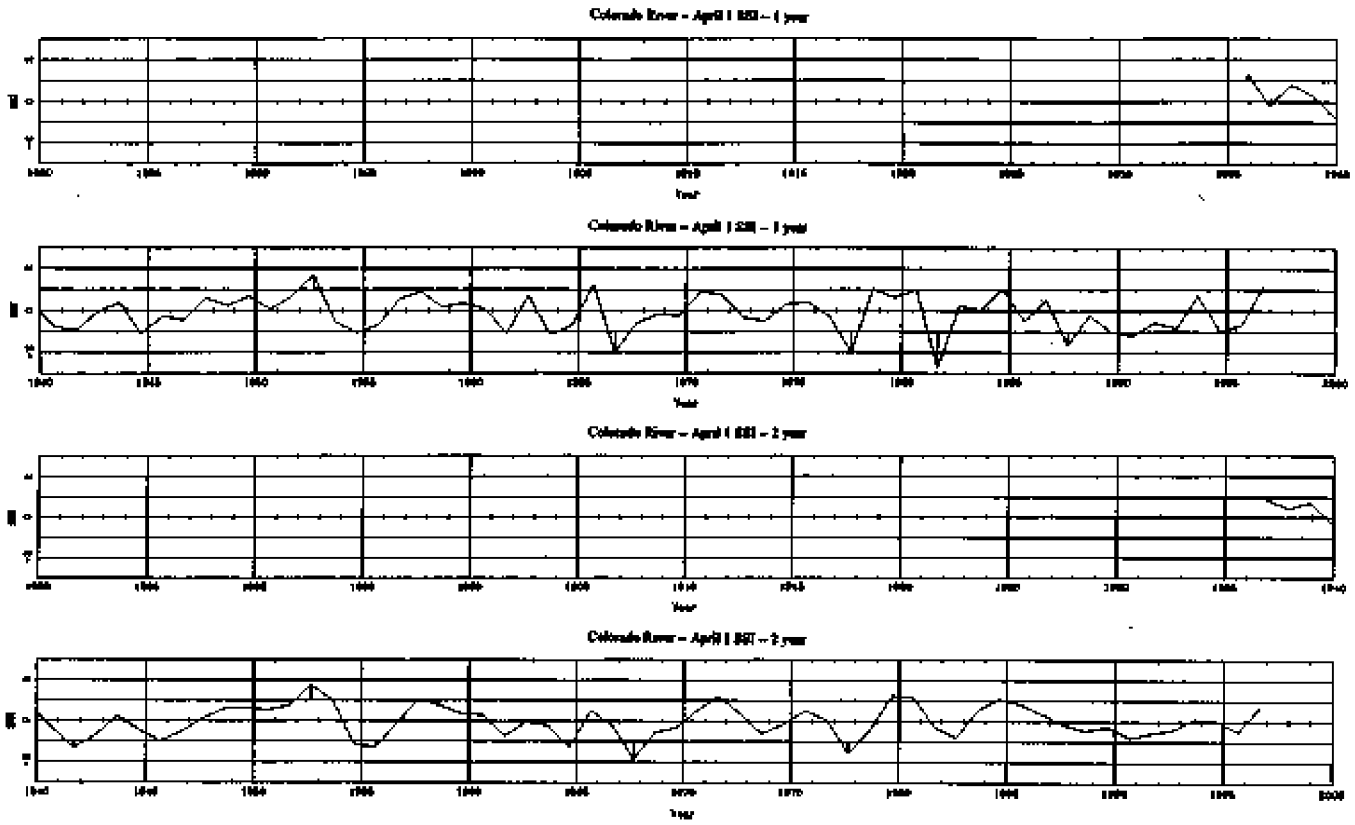
Table 15.

Correlation of April 1 SSI to water year streamflow (ST) (October - September).

	Yampa Y	White W	Colorado CO	Gunnison GU	San Juan Animas Dolores SA	Rio Grande RG	North Platte NP	Cache La Poudre CLP	Big Thompson BT	South Platte SP	Arkansas AR
Y	0.79	0.69	0.69	0.58	0.43	0.37	0.77	0.50	0.57	0.34	0.43
W	0.73	0.71	0.66	0.65	0.62	0.56	0.65	0.42	0.52	0.44	0.59
CO	0.75	0.67	0.66	0.57	0.41	0.34	0.73	0.55	0.60	0.35	0.46
GU	0.75	0.77	0.70	0.80	0.79	0.71	0.71	0.51	0.63	0.56	0.67
SA	0.58	0.64	0.54	0.69	0.83	0.74	0.57	0.46	0.58	0.47	0.60
RG	0.43	0.52	0.46	0.56	0.75	0.81	0.49	0.24	0.42	0.41	0.57
NP	0.62	0.59	0.63	0.53	0.43	0.38	0.74	0.58	0.61	0.40	0.52
CLP	0.67	0.58	0.59	0.45	0.31	0.26	0.76	0.54	0.55	0.30	0.42
BT	0.48	0.48	0.39	0.26	0.19	0.19	0.57	0.44	0.44	0.14	0.32
SP	0.62	0.65	0.59	0.65	0.62	0.60	0.63	0.39	0.55	0.45	0.51

The point of this table is one very simple one. A lot of people ask, "How are the winter snows related to the following summer precipitation?" A lot of people on the Plains who use irrigation water on the Front Range hope

Figure 12



that they're out of phase, that if we have a dry summer, they hope we have a wet winter just before so there's adequate irrigation water. The reality is they are unrelated. The winter snow and the following summer precipitation in the Plains are simply unrelated.

Now I'm going to change to snow. We have three characteristics in the whole climate system and water that we keep track of rather carefully in Colorado. One is precipitation, one is snow and the other one is streamflow. We also keep track of water in reservoirs, of course. The tough news is that all three of these variables are not easy to monitor. The problems are many.

With precipitation the problem is keeping weather stations long enough that the observations keep coming from the same location so you know they are inherently the same thing. That becomes kind of difficult. We work at that. We do have a reasonable number of sites in Colorado that have been in place for nearly 100 years. This study has used only those sites. It hasn't mixed them with short-term sites.

Snow has different problems. The records don't start until the 30s and 40s very well. Individual local measurements are not necessarily consistently representative of a large area. Sometimes they are quite local. When we look at the record of the snowpack and the record of the precipitation, they don't tell the same story all of the time. The precipitation records are dominated by summer and spring. The snow records are dominated by winter, and we don't have many ordinary weather stations in the high mountains because people don't live there.

Figure 12

When I look at the snow, this is a diagram of a snow history for the Colorado River Basin, it does have one trait in common with the precipitation. There is no long-term trend that we're getting drier or wetter. It moves up and down. You can clearly see from the snow record we do get bad years and no one will forget 1976-77 or 1980-81, the two bad years. They're as bad as we think we've had in a long time. But these snow records do not produce exactly the same picture as precipitation.

Figure 13

If we average them over a long time period, four and eight years in the same way we did for precipitation, we do find one very interesting trait. In recent years, while we've generally been wet, we've had a number of years in the Colorado River Basin since the mid to late 80s in which the snowpacks have been not terribly below average but just enough that over a longer time frame they are actually showing we are low.

Figure 14

The same thing is revealed in the streamflow. The streamflow of the Colorado River, this is its time history, has recovered in the last few years, but it did indeed go through period in the late 80s and early 90s that was quite dry. In fact that period of the late 80s and early 90s, the Yampa River saw its lowest flood ever during this period without any dramatically bad years, just several years in a row that were low.

Figure 13

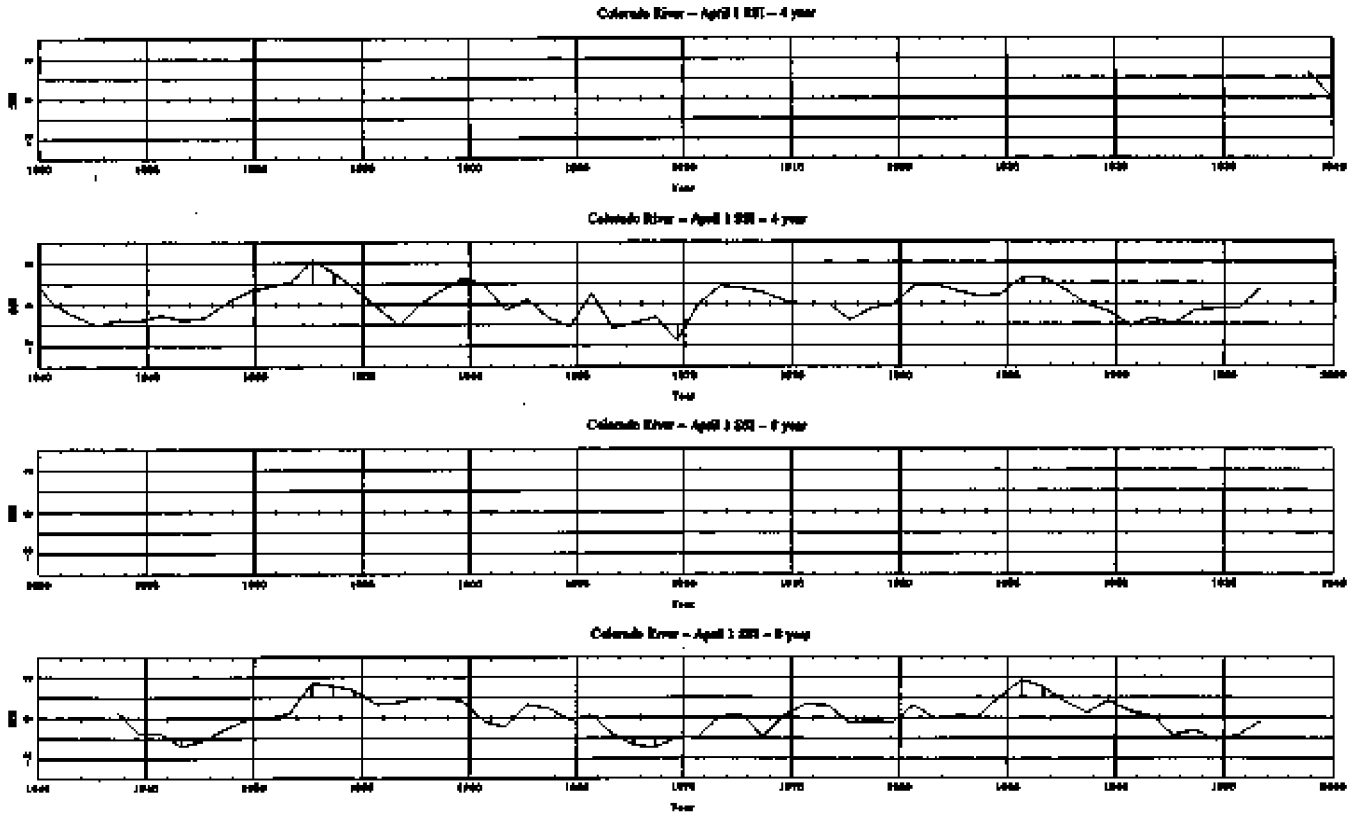


Figure 14

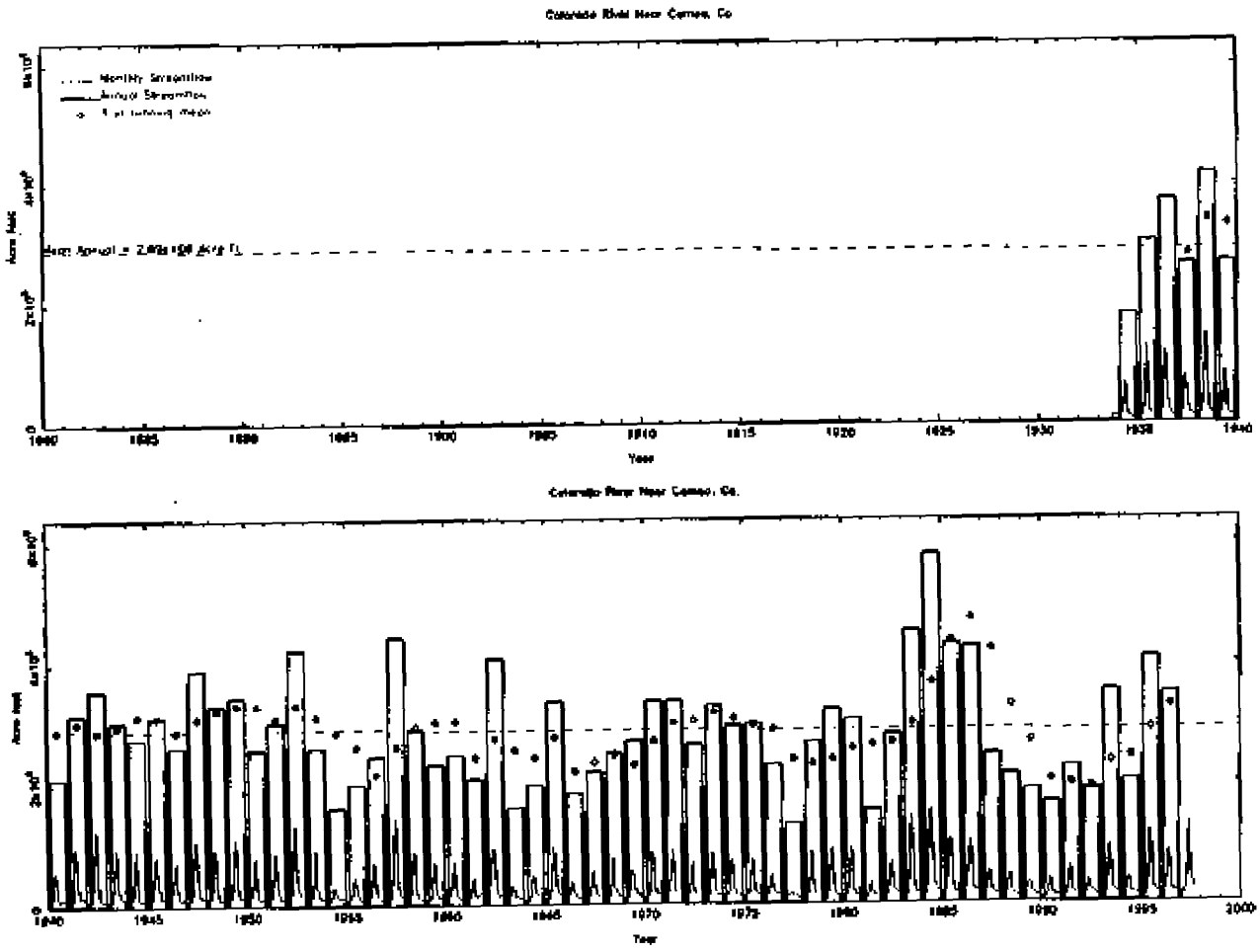
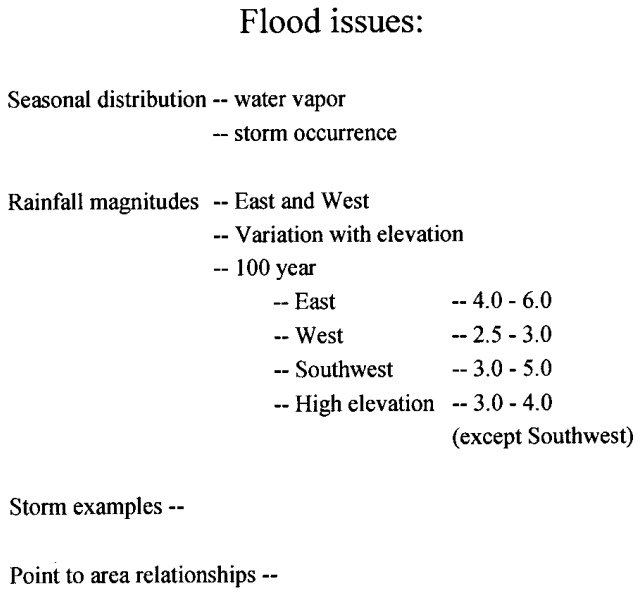


Figure 15



(the numbers in this figure are in inches)
I'd now like to turn my attention to flood more directly. The seasonal distribution of floods are much related to that one I showed you that we have a spring period in April, May and early June, a lull, then a very, very active July period when the convection appears and then it slowly tapers off into the fall season. In floods we also have dramatic differences east and west, and we have great variations with elevation. At the present time, we lack some physical understanding of flooding type rainstorms, and I'm hoping that the science will be able to help with that a lot in the future. One of the problems we're having trouble physically understanding is how floods vary with elevation. It's clear in Colorado that heavier rains occur at the lower elevations, and once we get above someplace in the lower foothills they begin to diminish with height. The paleohydrologic work of the last decade, primarily by Bob Jarrett and collaborators has clearly indicated that there are higher elevation zones in which all of the maximum stream flows have been due to snow melt. Is there a good explanation scientifically and physically why that might happen? Does it tell us or can we learn whether rainstorms of huge size do occur or do not occur and how likely are they? We are pursuing that now with the Department of Natural Resources and trying to understand how does this thing change?
But I want to really characterize floods in kind of two languages for you this morning. One is things that are characterized by a 100-year return period, which is by definition an event that has a 1 percent chance of occurring in a given year.
And at a local point, much of the studies of the past have been done to indicate very clearly about what these magnitudes are, and I've written them down here. In the eastern part of the state from the eastern boundary into the foothills it's about 4-6 inches in 24 hours. In the western part of the state it's mostly only 2.5 to 3 inches in 24 hours of a 100-year return event. In the southwest, particularly the south flank of the San Juan Mountain range, it's more like 3-5 inches. At high elevations, it's perhaps only 3-4 inches. This is one class. The other class of storms that cause floods are twice this and more, two times, three times or maybe four times the magnitude of these events. They are the ones that really cause the gigantic worries. However, the other one is point-to-area. The Governor commented that we see 100-year events every year. We should. The 100-year event is a point value for all of the scientific work that's been done. It's the probability of occurrence at a particular point. There is no known scientific connection to be able to rigorously map from a point to a broad area the probability of these things. I think with the advent of the radars it won't be too long until we begin to make that link and make it much better. However, things that occur at a point, and particularly in convective rainstorms that are only on the order of 10 miles to 15 miles in diameter, when we consider the whole of the plains of Colorado, the probability of finding them somewhere in the domain are enormously greater.
As of this conference, the concern becomes not only locally but also statewide, the frequency with which these things occur is actually common if our viewpoint is the entire state, and we see them on a very regular basis and we should expect to. Things of this category, Buffalo Creek was in this category, are going to be common occurrences in the state of Colorado. Preparing for them is something we prepare for, we can anticipate will happen regularly. The larger ones will not happen as regularly, the ones that get twice or three times this amount of rainfall. They become much rarer. Yet, we don't have to look very far in history to find them. They've occurred recently. We've had in fact in the last two years that are pretty hard to imagine.

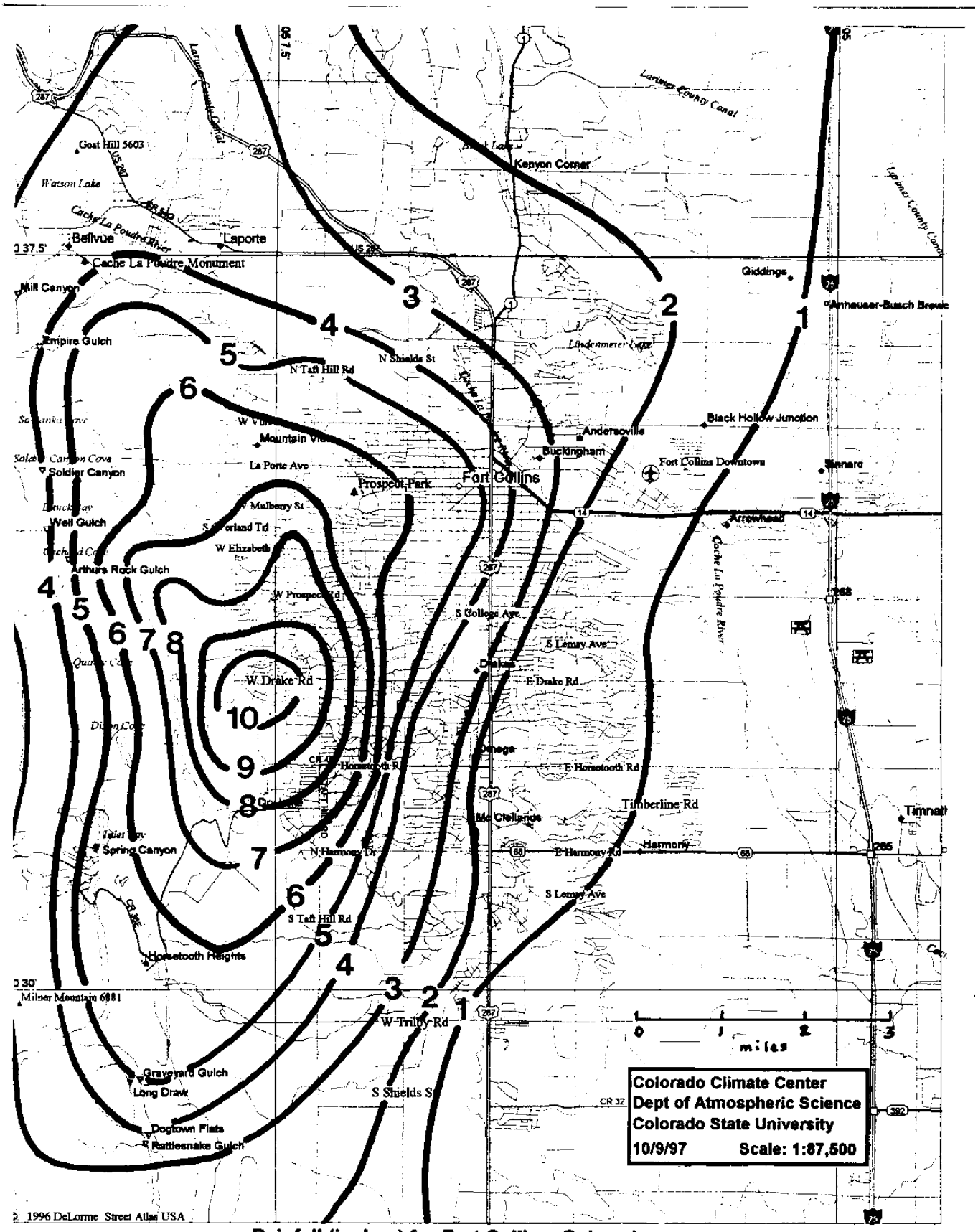
Figure 16

One of them was the Fort Collins storm. This is a precipitation map of the Fort Collins storm. This one occurred in about a five-hour period and had enormous damage that most of us are aware of. Even at that, the center of this is only two or three miles wide.

Figure 17

One storm that has not received nearly as much discussion because of the lack of total damage occurred the night after the Fort Collins storm. It was on Pawnee Creek west of Sterling. This thing is a monster. This storm could be the prototype for what is one of the worst imaginable storms that we could really expect anywhere in Colorado. If this storm were to occur closer to the foothills over urban areas, the damage would be unimaginable to me. It hasn't happened. But meteorologically or from the climate, there is no particular reason this couldn't happen here in terms of preparedness. In the spring of this year, we had the multi-day storm in the Arkansas. This summer we had more convective storms, one in the northwest corner of the San Juans, and one near Saguache that are large storms. So, we don't have to look very far in history. They are current and they are real, and we will have to face them.

Figure 16



Rainfall (inches) for Fort Collins, Colorado, for 5:30-11:00 p.m. MDT for July 28, 1997

Figure 17

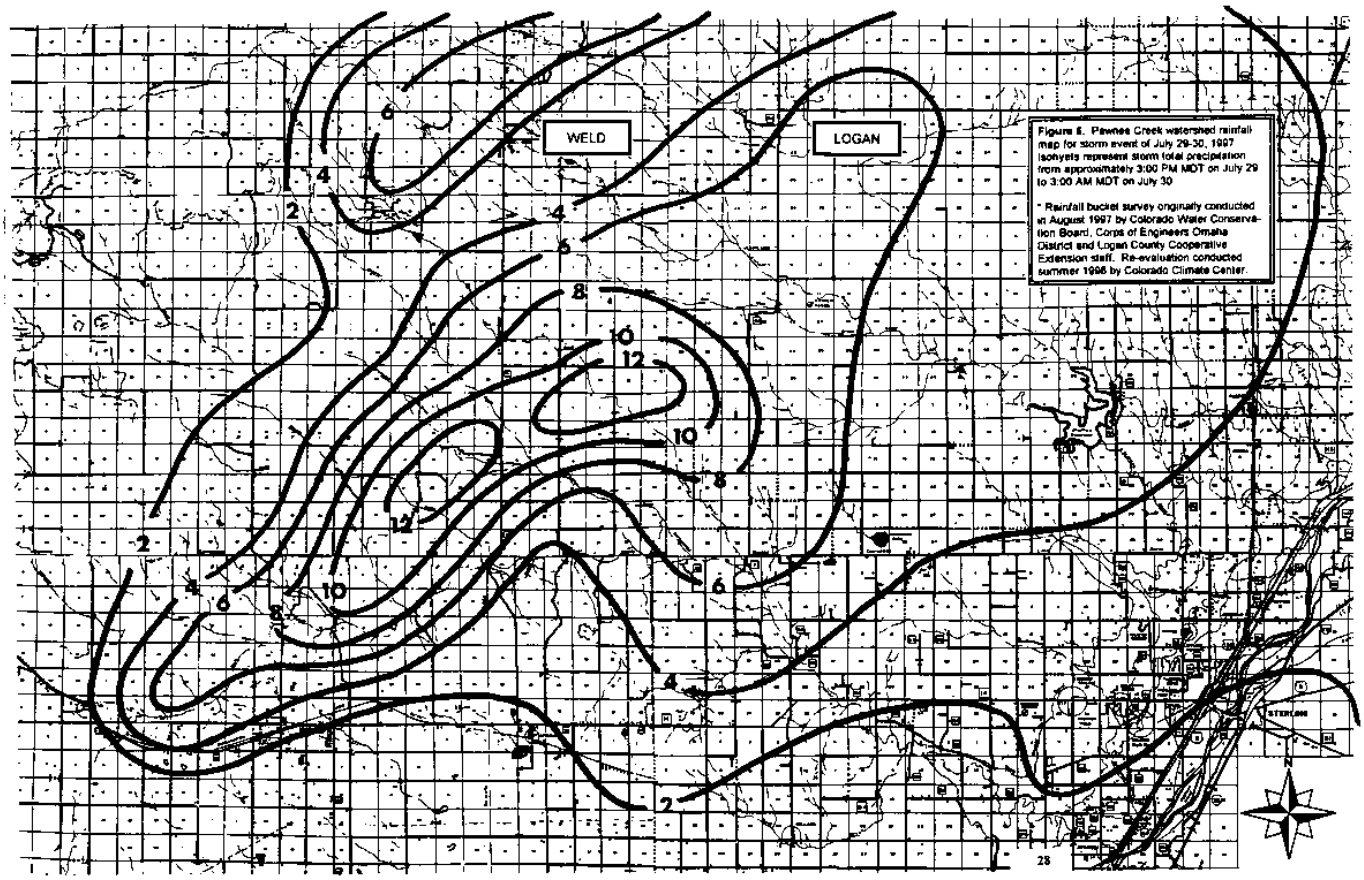


Figure 18

I would like to close with a comment about where are we now in terms of the climate in Colorado. This is a three-month view of the state at the end of October. We are marginally slightly dry in the northwest part, below average not much. The rest of the state is primarily wet. That's three months.

Figure 19

If we go on a longer time frame of two years, the last 24 months, and look at this diagram, again there are a couple of spots just barely below average in this vicinity near Steamboat to Kremmling. The southwest corner is slightly dry and the remainder of the state except for a point right near Akron is wet. In the last two years, we're still wet as wet as we've been since the early 1900s.

So far the monitoring of drought in Colorado in the Water Availability Task Force has been to take a very conservative approach of asking how bad is it, what's the probability it will clear up. If we can wait and not make a public outcry too often too soon, we hesitate to trigger the rest of these responses. But the data is available right now to do that. This list goes on. Drought at longer time scales occurs less frequently but lasts longer. There's no reason that I could expect from the climate record that we will not see long-term droughts again in the future. I know we will have one talk this afternoon in the drought session by Connie Woodhouse that indeed will look at a much longer time scale than we see in the limited time frame of 100 years. The 20th century has seen two wet periods of nearly 20 years or greater and two drought periods of 10 years, we haven't seen them in between. April 1 snowpack and precipitation are moderately well correlated, and we do get streamflow forecasts that work pretty well in our state. I don't think as a closing statement for drought that we can expect the wet period we've been in for the past 20 years to last indefinitely. It has been a wonderful period. In floods we've seen lots of them in recent years, and we have lot of examples in our clear memory to keep track of for the next years as we look forward to increased quality of forecasts and increased capability to plan and prepare.

Figure 18

Colorado

10/1999 3 mon. SPI

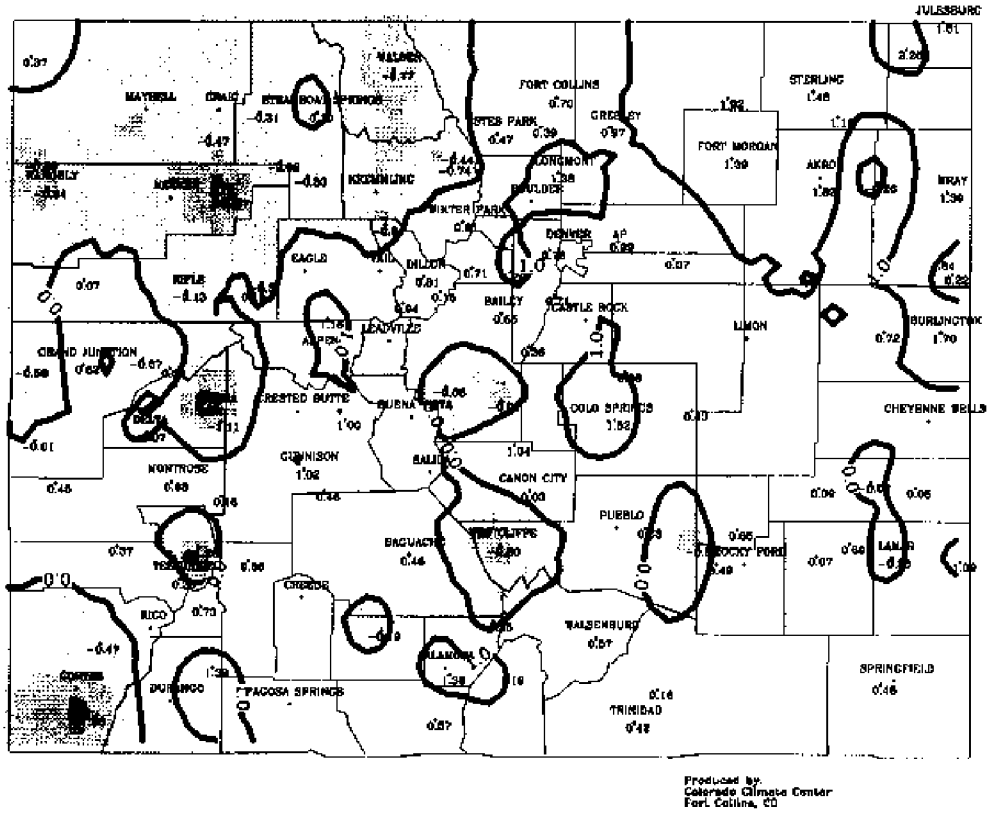
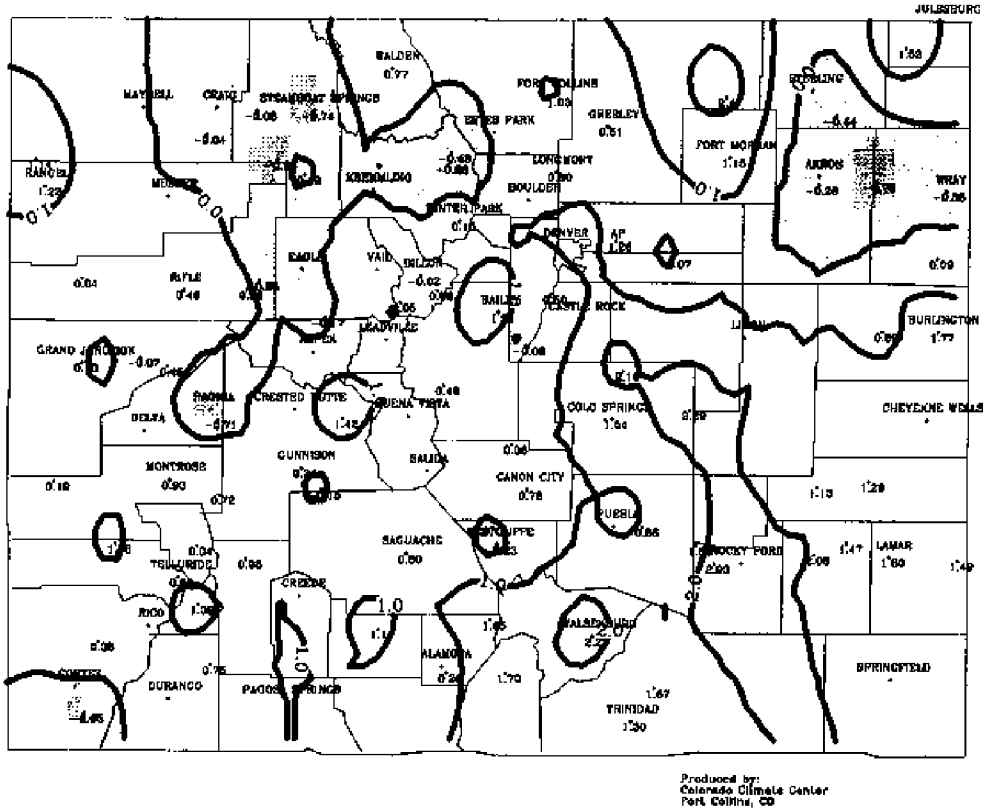


Figure 19

Colorado

10/1999 24 mon. SPI



The State of the State: How Vulnerable Are We?

Economic Perspective

Nancy J. McCallin, Ph.D.
Director
Governor's Office of State Planning and Budgeting

I'm going to talk first in general terms about how floods and droughts affect the economy and then talk more specifically as to how they have affected key industries within the state in recent years.

Floods tend to have some widespread impacts in the local areas in which they occur. People are displaced from their homes. Businesses are closed. Revenues are lost. Unemployment is increased, because businesses are closed and people cannot get to their jobs. Infrastructure, such as bridges and roads, is lost. Buildings tend to be ruined. There can be damage to parks. Floods also directly impact agriculture, which in Colorado is one of the top five industries and produces a little under $5 billion in receipts. Floods can result in a loss of crops, as well as a loss of livestock and a decrease in crop yields. My research into the subject of flood impacts also revealed at least one positive impact, albeit a temporary impact, and that is a temporary increase in construction activity to rebuild structures that have been damaged by the flood.
Droughts affect both the agricultural industry and the tourism industry. When you have drought clearly you have a loss of crops. A widespread drought can also affect national crop prices, which in turn affects the livestock industry by driving up the cost of feed. Colorado's agricultural industry has a mix of crop and livestock sectors that is somewhat different than the national mix. In Colorado, about two-thirds of our agricultural sector is in the livestock sector and about one-third is in the crop sector. The crop industry is far more important to the southeast portion of the state than many other areas in the state, and the livestock industry is far more important to other areas of the state such as Weld County, for example. However, as noted earlier, droughts can affect both the crop and the livestock sectors.
Droughts also affect the tourism industry, which is also among Colorado's top five industries. The most notable impacts are on the ski industry. There is a loss of skier days and a loss of revenue to the ski industry and to the local towns in which the ski industry exists. Hotel stays go down. Restaurant sales go down. We also see a loss of sales tax revenue to the state.

Also with droughts come an increased risk of forest fires and related economic impacts associated with fires. Additionally, it should be noted that agriculture and tourism are export industries. In other words, these are industries that bring in money from outside the state and truly enhance and improve the state's standard of living. Therefore, floods and droughts, which significantly impact these industries, have much bigger impacts than factors that might affect industries that are not export related. In general terms, what we see is that a flood will have widespread impacts within the local area in which it occurs, while a drought will have significant impacts on two of our key industries.

There are numerous types of assistance available to communities and businesses impacted by these natural disasters. You've got federal assistance. You can get low-interest loans from the U.S. Small Business Administration. You can get some debt disaster unemployment assistance. The Federal Emergency Management Agency (FEMA) also has a public assistance program. The state has some assistance to localities. Then you also have private individual insurance policies. But as many of you in this room know, even when you combine state, federal and private dollars together, the assistance typically never equals the damage that has occurred.

Let me give you an idea of what areas are at risk in the state in the event of a flood. Right now we have about 250,000 people living within 100-year floodplains. We have about 80,000 structures - 65,000 homes and 15,000 businesses - valued at $16.5 billion in those 100-year floodplains. The cumulative loss of property from floods since the 1900s in Colorado in today's dollars is about $4.5 billion. The average flood losses per year in this state are estimated at about $17.6 million. So there's fairly significant damages that can occur and have occurred due to flood losses. Yet, the number of flood insurance policies covering structures in our floodplains is relatively small compared to the risk. Specifically, only about 15,200 insurance policies are logged on the 80,000 structures within the floodplains. Those policies insure about just $1.8 billion of the $16.5 billion value of those structures. Since 1978, the insurance industry has received about 1,400 claims totaling $5 million. So, again, the amount of insurance that we as individuals and businesses take out in these floodplains is relatively minor compared to the amount of property and the amount of structures there.

Let me give you some recent examples of what the damage has been in various flood-related incidents in this state. The most recent flood-related incident, as you heard from Dr. Thomas McKee, was in Colorado Springs and 12 Eastern Colorado counties last spring and summer. The damage there is estimated between $61 million and $100 million. There had been some payments from both FEMA and the state to the counties and some insurance payments. But again those payments for the loss of damage were relatively small in comparison to the damage. You didn't have the full amount of the damage covered by insurance policies or other payment. In July of 1997, there was the flood in Fort Collins and in 13 Eastern Colorado counties that caused about $169 million worth of damage in 1999 dollars. Those of us who grew up in Colorado,

remember a couple of significant flood events real well - the Big Thompson River flood in the mid-1970s and the South Platte River flood in the mid-1960s. These are very distinct memories and have been etched in my mind for a long time. In the Big Thompson flood, as you know, we had 144 deaths and about $85 million worth of damage. But the most severe flood that we've had in terms of property damage occurred in June 1965 along the South Platte. There were fewer deaths, only eight recorded, but we had $2.2 billion worth of damage resulting from that. Again, that's a flood I remember very vividly, because I happened to be at Yale and Colorado Boulevard at the time and there was three to five feet of water there. It's hard for many people to imagine today how severe that flood was. But as I recall at that time, that was a very, very severe flood that caused a lot of property damage and was a fairly significant event for the state as a whole.

Examples of how droughts have affected Colorado can be seen from the impacts the last major drought had on the tourism industry. We have to go back to 1975 to 1978 to look at the last major drought that occurred. Though this drought did affect the farm industry, most notably on ranching, it had more of an effect on the tourism sector. Let me first talk a little bit about the agricultural sector and what we saw happen. The drought was most severe along the Western Slope where we had precipitation of 11 percent to a little bit under 50 percent of the normal. The Eastern Plains were also in a drought period, but not as severe as the Western Slope. We had about a 3 percent drop in farm income during that period, which was about $20 million in the 1975 to 1977 dollars, that is, not adjusted for inflation. The primary impact to the farm industry of that drought was that we had a lower harvest. In other words, more land was planted than was harvested, which impacted farm profits. For ranchers, the lack of precipitation ended up with the graze land not being replenished, forcing many of the ranchers to sell their cattle prematurely at a reduced cost or assume the additional costs of renting graze lands elsewhere or to buy feed from the open market where the drought increased feed crop prices. So, you saw some fairly significant cost increases in the livestock industry as a whole. During that period the Farmers Home Administration provided about $63 million in low-interest loans to about 1,200 farmers in Colorado, which caused an increase in farm debt. As you'll recall, we had very significant increases in debt that took a long, long time in Colorado to run off. In fact, the late 1970s and early 1980s ended up driving a debt-to-asset ratio in the farm industry by the mid-1980s of more than 40 percent. Part of that was due to problems within the industry as a whole, but also was precipitated in the very beginning by some drought issues that led farmers to increase their debt level. The greater impacts from the mid-1970s drought were on the ski industry. What we saw was a 40-percent decrease in the amount of lift tickets sold and a decline of 2.3 million skier visits. That's very, very significant for that period of time. The most severe decrease occurred at the destination resorts. These are resorts that are not day visits for people in Colorado, but tend to be further into the mountains and require some travel to get to and an overnight stay. Most significantly affected were Aspen, Crested Butte and Steamboat, which experienced a 60 percent decrease in the number of lift tickets sold. Telluride and Purgatory ski resorts closed for most of that season. The ski industry estimates that they lost $79 million in revenue as a result of that drought. Colorado has about eight counties that are more than 50 percent dependent on the ski industry. Those eight counties saw their hotel and restaurant revenues drop by 30 percent and retail sales losses of $7 million. Commercial airliners had a $15 million drop in revenues. The overall sum of what was occurring was a 15 percent drop in ski-related business employment because of the drought. So, the drought in the 1970s, which occurred when we didn't have any snowmaking equipment, had a very severe impact on our ski industry and on our tourism industry as a whole. We have made significant investments since then in snowmaking equipment, and as a result, some of these drought impacts in the future can be mitigated. But I think it's clear that you're still going to continue to see the ski industry having a negative impact because of drought conditions. In fact, although we didn't have it classified as a drought last season, lack of snowfall clearly caused a decrease of close to 5 percent in skier visits in Colorado. It was the first decrease we had in skier visits since the early 1980s.

In conclusion I want to leave you with the clear impression that when you have floods and you have droughts, there are economic impacts and those economic impacts can be severe. There is a loss of property, a loss of revenues and a decline in economic activity in two of our key export industries, agriculture and tourism. Those industries bring money in from outside the state and therefore have a fairly significant effect on our standard of living and can be impaired from these natural disasters.

Flood and Drought Challenges and Colorado's Water Future: Green is Beautiful

Hank Brown
President
University of Northern Colorado

Disaster prophecies and disaster fictions are popular across the United States these days. The public seems to have a fascination with the possibility, remote that may be, that our major cities will be wiped out by volcanoes, or earthquakes, or space aliens. Particularly in vogue right now is a global environmental wipeout in the form of meteor or comet impacts.
However, I believe that an environmental disaster of a less dramatic kind is in the making for the green agricultural empire of Eastern Colorado. It is the drying up of the rich farmlands that, more than 100 years ago, took the place of much of what early explorers called "the Great American Desert."

Lifestyles, rather than widespread loss of life, are at risk. The good news is that it is preventable. The bad news is that little is being done about it.
"Colorful Colorado," our license plates used to read. For most of us, it describes the way we feel about this beautiful state. That beauty includes some of the most spectacular mountains in the world as well as great cities filled with parks, grass and trees. And then there are the irrigated farms of Eastern Colorado, where in the spring and summer the earthtones of the Great American Desert have been replaced with beautiful expanses of green.
The pioneering settlers improved our environment by helping to turn the desert into a garden.
Earliest of all were the Spanish explorers who accompanied Coronado and gave the state its name. Colorado is Spanish for "red color," so named for the red rocks and topography. Those pathfinders and treasure-seekers wrote of the "great arid desert" to which Coronado's expedition had traveled.

Zebulon Pike, for whom Pike's Peak is named, said after visiting the area in 1807 that he "found desert everywhere." Major Steven T. Long, who followed Pike on an expedition in 1819, reported: "No one but nomads could exist there. There was no timber or water. The soil was poisoned. The countryside was covered with sand and cactus. It is almost wholly unfit for cultivation and of course uninhabitable by people depending on agricultural for their substance."
How could these explorers be talking about our Colorado? In many respects it was a different climate than we enjoy today. The Colorado of the explorers was transformed from a semi-arid desert into a garden by an extraordinary network of water storage and irrigation projects built by the early settlers. By capturing the spring floods coming from the mountains with dams and diversion projects, those pioneers literally transformed the desert into a productive green oasis.

Fortunately, they listened not to Major Long but to people like Horace Greeley, the famous editor of The New York Herald, who came to Colorado by stagecoach before the outbreak of the Civil War and saw it differently.
Greeley arrived in Denver, Kansas Territory, on June 6, 1859, painfully injured and bone weary after a harrowing 13-day stagecoach trip across the "desert" from Leavenworth. But, he gathered enough strength to chronicle the character of the land from his keen perspective as an agronomist. He said Denver and its rival settlement, Auraria, were plagued by too little water, and a rough population of several hundred, mostly men, deprived of nearly all of the creature comforts except whiskey.
The famous editor had traveled widely and had studied many cultures, ancient and contemporary. He was able to look beyond the dismal scene he found in 1859 and predict in his dispatches to The New York Tribune that great cities would grow along the Rocky Mountains all the way from Fort Laramie on the north to Taos on the south. He wrote: "This region is destined to be a favorite resort and home of civilized man. I have never visited a region where physical life could be more surely prolonged or fully enjoyed."

He also foresaw an agricultural empire in northeast Colorado. The key, Greeley wrote to his New York readers, would be the construction of "high and tight dams" in the mountains, so that the waters which fell in abundance in the High Country could be diverted to the fertile but dry prairie for, in his words, "manufactures, or for irrigation, as the need shall be most urgent."

Horace Greeley was much more than a journalist. Today it would be appropriate to say of him that he "put his money where his mouth was." Following the Civil War, many Americans, and European emigrants, began looking for gold, or land, or business opportunities Greeley became caught up in the Colonies movement in which prospective settlers got together in Eastern cities, pooled their resources and headed west, in wagons and later by rail, to stake out farms and start towns.

In 1869 Greeley joined with his agricultural editor, Nathan Meeker, in forming a successful agricultural cooperative called the Union Colony in Northern Colorado. Greeley never lived there, but Meeker did, and as President of the colony he presided over the construction of irrigation works that took water from the Cache la Poudre River to the farmlands. That was the beginning of the agricultural industry that today makes Weld one of the most productive farmland counties in the nation.

Meanwhile, before the turn of the century other visionaries began to design and build water supply and distribution systems east of the Continental Divide that taxed the engineering skills of the day. In addition to the Cache la Poudre, the waters of the South Platte and the Arkansas Rivers were captured and sometimes stored in the "high and tight dams" that the editor wrote of in 1859.

While Greeley recognized that water from such dams one day would be used for cities and towns as well as for farmland, he could not foresee the immensity of the water needs of those "civilized men" (and no doubt today he also would say "and women") in the century-plus that has followed. The state's population east of the Rocky Mountains has grown from the few thousand in 1859 to nearly three million today, and our lifestyles include water-dependent lawns and parks, home laundries and kitchens, and a myriad of industries and office complexes.

A search of Greeley's copious writings indicates the thought that Coloradan's might find it necessary one day to choose between water for agriculture and water for urban areas never occurred to him. Nor was it likely in the mind of President Theodore Roosevelt who, in his first message to Congress in 1901, said: "The western half of the United State would sustain a population greater than that of our whole country today if the waters that now run to waste were saved and used for irrigation. Great storage works are necessary to equalize the flow of streams and to save the flood waters."

Roosevelt then founded the U.S. Bureau of Reclamation, which built most of the most ambitious water storage and diversion projects in the West. But, he wasn't the only visionary. Smaller projects that were vital to the agricultural areas across the state, and to city and town-dwellers, were designed and built by private companies and by urban governments and special districts.

In my decades in public service I have observed very little awareness among those who move to Colorado from other states of the vital role of water storage projects in transforming Colorado into the kind of place they wanted to live. Once here they become concerned about further population growth. It is natural that such newcomers would question efforts to store and conserve Colorado's precious water resources because they come from areas with different climates.

Sometimes I have challenged them to do a little research on what our urban and agricultural environments would look like if we went back to the "good old days" where the only water flow in Colorado was the natural flow. It's worth reminding ourselves of the very positive role of water storage and conservation in the evolution of Colorado as one of the best places anywhere to live, raise families, raise crops, recreate and grow old.

Not nearly enough of Colorado's citizens, particularly the younger ones, have done this. That is ominous.

Ultimately, wise decisions by future leaders and voters should be based on water realities, not water myths. Some of the realities that I believe Coloradan's should know about follow.

Colorado provides the headwaters for seven different drainage basins. The pattern of flow out of our mountains for all of the basins is similar. Nearly two-thirds of Colorado's annual water is produced as part of the spring flow. The spring floodtides come in April, May, and June and in some parts of the state in May, June, and July. Because such an extraordinary portion of the annual flows comes during that period, we face periodic floods. Adding to the volatility of our spring run-offs is the propensity of the Front Range to be affected by convective thunderstorms, particularly in June, July and August.

The nightmarish Arkansas River flood at Pueblo in 1923, the Plum Creek-South Platte River killer flood in 1965 and the Big Thompson River major disaster of 1976 are just a few examples.

According to the National Weather Service the strip of Colorado that lies just east of the Front Range is more subject to immense downpours than anywhere else in the nation - even surpassing the hurricanes of the Gulf States in terms of 12-hour precipitation potential. Fortunately, such towering, violent thunderstorms boil up only once every decade or two.

For example, in the same 1965 convective storms that savaged parts of Arapahoe, Denver and Adams Counties wrecked havoc through northeastern Colorado and western Nebraska. The Bijou Creek, which joins the South Platte River downstream from Denver near Fort Morgan, and normally is made up more of sand than of water, carried almost as much water as the Mississippi River for a few days during the 1965 storm.

During the span of recorded history - as far back as the disastrous 1858 Cherry Creek flood through downtown Denver and as recently as the 1997 Fort Collins flood - Colorado has suffered from extraordinary volatility both in terms of the occasional convective storms and runoff during years of exceptional snowcap in the mountains. Water storage infrastructure has been a godsend for Colorado's environment simply because, along with flood control impoundments, it provides a way to control some of the worst excesses of Mother Nature. However, prudent planning sometimes needs a nudge from Mother Nature to get moving.

Before the 1965 Plum Creek-South Platte River flood there was limited support for the proposed Chatfield Dam on the plains just outside of Waterton Canyon. But after the 1965 flood and the devastation of lower downtown Denver, there was near-unanimous support in the state for what has become one of Colorado's best investments - Chatfield. Far from harming our environment, these water projects provide an essential safeguard for both life and property,

and often give us some wonderful outdoor recreation opportunities as a bonus.

Most years the natural flow on Colorado's rivers drops off dramatically beginning in September. Recent studies indicate that the flow on most of our rivers drops to one percent or less that of the annual average during the months of November, December, and January. Thus, over the years many of Eastern Colorado's rivers - including the South Platte and the Arkansas - would go dry during the winter months. That's what used to happen. Explorers and early settlers reported that, from the vicinity of Ft. Morgan and into Nebraska, the South Platte often became a river of sand during the late part of the year.

The dry side of extreme fluctuation of river flow, accompanied by the dry and arid climate, is what caused many of the early explorers to conclude that they were crossing a worthless desert. In fact, "semi-arid" turned out to be an accurate description.

While average annual moisture levels vary in the state from a low of eight inches a year in the Grand Valley on the West Slope and the San Luis Valley in Southern Colorado, up to a high of 18 inches a year in our good wheat country in the northeast, Colorado averages, overall, an extraordinarily dry 14 inches of precipitation. This is less than one-third that of some of our eastern states. Ironically, the U.S. Environmental Protection Agency (EPA) expert on water who was sent in to evaluated the need for Denver's proposed Two Forks Reservoir in the 1980's came from Georgia, where normal rainfall is 45 inches per year, and the natural riverflow normally is much less volatile than Colorado's. Like other newcomers to the state, he had difficulty understanding how our water supply works and seemed ignorant of how water storage has transformed much of Eastern Colorado from a semi-arid desert to a garden. He never did seem to grasp the water facts that seem so obvious to native Coloradans.

Many of our water storage and distribution projects have been multiple purpose. They have been designed not only to control the spring floods but also to store water for agricultural purposes later in the year. The greatest use of agricultural water in Colorado comes at the times we bring row crops such as sugar beets and corn to maturity in August and early September. Unfortunately, and apparently unknown to many newcomers and even some natives, this time of greatest need by agriculture is also a time that the natural streamflow falls off dramatically. Thus, one of the major purposes of water storage has been not only to control the spring and early summer floods but also to carry that water over to the late summer period, when it is desperately needed to finish our crops.

While other states, such as our neighbors in Eastern Nebraska and Kansas, have been blessed with natural moisture sufficient to produce crops, Colorado almost always depends on water stored from the spring runoff to turn our plains into a beautiful and valuable array of greenery.

Additionally, the visitors to our state enjoy recreational opportunities not present or even possible when the explorers first looked at Colorado. Whether it is the sailing on Grand Lake and Lake Dillon or the fishing and water skiing at Metro Denver's Chatfield and Cherry Creek Reservoirs, recreational opportunities have been dramatically expanded with the use of water in storage and flood control. Water-dependent recreation came to Colorado in areas where it could not have existed without our water projects. For example, the dependable year-around stream flow has created Gold Medal trout fisheries below many of our dams.

There was a time when it appeared that pumping of groundwater would greatly diminish the need for additional storage of water from streams. And indeed one need only to look down at the huge circles of center pivot irrigation greenery during the Eastern Colorado, and Western Nebraska and Kansas, growing seasons to understand the important role that water pumped from underground plays in the economy and environmental quality of the Great Plains.

However, use of groundwater at current levels may itself become part of Colorado's water supply dilemma - let alone a reliable and responsible alternative to dams and reservoirs. While it is true that great underground lakes, called aquifers, underlie large areas of Colorado, scientists have discovered alarming depletion of some of them because of heavy pumping.

Congress has funded several studies of the Ogallala aquifer in Colorado, Nebraska and Kansas in an effort to preserve this very precious resource for future generations. Colorado has acted responsibility to limit well drilling and pumping, and coordinate its use with that of surface water resources. This important option for scarce water resources has come under regulation and scrutiny, but without question it will need to be used carefully along with surface water in order to meet the state's needs.

Perhaps the most significant need for additional water storage for Colorado's future comes from the troublesome legalities of interstate water compacts that have made Colorado an unwilling guarantor of water supply for tens of millions of Americans in other states.

The best known of these interstate agreements, the Colorado River Compact, supposedly allocates half of the river's flow to the Upper Basin states of Colorado, Wyoming, New Mexico and Utah, and the other half to the Lower Basin states of California, Arizona and Nevada. This compact, which was facilitated by an Act of Congress and signed by most of the states in 1922, leaves less than a quarter of the Colorado River water that originates in Colorado for use by Coloradans - and in the future there could be even less. The problem is that the compact guarantees the quantities received by the lower basin states, but not the upper basin states. To make matters worse the assumption that actual riverflow averages 15 million acre-

feet per year at the dividing point between the Upper Basin and Lower Basin turned out to be false. It is too high by 2 million acre-feet, but the Compact has not been amended to acknowledge that fact.

Furthermore, late in World War II, as a tradeoff for stationing U.S. military forces South of the Border, President Harry Truman handed over 1.5 acre-feet of Colorado River flow annually to Mexico to irrigate produce farms. This was done without regard for the provisions of the Compact and, worse, in practice all of it has come out of the Upper Basin's share in low streamflow years.

During occasional years of above-average streamflow this situation thus far has imposed no extraordinary burden on Colorado. However, during periods of drought and, with increasing frequency, even during normal runoff years, it is a far different story. And, during times of widespread low precipitation Colorado suffers a "double whammy." Not only is the natural streamflow reduced but also, as populations in Lower Basin states grow, accompanied by increased water consumption, Colorado is required to make up for the shortfall out of our own storage reserves if called upon to do so by Lower Basin states.

Our present and future dilemma is that without more water storage, several-year periods of drought will wreak havoc to farmers and city dwellers in Eastern Colorado. And, it turns out that the droughts that have occurred since formal record keeping began in the mid-1800s - in the 1930s and 1950s, for example - were mild compared with what has happened in the past and what inevitably will happen in the future in Colorado.

How can we know this without written records? The answer lies in the fact that Mother Nature was keeping accurate records that have come to light only recently. They are in the form of tree rings from ancient Western forests that have been collected and classified by the Laboratory of Tree-Ring Research at the University of Arizona in Tucson.

In 1987 the engineering firm of Resource Consultants, Inc., of Fort Collins, studied tree cross-sections gathered in both the East and West Slope watersheds that supply Metropolitan Denver and found strong evidence of decade-long droughts much more severe in Colorado than occurred even in the Dust Bowl years. The tree rings indicate that profound droughts visited both East and West Slope watersheds from 1771 to 1784 and from 1814 to 1827.

For Colorado to ride out future periods of such profound drought, an additional safety margin is essential to meet the interstate compact with minimum hardships. When the next extended drought (or even a lesser event of, say, three years) comes along Colorado faces grim times unless we are able to add a lot more water storage capacity to our current inventory. That's a daunting political challenge in our nation today, but I believe that it's not only responsible planning but also that the environmental pluses would far outweigh the environmental minuses that major infrastructure projects bring.

Lessons can be learned from relatively recent and comparatively minor drought occurrences. Many Coloradan's will recall the drought of the 1954-55 period. A number of lakes around the state were literally dried up trying to meet agricultural and municipal water demands. And, in Denver and some suburban communities, lawn watering was severely curtailed.

As recently as the 1970s Lake Dillon in Summit County, the Denver Water Department's largest storage facility, was drained nearly dry because of a need to compensate for below normal streamflow.

Carrying water over from a plentiful year to a drought year in enlarged or new reservoirs ultimately may be the best and cheapest insurance policy any consumer could have and, even before that policy pays off, we will have valuable dividends in the form of protection from the impacts of burgeoning Lower Basin demands (they sometimes have droughts that don't affect Colorado) and much-needed new recreation facilities.

Many Coloradans - and often they are newcomers - have taken the position that growth needs to be strictly limited or stopped, and that the best way to accomplish that would be to place a moratorium on adding new water storage, or even abandon some of what we currently have, within the state. While they sincerely believe that such a position is correct, they clearly do not understand our water system. Wittingly or unwittingly, Federal agencies sometimes have helped limit and eliminate water storage, and not necessarily with population growth control in mind. For example, armed with what they evidently felt was a good cause, the U.S. Forest Service has blocked new water storage projects and even attempted to in essence confiscate century-old water rights within the state, supposedly to benefit fish in streams as far away as the Missouri River.

Over 90 percent of Colorado's water is used by agriculture, not by homes or industries. As many folks assume, even with river compact constraints enough water exists within Colorado to supply far more urban growth than most of us would desire - if we are willing to pay a heavy environmental price. Water resources are being bought away from agriculture and converted to municipal use when other supplies are unavailable. Cities and industries can pay many times what agriculture can afford to pay for water, and thus as the population grows we may be forced to convert more and more agricultural water to cities - unless we can build more storage capacity to better use our water rights. And, since water rights are bought and sold in the marketplace, and since existing agricultural water will support ten times the population that currently exists in Colorado, a shortage of water storage capacity to make better use of our current entitlements under the compacts will not stop growth. However, it will dry up the green

cropland if we fail to provide better answers. Already, thousands of acres of irrigated farmland have been taken out of production and the water transferred to cities. Whether it is the area near Sugar City in Crowley County or in the northeastern part of the state, the phenomenon of drying up farm ground is not new. What is new is the fact that this trend will dramatically accelerate should the state turn a blind eye to its need for more reservoir storage space.

Not everyone agrees on what constitutes good environmental quality. My viewpoint is that the drying up of irrigated farm ground is an environmental quality disaster in progress. It turns green, productive farmland on the Colorado plains back into a semi-arid desert. It will mean higher summer temperatures for the eastern part of the state because there will be less transpiration to moderate extremely dry climate such as existed in "the good old days".

Irrigation did change climates in large areas of Colorado - for the better.

I am not alone in believing that the explosive population growth in Colorado, and particularly in the eight-county Denver metropolitan region, is far from over. State of Colorado and Denver Regional Council of Governments demographers forecast that the region's population will grow by about 700,000 persons between 1999 and 2020, which would be just short of the combined current populations of Denver and Aurora.

The State of Colorado has just released the final report of the Metropolitan Water Supply Investigation, which was authorized by the Colorado General Assembly in 1993 with the following mission:
"To explore cooperative solutions to future metropolitan Denver area water supply needs that would minimize the conflicts often associated with development of large scale water supply infrastructure such as transbasin diversion projects."

A 45-member "blue ribbon" advisory group, the Front Range Water Forum, was appointed by the Governor to work with technical teams to bring forth what turned out to be a 141-page document, not including appendices, scoping what could be done - legally, technically and politically - to meet the region's municipal water needs through 2030. Major new storage facilities were left out of the picture. So were the potential savings from new water conservation programs, the effectiveness of which historically are difficult to predict.

Potential sources of additional water included:
· Conjunctive use, in which groundwater supplements surface water during dry periods, and the aquifers are recharged with surplus streamflow during wet periods.
· Recycling of the effluent from sewage treatment plants.
· Interruptible supplies, under which agricultural water users north of Metro Denver would be paid to give up their water during drought periods.

· Miscellaneous sources, such as expansion of current reservoirs, and better management of existing water rights.
Major potential problems in sewage plant discharge recycling and in obtaining interruptible supplies from farmers were anticipated in the study.

After "reasonably certain" future water supply additions that are planned by municipal water agencies were taken into account, future unmet needs were estimated, on the high side, at 138,000 acre-feet. To put that into perspective that's about one-fourth of the entire water storage capacity of the Denver Water Department today. It's also greater than the estimated total yield of the never-built Two Forks Dam and Reservoir.

No doubt some of the unmet needs can be handled by the sources included in the state's investigation, but it appears to me that:
1. Arriving at the "unmet need" may dry up thousands of acres of irrigated farmlands.
2. Droughts of the magnitude of those in the 1930's and 1950s would cause severe horticultural losses in Metro Denver and draconian rationing of domestic water.
3. A profound drought such as those in the 1700s and 1800s would be devastating to our lifestyle.
I do not easily recommend new studies, but nonetheless they might become necessary to help avert a disaster-in-the-making.

I believe that the State of Colorado must take the leadership role in facilitating ways to bring about a dramatic increase in our surface water storage facilities to preserve the environment.

While it may be unpopular in some quarters, that might very well turn out to be at least one major new reservoir on the east slope. I am not about to recommend a specific site for such a major facility. Finding a consensus on what to do, let alone where to do it, will be a daunting challenge. But, I am convinced that it is necessary for the well being of this and future generations.

What I do know is that Colorado must neither ignore the problem nor adopt a future water policy based on ignorance. I also know that those who want to go back to the "good old days" may want to come to understand Colorado's water system before they dismantle it or reflexively oppose any new water storage proposal.

Concurrent Sessions: How Prepared Are We? Track 1: Flood Issues

Moderator: Larry Lang, Chief, CWCB Flood Protection Section
Recorder: Mark Matulik, CWCB Flood Protection Section

Rural Case Study of Flood Impacts and Recovery Activities
Barbara Kirkmeyer
Weld County Commissioner

Weld County's most recent flooding experiences have been in 1997 and 1999. The county was included in Colorado's presidential disaster declaration each of these years. Historically, flood events have occurred in Weld County since before Colorado achieved statehood in 1876.

In 1997 and 1999, the county experienced $2-3 million in flood damages, mainly to roads and bridges. Not many residences or businesses were impacted by flood events during these years. In 1997, the county received $365,000 in federal aid to assist with flood recovery operations. The 1999 aid figures have not been finalized, but the county expects similar, or less, aid for the 1999 presidential disaster declaration.

Twelve to fifteen inches (12"-15") of rain fell over one Weld County watershed in 1997. But no federal dollars were available for individuals impacted from this storm in Weld County. However, housing dollars from the Colorado Department of Local Affairs (DOLA) were available to impacted residents. Commissioner Kirkmeyer observed that if lives are not lost in such an event, the general populace believes there probably wasn't any damage.

Commissioner Kirkmeyer stressed the need for an improved point of command during flood response and recovery efforts. She indicated that the Weld County Commission should serve this function. During 1997 and 1999, all Weld County governmental departments pulled together at the county's Emergency Operations Center (EOC) to coordinate flood response and recovery efforts. They also coordinated with the Federal Emergency Management Agency (FEMA), the Colorado Department of Transportation (CDOT) and the Colorado Office of Emergency Management (OEM).

Flood hazard mitigation has been embraced by the community through:
1. its participation in the National Flood Insurance Program (NFIP);
2. its desire to upgrade its communication operations during emergencies; and
3. a desire to encourage more master drainage planning in the county.

The southwest part of Weld County has recently completed a master drainage plan for the Tri-Town Area. In addition, 350 miles of floodplain have been identified by the county as needing detailed floodplain information.
The county feels that there were increased flood impacts along the South Platte River during the 1995 and 1997 flood events due to operational releases from Chatfield Reservoir in Denver. Better coordination through the state and federal governments is needed to ensure a minimum impact from reservoir operations during high water events. Lessons learned from the 1997 flood event made it easier for the county to move forward with the presidential disaster declaration process in 1999. There are 32 municipalities in Weld County, and the county works with all of them to secure grants following natural hazard disasters. The county feels that changes are needed in FEMA's Hazard Mitigation Grant Program (HMGP) because the funding is too limited and competitive.

At the end of the presentation, Fred Metzler of FEMA Region 8, gave a detailed explanation of the disaster declaration process.

Urban Case Study of Flood Impacts and Recovery Activities
Duncan Bremer
El Paso County Commissioner

Commissioner Bremer began his presentation with a PowerPoint slide show entitled "El Paso County Storms and Flood Assessment, April 28 - 30, 1999." He then provided a verbal explanation of the 1999 flood event. The flooding rains began on April 28, 1999, and over the next two days, up to 13 inches fell west of Interstate 25 in the Colorado Springs area. Five to nine inches fell on the eastern high plains in unincorporated El Paso County during the same period. The county's Emergency Operations Center (EOC) was opened and activated. The EOC provided assistance and support to Manitou Springs and Palmer Lake. It also provided assistance to local fire departments and local governmental agencies throughout the region. Stranded equipment due to high water was a common occurrence. EOC personnel checked jurisdictional dams at Monument Lake, McCray Reservoir and Lake Woodmoor. All checked out fine.

Several detention facilities across the region were also checked and found to be in working order. Stormwater facilities were checked, and only Stratmoor Hills had prob-

lems. The Sinton and Las Vegas outfalls worked well during the high water event and sustained no damage. However, energy dissipaters were damaged at Las Vegas Street and Sand Creek. Rock Creek Canyon Road was partially washed out, and residents had to "make due" until repairs could be completed.

El Paso County had 37 roads that experienced damage (from high to low) during the 1999 flood event. There were 11 road closures. Highly erodible soil was identified as the culprit in most cases of road damage.
El Paso County's next steps in the continuing recovery and mitigation process include:
1. Update/identify damaged areas.
2. Prioritize, design and implement construction efforts for:
a. property damage;
b. damage to county facilities;
c. damage to utilities;
d. loss of access; and
e. imminent hazards.

Serious impacts which have been prioritized by the county include:
1. closed roads;
2. site damage due to adjacent grading;
3. site grading with erosion and drainage problems;
4. no maintenance for several detention facilities;
5. migrating channel of Fountain Creek; and
6. erosion impacts on banks, homes, roads, etc.

Damage estimates from flooding in 1999 for Colorado Springs, El Paso County (EPC), small municipalities in the Pikes Peak Region and special districts are estimated at over $14 million. Flood damage prevention projects currently underway can be found on the EPC website. This alleviates the need for county staff to respond to phone calls.

Current flood-related capital needs in Colorado Springs and El Paso County are estimated at $236 million. An additional $34 million is needed for the remaining governmental entities in the region.
The county feels that effective hazard management plans are crucial for the region. Critical components of these plans include:
1. regulations (codes and criteria)
2. master watershed plans; and
3. a dedicated funding source.

With regard to funding, Commissioner Bremer agreed with an audience comment that subdivision fees could be a source of funds for these activities. But he felt that the fees were not proportionate to the level of risk (vulnerability). Consequently, there are shortfalls. And a "backlog" of problems (risk) exists because many subdivisions in the county were built before effective land use regulations were adopted.

Another problem being experienced by the county is sediment transport in highly erodible watercourses. Sediment transport science is a problem according to the commissioner. But the county recognizes the fact that there is:
1. increased streamflow due to urbanization;
2. increased streamflow due to trans-basin diversions; and
3. more municipal use, therefore, more treated water than ever (groundwater included) being put back into watercourses.

Two minor intergovernmental cooperation issues have been amplified due to the 1999 flood event. First, the area's regional Stormwater Services Project is lacking an adequate funding mechanism. This realization came about due to the magnitude and extent of the recent flood event. Second, the Fountain Creek Watershed Form has been established to examine various issues affecting the basin. The effort is currently at the consensus-building stage of development but is having trouble with this effort. U.S. Army Corps of Engineers, Albuquerque District, Program Manager Jim White commented that the Corps' present authorities cannot adequately address erosion problems in watersheds. He wanted to be perfectly clear that a General Investigation (GI) by the Corps in the Fountain Creek basin would not lead to solutions for the erosion problem unless a Congressional policy change was effected to alter the Corps' authority.

Commissioner Bremer then commented that he felt the county should take a conservative approach to the type of development it allows in and near the floodplain. He also felt that sediment modeling improvements are sorely needed. He noted that there is a potential lawsuit from landowners along Fountain Creek downstream from Colorado Springs due to damages suffered during the 1999 flood event. But even if the county would like to assist, Amendment 1 (TABOR) problems exist in trying to move money from one dedicated function to more flood control projects without voter approval. Commissioner Bremer strongly felt that a two- to three-year program of heightening public awareness would be needed before a ballot issue to establish a funding mechanism for flood control and hazard mitigation could be brought before the region's voters.

Prevention Versus Reaction: Pay Now or Pay More Later
Ann Azari
Former Mayor
City of Fort Collins

Former Fort Collins Mayor, Ann Azari began her presentation with a video of the 1997 flooding in her city. Its emotional images clearly portrayed the horrors and devastation which floods can render. Just 30 days prior to the July 28, 1997, flood event, the City of Fort Collins was feeling extremely proud of awards it had recently received from the state and Federal Emergency Management Agency (FEMA) for flood hazard mitigation efforts in the community. But when an estimated 500-year flood event strikes,

the memories of those awards vanish quickly.
During the 1997 flood event, Colorado State University suffered over $100 million (estimated) in damages. Fort Collins and surrounding had another $100 million. But everyone in the community came together for assistance and support. The Emergency Operations Center was activated and staffed by excellent personnel. Everything was in order and things started getting better quickly - except for the emotional toll such an event has on the residents of a community.

In the first 24 hours, residents were dealing with the immediacy of loss of life and property. The "human piece" of the disaster drove the first 24 hours. Mitigation measures implemented in 1990 removed over 100 persons from the Spring Creek floodplain just adjacent to where five lives were lost during the 1997 flood event. The city feels sure that if that project had not been completed the death toll in 1997 would have been much higher and possibly close to 100 lives.

After the initial response and recovery efforts were underway, the citizenry began to get mad. As is human nature, they needed someone to blame and the city was the most convenient target. Never mind that the City of Fort Collins has one of the most aggressive stormwater management programs in the United States. And too much local, regional and national publicity about the flood event didn't help either.

In the end, however, city staff have had many opportunities (in Colorado and nationwide) to share their experiences and teach the lessons they have learned. But as always following a flood event, the question is asked "Where do we go from here?" To begin that part of her presentation, Former Mayor Azari provided a historical perspective on floods in the community.

Fort Collins was established in 1864. In 1865, the "city center" was moved due to floods. Then in 1891 there was another memorable flood followed by more flooding in 1902, 1904, 1938, 1951, 1965, 1992, 1997 and 1999. The city is still having floods after all these years and after the establishment of a city-wide stormwater management program. But continued mitigation efforts, coupled with initiatives like FEMA's Project Impact, are bringing Fort Collins closer to realizing their dream of becoming a "disaster resistant community."

Given these facts, the former Mayor couldn't help wondering, "Why don't we learn from our mistakes?" and "Why do we think we've done everything we can do?" Political debates are now occurring in Fort Collins about whether the city should regulate the 500-year floodplain and size its stormwater projects to accommodate such events. But recently, the city's voters chose to take the "slow road" for drainage improvements given the costly nature of such projects.

And the community leaders are re-thinking the age-old question, "How much public risk is acceptable?" One hundred-percent protection just doesn't seem possible given cost constraints. Therefore, those residents who live in floodplains should be willing to share a portion of the risk. The purchase of flood insurance is one option they have. Former mayor Azari's message was crystal clear: "Share the risk and don't forget the past!" Following the presentation, Fred Metzler of FEMA Region 8, spoke to the audience about flood insurance.

Buffalo Creek Case Study From The Landowner's Perspective
Judge Donald P. Smith (retired)
Buffalo Creek

Judge Smith and his wife are residents of Buffalo Creek, an unincorporated town located in southwestern Jefferson County, Colorado. The town's winter population is 45 residents. In the summer, it "swells" to 145 persons. On May 18, 1996, a forest fire burned 12,000 acres in the area surrounding the community. The town lies at the confluence of Buffalo Creek and the North Fork of the South Platte River.

The forest fire denuded the Buffalo Creek watershed and created a hydrophobic soil condition. Thus, the stage was set for disaster on the night of July 12, 1996, when rains of three to four inches fell in just over 45 minutes upstream of the community. The result was 7,000 cubic feet per second (cfs) of floodwaters in Sand Draw, a tributary to Buffalo Creek, just outside the Smith's front door. Buffalo Creek carried an estimated 11,000 cfs. The ensuing devastation caused a community to pull together to demonstrate the indomitable will of the human spirit following a natural disaster.

Although there was an estimated $2 million in damage and parts of Colorado Highway 26 were washed out, it was initially difficult for the community to obtain help other than immediate response assistance from Jefferson County government and the state. This was due mostly to the fact that the community had no official government structure. The town's fire station was destroyed and it's community center was moved off its foundation by floodwaters.

With the problem in mind, Judge Smith formed the Buffalo Creek Crisis Committee to serve the function. In the days and weeks following the flood, the committee met at Judge Smith's residence every day. Decisions were agreed upon so the community could receive further assistance in the form of grants. But the assistance didn't keep the community from feeling a sense of abandonment with no one wanting to accept fiscal responsibility for recovery and mitigation efforts.

Immediate needs for food, pure water and bathrooms were provided by the Red Cross and the State. But the prob-

lems of the community's severely damaged central system loomed large and daunting. But these problems caused the Crisis Committee to work even harder, become a non-profit (501(c)(3)) entity, and obtain grants and loans from various entities, public and private, to undertake the task of rebuilding their water supply system. The community now owns its water system and in mid-December 1999, the voters will decide whether or not to form a water district. Judge Smith feels there are several lessons to be learned from this challenging experience. First, all governmental emergency plans (local, state and federal) need to take into account the fact that disasters can occur in areas with no formal governmental structure. Therefore, the community must identify natural leaders beforehand and build a de facto government to make important decisions. Next, the state needs to revisit its emergency designation process with the idea in mind that, even though smaller disasters can occur, there has to be a way to assist communities even if disaster declarations are not enacted. Lastly, local and State emergency management offices need to be able to assist small unincorporated areas in working through the "red tape" that is always associated with disasters. And they need to be sensitive to a community's desire to accomplish recovery and mitigation on their own.

The community now has its own emergency notification system (phone tree) when summer thunderstorms present the threat of further flooding in the community. In fact, Buffalo Creek has had at least one flood every summer since 1996 due to state deforestation in the Buffalo Creek watershed. The town has developed a strong sense of community vigilance but knows that when big flood events occur it can't go it alone. Only through successful intergovernmental cooperation can the community recover and face the challenges that nature often thrusts upon it.

EL PASO COUNTY AREA STORMS & FLOOD ASSESSMENT

April 28,1999

thru

August 30, 1999

Overview of Events

- Wednesday April 28, 1999 rains begin
- Up to 13” of rain fell west of Interstate 25
- 5” to 9” of rain fell in the eastern plains
- Double shifts used over the four day period
- Emergency Operations Center activated the evening of Thursday April 29th
- Overall: A *20 to 30-year* event

- E.O.C. requests assistance.
  - ***Manitou Springs***, Engineering Assistance, equipment operators, “Flood Routing”, sand bags and sand, general clean up.
  - ***Palmer Lake,*** Engineering assistance**,** funding options,
  - Provided emergency assistance to various fire departments, and local agencies. Including assistance with stranded equipment.

Rock Creek Canyon

JD JOHNSON ROAD


Fountain, Columbine Ave. Area
From Utility Rd South
Appx 60 deg magnetic
To 100-Year '97 Floodplain: 250 feet!


Fountain, Columbine Ave. Area
Former Back Yard,
(from utility rd south)
Appx 40 deg magnetic
Blue House
Approx. Pre-April 30
Creekbank Edge

El Paso County Federal / State Flood Assistance

FEMA Public Assistance: $5,169,580

- County Agencies 123,840
- Small Municipalities & Special Dists 632,424
- Col. Springs 4,413,316

NRCS County 4,850,000
Col Springs 3,150,000

FHWA 295,000

FEMA Individual Assistance 986,406
(Includes 1,034 Col Springs Appls
202 County/Other)

GRAND TOTAL $ 14,450,986

Flood Damage Projects on El Paso County Website

Proj. No.	FEMA #	Location	Submitted to:	Prelim. $ Estimate	Revised Estimate	Status	By
35 79		Abilene Drive		$ -		Delete	
35 49	5604	Antelope Road	FEMA	$ 5,000.00		Repair only	RM
35 82	5633	Arrowwood		$ 5,000.00		Delete	
35 60		Baggett Road		$ -		Delete	
35 93		Beacon Lite Road		$ 10,000.00	0	Delete	
35 70	5621	Blaney Road	FEMA	$ 5,000.00		FEMA repair only	JW
35 92	5605	Blasingame Road	FEMA	$ 5,000.00		FEMA repair only	RM
35 68	5619	Bluegill/Cottontail	FEMA	$ 10,000.00		FEMA repair only	JW
35 64	5617	Book Road		$ -		Delete	JW
36 05		C.J.C. Access Road	NRCS	$ -	$ 90k	Facilities handling	
35 98	5647	Chelton Road		$ 5,000.00		Delete	
35 89	5640	Chennault/Doolittle	FEMA	$ 5,000.00		FEMA repair only	
35 92		Cloven Hoof Drive		$ 5,000.00		Delete	
36 10	5661	Corning Place	FEMA	$ 30,000.00		FEMA repair only	
36 11		Crestridge Drive		$ 5,000.00		Delete	
35 94	5645	Dawson Road		$ 10,000.00		Delete	
35 57		Eastonville Road	FHWA - 6/1/99	$ 25,000.00	$5,661	FHWA	DH
35 94	5635	El Rancho Way		$ 5,000.00		Delete	
35 95		Ellicott Highway		$ 5,000.00		Delete	
35 63	5616	Ellicott Hwy. Bridge	FEMA	$ -		Submit for FEMA upgrade.	RM
35 54		Falcon Highway		$ 10,000.00		Delete	JW
36 07		Fontaine/Grinnell		$ 5,000.00		Delete	
35 58	5612	Garrett Rd	FEMA	$ 5,000.00	$21,113	Submit for FEMA upgrade.	JW
36 09	5660	Golden Lane		$ 10,000.00		Delete	
35 81		Golden Pine Lane		$ 5,000.00		Delete	
35 75		Hanford/Corning		$ -		Delete	
35 85	5636	Hay Creek	FEMA	$ 5,000.00		FEMA repair only	
35 87		Higby Road		$ 5,000.00	$3,921	Delete	
35 53	5608	Highway 110	FEMA	$ 15,000.00		FEMA repair only	RM
35 78		Hodgen Road		$ 5,000.00	$930	Delete	
36 12	5663	J.D. Johnson Road	FEMA	$ 15,000.00		Submit for FEMA upgrade.	RM
20 84		Jantzett Road Bridge		$ -		Delete	
35 99	5650	Jones Road	FEMA	$ 5,000.00		FEMA repair only	RM
35 42		Judge Orr Bridge #2	FHWA - 6/1/99	$ 10,000.00	$2,700	FHWA	JW
35 45		Judge Orr Bridge #3	FHWA - 6/1/99	$ 10,000.00	$23,150	FHWA	
36 00		Kane Road				Delete	
35 47	5603	Knollwood	FEMA	$ 15,000.00	$6,870	Submit for FEMA upgrade.	
35 51	5606	Log Road	FEMA	$ 15,000.00		FEMA repair only	RM
19 06		Markscheffel Road		$ 5,000.00		Delete	
35 83		Martindale		$ 10,000.00		Delete	
35 52	5607	Mc Clelland Road	FEMA	$ 10,000.00		Submit for FEMA upgrade.	RM
35 48		Meridian/Stapleton	FHWA - 6/1/99	$ 5,000.00	$18,670	FHWA	JW
35 62		Meridian/Walker	FHWA - 6/1/99	$ -	$5,705	FHWA	JW
35 66		Meridian/Widman Hills	FHWA - 6/1/99	$ 5,000.00	0	Combined w/3548	
36 04		Mohawk Trail #9 B-70		$ -		Delete	
35 44	5601	North Monument Lake Rd.	FEMA	$ -		Submit for FEMA upgrade.	JW
35 71	5622	Murr Road	FEMA	$ 5,000.00		FEMA repair only	JW
36 03		Nampa Road		$ -		Delete	
35 90	5641	Nursery Road	FEMA	$ 10,000.00		Submit for FEMA upgrade.	
35 96		Oil Well Road		$ 5,000.00		Delete	
20 82		Old Pueblo Road	FHWA - 6/1/99	$ 50,000.00		FHWA	
35 76		Old Stage Road		$ 15,000.00		Delete	
35 65		Palmer Lake Road		$ -		Delete	
36 08		Peaceful Valley Pond		$ 5,000.00		Delete	
35 67		Peyton Highway	FHWA - 6/1/99	$ 5,000.00	$62,770	FHWA	
35 46	5602	Rampart Terrace	FEMA	$ 5,000.00		FEMA repair only	JW
35 72	5623	Rio Road	FEMA	$ 10,000.00		FEMA repair only	
35 88	5631	Rock Creek Canyon	FEMA	$ 15,000.00		FEMA repair only	

Capital Needs

- Total of all known projects for City of Colorado Springs and El Paso County: ***$236,000,000***
- Estimate of needs throughout the region:

  $270,000,000 (includes channelization, detention ponds, culverts, other structures)

Where do we go from here?

- "Regional Stormwater Services Project" (City/County) -to form a Drainage District or other Regional Authority with a funding mechanism
- "Fountain Creek Watershed Forum" including City of Pueblo & County of Pueblo-examining various water quality issues affecting this basin

Track 2: The Paleoclimatic Record of Past Droughts: 20th Century Droughts in Perspective

Connie A. Woodhouse, Ph.D.
Institute of Arctic and Alpine Research
University of Colorado at Boulder

Introduction

When evaluating extreme events, such as drought, it is important to put 20th Century climate events into some kind of perspective. For example, a Denver Post article recently proclaimed, "Midwest remains parched. Little relief from drought in sight" (Lozano, 1999). How are we to evaluate such a report? We can evaluate some droughts in the context of the instrumental record, which exists for 100 years (or less) for most of the western United States. The drought reported in the Denver Post and other recent droughts, such as the 1998 drought in the southern Great Plains, pale in comparison to the spatial extent and duration of the major 20th Century droughts, the 1930s Dust Bowl and 1950s droughts. But how do we put the 1950s drought, and the even more severe (in terms of spatial impact) Dust Bowl drought of the 1930s into some sort of perspective? These droughts covered large parts of the nation and lasted five to eight years. How unusual are these droughts? The instrumental record is just too short to answer this question. And, how representative the 20th Century of long-term natural climate variability? Since the 20th Century record is used as the basis for planning and management decisions, this is also an important question

To answer these questions, we turn to paleoclimatic data which can provide us with information about climate before the time of instrumental records. Paleoclimatic data comes from environmental recorders or indications of climate, such as tree rings, corals, sea and lake sediments, and ice cores. Tree rings are the best source of proxy climate data for mid- to high-latitude continental areas, with records spanning centuries to several millennia (and longer in a very few cases). Tree rings are precisely dated to each and every calendar year and they record climate information at monthly to annual scales. Series of ring measurements are directly calibrated with climate or climate-related variables so that the relationship between climate and tree growth can be defined and evaluated statistically. Independent climate data is used to verify tree-growth/climate relationships, enabling an assessment of the reliability of the climate reconstruction generated from tree rings.

Dendrochronological evidence of climatic and hydrologic variability

A set of over 400 tree-ring chronologies was used to reconstruct drought for a network of grid points across the coterminous United States going back to 1700 (Cook et al 1999). Maps of reconstructed patterns of drought were generated for each year and provide a way to evaluate 20th century droughts in the context of the last 300 years (to view the full set of maps, see http://www.ngdc.noaa.gov/paleo/drought.html). The maps of reconstructed drought can be compared to maps of actual (observed) drought to evaluate the quality of the reconstructions. Figure 1 shows a comparison between actual drought and reconstructed drought for the years 1934 and 1956. The reconstructions show the same spatial patterns as the actual data, but do not quite duplicate the severity of the drought . Thus, tree rings provide conservative estimates of past drought severity. When this set of maps is examined, several droughts comparable to the 1950s drought are evident (figure 2). Widespread droughts are centered on the years 1729, 1735, 1847, and 1863, each lasting from four to six years. No droughts appeared to be as extensive as the 1930s Dust Bowl drought.

Prior to 1700, fewer tree-ring records exist, but several long reconstructions have been generated, such as the reconstruction of annual precipitation for west-central New Mexico which extends back to 136 BC (Grissino-Mayer 1996). When only the most recent three centuries of this reconstruction are examined, the 1950s drought appears to be comparable to about half a dozen others (figure 3, top). However, when the full reconstruction is evaluated, it is obvious that the 1950s drought was relatively minor compared to a number of droughts in the more distance past (figure 3, bottom). In particular, the drought of the late 16th Century is remarkable, both for its severity and for the fact that it occurred fairly recently. This drought is documented in a number of different proxy records for North America (Woodhouse and Overpeck 1998, Stahle et al. 2000) and paleoclimatic evidence suggests that this drought was several decades in duration, covering at times large portions of the Unites States as well as western Canada and Mexico. A few long moisture-sensitive tree ring chronologies exist for the Colorado Front Range and some of these document this drought. More evidence for this drought can be found in the reconstruction of Upper Colorado River basin streamflow (Stockton and Jacoby 1976). The reconstruction of annual runoff at Lees Ferry extends back to 1564, and shows a period of anomalously low flow in the last decades of the 16th Century (figure 4). This reconstruction also illustrates the problem of basing planning decisions solely on the instrumental record. The Colorado River Compact, drawn up in 1922, was based on the anomalously wet years of the early 20th Century.

Colorado Front Range hydroclimatic reconstructions

A collection of tree-ring chronologies from ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) is being used to generate a set of reconstructions for the South Platte River basin. The three reconstruction variables investigated are 1) regional spring precipitation for the South Platte River basin (averaged from ten station records)(Woodhouse 1999), 2) mean annual streamflow for Middle Boulder Creek, which drains a small watershed east of Boulder, and 3) region April 1 snow water equivalent (SWE), based on three snow course sites near the Continental Divide, within the South Platte River drainage. The instrumental records of these three moisture-related variables show expected similarities, as well as some differences (figure 5). These differences are related to spatial coverage (a small watershed to the entire South Platte basin), elevation (about 1500 meters to above 3300 meters), and the seasonal moisture reflected (cumulative winter season, mean annual conditions, or spring only). The reconstructions, which explain 43% (precipitation), 46% (SWE), and 65% (streamflow) of the variance in the instrumental records, also show these variable-to-variable differences, as well as the variations of each variable over the past 200-300 years (figure 6). Specifically, the South Platte regional spring precipitation reconstruction shows periods of drought around 1820 and 1860 that are similar to the 1950s drought. Although the period of lowest precipitation occurs during the 20th century (1960s), the longest period of below average precipitation is suggested in the second quarter of the 18th century. The Middle Boulder Creek flow reconstruction shows periods of low flow in the 1870s and 1880s and during the 1840s. Both of these periods are more severe than any in the 20th century. The very preliminary regional April 1 SWE reconstruction shows low winter snowpack conditions in the 1880s and 1890s, as well as about 1810, but none of these periods seem quite as dry as the winter drought of the 1960s.

These reconstructions suggest that, for the most part, the severe droughts of the 20th Century are not unusual events when viewed in the context of the past 200-300 years. Although the driest years for the precipitation and SWE reconstructions occurred in the 1960s, droughts of a magnitude similar to the major 20th Century droughts have occurred in the past. Reconstructions also suggest that the 20th Century records are generally representative of past hydroclimatic variability in the case of SWE and precipitation. However, the Middle Boulder Creek flow reconstruction suggests that longer and more severe period of low flow have occurred prior to the 20th Century.
These reconstructions are limited in temporal coverage, and more work is needed to collect chronologies which can be used to extend reconstructions back in time. Longer records will enable an examination of the impact of the late 16th Century drought on the Front Range and Great Plains. New chronologies are especially crucial for snowpack reconstructions, because SWE records only go back to the 1930s, necessitating recently collect chronologies for an adequately long calibration period. Work to date indicates that high quality climatic and hydrologic reconstruction are possible for the Colorado Front Range. These reconstruction provide a long-term perspective on hydroclimatic variability and may prove to be useful in water resource planning and management.

References cited

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Stockton, C.W. and G.C. Jacoby, 1976: Long-term surface water supply and streamflow levels in the upper Colorado River basin. Lake Powell Research Project Bulletin No. 18, Inst. of Geophysics and Planetary Physics, University of California, Los Angeles, 70 pp.

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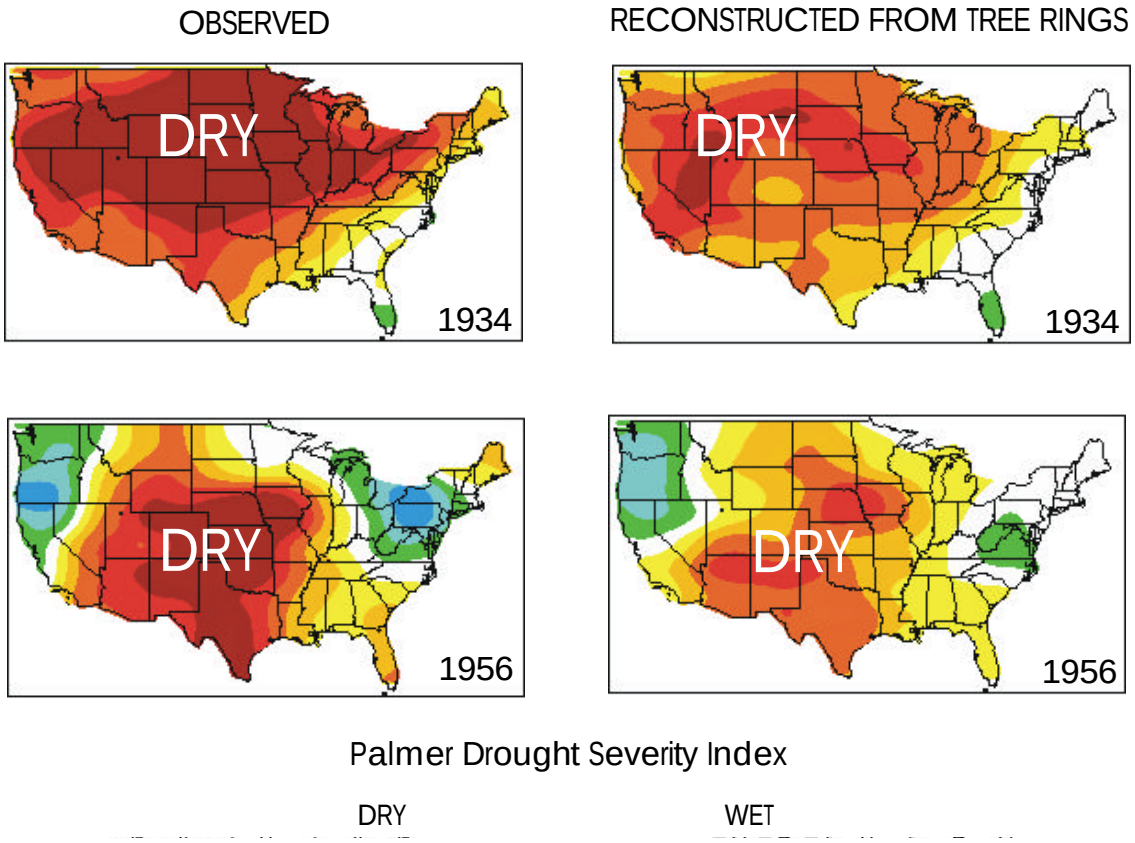
Watson, and B.H. Luckman. 2000. Epic 16th century drought over North America. EOS, Transactions of the American Geophysical Union. (in press).

Woodhouse, C.A. and J.T. Overpeck. 1998. 2000 Years of Drought Variability in the Central United States. Bulletin of the American Meteorological Society 79(12):2693-2714.

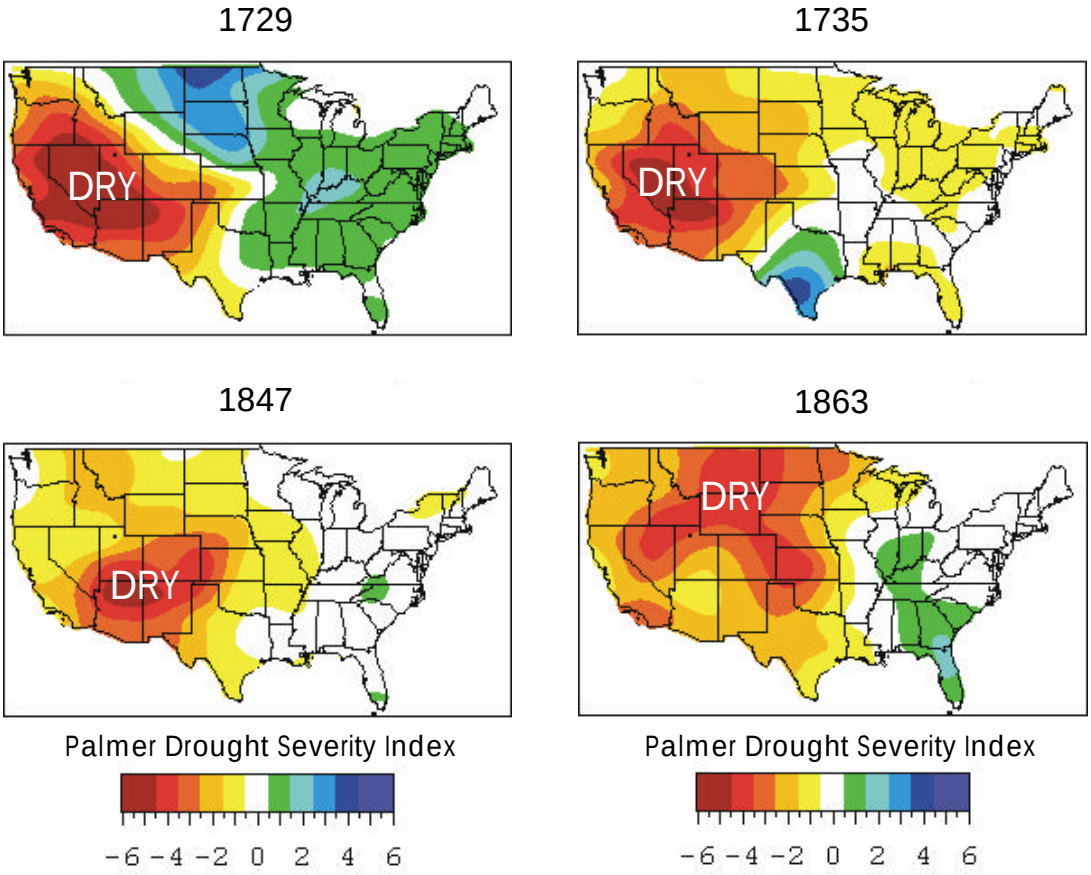
Woodhouse, C.A. 1999. Artificial neural networks and dendroclimatic reconstructions: an example from the Front Range, Colorado, USA. The Holocene 9(5):521-529.

FIGURE 1



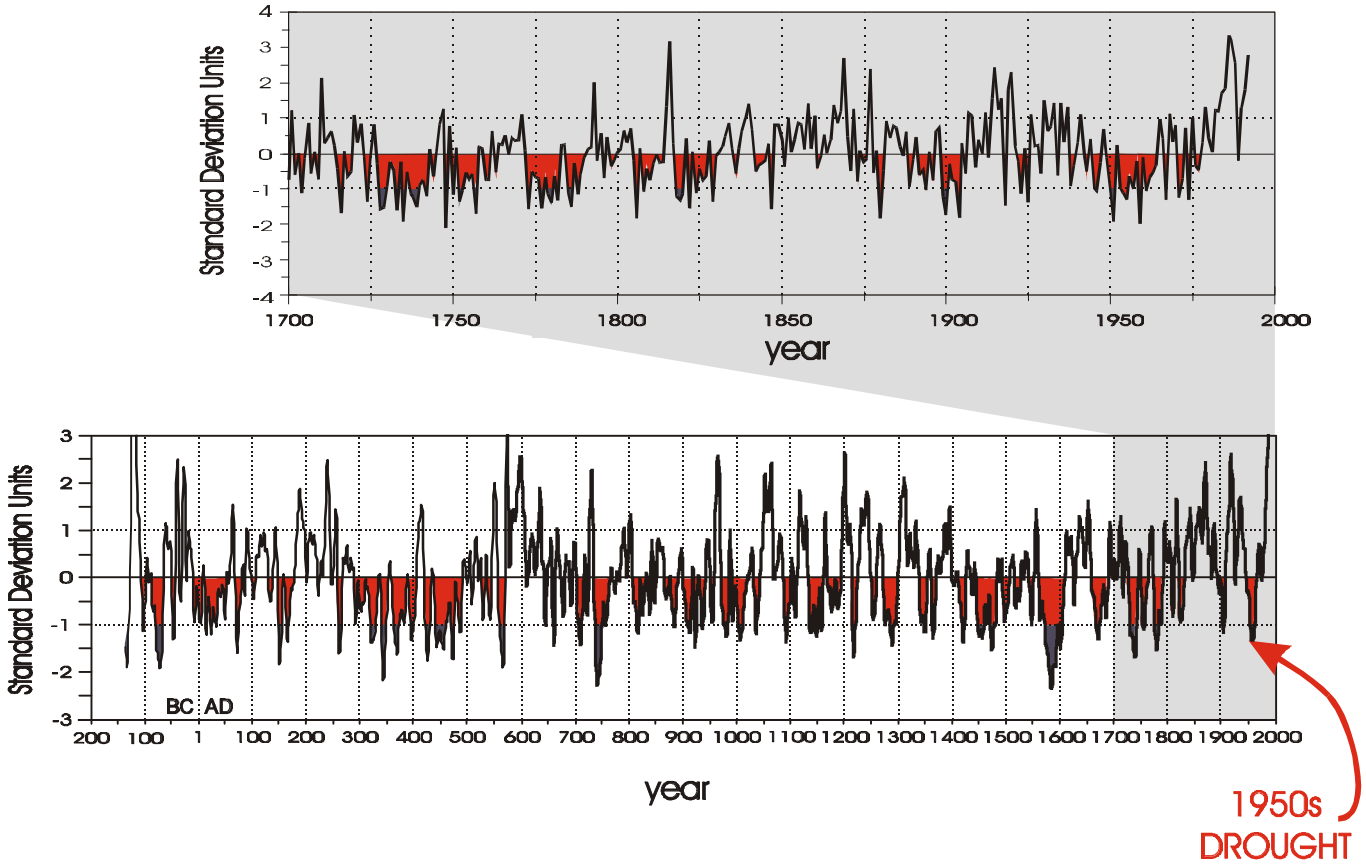
1. Comparison of actual (observed) patterns of drought (left) and patterns of drought reconstructed from tree rings (right), for 1934 and 1956. For complete set of observed and reconstructed drought maps, see http://www.ngdc.noaa.gov/paleo/drought.html

FIGURE 2



2. Reconstructed droughts that are comparable in severity to the1950s drought. Droughts are centered around years shown, each lasting four to six years.

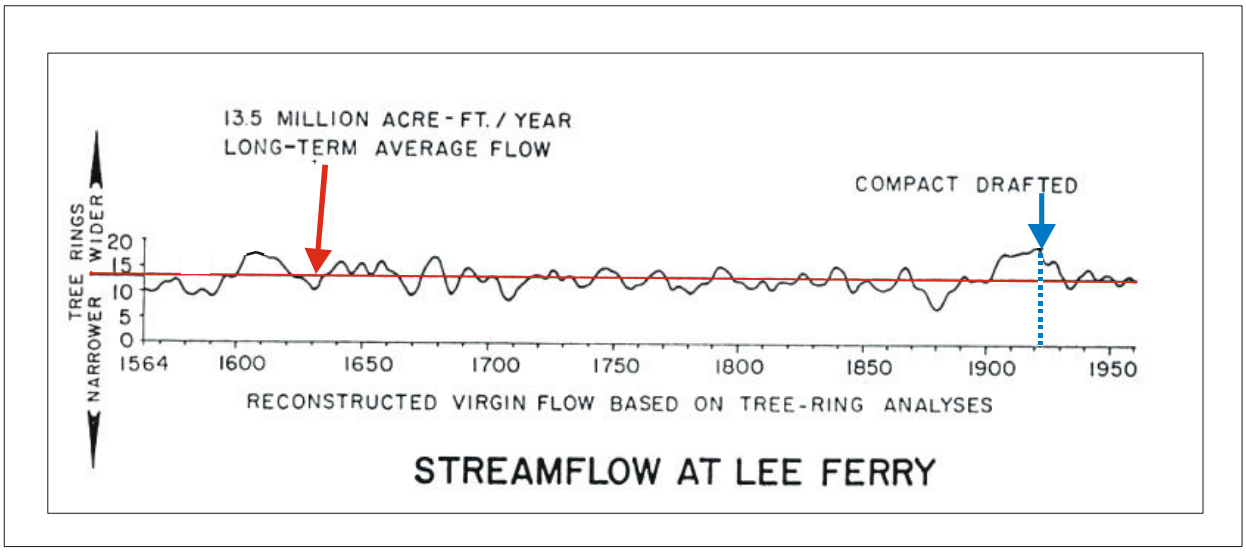
FIGURE 3



from Grissino-Mayer 1996

3. Reconstruction of annual precipitation for west-central New Mexico from tree rings, from Grissino-Mayer 1996. Units of measure are standard deviation units. Dotted lines show one standard deviation above and below average precipitation. Top graph shows the last three centuries. Bottom graph shows the complete reconstruction back to 136 BC.

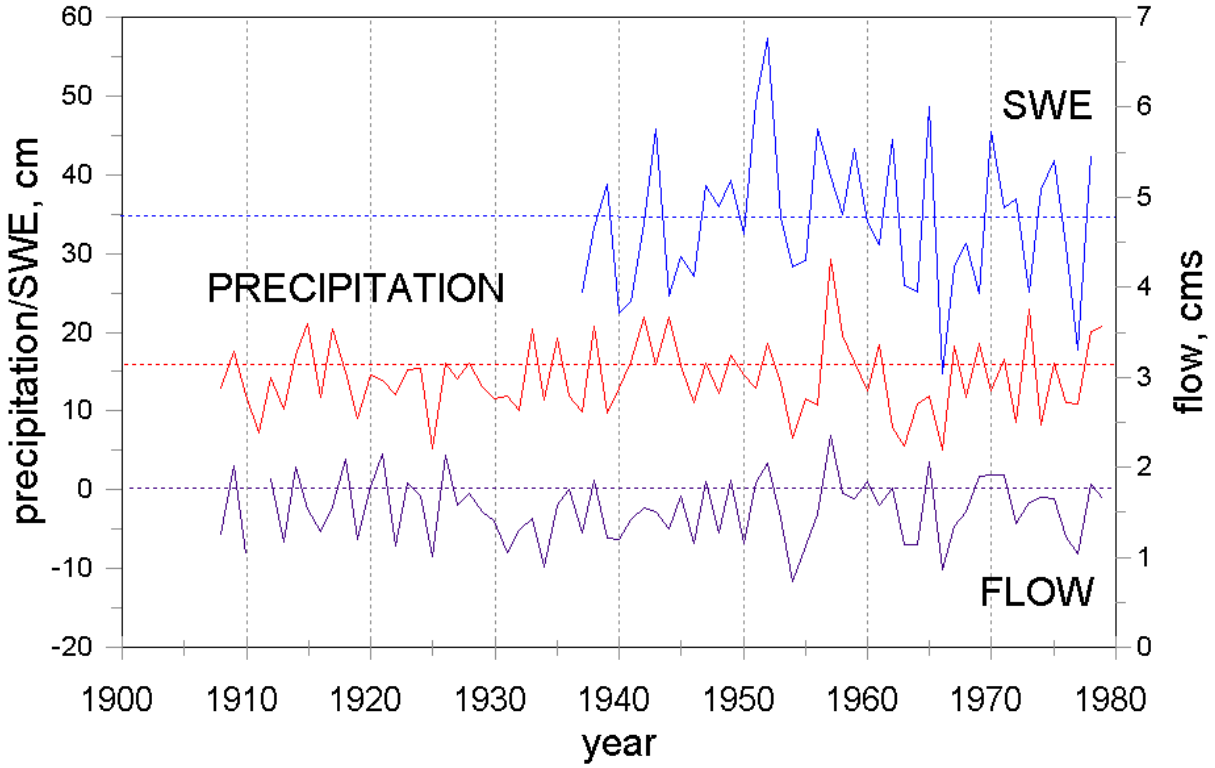
FIGURE 4



from Stockton and Jacoby 1976

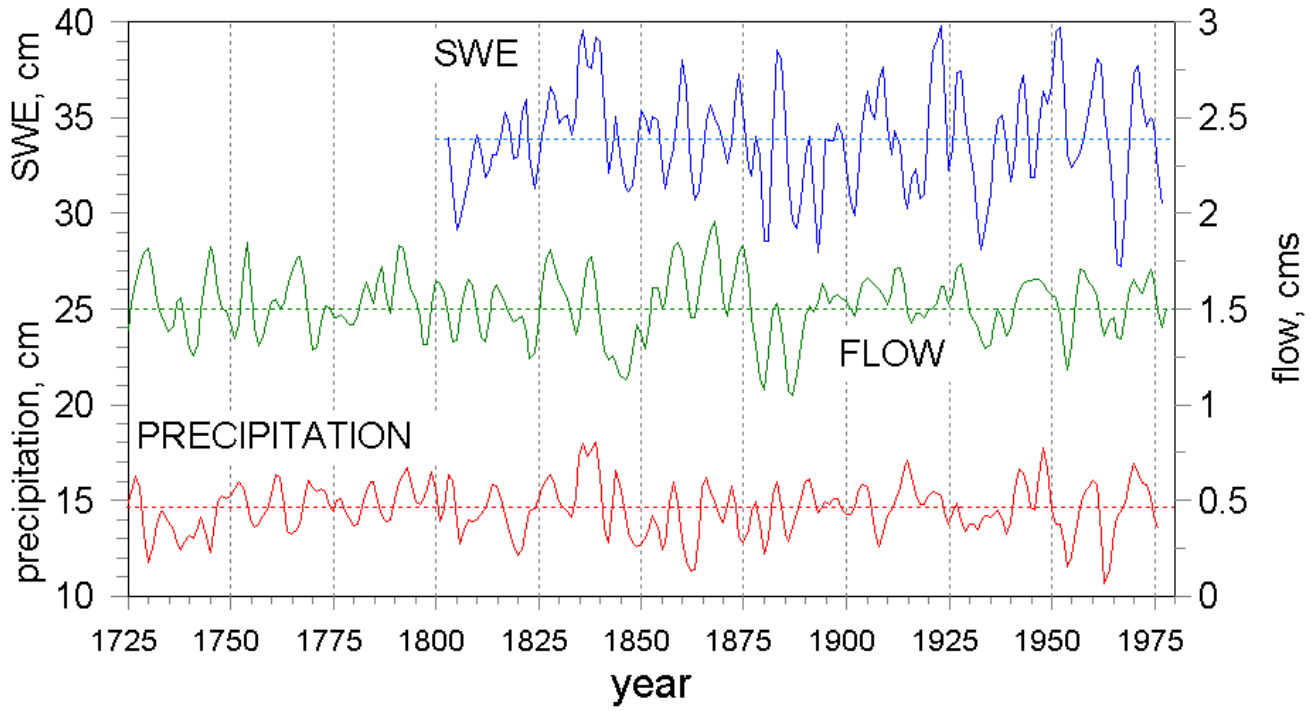
4. Reconstruction of annual runoff for Upper Colorado River at Lees Ferry, Arizona from tree rings, from Stockton and Jacoby 1976. Smoothed reconstruction extends from 1564-1962.

FIGURE 5



5. Instrumental records for South Platte River basin. Top, regional April 1 SWE. Middle, regional spring precipitation. Bottom, mean annual streamflow for Middle Boulder Creek.

FIGURE 6



6. Reconstructed hydroclimatic variables, smoothed with a 5-weight binomial filter. Top, regional April 1 SWE. Middle, mean annual streamflow for Middle Boulder Creek. Bottom, regional spring precipitation.

Colorado's Drought Plan

Jack Truby, Ph.D.
Planner
Colorado Office of Emergency Management

It is particularly useful to meet in this forum for consideration of flood and drought, but it does not follow that the consequences of drought have much similarity with flood damages.
In Colorado and the West, droughts impact society in very subtle but very pervasive terms, usually cutting across a variety of social and economic sectors with problems that are not easily identified - there is little if any structural damage. But these impacts are extremely costly. This ambiguous risk potential is an important reason that drought planning around the country has progressed much more slowly than has response to most other natural hazards and requires consistent attention.

Plan, Concept, Characteristics, Needs

In western states and in Canada, ineffective response to the 1977 drought was based on lack of accurate knowledge of: where problems were occurring, extent of damages, costs, and most effective ways to respond.

Problems were partially due to vulnerabilities and needs that were quite different from other natural hazards.

Elements Needed to Insure Effective Response

As the 1982 drought developed, a number of conceptual elements were needed in a plan to insure effective response:
· A means to identify and monitor all major drought related needs, impacts, costs and particularly, water availability, (how much available and where located).
· A system adaptable to long recurrence cycles and able to operate over long periods of time and changing conditions, at very low cost; must be able to bring expertise to bear quickly.
· Full state coverage by river basin and water sources.
· Should not impose a new management system or disrupt ongoing governmental processes.
· Should reflect immediate response needs but also insure short- and long-term water conservation and a means to mitigate growing problems.
· An index system to reflect the general severity of the problem.

How the Plan Works

The plan is structured in two separate elements:
(1) assessment/monitoring; and (2) response.

The assessment element is further divided into two sets of Task Forces: (1) water availability; and (2) impacts, supported by assessment Task Forces and lead departments for problem solution.

Assessment TFs
The water availability Task Force (WATF) is composed of a variety of water analysts from state and federal agencies, universities and business related groups. It has met every quarter (since 1982) and more often during water shortage periods. It assesses water availability on an ongoing basis, stressing conditions of soil moisture, stream flow and reservoir storage.

The WATF uses several indices to reflect changing conditions: the Palmer (a national index used by the Department of Agriculture and fully recognized by federal agencies) and the Surface Water Supply Index (SWSI), which is more useful to the state to cover water availability developed by our friends in the U. S. Department of Agriculture (then the soil Conservation Service, now NRCS - National Resource Conservation Service) and our Department of Natural Resources. It is used as a guide to alert response agencies when shortages occur on a serious basis (at -2.0); when entry into drought conditions appear imminent The Governor is requested to activate the impact TFs.

Impacts TFs
The impact TFs analyze impacts that are likely to or that are occurring. TFs are made up of a variety of officials knowledgeable about the subject areas, drawn from a variety of agencies; and are headed by a state official and meet at his/her call. Health and energy have never been activated, as droughts have thus far not extended long enough. However, we know that they will be necessary someday, since wells become contaminated when water levels are very low and about 15 percent of the state's hydroelectric energy will be lost if reservoirs go down.

Impact TFs are expected to dig into their subject areas at state, regional or local levels to find out critical needs. Once problem areas are identified and monitored, they are transferred to action/response agencies of government.

A review and reporting TF composed of impact TF leaders reports to higher government levels and to the media response operations.

Lead Agencies
As drought develops, lead agencies accept problem/impacts from assessment TFs and take the lead in problem solution. Interaction between assessment and response agencies initiates as problems develop and is

continuous, direct and immediate.

It is expected that departments will handle drought problems by integrating them with other normal activities, assessing priorities as necessary. The plan does not impose any special operating system on state government.

Problems are handled within departmental capability where possible. When they require special emphasis, coordination or extra funding, an interagency coordinating group (IACG) comprised of senior departmental officials should be established. The goal of the IACG is to facilitate full governmental coordination of key problems as soon as possible before recommending action to the Governor and the legislature.

Since most of the problems that occur in the early phases of drought are similar throughout the western states, OEM has developed a historical summary of action taken in Colorado and other states that have recently gone through a drought. Response officials and telephone numbers are identified to facilitate informal coordination on problems already dealt with in other states that may be useful to Colorado officials.

Lead agency responsibilities have been highlighted in the plan where special emphasis is required, i.e., the Department of Natural Resources will conduct water conservation activities on a statewide basis. All departmental assignments in plan have been coordinated and approved by departments as with all revisions now underway.

It is noteworthy that large-scale drought responses have not taken place since this plan was developed, so the response portion of the plan has not been fully tested, but several departments have taken a variety of actions as occasional water shortages have developed.

Plan Support

This is a state-level plan, which will incorporate local needs through the impact TFs. But it is noteworthy that additional means may be needed to complement the assessment and response system. The Office of Emergency Management (OEM) can perform this function or a separate network can be set up through councils of government (COGs), and such agencies can be used to insure that impacts are effectively dealt with.

The prospect of long-term drought is a much more serious issue, particularly as reservoirs go down and as shortages become serious - as will surely happen; at this time. Water management and major steps in mitigation become even more important than at present, so leadership in drought mitigation and overall management is more in the role of the Department of Natural Resources. Mitigation and long-term management could then be conducted under this changed structure.

In droughts experienced in the past, help has been needed to bring assistance from Congress, but since no federal lead agency has existed, this help has consistently been quite late.

The Western Governors Assocation (WGA) has in the past been a significant help to western states in lobbying Congress and has now improved their understanding of the drought planning process so that they can assist more readily. However, their future capabilities may be changed significantly as the National Drought Policy Commission concludes its deliberations.

Once the federal government has established a drought response system, assistance may be more readily available to states, but currently, effective, timely response cannot be assured.

Abstract
Risk based Assessment of Drought Vulnerability

Two case studies presented by
Noel Hobbs, P.E., Water Resources & Water Supply Consultant
and
Joesph S. Stibrich, P.E., Principal Engineer

For this paper the authors presented two case studies and two differing methodologies for assessing drought vulnerability.

1. City of Louisville

The City of Louisville, Colorado is a municipal corporation whose water system is charged with meeting the water demands of residential, commercial, business, and industrial customers. The City owns a variety of water rights on South Boulder Creek in the South Platte River watershed that were either originally decreed by the City or consist of agricultural water rights which have undergone transfer to municipal use. Faced with a diminishing supply of available senior water on South Boulder Creek, the City initiated a Raw Water Master Plan to define its direction in meeting the future water needs of its service area.

The cornerstone of the master plan was the development of an operational computer model of the City's raw water supply system. The model was designed to simulate the diversion, conveyance, storage, and delivery of water supply to current and future demands at both an existing and a proposed water treatment plant. In evaluating the capability of the City's raw water supply system, periods of intense and prolonged drought were of greatest concern. The computer model was designed to simulate the operation of the City's system under various drought conditions, patterned after historic droughts. Though modeling the system over a selected period of record can show whether the existing system is capable of withstanding the drought(s) occurring during that period, the results will not provide an estimate of the statistical "reliability" of the system; i.e., is the City protected against the once in 50-year drought, the 100-year drought, etc.?

A statistical analyses of the historic streamflow record was conducted to characterize past droughts in terms of magnitude, duration, and severity (probability of occurrence). Partial duration drought analyses were performed to develop mass-frequency-duration (MFD) curves of streamflow records. The MFD curves were used to predict expected flow volumes for varying drought durations and recurrence intervals. As part of this evaluation, a computer program was developed by Mr. Stibrich and used to conduct the partial duration analyses on a monthly flow record for any number of drought durations and recurrence intervals. A method was also developed to plot the MFD curves on a semi-logarithmic versus extreme value probability scale using standard spreadsheet software.

A concern with the partial duration analysis, particularly in areas such as the Front Range of Colorado where the majority of the annual water runoff occurs over a relatively short period of time as a direct result of snowmelt, is that the statistics of the analysis for short duration droughts (six months or less) are biased by the inclusion of the low flow season data in the analysis. Frequency duration analyses were conducted using the Log Pearson Type III distribution on runoff season flows to evaluate the effect of such a bias.

The drought analysis results revealed that giving any period a specific drought label (e.g., the 50-year RI, 24-month duration drought) is not a clear-cut decision and can be misleading. Any such drought could also be shown to be comprised of a multitude of both dependent and independent droughts of shorter durations and both lesser and greater severity. Rather that selecting the "worst drought of record" as the design period for the Master Plan, drought periods in the historical record were located on the MFD curves to identify candidate simulation periods for modeling the City's system at acceptable levels of protection, defined by both duration and frequency of occurrence.

2. City of Loveland

The City of Loveland, Colorado, located 50 miles north of Denver, has a multi-faceted water supply system with numerous raw water sources. These include direct-flow river rights, ownership in local irrigation companies, the Colorado-Big Thompson (C-BT) and Windy Gap Projects, and a small City-owned reservoir. The City was concerned about the system's capability to provide a firm supply under drought conditions. Additionally, the 1976 Big Thompson flood resulted in a temporary loss of the City's C-BT supply, and emergency situations adversely effecting water quality in the Big Thompson Canyon have historically forced the City to suspend diversions from the river. To address these concerns, a comprehensive water resources planning study of the City's raw water supply system was conducted to: 1) evaluate the system's ability to provide a reliable water supply under drought conditions for a 30-year planning horizon; 2) evaluate and recommend alternatives for providing an emergency and firm water supply; and 3) conduct an economic feasibility study of the recommended alternative.

Increases in raw water demands and acquisition of additional water supplies were projected for Loveland under three population growth scenarios through the year 2015.

Two computer models were then developed to simulate the monthly operation to the City's system. The first model (BTRIVER) simulates the diversions of the City's and other water rights on the Big Thompson River. The second model (LOVESYS) simulates the operation of the C-BT and Windy Gap systems and then allocates all raw water sources to direct demand and storage. Deficits are then computed where supplies are insufficient to meet demand. Using historic streamflow records on the Big Thompson and Colorado Rivers and regional precipitation data, 1000-year synthetic streamflow records on the Big Thompson were developed and input to the models. The synthetic records allowed operational tests of the system's ability to meet demands under a wide range of drought conditions, providing a statistical basis to characterize the objective that sufficient water supplies should be developed through the year 2015 to eliminate deficits at the 100-year recurrence interval.

Twelve alternatives were identified and evaluated based on their ability to reduce or eliminate the projected 100-year deficit. The alternatives included additional raw water storage, purchase/lease of additional water, reuse, exchanges, water conservation, revised operations, ground water, and various combinations. The evaluation process considered cost, environmental and social impacts, and operational constraints. Throughout the study, public input was received via monthly Citizens Forum meetings and workshops with the Loveland City Council and Water Board. The recommended alternative to eliminate the 100-year deficit primarily included expansion of the City's reservoir and purchase of additional C-BT units. Both computer models have been installed on the City's computer system. The models are used to periodically update study results as population grows and additional water supplies are acquired, and to evaluate the sensitivity of the water supply system to the study's assumptions and input parameters.

Based on the planning study results, the City Council approved a series of eight annual water rate increases to provide revenues for bonding the expansion of the reservoir. In addition, up to fifty percent of the construction and engineering costs of the recommended alternative can potentially qualify for state funding under the CWCB's Construction Fund program. To indicate how the City will finance the project, an economic feasibility study pursuant to CWCB guidelines has been completed.

DENVER WATER'S DROUGHT RESPONSE PLAN

By
Dave Little, Manager of Water Resources, Denver Water
December 2, 1999

I've been asked to talk about drought from a municipal perspective--Denver Water's perspective. A municipal perspective is a little different from an agriculture perspective or from other perspectives that you have heard about today. I would suggest to you that drought is a relative term related to where your water source comes from and how the water is used.

So, what is a drought? Checking my college dictionary I found this definition:

"A period of dryness especially when prolonged that causes excessive damage to crops or prevents their successful growth."

The operative word in this definition is crops. This definition is more related to rainfall than it is to snow pack. So let's look at some rainfall statistics for Denver and see if there is any correlation for use in our planning. Looking at the precipitation record from November 1996 to May 1997, with the exception of April, precipitation was quite low--below average throughout that entire period. This would tell us that we might be in a drought. In fact, some dry land farmers were probably worried about a drought. However, Denver Water is primarily interested in the mountain snow pack, not the rain events, because that is the source of water to fill our reservoirs. Therefore, I overlaid snow pack information on the rainfall information for the same year. As you can see, we had a lot of snow that year, much greater than average. This simple exercise taught me that precipitation or, more accurately, the lack of precipitation is relative to geography. Again, I learned one of the first rules of statistics: decide what you're interested in before looking at statistics. Based upon that understanding, we developed our own definition of drought as:

"An extended period of below average stream flows that stresses our customers' water supply needs."

Using this unique definition, we developed our Drought Response Plan. We selected the word response instead of management because no one can manage a drought. This is what it looks like; it's two volumes. If you would like a copy of Denver Water's Drought Response Plan, call me at 303-628-6533.

Based upon the previous graphics it would be fair to assume that Denver Water uses snow pack as its drought indicator. However, this graphic is a trace of snowpack for last year. As you can see, snow pack was quite a bit below average even as late as mid April. Are we in a drought? The newspapers thought we were, and for some people they were in a drought. I can guarantee you that the ski areas thought they were in a drought. But, is Denver Water in a drought? No. Towards the end of April it started to snow, and snow, and snow. It also started to rain in Denver, reducing people's desire to irrigate lawns. Prior to mid April, we called a meeting at Denver Water to review the necessary steps if the water supply picture continued poor. Within a very few days of that meeting, Denver Water was in a flood control mode. Again in 1985 a similar situation occurred--below average snowfall. Alarmists were projecting a drought and some were spending money and operating systems as if a drought were occurring. But, again Mother Nature fooled us and we had a flood control type-year in Denver's system. That's why it's important to recognize where your water supply comes from and what your water needs are before you can make an informed decision about drought.

The previous examples display why Denver Water does not rely on snow pack to determine when there is a drought relative to its system. In fact, we don't start thinking that we might be in a drought until sometime after April 1st. In most cases, reservoir operators who rely on the mountain snow pack for water supply wait until the April 1st snow pack readings before speculating whether or not a drought could be occurring.

Whether or not you are in a drought is relative to the seniority of your water rights. It could be an average year, but, depending on your water rights, you could still be in a drought. I always liked this graph of South Park water rights. Depending on the water right priority, you may only be able to divert a few days, even during a relatively wet year. For example, in an average year, a 1887 water right can divert about 90 days. Are you in a drought the other 275 days? Could be. That is why my predecessors at Denver Water constructed storage.

Some people look at this picture and think this is a lake. It's not a lake; it's the crown jewel of Denver's water system, Dillon Reservoir. Dillon is capable of storing 254,000 acre-feet of water, about half of Denver's storage. We have been having a long period of above average runoff into Denver's reservoirs. Consequently, Dillon Reservoir has remained full for many years, lending to the myth that Dillon is a lake.

How many people in the audience were in Colorado in 1977? Do you remember when Dillon Reservoir looked like this? When Dillon Reservoir looks this empty, Denver knows that it is in a drought. This picture is looking down the Blue River arm of Dillon Reservoir in 1978. This next picture shows the Ten-Mile Creek arm. At the time these pictures were taken, Dillon Reservoir was down to 100,000

acre-feet. Three-fifths of our storage was gone.

As a general rule, Denver knows its system is in a drought when its reservoirs don't fill during the spring runoff season of May through July. In fact, we use reservoir levels as a trigger for different levels of response in the Drought Response Plan. This approach of when we are in a drought is relatively simple for Denver Water and the first of four items addressed in the plan. The other three are 1) drought length, 2) how to avoid "crying wolf," and 3) fairness for all customer classes.

As I mentioned before, a drought for Denver may not be a drought for someone else. This graph shows how our reservoirs will operate during another drought like we experienced in the fifties. Denver uses the 1950's drought as a test of how its water supply system will perform. The fifties' drought is a very strong drought. Our studies show a drought of about 3.8 years' duration. The results of our modeling convince us that Denver's existing system can meet 345,000 acre-feet of demand during a fifties'-type drought without water use restrictions. Of course, our reservoirs would be empty at the end of another fifties'-type drought.

We always base our modeling runs on the assumption that no water use restrictions will be in place during a drought. Not that we won't restrict our customers during a drought, but we assume we won't as a safety factor for modeling purposes. A logical question to ask is how often will a fifties'-type drought occur? We have estimated that the fifties' drought for Denver's system has a return period of about 40 years. In contrast, the fifties' drought for other water users in the South Platte River has a return period of 100 plus years. The reason for this discrepancy is because Denver's system draws on both the South Platte River and the Colorado River for its supply. That diversity of two basins tends to buffer the extreme drought events of any one basin. Again, my predecessors were real good at designing and building a very reliable water supply system for the Denver area.

Another interesting concept in drought planning is what I call "the lost year." One year of drought will pass before Denver realizes that it's in a drought. Why a year before we know that there is a drought occurring? This simple graphic hopefully displays the problem. During September of one year through March of the next year, Denver is drawing on its reservoirs waiting for the spring runoff to occur. In May and June our reservoirs begin to fill. By July of most years our reservoirs are full and we know that the last year was not a drought. Remember, if our reservoirs are full or spilling, Denver is not in a water supply drought. However, during a year like 1953, we again draw down the reservoirs during the fall, winter, and early spring, but this time, the reservoirs do not fill during the spring runoff season. Hence, Denver's system was in a drought for the previous year. The "lost year" concept was important for us to understand to properly develop a workable drought plan.

What is the drought duration that Denver Water should anticipate in its planning? For our system, 1954 was a one in thirty-year event. A consecutive 1954 and a 1955-type drought is a one in forty-year event. But, is this long enough? We decided that planning for a drought event only as severe as the fifties drought was not prudent since a much more severe drought can be expected. However, planning for the "ultimate" drought is not justified or cost effective. How long of a drought should we use in our planning? Again, we settled on a simple technique. In essence we decided to plan for consecutive 1954-type drought years because in 1954, the water supply inflow to our system was one of the lowest of record. The theory was to increasingly restrict demand over a sustained drought so that demand would equal inflow to our system in a 1954-type year by the fourth year of a drought. That way, Denver's customers could survive a severe drought of extended duration (four or more years). Four consecutive 1954-type hydrology years is a 1 in 2,000-year event. One funny thing about statistics is that this 1 in 2,000-year event could occur this year, next year, or in twenty years.

The next task was to calculate the amount of inflow available to Denver's collection system in a 1954-type year. Based upon our water rights and the hydrology, we calculated that about 130,000 acre-feet of inflow is available to our system during a 1954-type year. Since our present demand is about 265,000 acre-feet, the theory calls for a reduction of 50% in demand by the beginning of the fourth year of a drought.

The next task was to determine what level of demand reduction should be required and when. As I mentioned before, when our reservoirs don't fill during the spring runoff, Denver's system is in a drought and has been for the past year. However, if we declared a drought every time our reservoirs failed to fill, even by a small amount, would be "crying wolf." For that reason, we establish reservoir content triggers to be used as a guide for when we declare different levels of drought urgency. Originally we started with four reservoir triggers, but quickly narrowed the number to three: 90 percent full equals a mild drought, 70 percent full equals a moderate drought, and 50 percent full equals a severe drought. Using these three trigger levels, our customers would be on restrictions 20 percent of the time or one out of every five years. We felt that restricting our customers this frequently would still be "crying wolf." Modifying the triggers to 80, 60, and 40 percent of full dropped the frequency of restriction to about 8.5 percent of time. We also checked to see if 70, 50, and 30 percent triggers provided any more benefit. However the frequency of restrictions remained about the same as with the 80-60-40 triggers. However, going to the 70-50-30 triggers increased the risk that the planned demand reductions would not be realized in time. Therefore, we adopted the 80-60-40 triggers for use in the Drought Response Plan.

At this point in developing the Drought Response Plan, we

had all the pieces of the puzzle put together. When the reservoir contents reach 80 percent of full, Denver Water will declare a mild drought and will install voluntary and incentive-based programs to reduce demand by 10 percent. If the reservoir contents reach 60 percent of full (40 percent empty), Denver Water will declare a moderate drought and install programs to reduce demand by thirty percent. In the event that the reservoir contents reach 40 percent of full (60 percent empty), Denver Water will declare a severe drought and install programs to reduce demand by 50 percent. A 50 percent reduction in today's demand would require Denver's customers to live off the inflow expected in a 1954-type year. Theoretically, if the drought does not reduce inflow below that experienced in 1954 Denver's customers could survive a very severe protracted drought. Unfortunately, most blue grass lawns will die and shrubbery/trees will die or become extremely stressed because a 50% reduction in demand requires that all outside watering be stopped. It is important to remember that all these calculations are based upon today's level of demand. As Denver Water approaches build-out of its Combined Service Area, demand will approach 315,000 acre-feet while inflow during a 1954-type year will remain about 130,000 acre-feet. Consequently, demand would have to be reduced about 60 percent to survive on inflow in a 1954-type year. This is one reason why the Board of Water Commissioners directed staff to retain a 30,000 acre-foot safety factor between available supply and demand.

The last component was designing ways to get the demand reductions needed for the different trigger levels. Recognizing the highly political climate that the Board of Water Commissioners is likely to find itself in during a drought, staff decided to develop a menu of demand reduction options for the Board's use. Actually we developed three menus of demand reduction options for the Board's use, one for each trigger level. If you are interested in more detail on the options, I would suggest that you call me at (303) 628-6533 and I will send you a copy of Denver's Drought Response Plan or see me after this session.

One of the more interesting facts we uncovered during development of the Drought Response Plan is the interaction between conservation programs implemented today and restrictions implemented during a drought. As most of you know, Denver Water has aggressively pursued conservation to meet a portion of new demand, instead of constructing additional water supply facilities. In other words, the more water our existing customers conserve the more new customers we can serve with the same volume of water, all things being equal. However, the more effective Denver Water and its customers are today at improving the efficient use of water, the less flexibility there is to exploit savings brought about by drought restrictions. This important concept deserves repeating. If we squeeze most of the inefficiencies out of water use through conservation measures and use that saved water to meet new customer demands, the ability to reduce demand during a drought is reduced. This simple mass balance fact produces an interesting dilemma for water supply planners.

A critical issue raised in the stakeholder meetings held during development of the plan was a concern that any demand restrictions be applied in a fair manner? Denver Water always tries to treat its customers fairly. However, everyone has a different view of what fair is. Car washes, in my opinion, should be affected by drought restrictions first. However, you can bet that owners of car washes would not agree. The consolation I can give car wash owners and others interested in fairness during a drought is that Denver is committed to actively soliciting our customer's input on how demand should be restricted and on the different priorities for restricting demand. I believe the way Denver Water actively involved its customers and stakeholders in the development of the Drought Response Plan is a good example of the approach that will be used during a drought.

These are the components and the thinking that went into development of Denver Water's Drought Response Plan. One critical purpose of the Drought Response Plan is to get people ready for a drought. If you develop a response plan prior to the crisis of a drought, better decisions will be made and pain will be more evenly distributed among customers during a drought. The alternative is to wait and respond to the crisis. I suggest to you that the latter approach is a formula for disaster. And, that's all I have to say about that. Are there any questions?

Drought

A Municipal Perspective
December 2, 1999

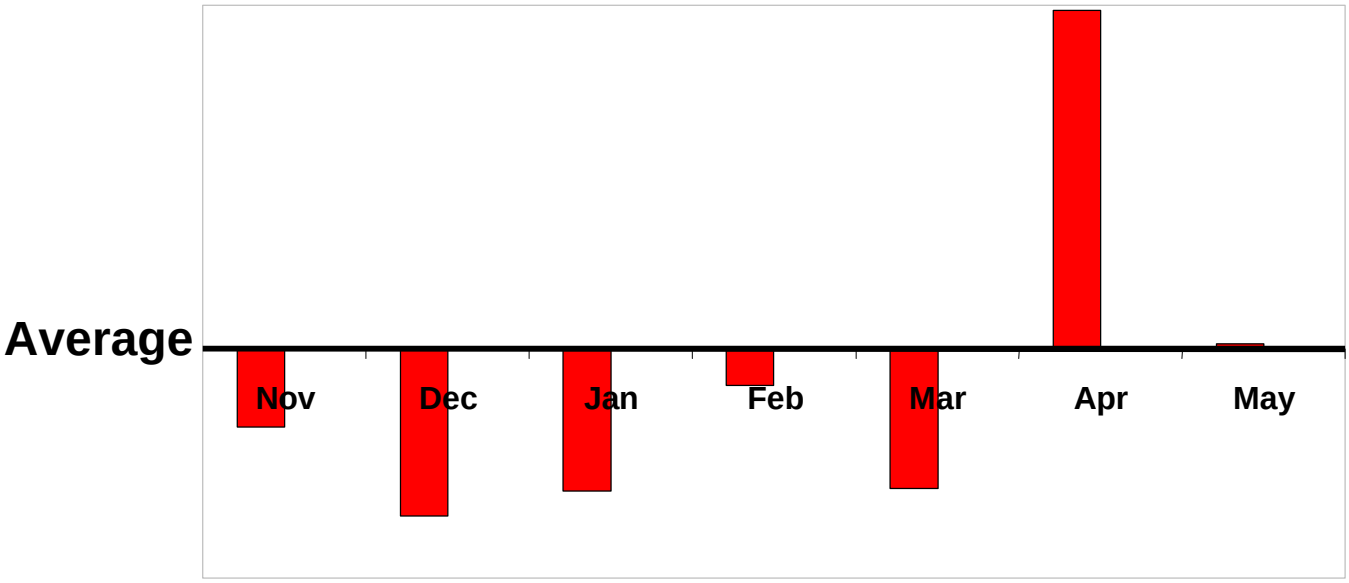
What Is A Drought

"A period of dryness especially when prolonged and causing extensive damage to crops or preventing their successful growth"

Webster's Ninth New Collegiate Dictionary

Denver Precipitation

1996 - 1997

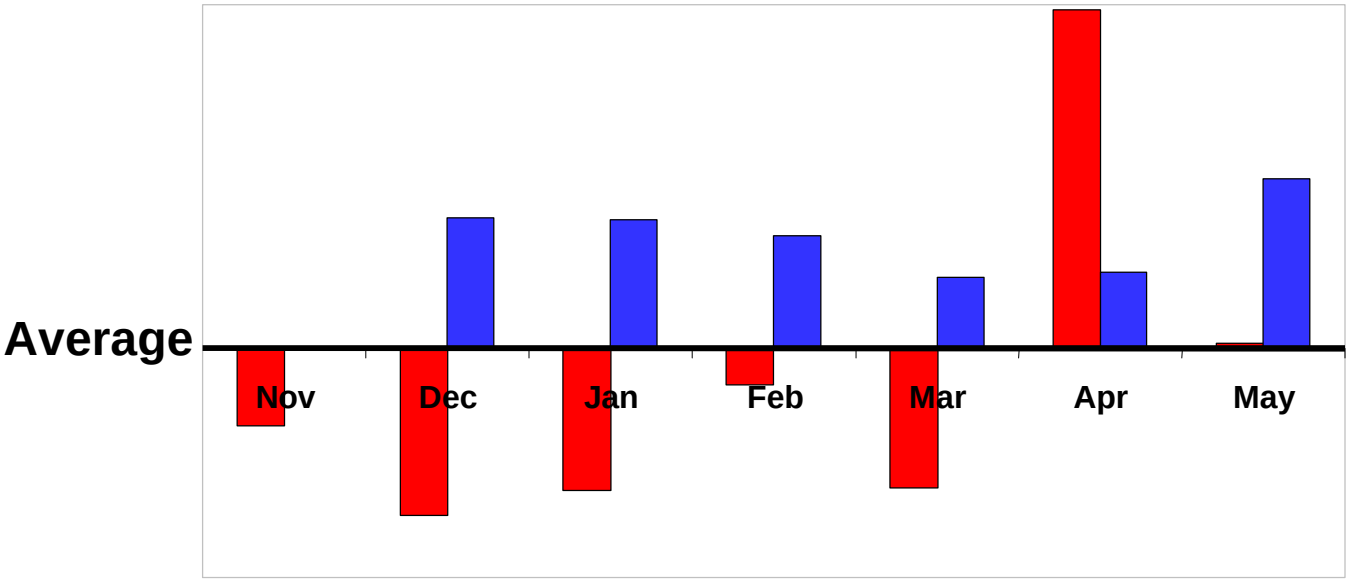


Mountain Snow Pack

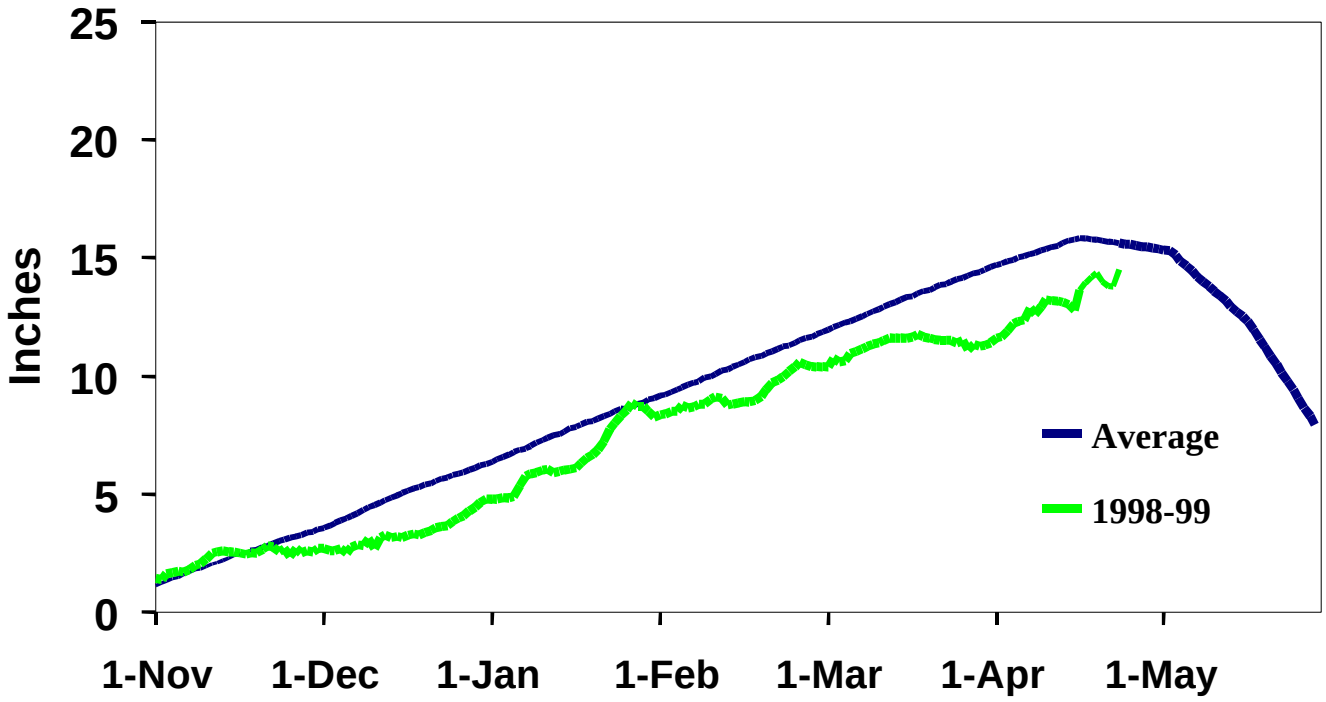
vs.

Denver Precipitation

1996 - 1997



Drought?



The Speculation Begins

Colorado & The West

Richard S. Chapman, State Editor — (303) 892-2783 • e-mail — metro@denver-rmn.com

"We are on the verge of a drought. In the last 18 years we've only flirted with a drought a couple of times."
— Leonard Boden, [illegible]

Snow tops the grass in Bailey on Wednesday from a storm that temporarily lessened fire danger along the Front Range.

State on the verge of widespread drought

Forecasters call for continued dry skies

By Deborah Frazier
[illegible]

would make federal loans available for agriculture, allow the state to have the National Guard haul water, impose fire restrictions and take other steps.

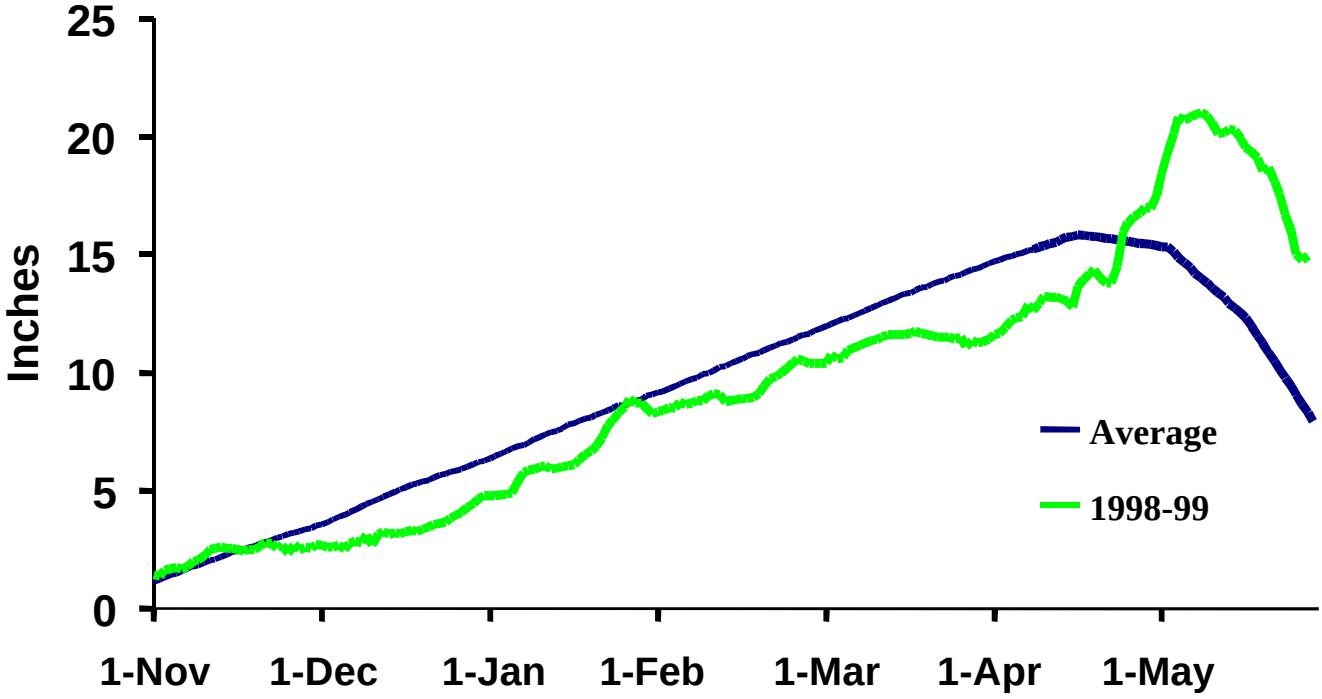
DRY WINTER'S EARLY IMPACTS

Diane Carman

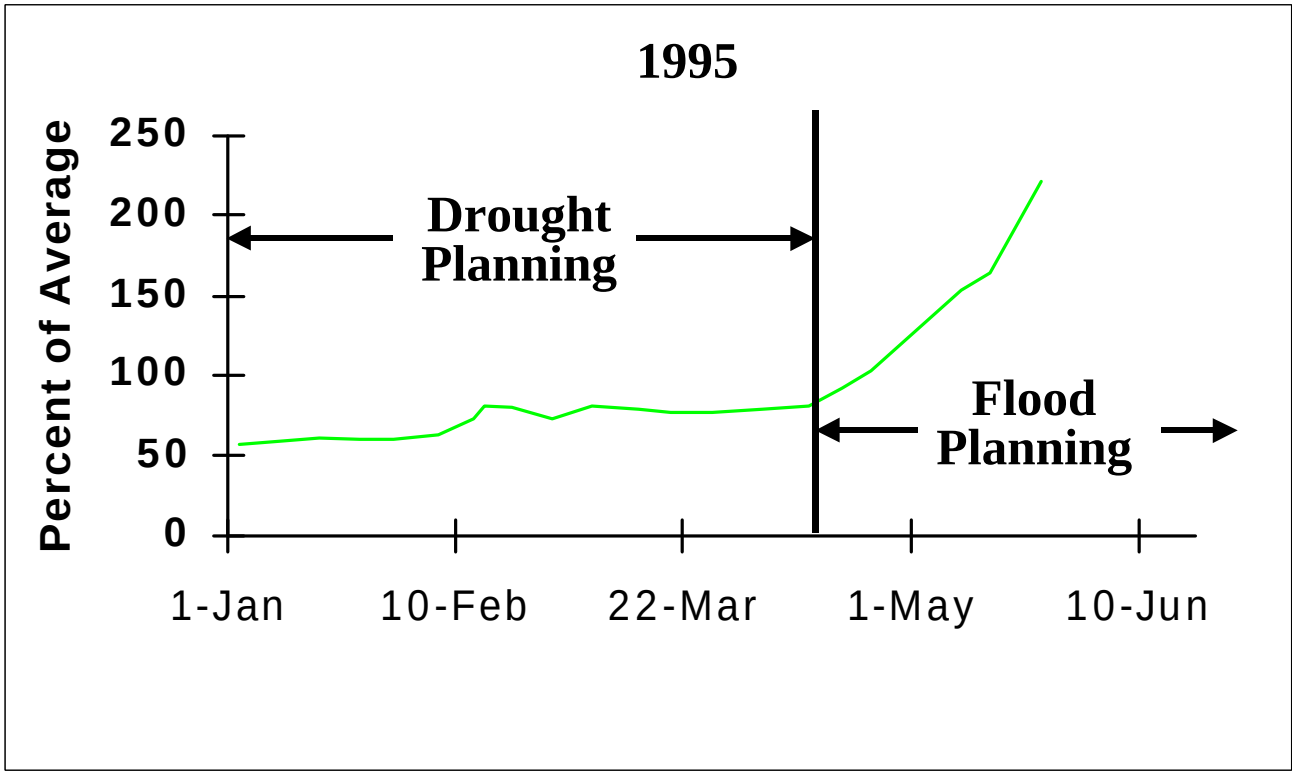
Water, water, nowhere

Here in Colorado, we're only 60 percent of normal. The outlook is grim. Our color has taken on a decided pallor, and our forecaster has been just a little too sunny. But we're hoping to improve our sever-

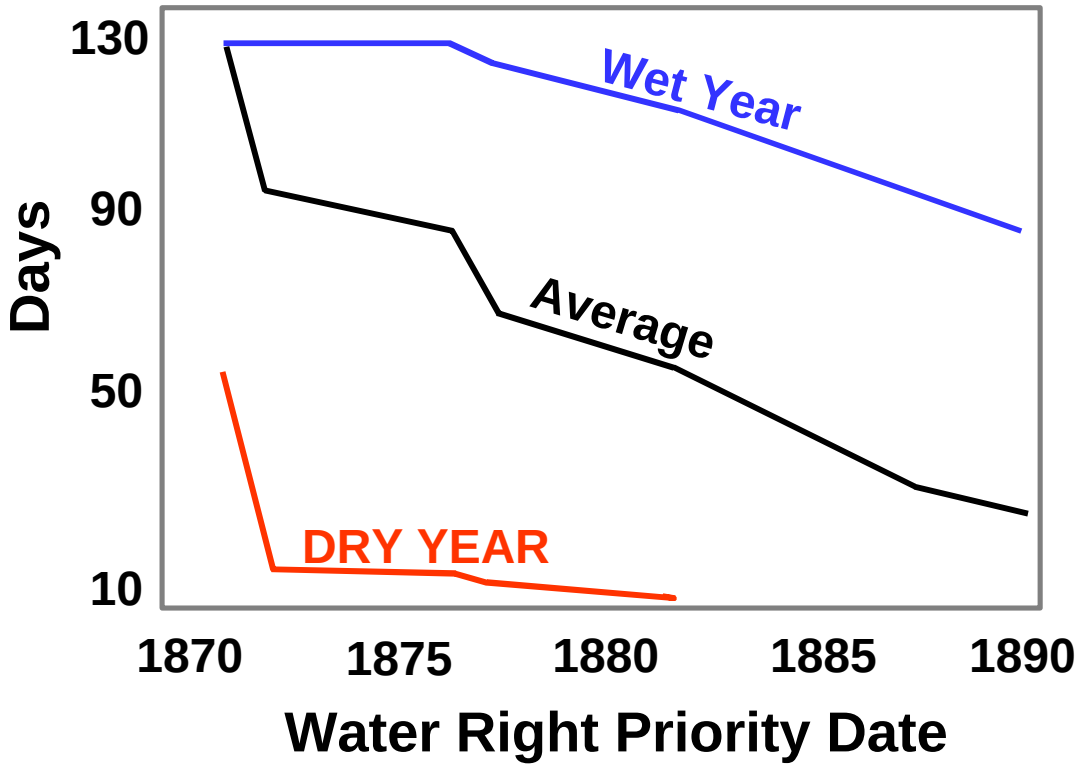
No!



How Mother Nature Fools Us



Valuable Water Right?



DROUGHT RESPONSE PLAN

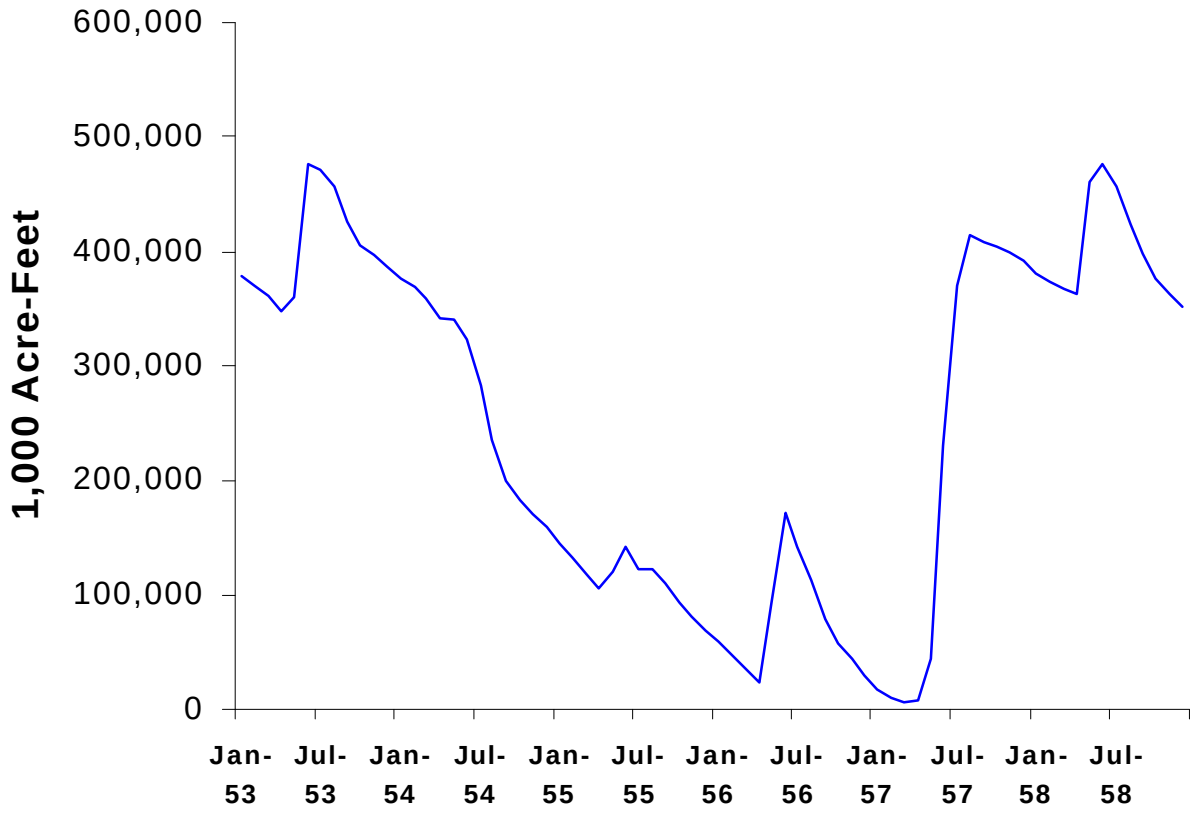
Denver Water's Drought

- When: Reservoirs don't fill
- Length: Fifties' test period (3.8 years without water restrictions)
- Return period: 40 years

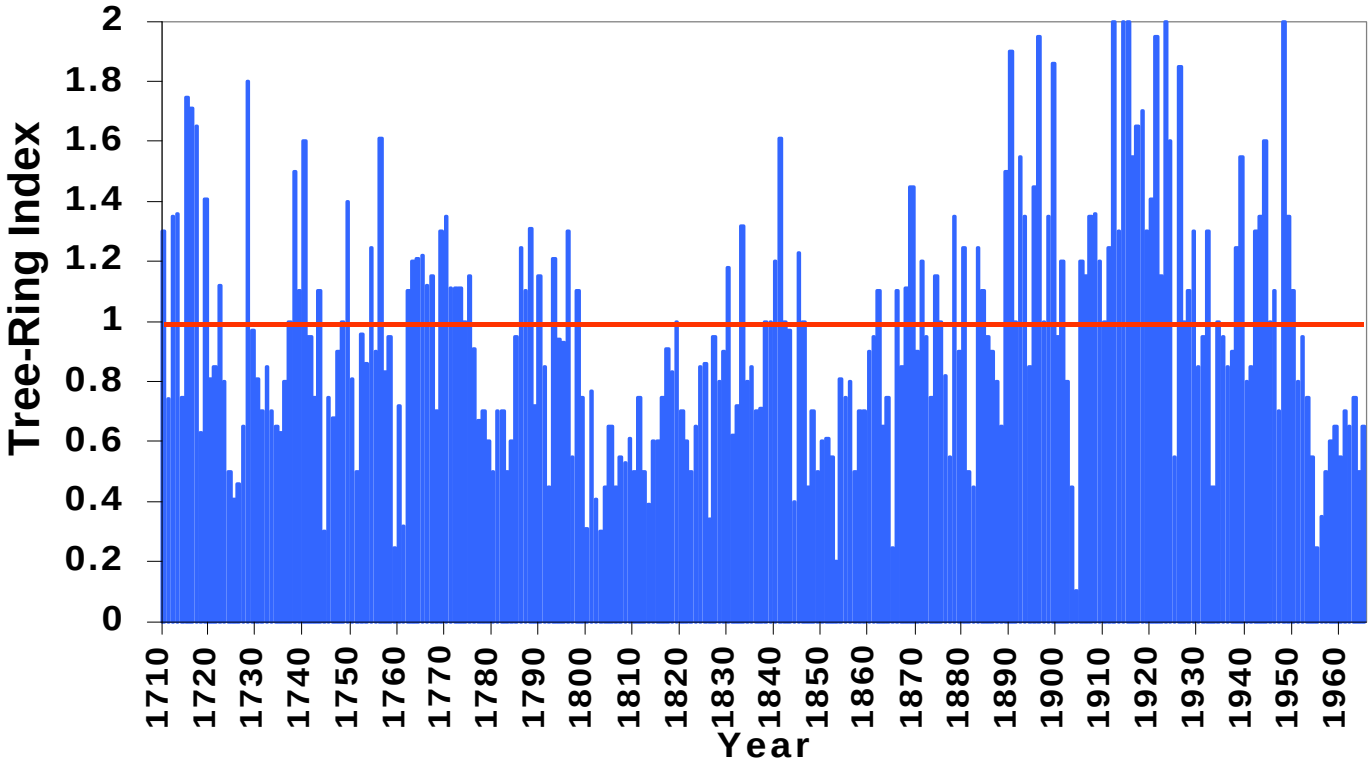
Drought Response Plan

- When are we in a drought?
- Drought length?
- Avoid "crying wolf"?
- Fair for all customer classes?

The Lost Year



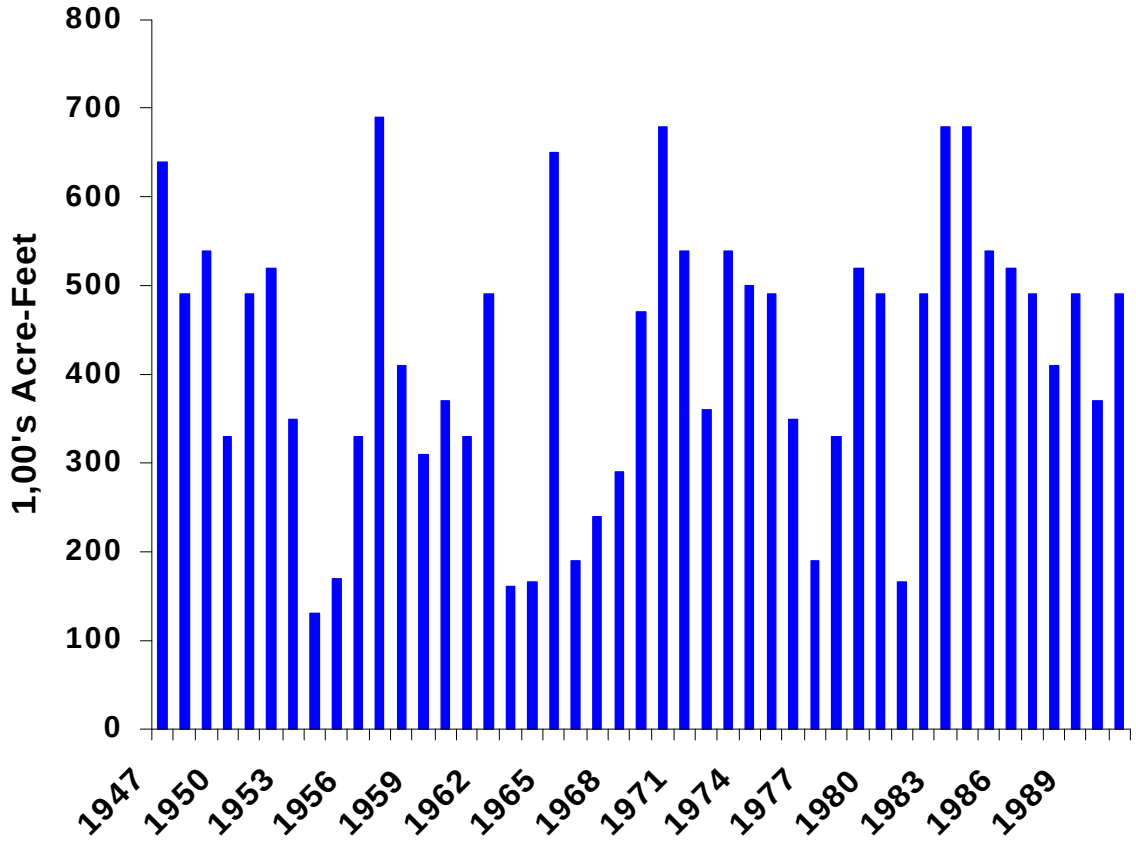
Drought Length



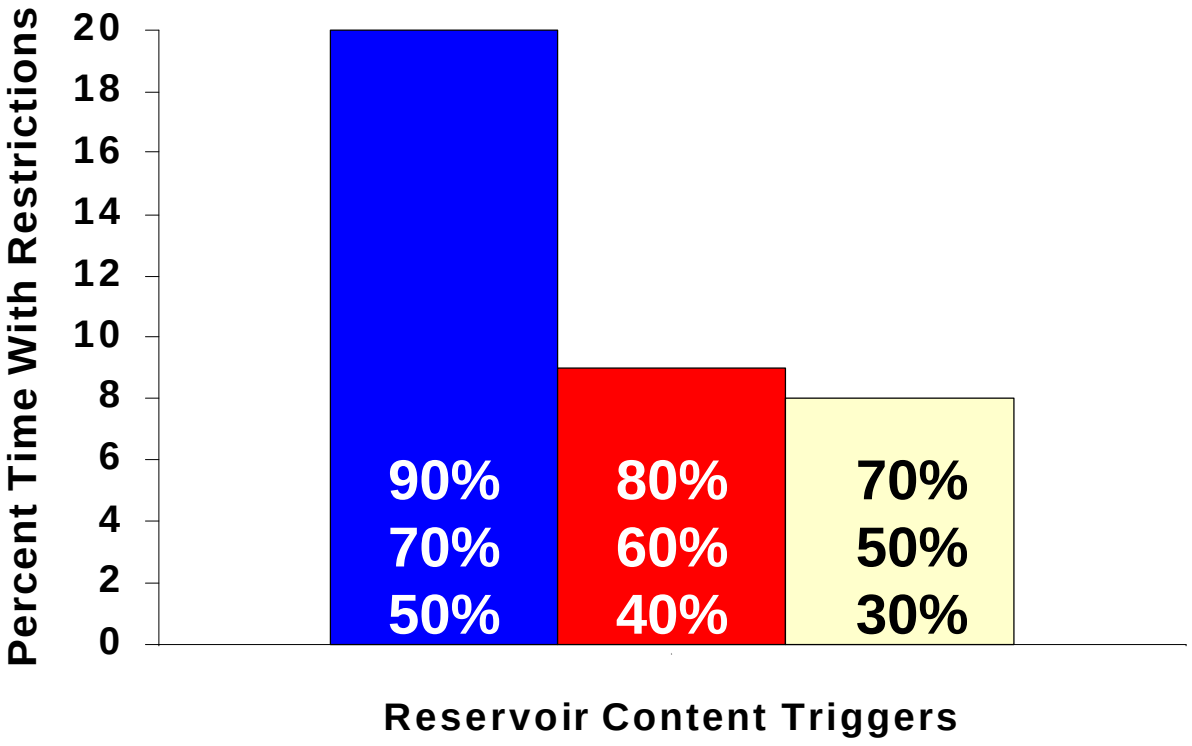
Fifties Drought

• 1954	1 in 30 years
• 1954-55	1 in 40 years
• 2 consecutive 1954s	1 in 100 years
• 3 consecutive 1954s	1 in 500 years
• 4 consecutive 1954s	1 in 2000 years

Water Available



Avoid "Crying Wolf"



Drought Triggers

Reservoir Contents	Drought Level	Reduction Target
80%	Mild	10%
60%	Moderate	30%
40%	Severe	50%

Fair For All

- At the mild drought stage, water use cuts would be voluntary
- As drought intensifies, discomfort, difficulty, and potential loss should be shared as equitably as possible
- Customers' ideas and preferences are important in selecting and prioritizing drought response measures

Track: 3 Role of Reservoir Storage in Flood and Drought Mitigation

John R. Fetcher
Secretary-Manager
Upper Yampa Water Conservancy District

Before we get in the subject, I would like to tell you a little of my background and how I got into the subject of water.

My brother and I came out West in 1949 and put money down on a cattle ranch in the Elk River Valley. We moved onto the ranch with our adventurous wives and five little boys. We thought anybody could become a rancher. Little did we realize what we were into. We didn't even know which end of the cow gets up first, and I didn't learn how to shoe a horse at Harvard.

It was on the ranch that I learned about water in the West. Coming from Philadelphia where rainfall was plentiful, it was very hard for me to realize that we could not produce a hay crop without irrigation. In drought years, when the streams drop or go dry, even the senior water rights don't produce water. There is only one answer and that is storage.

Most of you will remember 1977 as a major drought year statewide. A number of ranchers in the upper end of the Yampa Valley had no water to irrigate their hay meadows, even those with senior Yampa River flow rights. With no winter feed, they had to sell their herds.

It was about at that time that a group of us organized the Upper Yampa Water Conservancy District. This provided us with an organization that could levy taxes, borrow money, deal with state and federal agencies, and build projects.

The Yamcolo dam and reservoir was the result. Since its construction in 1980, the ranchers have not been short of water and they never will be. Every year, including wet years, the reservoir is drawn down to provide a full demand for irrigation.

On the subject of water storage, it seems to me that other basins must provide additional storage in anticipation of future drought years to come. Onstream construction of dams is getting more and more difficult. When we built Yamcolo in 1980, it took seven permits and approvals. That figure jumped to 70 when we built Stagecoach eight years later. Perhaps the answer is offstream storage, which has fewer environmental impacts.

On the subject of flooding, this does not appear to be a major problem in the Yampa Valley. We live on the headwaters where major river flows come from snow melt and not from gigantic rainfall events which are unheard of on our side of the Divide. Occasionally the Yampa overflows its banks and those in the floodplain suffer. It goes without saying that there should be restrictions on building in floodplains.

However, to reduce the impact of flooding, we have the Stagecoach dam and reservoir. Here is how it mitigates flooding. Because my background was electrical engineering, we decided to install a hydroelectric plan, which by the way kicks out about $20,000 every month. Here is how we operate. Come late summer when the Yampa inflow drops, we start pulling storage out of the reservoir to maximize power generation. The refilling of this storage space during the spring runoff reduces potential flooding downstream.

A subject I don't even like to talk about is possible flooding from a dam break. Both of our dams are classified as high hazard and a failure could be a disaster. To mitigate against such an event, all we have is our Emergency Action Plan. All it does is notify people to run for their lives.

The Role of Reservoir Operations In Flood and Drought Mitigation

Hal D. Simpson
Colorado State Engineer

Importance of Reservoir Storage in Colorado

Reservoirs play an important role in capturing excess snowmelt runoff from our streams where two-thirds of the runoff comes in one-fourth of the year, usually in the months of May, June, and July. Colorado's water users have constructed about 2000 dams of jurisdictional size that store 7,762,000 acre-feet of water. This volume is about one-half of the annual water supply produced annually from our various river basins.

Proper maintenance of dams and outlets is necessary in order to utilize the full storage capacity of these reservoirs. Dams that are unsafe are restricted in active storage available through orders of the State Engineer in order to make the dams safer. Dam owners can utilize the Colorado Water Conservation Board's (CWCB) Construction Fund through low-interest long-term loans to obtain funds for the repair of these restricted dams. Currently, 192 dams are restricted with a total capacity of 131,619 acre-feet of lost storage. Dam owners have not had to deal with a drought of any significance for over 40 years, and the loss of this storage capacity has not been missed.

Reservoir Operations and Flood Mitigation

Federal Dams

The Corps of Engineers (COE) operates flood control dams in the South Platte River basin (Chatfield, Cherry Creek, and Bear Creek dams), the Arkansas River basin (Trinidad, Pueblo, and John Martin dams) and the Rio Grande basin (Platoro dam). The COE takes control of these dams when downstream flooding is occurring or content of the reservoir exceeds the top of the conservation pool. In Colorado, three COE District offices have jurisdiction over portions of Colorado. The Omaha District for the South Platte basin, the Sacramento District for the Colorado River basin, and the Albuquerque District for the Rio Grande basin.

This multiple jurisdiction can cause problems in that each District has different mind sets on the seriousness of the flooding. For instance, the Albuquerque District will work very closely with our staff to prevent flooding downstream of their dams and to maximize the use of the released water. The Omaha District is not as cooperative and seems to have the big river mentality and has allowed downstream flows to exceed channel capacity with some damages to crops having been claimed by farmers. One solution is to have one District in control of the entire state for consistent operations. We would strongly urge the COE to do this and have requested it in the past without success. A second solution is to have the COE improve its coordination with DWR staff and we have attempted to do this since the last incident.

The Bureau of Reclamation (BOR) operates several dams in Colorado for conservation storage and are under the direction of the Loveland and Grand Junction offices of the BOR. We have had good working relations with the BOR in operating reservoirs to minimize flood damages by releasing water early to make space available to capture peak flood flows.

Privately Owned Dams

Our seven Division Engineers have identified many examples of operations by dam owners to voluntarily operate their dams to reduce flooding downstream of the dams. Some reservoirs have been allowed to store water out-of-priority to reduce the peak downstream and to release it a later time when it can be diverted and used.

Reservoir Operations and Drought Mitigation

The value of reservoir storage is very important going into a drought situation and the conservation of this valuable resource is also important. The efficient use of the stored water is vital to its maximum beneficial use. Agricultural users can increase efficiency of its uses by lining delivery systems, using gated pipe, or doing irrigation scheduling. Municipal providers can reduce demand through rates and limiting outside uses.

During drought, reservoirs can be drawn down and this can cause problems if the stream flowing through the reservoir removes silt from the bed of the reservoir and creates a heavy silt load in the stream which can cause aquatic wildlife to die. This has happened twice in the past six years, and the reservoir owner can face serious consequences if the action is viewed as a careless act. As a result of these incidents, this agency, the Division of Wildlife, and the Water Quality Control Division have entered into a Memorandum of Understanding (MOU) to try to minimize damages in the future.

The Division of Wildlife reservoirs can also be used to provide an emergency supply in a drought to a domestic water supplier in accordance with CRS 37-88-109. The beneficiary of the water has to restock the reservoir once it has refilled in priority.

Since the last major drought of the 1950's, reservoirs have been used for the release of water to augment out of priority depletions of wells that are now subject to rules promulgated in the 1970's and 1990's.

Colorado's Use of Technology to Manage and Monitor its Water Resources

Colorado has been a leader in the use of new technology to manage its water resources. These include the following:

· The Satellite Linked Streamflow Monitoring System (SMS), transferred to DWR in 1985.

· In 1995, the South Platte Water Rights Management System was completed.
· The Colorado River Decision Support System was completed in 1999.
· The Rio Grande Decision Support System is under development now.
· Our website for real time stream flow became operational in 1997 and will be revised in early 2000.

The problem we are facing is that all of these tools require the use of real time stream flow data from the SMS and it is requires that we have equipment that meets the federal standards. We have just learned that we must upgrade our data collection platforms (DCP's) to send data at a faster rate. This will require approximately $ 1.8 million over the next 10 years. We must find a way to convince the legislature that the maintenance of these facilities is a state obligation since these are state owned buildings. In addition, we must maintain the gaging station and structure at an additional cost of $100,000 per year. We have been using the CWCB's Construction Fund for the last four years to perform the maintenance but this may not be an appropriate use of the fund.

Agency Resource Needs in Floods and Droughts

Extreme floods require significant additional staff time to monitor floods, coordinate with local emergency coordinators, and make peak flow measurements for improved rating curves. This requires that we have staff working overtime and some of them are not exempt from the Fair Labor Standards Act so we have to pay them overtime wages. In 1999, we used up most of the overtime allocations for some staff in one flood event.

In extreme droughts, a similar situation develops as staff are required to administer water rights over a much longer period due to the calls by senior water rights coming on much sooner. This requires overtime and more miles driven by the water commissioners. We also have to enforce more orders and follow-up on head gate curtailments and well augmentation compliance.

The CWCB staff also have additional needs in flood situations that require them to monitor flood situations and to quickly obtain aerial photos of flood areas for damage assessments.

All of these additional resource needs currently are not in either agency's budget, and it would be most helpful if a special fund could be created by the legislature to be used for the extraordinary needs of the two agencies. This fund would be established by legislation and should be funded through the General Fund.

Summary

I would recommend the following actions if accomplished would greatly enhance our flood and drought mitigation capabilities:

· Require the Albuquerque District of the COE to manage all flood operations in Colorado.
· Establish a long-term maintenance program for the SMS that will allow it to serve Colorado's needs.
· Create a Flood and Drought Response Fund for the CWCB and DWR to use in floods and droughts.
· Develop a long-term plan to deal with the next serious drought that will occur all too soon.

Floods and Drought: Nonstructural Approaches to Mitigation

Mary Fran Myers
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Thank you Marilyn, for that kind introduction. I am honored to be here this afternoon, to have the opportunity to speak with you regarding nonstructural approaches to mitigating the impacts of flood and drought in Colorado. As Marilyn mentioned, I am with the Natural Hazards Research and Applications Information Center at CU, Boulder. And though I'm now in the lofty ivory towers of a University, I come from the practitioner side of the house. Before moving to Colorado over 12 years ago, I worked as a floodplain manager for the water resource agencies of the states of North Dakota and Illinois. So while our center deals with all natural hazards, my particular roots and expertise are in the flood hazard. And, as such, I have less knowledge about drought hazards, though I think many of the lessons we learn from one hazard can easily be transferred to another-especially when we think about dealing with an extreme natural event in a nonstructural way.

I will spend my time this afternoon talking about the impacts of flood and drought, and how we as a society have managed these extreme environmental events with an emphasis on the nonstructural approach. I will close with some lessons about these approaches based on a study we released from our center this year, in which we tried to answer the question, "Why, despite all our scientific knowledge about the causes of hazards and technological ability to deal with the consequences of them, do losses from disasters continue to rise?"

Floods are the most prevalent, costly, and deadly type of natural disaster to which this country is subject. It is not unusual in any given year that 75% of all Presidential disaster declarations are flood related and average annual damages due to floods in this decade is estimated at $5.5 billion.

Droughts hold their own in terms of damages as well. From 1980-1999, NOAA's National Climatic Data Center reports that the United States has sustained 44 weather-related disasters in which overall damages exceeded a billion dollars. Of those, nearly a quarter were disasters due to drought conditions.

While big events like the recent earthquakes in Turkey and Taiwan, or the many hurricanes which hit the East Coast these past few years seem truly catastrophic (and they are) and garner much media attention, floods and drought are really the worst type of natural disasters this country experiences - in many ways because of their pervasiveness; no part of the country can claim to be safe from them.

Floods and droughts, however, are of course natural environmental events. From time to time, extreme rainfall or excess snow melt cause rivers and creeks to overflow their banks and reclaim floodplains. And, from time to time, a dearth of rain and snowfall causes the opposite scenario. These kinds of natural events really are not a problem in and of themselves. Rather, they present a hazard and may cause a disaster only after we humans construct a built environment on flood prone lands, or we humans create a society that demands water in excess of what nature provides.

And since this is something that we as a society have chosen to do quite extensively, floods and droughts - like all natural hazards - now need to be "managed." Today, the common framework within which hazards are dealt comprises three general types of activities: modifying them, modifying susceptibility to them, and modifying the impact of them.

Modifying hazards refers to structural measures such as reservoirs or levees that attempt to keep the flood waters away from people and buildings, or that keep an adequate supply of water on tap when natural resources dwindle. The others on this panel today have addressed this approach to dealing with floods and droughts.

Modifying susceptibility to hazards, on the other hand, refers to activities designed to keep people and buildings away from the flood hazard or, when thinking about drought, that are designed to reduce society's dependence on water. These are generally called "non-structural" mitigation measures and include a whole host of tools. Let me give you some examples.

First, in regard to the flood hazard, zoning ordinances are regulatory tools used to limit the type and extent of development. In regard to flood prone areas, zoning ordinances can prohibit new development that is unsuitable for use. Zoning ordinances might also prohibit the placement of critical facilities in hazard prone areas; for example, it is common to disallow "critical facilities" such as hospitals, nursing homes, etc. in all areas except those outside the 500 year floodplain.

Building codes can be designed to ensure that new structures built in hazard-prone areas are resistant to damage. For example, in flood areas, building codes can require that structures be elevated above flood heights, or are built with flood resistant materials.

When dealing with existing buildings, flood proofing techniques other than elevation can be utilized. For example,

the Boulder municipal building - which is located in the floodway of Boulder Creek - was retrofitted a few years ago by adding a system of automatic sealing gates on flood walls that surround the building. In addition, I understand that city records once stored in the basement of the municipal building have been moved to higher floors. This can be really important. As an example, the Grand Forks, North Dakota, county courthouse was badly flooded in the spring of 1997. Some of my Federal Emergency Management Agency (FEMA) friends who worked with the community on a buyout program had an increased level of difficulty because many of the original deeds to the structures were destroyed.

And speaking of buyouts, acquisition and relocation of flood prone buildings is perhaps one of the best ways a community can modify its susceptibility to flood damages in the long run. This particular management tool has been promoted quite extensively by FEMA in the post-disaster time frame, but a better idea would be to use it in the pre-disaster time frame. It's an expensive, but permanent, approach and some places in Colorado are certainly using it. For example, the City of Boulder's comprehensive urban drainage management plan has targeted structures in the Boulder Creek floodway that the city wants to acquire and move. As these structures come up for sale, the city has the opportunity to bid on them. Several houses and an apartment building have been acquired in the floodplain, and that land is now in permanent open space as part of the city's greenway.

A community's growth management or development policies that address the location of services and utilities can be used to keep people and buildings out of harm's way. Refusal to extend lifelines such as water and sewer into flood prone areas goes a long way toward preventing new subdivisions in those areas. I, for example, feel fortunate to live in Boulder - a place where both the city and county are dedicated to acquiring open space. The lands being preserved in open space - such as the ones I just mentioned - and the mountain parks truly are hazard prone. One can imagine the wildfire risk that might exist during drought periods if all the mountain park open space were fully developed residential areas.

A community's susceptibility to flooding can also be reduced with good flood detection and warning systems. Given adequate time, there are several steps individuals can take to limit their losses in a flood. Since much of Colorado, especially on the front range, is faced primarily with the flash flood hazard it is not likely that people will be able to evacuate many of their personal goods to higher floors, but it becomes even more critical to have a good detection and warning system in place so that lives will not be lost. Further, an ongoing information and education program about the flood risk and what to do when warnings are issued then become even more critical.

In thinking about "modifying susceptibility" to the drought hazard, I think it is obvious that many of the nonstructural approaches used to modify susceptibility to floods can also be used to modify susceptibility droughts.
For example, legislation or public policy tools can be used to impose limits on urban development, to facilitate or require water recycling programs, or to protect instream flows and groundwater resources. A different alternative might be a building code which requires the use of water-saving plumbing (e.g., ultra low-flow toilets) in new construction.

Good warning and monitoring of emerging drought coupled with good information and education programs can make sure the public is aware of the risks presented by drought and know what steps they might take to reduce their vulnerability to this extreme.

An important nonstructural approach to dealing with drought is demand management - as opposed to increasing supply of water. There are many water-saving measures that a community might employ. For example, a community can modify its rate structure for water to influence consumer use of water. A schedule rate that charges more per 1,000 gallons as the use increases, might well work to decrease water use for lawn watering or car washing. Communities can impose lawn irrigation restrictions or require the use of non-potable water for irrigation. Such practices will likely be more effective if they are accompanied by an education program that features alternatives such as "how to xeriscape" or provides list of drought-resistant grasses or other lawn covers. A community that monitors and maintains its water system will reduce loss of water through leaks.

The third approach that society uses to manage hazards are also considered "nonstructural" and are those which attempt to modify the impact of them on people. It's important to note that these activities don't necessarily reduce the amount of damage a flood or a drought might cause, but they do help spread the costs associated with those damages.

Insurance is the obvious example of a tool that modifies the impact of flood or drought. Floods are not covered under a standard homeowner's property insurance policy, but flood insurance can be purchased as a separate coverage through the National Flood Insurance Program. Farmers can purchase crop insurance to cover losses which result from either a flood or a drought.

Disaster and emergency preparedness measures can be effective tools to modify the impact of either a drought or a flood. Individuals, local governments, and other organizations that are well prepared to deal with either of these events (for example, through well-thought out emergency sand bagging plans and procedures, or a plan for water hauling programs for livestock in times of drought) can go a long way to reducing the impact of a flood or drought and facilitate a speedier recovery from them.

Other forms of "modifying the impact" of a hazard are tax adjustments. For example, if you suffer a loss in a disaster, you are allowed to deduct those losses from the income on which you pay federal taxes.

Disaster relief is another way in which the loss from floods and droughts get spread to all of the tax payers.
These three types of activities-modifying hazards, modifying susceptibility to hazards, and modifying their impacts-dominate the way this nation deals with floods and droughts. Though the balance with which each type of activity is used certainly varies, I think it is safe to say that in large part, for the past 30 years, the nation has taken a comprehensive, integrated approach to managing its hazards.

So after decades of "managing" hazards from what appears to be a comprehensive framework, we can ask, "Are things getting better or worse in regard to floods and droughts?" Unfortunately, this nation does not have a methodical and systematic way of documenting losses due to disasters. The information that is available, however - as I mentioned earlier today - suggests that the impacts are considerable. Further, most loss estimations that are available do not take into account many of the difficult to quantify losses such as negative impacts to the environment, income disruption, losses due to transportation failures, and illness. In addition, conclusions drawn are based on historical data, as though the future will progress much like the past. They measure what has happened in the past and do not take into consideration the broad range of factors which may contribute to increasing flood and drought losses in both the short- and long-term future. Some of these factors include an increase in the population and built environment at risk, aging infrastructure which becomes more vulnerable to damage from flood or less reliable in times of drought, and changing climate patterns which may increase the frequency of extreme events Without careful scrutiny of these factors, one could be lulled into complacently thinking that things are not getting worse, that we are "holding our own," and that things might be improving slightly.

Regardless of whether current data show losses to be declining or increasing, the fact is that flood and drought losses experienced by this country are a sad reflection on the limited success of the nation's efforts to protect its people, buildings, infrastructure, and natural environment. The rising cost of disaster recovery, and the unquantifiable losses to the environment, economy, and people's sense of safety suggest that the nation could be doing much better in its flood and drought management programs. It also indicates we are not yet prepared for the increasing risk that the nation and the state of Colorado will face in the future.

Problems with Current Hazard Mitigation Plans

For the past five years, we at the Natural Hazards Center have been taking stock of knowledge about what is known and not known about natural hazards, including floods and droughts, and the nation's programs to reduce damages from them. The sobering fact is that despite society's scientific knowledge regarding the causes of hazards and technical capability to make accurate predictions of time and place of occurrence, damages are continuing. The Center's study - Disasters by Design: a Reassessment of Natural Hazards in the United States (Mileti, 1999) - concludes that losses are rising for a variety of reasons.
First, as mentioned in the previous section, many factors are excluded or ignored when calculating the frequency, severity, and cost of future disasters.

Second, hazard management programs have been too narrowly focused on simple loss reduction. Programs have been carried out in a closed framework that does not embrace the larger context of how society relates to its natural environment. Without taking this larger context into consideration, some flood and drought mitigation programs might have unanticipated outcomes that actually increase, rather than decrease, potential losses in the future.

Third, the traditional perspective on hazard management is that it is cyclical: we prepare for, respond to, recover from, and attempt to mitigate vulnerability to floods and drought. These environmental extremes tend to be viewed in and by themselves, and from a profession by profession perspective, and not an integrated one. The belief is that all flood and drought mitigation and preparedness is good and that "constraints" are to blame for a lack of headway in reducing losses. For example, constraints such as pressure for economic development, the low salience of flood and drought problems in the public, and a decentralized political system are cited as reasons that our mitigation programs fail.

We have come to believe, however, that these ways of viewing and organizing hazard management are, themselves, partly responsible for increased catastrophic losses. There is a focus on short-term gains instead of long-term implications and there is an artificial separation between flood and drought issues and other community issues. This focus tends to lead to singular solutions and technological fixes rather than integrated and interdisciplinary problem solving mechanisms that have local saliency.

A New Paradigm - Sustainable Hazard Mitigation

We suggest that a change in national culture may be necessary if society is ever to overcome the devastating losses from natural disasters and that alternative ways to view these extreme environmental events are needed before any real progress in flood and drought hazard management and loss reduction is made. Central to this view is a recognition that the nation cannot be made 100% hazard-

proof. This also requires that somewhere, someone, somehow will have to define acceptable risk and then be willing to take responsibility for the decision of that definition. We suggest this decision making and acceptance of responsibility be undertaken throughout the nation on a community-by-community basis.

People who work to manage flood and drought hazards must reorient their approach and use their expertise from the local community's viewpoint, across adjustments and across hazards, and in the context of non-hazards community goals. Further, local stakeholders' capacities to manage their own environment, resources, and hazards must be increased, in order for them to make the decision about what they are willing to lose in future disasters.

The major findings emerging from the Center's analysis suggest there is a need for a new paradigm of hazard reduction called "sustainable hazard mitigation." It is one where local citizens look forward, consciously plan, and "create" their future, rather than simply responding to the results of a lack of planning. Sustainable hazard mitigation calls for the creation of empowered stakeholder networks, embraces the notion of adjusting to the environment, incorporates a global systems perspective, embodies the concept of sustainability, and derives its moral authority from local consensus. In short, the new paradigm must go beyond simply reducing flood and drought losses to building sustainable local communities throughout the United States.

To be "sustainable" over the long term, a locale would undertake actions to reduce flood or drought losses only when those actions also: (1) maintain environmental quality, (2) maintain a certain quality of life for all residents, (3) promote disaster resiliency, (4) promote a vital local economy, and (5) ensure intra- and inter-generational equity. Further, under this paradigm, actions to reduce flood and drought losses must be based on local stakeholder consensus about the communities being designed for their great grandchildren's grandchildren. This requires that disciplinary and hazard-specific views be abandoned and that flood and drought experts work with local officials and others who seek different worthwhile societal goals like economic development and ecosystem preservation. It requires people to think about what life might be like in 100 years, how floods and droughts fit into that life, and how decisions made today affect how floods and droughts will impact life in the future rather than ignoring or simply tolerating them.

The United States has made some important progress toward sustainable hazard mitigation already. For example, I mentioned FEMA's emphasis on providing recovery assistance to flooded communities now focuses on recovering and rebuilding in a manner that avoids damage in the future, through the use of buyouts. The relatively recent creation of a National Drought Policy Commission (July 1998) points to the fact that drought is now being looked at in a comprehensive way. Similarly, FEMA's new "Project Impact" program facilitates local community mitigation programs and encourages strong partnerships with the private sector to ensure that those mitigation programs also contribute to a community's overall economic livelihood. While these efforts are headed in the right direction, there is still much work to be done to ensure all the integral parts of a sustainable community are fully included in these kinds of programs.

Floods and drought are just one aspect of the natural environment within which they occur. In the same way, human activities that increase or decrease risk to any natural hazard are part of larger social, economic, and cultural systems. Sustainable hazard mitigation puts hazards into the wider framework of sustainable development. It calls for people to establish consensus within their communities about how they will cope with floods and droughts, how they will use their floodplains and drought prone areas, and how they will pay for and recover from future disasters.

We believe that using this localized, yet broader, approach to hazard management can overcome some key obstacles to reducing losses under the present programs, namely the low priority local governments (and people) give to flood and drought risk, and local resistance toward federal mandates. It would also place the burden of coping with floods and droughts upon those who choose to bear the risk.

Recommendations for the Future

Sustainable hazard mitigation sounds great, but can it be implemented? To begin with, it is useful to think of resiliency to floods and drought as a specific aspect of a sustainable community. Resiliency is the quality of being able to "bounce back" fairly quickly from an extreme natural event without permanent, intolerable damage to or disruption of natural, economic, or structural systems. It also means that the community can do this without massive amounts of outside assistance.

For example, a flood and drought-resilient environment could be one in which there are riparian areas in natural or restored condition; flood-induced pollution has been prevented; runoff infiltrates or reaches drainage ways in an appropriate manner; habitat is preserved; and natural storage areas like wetlands remain. Flood and drought-resilient infrastructure and housing stock could mean that there are a minimal number of buildings at risk; those buildings that are at risk are insured; and infrastructure and critical facilities are resistant to flood and drought damage by virtue of their location, or some other technique. Flood and drought-resilient residents (providing a vital workforce) would be those that understand and have adopted acceptable levels of risk; know what to do when flood and drought threaten; and are adequately insured. A flood and drought-resilient economy could mean that the local business locations are not at risk for floods, or that the economy is diversified and not reliant on a single large

employer that could be disrupted by a flood or drought. The Center's project offers several recommendations for actions to achieve sustainable hazard mitigation. Most decisions about flood and drought resiliency should be made at the local level, but there are a variety of actions that research groups and/or the federal and state governments could take to make the local work easier. Here I will mention three of them.

Initially, because communities should not be asked to make decisions in the dark, there is a need to provide them better information and decision making tools. They should have up-to-date scientific information at their disposal, as well as guidelines regarding how to proceed. To begin with, some fairly significant data needs to be gathered. Ideally, a national or state risk assessment (of physical systems, social systems, and the built environment) should be conducted at a scale that is useful at the local level. While in Colorado, most communities already have access to maps which show the location of flood prone areas in their vicinity, most of them do not have information regarding the number of buildings or the size of the population that reside in those areas. Further, even less information is available on the level of vulnerability of these buildings (e.g., the relationship of a structure's lowest floor to expected flood levels) and these citizens (e.g., the extent to which they are insured against flood losses). From a drought perspective, communities need good climatic data and methods to be able to make risk-based assessments of drought vulnerability. It may not always be appropriate just to base the analysis on the driest period in recent memory.

In addition to this basic information, decision support systems must be provided to local stakeholders that not only estimate loss based on today's situation but that also project: (a) alternative levels of vulnerability based on future population growth and other factors, (b) losses in future disasters based on alternative mitigation decisions made today, such as different land use and building code decisions, and (c) impacts on and changes in other aspects of sustainability like environmental quality, economic vitality, and social equity. The systems need to enable network decision makers to "see" the community-of-the-future consequences of every decision they make today.

Second, the United States currently has several different programs in place that are meant to contribute to hazard resiliency at the local level. The aforementioned National Flood Insurance Program and "Project Impact" are but two of them. Seldom, however, are such programs evaluated to assess what the results of those programs are on the ground. Local, state, and federal policy makers alike really have no empirical data on which to make judgements about whether programs designed to reduce losses actually achieve that goal, much less what those programs' effects are on the other aspects of sustainability. With good evaluations, programs could be adjusted (or discarded) as appropriate. At the same time, as state government and local communities should evaluate their own programs, so they may give the federal government advice on what kind of assistance would be most beneficial to them. Finally, a major challenge for sustainable hazard mitigation is posed by the fragmented character of national and state flood and drought management programs. As many as a dozen federal agencies (and who could count all the state and local government organizations) have some responsibility for water management in the United States. Although there does indeed exist an a National Drought Policy Commission that is supposed to ensure congruity among the agencies' goals and objectives, it is too new for us to see how effective it might be. On the other hand, the "Interagency Task Force on Floodplain Management," with the same purpose has been around for more than two decades, but it has not been markedly successful. For example, the federal government administers a flood insurance program designed to promote wise development in flood prone areas and provide affordable insurance for existing development. But, it also administers disaster relief generously enough to dissuade many people from purchasing the insurance.

Our study believes that this kind of inconsistency stems from the lack of a holistic view of hazards and risk in most of the state and federal hazards programs. We believe that state, federal, and local officials must come together to reexamine the statutory and regulatory foundations of mitigation for all hazards, and begin work to first integrate and render consistent all hazards policies and programs and secondly to build the principles of sustainable mitigation into them.

Cautious Conclusions

I will conclude my remarks today on a cautionary note, or a reality check, if you will. It is easy to say we need to move in a new direction. Many documents floating around today mention sustainability and often there is discussion of the need for new "guiding principals," "collective consciousness," or, as we say, a new "culture." Rarely, however, is it acknowledged how incredibly difficult it is to change culture. Rarely do we hear about the difficulties and downright failures experienced by those trying to recreate a fabulous looking paper plan on the ground in a community. Rarely do we hear concrete suggestions for how to "integrate local, state, and the federal projects." Things are messy, people disagree, "turf" is invaded easily, and the plans drawn up in Washington, D.C. or Denver, CO, often have little saliency in West Slope, Colorado. Take, as an example, something happening just up the road from here, where a state entity - namely my employer, the University of Colorado - purchased a piece of flood prone land south of Boulder that was designated as open space in the county's comp plan. Though some regents were quoted as saying development won't happen here for 20 years, it now boasts a sign that says something like "Home of CU-South" and a variety of rumors exist about what is going to be built there and when. In planning to develop a floodplain, the regents are doing what they think is best for higher education for the citizens of Colorado.

Yet, one might question if they are thinking at all of the tradeoffs - of what the extent and limits of responsibility of present generations are for future generations. Are the regents consciously planning for, and willing to assume the costs of, the future flood that will happen there?.

Discussion of the Flatirons issue could go on for quite some time. I point to it only to acknowledge how hard what our study is suggesting actually is on the ground in the real world. We do have some suggestions, though. One suggestion for proceeding in this direction is that disaster professionals should consider the process as seriously as they consider the plan. An implemented plan is of little value if local people feel little ownership of the plan. For example, how, exactly, will city flood and drought managers coordinate their efforts into regional efforts? What pitfalls do the managers predict, and how can the institutional ties be developed so that such problems do not cause a breakdown of the ties themselves? In other words, the institutions we build in the process of creating resilient communities, must, by definition, be resilient to their own social or financial "disasters."

A second suggestion is that hazard mitigation professionals begin to take local issues, such as the economy, the environment, poverty, or crime, as seriously as they ask others to take flood and drought management. A good starting point would be to make connections between the implications of hazards on other issues. For example, cities that have turned floodplains into scenic parks and walkways, have noted that these changes were good for the economy - they draw tourist dollars, and add to the perceived quality of life and property values in the city. In this way, hazard management is serving more than one beneficial cause (safer floodplains, economic vitality, and improved quality of life) rather than gaining one at the expense of the other. By understanding and capitalizing on the connections between flood and drought management and other city concerns, hazard issues may gain some much needed community support.

Third, mitigation professionals need to consider consulting with people beyond the disaster or resource management fields, people who have expertise in areas like conflict management, grassroots organizing, integrated systems management, environmental ethics, or community development. Such professions could add insight into why hazard managers have had a hard time developing local interest and consensus, and could trouble-shoot some potential future problems.

Promoting this new "culture" - that of sustainable hazard mitigation - is yet another "nonstructural" approach to dealing with flood and drought hazards. It will, no doubt, require a delicate dance between all levels of government, the private sector, and cultural institutions, as well as political and moral convictions. The questions will be difficult, the answers will be harder, the recommendations will not be easy to implement, and the process will be long. In fact right now the proposed changes do not seem possible.

However, fairly radical and rapid social change can happen when groups begin moving in the same direction. Many of the most egregious civil rights injustices of the early 1960s seemed impossible by the 1980s. On a very different topic, our nation once felt sorry for smokers who got lung cancer; now we simply think they are stupid. Our collective culture regarding civil rights and smoking has changed radically, and often in fairly short time spans. A similar cultural shift is possible in regard to the way we relate to the natural environment and we suggest the steps recommended above as an initial step toward achieving that shift.

Water Rights in Relation to Flood Mitigation Issues

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An analysis of water rights in relation to flood mitigation issues is made difficult by the fact that flood control and allocation of the right to use water are fundamentally different. The Colorado doctrine of prior appropriation allocates rights to beneficially use water as a scarce and valuable resource, while flood control is a governmental function which recognizes water as a menace to public safety during times of temporary overabundance of water. Further complicating the analysis is the additional fact that the major flood control projects in Colorado are federal multi-purpose projects which include flood control as a purpose. Congress has given the U.S. Army Corps of Engineers authority over the operation of federal reservoirs for flood control, and such operations are not subject to state water rights. Nevertheless, "flood control" is recognized as a beneficial use of water in Colorado, and thus is a part of water rights administration.

In Colorado, a water right is the "right to use in accordance with its priority a certain portion of the waters of the state by reason of appropriation of the same". "Priority" means seniority by date of entitlement to use water from a common source ("first in time, first in right"). The right to use water is guaranteed by the Colorado Constitution, which provides that "[t]he right to divert the unappropriated waters of any natural stream to beneficial uses shall never be denied". "Beneficial use" is defined as "the use of that amount of water that is reasonable and appropriate under reasonably efficient practices to accomplish without waste the purpose for which the appropriation is lawfully made."

A water right can apply to the right to capture and store water in a reservoir. A "storage of water right" is "the right of impounding water for future beneficial use". Storage, of itself, is not a beneficial use of water sufficient to create a water right, but the water can be applied to beneficial uses while held in storage, such as fish and recreational uses and flood control.
The purpose of obtaining a water right is to protect the right to use water in priority, so that if a shortage of supply occurs the water right holders with senior priorities may use water to the exclusion of junior rights. Therefore, it could be argued that obtaining a water right for storage of water for flood control, thus submitting that storage to the priority system, is illogical. Water rights are not normally administered during floods because when the river is overflowing its banks, the supply of water exceeds the demand of all water rights on the stream, making priority among those rights irrelevant. In those conditions, if reservoir capacity is available, water could be stored without reliance upon a water right. Using a senior water right to call water past a headgate (or through an upstream reservoir, where its diversion or storage would have reduced the river's flooding) only to store it downstream in another reservoir makes little sense in terms of flood control.

However, the Colorado Supreme Court specifically concluded that flood control does constitute a beneficial use of water so as to justify granting a water right to the Southeastern Colorado Water Conservancy District for flood waters captured and stored in Pueblo Reservoir. It should be noted that, although the court cited dicta in two prior cases in support of its conclusion , it relied heavily on the statutory right of water conservancy districts to obtain water rights for the purpose of preventing floods. The legislature, the court reasoned, would not have granted conservancy districts that right unless it considered flood prevention a beneficial use of water. Nothing in the ruling, however, limits its application to conservancy districts, and thus it appears that under Colorado law one can obtain a water right authorizing the storage of flood waters in a reservoir without the need for identifying a future beneficial use to which those waters will be applied.

As a practical matter, reservoirs requiring water rights are not constructed, and water rights therefor are not obtained, solely for flood prevention. As a result, the logical quandary examined above is unlikely to come into play, and a water right for "flood control" is appropriately included among the numerous beneficial uses for the waters impounded in a reservoir constructed and operated for multiple purposes.

Federal Emergency Management Agency's Role in Flood and Drought Mitigation

Richard P. Weiland
Regional Director
Federal Emergency Management Agency, Region VIII

Thank you for that introduction, and thank you for the invitation to speak this morning at the Governor's Flood and Drought Preparedness Conference. I appreciate the opportunity to be here.

Let me start by commending Governor Owens and the State of Colorado for having the foresight to host a Flood and Drought Conference that is focused on pre-disaster preparedness and prevention, rather than response after an event. It shows great leadership to draw people together in the spirit of mitigating and preventing disasters.

At FEMA, we know two sure things: One, we know there will always be another disaster - Colorado floods and droughts won't stop coming. And two, we know that, working together before the next disaster strikes - we can save lives, cut property and business losses, protect our environment and make our communities safer and stronger for our children and their children.

FEMA started emphasizing prevention in 1993 with the creation of the Agency's first ever Mitigation Directorate. In the aftermath of the 1993 Midwest Floods, we worked with the Administration and the Congress to initiate a property buy-out program that removed over 20,000 properties from the floodplain and returned them to open space land use. We have placed greater emphasis on rebuilding communities safer and stronger after disaster strikes. These changes have made a real difference. But they are not enough.

Losses

The National Wildlife Federation's recent report, Higher Ground, shows in painstaking detail the cost of rebuilding in areas we know will suffer repetitive flood losses. Taxpayers have spent $140 billion recovering from natural disasters in the last 25 years, and flood losses are up to an average of more than $4 billion a year.

In the past 10 years alone, FEMA has spent $25 billion to help people repair and rebuild their communities after natural disasters. And that is not the total cost. Insurance companies spent additional billions in claims payments; businesses lost revenues; employees lost jobs; other government agencies spent millions more.

Yesterday, you heard about the economic impacts of past flood and drought events in Colorado. Between 1900 and 1997, floods killed 339 people and caused $3.6 billion in property damage across the State. On average, floods cause $17.6 million in property damages annually in Colorado.

Many of you know from recent experience the damages we can prevent.

Estimates of the recovery costs for the 1997 flooding event in Fort Collins and other parts of northeast Colorado were $161 million.

Since this past May, our regional agency has been working hard with the State to address the terrible destruction and suffering caused by floods in southeastern Colorado. As of November 1, disaster recovery costs have included $7.3 million for Individual and Public Assistance, $1.8 million in flood insurance claim payments, and $6.6 million in Small Business Administration disaster loans.

Changing Perspectives

These serious problems might be avoided with better preparation.

Much of the losses from flooding disasters in the State of Colorado can be prevented with leadership.
The fact is, we can cut losses. We have the know-how to reduce the risk. But it means we must change the way we think, the way we plan, and the way we budget. We must do more in prevention.

Having learned this lesson, FEMA has been working to lay the foundation for an improved pre-disaster approach to emergency management. We are looking at disasters, like floods and droughts, as known hazards, as an event we know is coming.

We're supporting what we believe is a growing change in the way Americans address disasters. Americans are ready to reduce the loss of lives and property. They are tired of paying the prices emotionally and financially. And they are ready to take action.

Government, community and business leaders in big cities and small towns are ready to work in new ways and in new partnerships to change the way America prepares for and prevents disasters.

To be successful, we have to change perspective. Just as you have reached out in this conference to engage a broad range of citizens in helping to define strategies for reducing Colorado's vulnerability, we know we need to reach out to a broader audience - it is not enough for us to think of how disasters impact government, and what we can do in a vacuum to reduce those impacts.

We need to become relevant to community needs. We need to look at the consequences of a flood or drought for workers and their bosses. For a neighborhood business owner - and that business' customers. For someone concerned about the consequences of building in a wetland - and a City manager seeking to expand his or her City's tax base.

We need to implement incentives that help people take greater responsibility for the risks they face. We must invest in Colorado communities and their economic viability by making them disaster resistant.

Project Impact

That is what we are trying to do through a FEMA initiative called Project Impact.
Project Impact is a national effort to shift the focus of emergency management from responding to disasters to preventing damage before disasters occur. Our goal is to change the way America prevents and prepares for disasters.
Project Impact isn't a government program, it's a partnership - not just with FEMA, but with partners in business, local government, law enforcement, utilities, fire services, community groups and more.

Project Impact operates on a common sense, damage-reduction approach, basing its work and planning on three simple principles:

· It is community based: FEMA and our State partners alone cannot make prevention an everyday activity. It must be a local effort. The entire community must be involved.
· We must protect the well being of our communities. Private sector participation in this initiative is vital. Disasters destroy jobs and wreck local economies. The private sector wants to be involved. They realize the investment they have in the people and infrastructure of the communities in which they work.
· And the final principle - prevention is a long-term investment. FEMA estimates that for every dollar spent in damage prevention, two are saved in repairs.

Through Project Impact, we are encouraging communities across the country to assess their risk, identify their vulnerabilities, and take steps to prevent disaster damage before disaster strikes. We do this by asking local officials and the private sector to plan together to prepare for future disasters. For communities in floodprone areas, this includes floodplain management and land use planning.

We like to say that, through Project Impact, FEMA is trying to change the way America thinks about disasters. But I also think our mission is broader -- We can change the way America thinks about where we decide to live - and that, in turn, provides local officials with an opportunity to change the way we plan our cities. We support the Governor and the State of Colorado in including natural hazard mitigation in the Governor's Smart Growth Initiative.

We will enlist the active participation of local elected officials and floodplain managers and encourage them to take responsibility in the fight to cut repetitive flood losses. We'll ask them to follow the example of Mayor Susan Savage of Tulsa, Oklahoma - who you will hear from directly during the next panel. On Memorial Day weekend in 1984, more than 14 inches of rain fell on Tulsa, flooding over 6,800 homes and businesses and killing 14 people. Tulsa learned from this tragedy and launched a major storm-water management program that is a model for this country and has significantly reduced the flood risk to Tulsa citizens and to business owners. Tulsa has recently taken another significant step toward becoming a disaster-resistant community - they became a partner in the Project Impact Initiative. As Tulsa proves, disaster prevention is done best at the local level.

Across America, Project Impact is ending the incentives to build in floodplains and instead is helping people to move to higher or safer ground. We're encouraging communities to work hand in hand with the environment, harnessing rather than undermining the natural resources that can be our best weapon in disaster prevention. We're retrofitting buildings to withstand the next flood event.
We already have 120 Project Impact communities nationwide- at least three in every state - and more than 1,000 corporate partners.

Three Colorado communities have joined the Project Impact - Building Disaster Resistant Communities Initiative in the past two years. Their accomplishments in this short time have been outstanding.

The City of Fort Collins, our first Project Impact Community in Colorado, has been a leader in projects to address comprehensive floodplain management issues. The city had already undertaken many "hard" mitigation projects after the 1997 flood. Now they are establishing an advanced system with technology, such as stream water gages and computer modeling, to gather data and project future flooding. This information is being incorporated into long-term planning efforts. Most importantly, Fort Collins is making an incredible effort to share this information with the community. Blue Knight Graphics, a Project Impact business partner, is helping the city develop and manage a related website.

Clear Creek County has embraced the idea of partnerships that support the county's land-use planning efforts. A cooperative planning group that included CDOT and other state agencies was established to evaluate and mitigate hazards along Interstate 70 - such as floods, landslides, heavy wind, snow and ice. Another Project Impact partner, Greater Outdoors Colorado, has provided funding to support land acquisition along the Virginia Canyon and provided guidance on transforming the land into open space with recreational use. Finally, student engineering

teams from the Colorado School of Mines are assisting Clear Creek County in evaluating geological hazards through field visits, survey and analysis.

Morgan County has developed an innovative storm shelter program with the help of schools, businesses and voluntary agencies. Fort Morgan Middle School students built three home tornado shelter models that have been exhibited at events throughout the County. The Executive Director of the Chamber of Commerce personally engaged local business partners like the Willard Reed Lumber Company and Country General Stores who donated materials and supplies for the effort. And the local newspaper, The Fort Morgan Times, has covered every event about the storm shelter program and other county project impact activities.

For the year 2000, two more Colorado areas have just joined the Project Impact Initiative: the City of Delta and a set of counties and communities within the San Luis Valley. We look forward to similar impressive accomplishments from these new participating communities in the year to come. All of the Project Impact Communities in Colorado should be commended for their commitment to becoming disaster resistant.

Project Impact is indeed having an impact. We are changing the way communities view disasters and stimulating a process that requires grassroots participation. As a result, citizens are getting the message that you can take action and avoid the misery of being a flood victim.

Other Mitigation Programs

In conjunction with FEMA's Project Impact Initiative, our Hazard Mitigation Grant Program is buying people out of the floodplain and restoring natural open space.
For example, the Hazard Mitigation Grant Program funding generated from the recent flooding disaster here in Colorado is being used to purchase and remove 48 homes from the floodplain in Otero County.

At FEMA, we believe preserving open spaces - by helping people move out of the floodplain - and working with our environment - such as preserving wetlands- are essential components of disaster prevention. We think working with nature's resources is the best protection against nature's disasters.

Our National Flood Insurance Plan Repetitive Loss strategy is focused on properties that have had at least two losses of $1,000 or more within any 10-year period. We'll extend a helping hand to owners buying them out or elevating their structures. If they decide to stay put, they must bear the full actuarial cost of flood insurance.
FEMA is also committed to modernizing our flood maps. We can no longer afford to have communities basing land use decisions using outdated maps and even more outdated technology. Up-to-date maps are essential for avoiding further repetitive losses and for preventing first-time losses as well.
Our map modernization plan focuses on increased community involvement in preparing maps, better public awareness and the latest technology. FEMA has developed an innovative Cooperating Technical Communities Partnership Program that is designed to share ownership of flood hazard maps among state, regional, and local entities through increased involvement in the mapping process. Colorado should be proud that the Denver Urban Drainage and Flood Control District became one of the first groups to join FEMA in this new partnership.

Drought

I've spoken this morning primarily about the prevention and mitigation of flood losses. I'd now like to touch briefly on drought issues.

FEMA agrees that a coherent national policy on drought is needed and that a lead federal agency should be designated to coordinate the federal government's response to drought. To that end, FEMA has been active on the National Drought Policy Commission and has supported the lead role being taken by the US Department of Agriculture. Later during this panel, Leona Dittus of USDA's Farm Services Administration will tell you more about the work and findings of the National Drought Policy Commission.

Although USDA has taken the lead on drought, FEMA has been involved in a number of national drought initiatives over the past few years. In 1996, FEMA chaired a Multi-State Task Force to address the devastating drought in the southwest. In 1997, we, along with several other federal agencies, also signed a Memorandum of Understanding that formed the Western Drought Coordination Council to improve drought preparedness, mitigation and response in the West.

At the state level, FEMA Region VIII has supported the Colorado Drought Task Force and its efforts to encourage long-term planning, and the development of water resources policy and water conservation measures. We also encourage the update of the 1981 and 1990 Colorado Drought Plans, which focus more on response, to a 2000 Plan that places greater focus on prevention and long-term mitigation.

Closing

We know we can't prevent disasters from striking, but Colorado disasters such as floods and droughts do not need to cause the disruption and generate the costs they have in the past. But we have to take action now. Pre-disaster mitigation is good public policy, good business, and makes good sense.

When FEMA launched Project Impact, we held a theory that if we could draw out the finest in people and businesses in responding to disasters, then we should be able to draw on that same spirit to prevent disasters. You in this

room are proof of that theory - committed Colorado citizens with a vision of improving your state and the communities within it.

The work that you begin today on strategies for the Governor's Action Agenda will prevent disaster damage in the future. With your help, we can take a bold step forward to help make pre-disaster mitigation a part of the way the State of Colorado and our communities conduct their day-to-day business.

I am pleased that the Governor and the attendees at this Conference are taking a leadership role, and I and the Denver-based staff at FEMA Region VIII look forward to working with you to make pre-disaster mitigation and preparedness for floods and droughts a reality.
Thank you.

Corps Role in Flood and Drought Mitigation

Charles M. Hess
Operations Division Chief
U.S. Army Corps of Engineers

Introduction

The U.S. Army Corps of Engineers and the nation face many challenges in flood and drought mitigation:

· Past Development: Past development without adequate attention to environmental sustainability has created requirements for restoration and retrofitting of communities and projects.

· Continued Development: Continued development in flood-prone areas creates the prospect of increasing economic and social costs from floods.

· Aging Infrastructure: In addition, the nation has an aging water resources infrastructure that requires maintenance and modernization to reduce the risk of serious impacts to our prosperity.

Overview of Presentation

Today I would like to discuss:

· Background of the Corps and our Civil Works mission
· Emergency/Disaster Management Role
· Authorities for providing Drought Assistance
· Cooperation in Flood Plain Management:
· Flood Damage Reduction (Non-Structural / Structural Solutions)
· Challenge 21
· Corps/FEMA Partnering
· Education Initiatives/ Outreach

USACE Overview

I would like to give you some background regarding the Corps' authorities and how we have come to be involved in the planning, designing, building, operating and maintaining of projects that provide river and harbor navigation, flood control, water supply, hydroelectric power, environmental restoration, wildlife protection and recreation;

· General Survey Act of 1824: This act authorized the President to use Army engineers to survey road and canal routes and established the Corps as the nation's primary engineering agency for civil works projects.

· Flood Control Act of 1936: This act recognized flood control in general as a federal activity throughout the nation and gave responsibility for most federal flood control projects to the Corps.

· Energy and Water Development Appropriations Act: Funds for the Civil Works program are provided through annual Energy and Water Development Appropriation Acts and through contributions from non-Federal entities for planning or construction of specific projects as prescribed by law.

Civil Works Mission

Today, the Corps' Civil Works mission is to contribute to the national welfare and serve the public's needs by providing:

· Development and management of water resources infrastructure,
· Protection, restoration and management of the environment,
· Response to emergencies/disasters
· Engineering and technical services.

Emergency/Disaster Management Role

The Corps also has important planning, response and recovery missions under our own authorities and as an "agent" for FEMA:

· PL84-99 Flood Control and Coastal Emergencies Act: Under this Corps' unique Authority, USACE supplements state efforts in:
- All Hazards Planning
- Emergency Operations/ Flood fighting operations and technical assistance
- Rehabilitation of FCWs
- And at the request of the Governor, Advance Measures to reduce damages in the face of immediate threat to life and property.
- Emergency Water (I'll address this authority separtely)

· Stafford Act (Federal Response Plan (FEMA Authority). Under the Federal Response Plan, DOD has the responsibility for Emergency Support Function#3 (Public Works and Engineering):
- DOD designated USACE as Operation Agent for ESF#3 planning preparedness and response.
- Typical Missions Include: Water, ice, power, housing, roofing, debris.

Drought Assistance under PL84-99

USACE is authorized to transport emergency supplies of clean drinking water for human consumption to any locality designated as a drought distressed area, and to construct wells in such drought distressed areas. Assistance will only be to meet minimum public health and welfare requirements.

· Qualifying Requirements: State and local agencies must make full use of their own resources, including the National Guard. Requests for assistance to the Corps must be initiated by the Governor or his/her authorized representative. A permanent solution is being actively pursued at the local level.

· Form of Assistance: Emergency supply of clean drinking water for human consumption, and construction of wells if not commercially possible. Water normally provided by tank trucks or small diameter pipelines.

· Limitations:
- USACE assistance is supplemental to state and local efforts.
- Permanent restoration of water supply is a local responsibility.
- Water is provided only for human consumption, not for livestock.

Cooperation in Flood Plain Management

People that live and work in the flood plain need to know about the flood hazard and the actions that they can take to reduce property damage and to prevent the loss of life caused by flooding. USACE Flood Plain Management Services (FPMS) Program was developed by the Corps of Engineers specifically to address this need.

· Objective of Flood Plain Mgmt Program: To foster public understanding of the options for dealing with flood hazards and to promote prudent use and management of the Nation's flood plains.
· Types of Assistance. The FPMS Program provides the full range of technical services and planning guidance that is needed to support effective flood plain management.
- General Technical Services. The program develops or interprets site-specific flood data and information on flood loss potentials before and after the use of flood plain management measures.
- General Planning Guidance. On a larger scale, the pro gram provides assistance and guidance in the form of "Special Studies" on all aspects of flood plain management:

- Flood Plain Delineation/Flood Hazard Evaluation Studies
- Dam Break Analysis Studies
- Hurricane Evacuation Studies
- Flood Warning/Preparedness Studies
- Comprehensive Flood Plain Management Studies
- Flood Damage Reduction Studies
- Urbanization Impact Studies
- Stormwater Management Studies
- Flood Proofing Studies
- Inventory of Flood Prone Structures.
- Guidance forNational Flood Insurance Program
- Workshops and seminars (such as Flood Proofing).

Flood Damage Reduction

The Corps is also a leader in flood damage reduction techniques:
· The Corps manages 383 major reservoirs with flood damage reduction storage.
· The Corps has placed 8,500 miles of levees.
· Corps projects reduced flood damage an average of $19.7 billion over the last 10 years.
· Through 1997, the Federal investment in flood control projects has yielded $6.00 for every $1.00 invested.

Non-Structural/Structural Solutions to Flood Damage Reduction

It is the policy of the Corps of Engineers to consider in the planning process all practicable and relevant alternatives applicable to flood damage reduction.
· No one alternative is pre-judged superior to any other.
· Consideration is given both to measures intended to modify flood behavior (structural measures) and those intended to modify damage susceptibility by altering the ways in which people would otherwise occupy and use flood plain lands and waters (nonstructural measures).
· The goal is to develop, define and recommend a robust solution that has public and institutional support (having appropriately determined how well an economical plan can be made to function, how capable are the responsible interests to operate and maintain it, and how safe will be the people who will depend on it).

Challenge 21 (Section 212 of WRDA 99)

Under WRDA 99 the Flood Mitigation and Riverine Restoration provision known as "Challenge 21" provides authority for the Secretary of the Army to implement projects that reduce flood hazards and restore the natural function and values of rivers and that meet other specific criteria without seeking individual authorization for each project.

· The Corps does not currently have appropriations to implement this program. However, the Corps is conducting studies using other authorities and may seek authorization for projects that meet the goals of this program.
· The program emphasizes the use of nonstructural approaches to preventing or reducing flood damages and coordination with FEMA and other Federal, State, and local agencies, and tribes.
· Each project will require a non-Federal sponsor willing to provide 50 percent of the cost of a study and 65 percent of the cost of implementation.
· Federal spending on an individual project is limited to $30,000,000.
· Appropriation authority is limited to $20,000,000 for FY 2001, $30,000,000 for 2002, and $50,000,000 for FYs 2003-2005.

Corps/FEMA Partnering

We already have a good working relationship with FEMA in our Response and Recovery activities. Now, we clearly need to work with FEMA and other partners to develop a common National vision for pursuing floodplain management programs and initiatives. For example:
· The Hazard Mitigation Grant Program (HMGP): HMGP is FEMA's program to assist States and local communities in implementing long-term mitigation measures following a Presidential disaster declaration. The objectives of the HMGP are:
- To prevent future losses of lives and property due to dis asters;
- To implement State or local mitigation plans;
- To enable mitigation measures to be implemented during a State's or community's immediate recovery from a disaster; and
- To provide funding for previously identified mitigation measures that benefit the disaster area.

· HMGP Workshop: At a recent interagency workshop, there was consensus that USACE/FEMA must do a much better job of coordinating our flood damage reduction programs with State and local sponsors. Mr Witt is strongly opposed towards allowing any new structures (levees included) to cross HMGP deed restricted properties.

Conclusion

On behalf of General Ballard and the entire Corps, I want to thank you for this opportunity to participate in this important conference. The Corps stands ready to continue to work with Colorado, FEMA and all levels of government and the private sector as we work together to insure the Nation's competing water resources needs are met today and in the future through planning, effective management and prudent infrastructure investments.

U.S Bureau of Reclamation's Role in Flood and Drought Mitigation

Maryanne Bach
Regional Director
Great Plains Region, Bureau of Reclamation

I would like to thank Governor Owens and the Colorado Department of Natural Resources for giving the Bureau of Reclamation the opportunity to participate here today. Let me also commend the Governor and his senior staff for getting ahead of the curve in bringing leadership to these issues. I have participated in nearly one dozen national and regional drought conferences over the last five to six years; in all cases except for today's, there has been a threat upon the affected communities. So I commend Colorado and the Owens Administration for taking to heart the "spirit" of preparedness, something the four federal agencies sitting at this podium today preach to state and local communities. I would also offer this observation; I have yet to speak at one of these conferences, when there has not been some form of precipitation and the snow today, clearly, provides no exception!

Secondly, if you remember nothing else about this conference, remember these four points regarding planning for floods and droughts: monitoring and prediction; mitigation and preparedness; response; communications/interaction with the press and with communities.

Finally, with my remarks I will emphasize that when it comes to drought and flood coordination, these four federal agencies (Corps of Engineers, FEMA, Reclamation and Department of Agriculture) are certain of their respective roles and complement each other well in the field.
I am here representing Eluid Martinez, Reclamation's Commissioner. As mentioned in my introduction, I am the Director of Reclamation's Great Plains Region which includes all or part of the nine states just east of the Continental Divide.

To help you understand Reclamation's role in the Colorado water business and in flood and drought issues, I'd like to very briefly describe our agency and operations. The Bureau of Reclamation is an agency of the Department of the Interior created nearly 100 years ago to help bring water to arid areas of the seventeen western states. Our mission is to manage, develop and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Today around the West we administer 348 reservoirs with a total storage capacity of 245 million acre-feet. We are the nation's second largest wholesale water supplier. We operate 58 hydroelectric powerplants averaging 42 billion kilowatt-hours annually which makes us the fifth largest electric utility in the seventeen Western States.

My region manages facilities in the eastern portion of the state of Colorado, principally through our Eastern Colorado Area Office in Loveland. Reclamation's Upper Colorado Region, headquartered in Salt Lake City, manages the western portion through its Western Colorado Area Office with two office locations, one in Grand Junction and one in Durango.

On the West Slope the Upper Colorado Region manages projects which include fifteen major dams, seventeen minor dams, ten powerplants, ten pumping plants, and an extensive irrigation distribution system that services over 160,000 acres of farmland. The Great Plains Region, while primarily operating in the eastern half of the state, does operate some facilities on the West Slope which divert and store water that is transported under the Continental Divide for use by farms and cities on the East Slope. These operations are part of the Colorado-Big Thompson and Fryingpan-Arkansas projects.

The Colorado Big-Thompson Project is one of the most ambitious projects ever undertaken by the Bureau of Reclamation and includes over 100 water and power facilities which store, regulate and divert water which is delivered to 125 water user organizations on the East Slope. Much of the Colorado-Big Thompson Project is operated on a day-to-day basis by the Northern Colorado Water Conservancy District.

It's a pleasure for me to recognize our customers in the audience. I notice that Eric Wilkinson is here today; Eric is the General Manager for Northern and I see that there are some members of his staff, as well as members of the Board. If you'd kindly raise your hands.

The Southeastern Colorado Water Conservancy District (SECWCD) is the sponsoring agency for the Fryingpan-Arkansas Project which includes five major dams and reservoirs and 17 diversion dams including the large Pueblo Dam and Reservoir, one of the largest and most used facilities in the state.

At this time I'd also like to acknowledge in the audience is Steve Arveschoug, General Manager for the SECWCD. With this brief overview as a point of reference, I would like to describe how we fit into the flood and drought issues facing the state of Colorado and discuss what we believe we can to do assist.

Let me first discuss floods. The Flood Control Act of 1944 defined how the Bureau of Reclamation would operate its facilities during flood events. It establishes a relationship between Reclamation and the Army Corps of Engineers. Whenever runoff to Reclamation reservoirs accumulates into the flood control pool of a facility, the operation of that

facility is coordinated by the Army Corps of Engineers. If the Corps operates facilities in the same drainage, the flood operations would, of course, be coordinated with their own facilities to minimize flood damages while at the same time protecting as much of the water supply as possible in all of the facilities. Once flood waters evacuate the flood control pool, the operation of the facility is returned to Reclamation.

It is Bureau of Reclamation policy to operate our facilities to optimize the benefits for which they were developed. At the turn of the century, our facilities were developed primarily for irrigation. As the multiple use philosophy became more prevalent in water management beginning in the 30's and 40's, other project purposes were identified. Today, Reclamation projects are managed for a variety of uses including power, municipal and industrial, fish and wildlife, recreation, etc.

During periods of high runoff, we manage facilities, of course, to maintain the structural integrity of the dam and minimize downstream flooding while at the same time holding as much of the flood water as possible to meet the multiple needs of the stored water. It is, as you might expect, a serious balancing act.

Demands on water in the West continue to grow rapidly. One principle of meeting multiple water needs is that the flexibility of dam operations is essential for efficient water management. One challenge the Bureau of Reclamation and other dam and reservoir operators face in the West is that land development has been allowed to encroach into the flood plains below our dams and therefore affects the operational flexibility needed to meet the variety of resource challenges we face on a day-to-day basis. The Bureau of Reclamation has been working closely with the Western Governors' Association, or WGA, on this issue. Recently, the association received an issue paper concerning development in flood plains. The paper was developed by Reclamation in coordination with the Army Corps of Engineers and Natural Resources Conservation Service. It was an outgrowth of discussions by WGA's Western Flood Task Force. The paper points out that extensive development has been allowed by local governments in flood plains that has not only adversely impacted the flood plain by reducing its natural resources and functions, but has also significantly decreased the operating flexibility of dams and reservoirs located above these areas.

The construction of dams has provided a perception to the public and to local governments of flood protection to downstream areas. However, the dams have created a false sense of security. With the perceived threat of flooding alleviated, local government entities controlling land uses have permitted residential and commercial development in flood plains. This encroachment poses a significant problem for dam operators who must manage the release of water for a variety of reasons including preparing for and safely routing high flood runoff through the reservoir, conducting dam maintenance, providing "spike flows" for the removal of sediment and vegetation from the stream channel, and providing the desired flows to meet the biological needs of fish and wildlife. Operators must alter releases to limit impacts to downstream development and to prevent loss of life, while also meeting the wide variety of multiple use requirements.

Operations which are, in a sense, artificially altered because of encroachment in the flood plain are inefficient from a water use perspective and in many cases do not allow us to achieve our desired management goals. Dam operators may need to release water earlier in the storage cycle and at a reduced rate of flow to ensure reservoirs have ample storage capacity to handle a potential large influx of water later. These early releases may occur when there is significant uncertainty whether a large runoff may even materialize. Limiting the operating flexibility of the reservoir leads to less efficient use of the available water supply.

The paper makes several recommendations. Among them is the recommendation to work with local governments to help them understand the impacts of development in flood plains, to work together to bring local, state and tribal governments together with federal agencies to address these issues, and to encourage public education on appropriate land use practices and prudent flood plain management. Each of Reclamation's facilities has SOPs or standard operating procedures. The contacts with other state and federal agencies outlined in these plans are kept up to date and thus serve as an invaluable way to coordinate with respective government agencies at all levels. We also conduct emergency exercises at our facilities and invite our sister agencies so we can maintain these working relationships.

It is not within the Bureau of Reclamation's direct jurisdiction to clean up once a flood has occurred. We do, however, often provide skilled technical people to other agencies, most notably FEMA, to assist in rebuilding. We agree it would be more effective to work together with a variety of entities before the floods to prevent them or minimize their impacts.

Now let me address the Bureau of Reclamation role in drought mitigation. As a major federal water management agency in the West, the Bureau of Reclamation is involved in drought planning and remediation on a number of fronts. Let me highlight the most current activities and then trace back to the origin of specific authority we received from Congress nearly a decade ago for nationwide assistance. On the intra-continental and intercontinental scene, Reclamation is the lead agency for the Department of the Interior on the National Drought Policy Commission which was created by legislation signed into law a little more than a year ago. Since Commission Director Leona Dittus follows me on the program, I will not get into the details of the work of the Commission.

Beyond the work of the Commission, Reclamation believes it has a role to assist states in the West as a facilitator of thinking and good planning. We are trying to fulfill a role as a convener.

As an example, Reclamation was one of the co-sponsors of the recently completed United States/Mexico Border Drought Workshop (October 12-13). We worked with the International Boundary and Water Commission of the United States and Mexico, the National Water Commission of Mexico and the Western Governors Association. The workshop sponsors welcomed over 180 participants from the United States and Mexico who discussed issues of water policies, practices, and barriers at the border. They addressed how the two nations can cooperatively seek solutions by being open minded in sharing information, generating and sharing ideas, and moving forward on cooperative effects to overcome technical and political barriers in both countries for better water and drought management. The session helped create a tremendous atmosphere of sharing and cooperation between the two nations.

Reclamation also provided leadership and funding to begin drought contingency planning by sponsoring a series of regional workshops in New Mexico, Utah, South Carolina, and Kentucky between 1997 and 1999. The workshops were conducted, under agreement with Reclamation, by the Drought Mitigation Center at the University of Nebraska-Lincoln. The National Governors Association and Western Governors Association also were co-sponsors. The workshops have helped tremendously to enhance the capacity of Federal, state and local entities to work together to address drought issues.

We have helped finance drought-related websites through the WGA/Western Drought Coordination Council (http://enso.unl.edu/wdcc) and the National Drought Mitigation Center (http://enso.unl.edu.ndmc). As a result of the coordination of federal agencies with WGA, all existing state drought mitigation plans, as well as several available municipal plans are available through these Internet sites. Funding provided to the Drought Mitigation Center was also used to prepare a white paper entitled, "A Methodology for Drought Planning." This paper provided a revision of the 10-step drought planning methodology that had been in wide use. The idea for the revised process came out of the four regional workshops.

The Bureau of Reclamation has also been involved in direct assistance to the states to help relieve the effects of prolonged droughts. I should point out that we have no regular appropriated funding to do this, but on occasion in recent years have been a conduit for special funding provided by Congress.

In 1991 $30 million in dire emergency drought supplemental funds were provided through Reclamation to aid in the relief of drought throughout the West. Because the effects of the drought lingered beyond the availability of funding, Congress elected to pass the Reclamation States Emergency Drought Relief Act to provide additional authorization and funding to help western states stricken by drought. About $90 million was appropriated and about $50 million has been authorized by Congress in the last six years.

These funds have been used to assist a variety of entities, including other federal agencies, tribes, and state and local governments in addressing drought preparations and mitigation and to provide funding for building temporary facilities that ease the effects of drought until conditions return to more normal.

Some of these projects have included:
1. Construction of municipal wells to augment water supplies.
2. Temporary projects such as water supplies for wildlife refuges, temporary diversion structures, dust abatement projects, shoreline stabilization projects, fish hatchery projects, and water catchment devices.
3. Cooperative efforts with state agencies to assist in the preparation or updating of drought contingency plans.
4. Funding and technical assistance were provided to seven Indian tribes to help them develop drought contingency plans.

In conclusion, let me state that the Bureau of Reclamation takes very seriously its role as a manager of water in the West. We recognize and respect the state and local jurisdictions in water issues and we strive to work closely with you. We want our operations to meet the needs for which they were authorized by Congress as well as to complement the operations and needs of other entities.

I need to point out that we have had a long and successful relationship with the Western Governors' Association working on these issues. Governor Owens and the state of Colorado have provided considerable leadership through WGA on flood and drought issues, and we look forward to continuing and strengthening these relationships. We'll continue our support to the state, and again my compliments to the professionalism we enjoy in Reclamation working with the staff of the Colorado Department of Natural Resources, State Engineer's Office and the state emergency management agencies.

We recognize the need to work together and we offer to continue to function in the role as a facilitator or a convener to help assure that the best thinking and planning is used at the local, state and Federal level.
Thank you again for inviting us.

National Drought Policy Commission Perspecitives

Leona Dittus
Executive Director

I too want to compliment Colorado for being pro-active. At recent National Drought Policy Commission hearings, the need to prepare rather than just to respond was repeatedly emphasized.

I'm with the Department of Agriculture's Farm Services Agency, so I'm not a stranger to disasters and disaster programs. I grew up on a farm and farmed in North Dakota until I moved to Washington, D.C. I have experienced drought first-hand.

People don't think about drought until it's happening, and then when it's over, they forget about it until it comes around again. So, we are usually not prepared.

I'd like to highlight the significant drought events of the past century. In the 1930s, the Great Plains drought created the Dust Bowl, one of the most significant events of the 20th Century. In 1950-54, drought across the Southwest and Southern Plains claimed the lives of millions of cattle and forced hundreds of ranchers to ship their livestock to other regions of the country. In the early 60s the Northeast experienced drought for several consecutive years. In 1975-77, lack of winter snowfall resulted in extreme drought conditions in the West. Again, in the mid-80s and the 90s, there was prolonged drought in California, the Mid-west and the Southeast. 1988 was a particularly bad year for droughts. In the late 1990s there were a lot of drought occurrences. 1996 was when Federal Emergency Management Agency (FEMA) got heavily involved in what could be done about drought and started holding meetings, the first one in Albuquerque. Of course in 1999, I'm sure you've all heard about the drought in the East. Everyone thought drought is strictly a Western phenomenon, and they found out very quickly this year that this is not so. Media attention brought a lot of attention to drought this year. The Secretary of Agriculture did a lot of drought tours, and because of the priority the drought was given, the White House established a drought task force in August to look at and consider what could be done to help alleviate some of the immediate drought impacts that were occurring without infringing on the Commission's goal to look at long-term issues. Then we had Hurricane Dennis and everyone forgot about the drought.

The National Drought Policy Act, Public Law 105-199, was signed by the President July 16, 1998. The Act created the National Drought Policy Commission, which is chaired by the Secretary of Agriculture and also includes representatives from the Bureau of Reclamation with the Department of Interior, the Department of the Army, the Department of Commerce, the Federal Emergency Management Agency and the Small Business Administration. The law also specified that there would be members from the National Governor's Association, a nominee from the National Association of Counties and a nominee from the U.S. Conference of Mayors, who are appointed by the President. There are six additional at-large members appointed by the Secretary of Agriculture in coordination with the secretaries of the Interior and the Army. Those six people are intended to represent groups acutely affected by drought, such as agriculture production, the credit community, urban and rural water users, Native Americans, fishing and environmental interests. This gives us a broad spectrum of members to ensure that we consider all aspects of drought.

The Commission was charged with conducting a thorough study, holding public hearings, and consulting and collaborating with entities such as the National Drought Mitigation Center, Western Drought Coordination Council and others.

In conducting the study, the Commission was asked to:
1. Determine the need on federal, state, local and tribal levels to prepare for and respond to drought emergencies.
2. Review all existing federal laws and programs relating to drought.
3. Review state, local and tribal laws and programs relating to drought.
4. Determine what differences exist between the needs of those affected by drought and the federal laws and programs designed to mitigate the impacts of and respond to drought.
5. Consider regional drought initiatives and their application at the national level.

We have reviewed what programs are there and what are the needs. The next step was to determine what differences exist between those needs and what's available and to define the gaps. The Commission was also asked to look at regional drought initiatives to see what of those might be useful at the national level.

The Commission is to prepare a report for the President and Congress, which we hope to submit by the middle of 2000. It is taking a little longer than we had hoped to analyze all of the various programs and to do a thorough job of getting public comment. The Commission is very concerned about doing a good complete report, and therefore, chose to take a little additional time rather than rush and not have a good product.

The Commission's report will contain a detailed statement of findings and conclusions. It will also include recommendations for legislation and administrative actions it considers appropriate. The recommendations will address how federal drought laws and programs can be better integrated with ongoing state, local and tribal programs in order to establish a comprehensive national policy to mitigate the impact of and respond to drought emergencies without

diminishing the right of states to control water through state law and also considering the environment. The Commission will recommend ways to improve public awareness of the need for drought mitigation, prevention and response. Last but not least, the Commission was asked to make a recommendation on whether it felt all of the drought preparation and response programs should be consolidated under one existing federal agency, and if so, to name that agency.

The Commission will terminate 90 days after it submits its report.

As you all can imagine, looking at drought as a whole is a very big job. We're not looking just at agriculture or urban water. We're looking at the entire aspect of drought on a national basis. In order to facilitate that, the Commission established a working structure made up of a Commission staff of which I am the executive director. We have an Interagency Contact Group, which has a member designated by each commission member to assist me and my staff to make sure that we review all of the drought data and concerns of each of those members. In addition, the Commission established working groups to facilitate the review They are Agriculture; Municipal and Industrial Water; Local Government, Community and Businesses; Environmental Issues; and Monitoring and Prediction. Those working groups are made up of members nationwide from federal and local levels. I commend Colorado for being very active. There are many individuals from Colorado on each of those working groups. The working groups each prepared a report, which they submitted to the Interagency Contact Group and the Commission. Those reports were reviewed, analyzed and synthesized to come up with a much smaller report.

The Commission held its first meeting on July 22, 1999, in Washington, D.C. and had a second meeting on September 22, again in Washington to hear about the concerns of people in the East who had just experienced a severe drought. A third meeting was held December 2 in Los Angeles. Additional meetings will be held as necessary to complete the Commission's activities, in addition to several conference calls. All meetings and hearings are noticed in the Federal Register and are open to the public. Hearings were held July 21 and September 22 in Washington, D.C., October 13 in El Paso, Texas, and December 1 in Los Angeles. In different places we heard different concerns from different people. During the second hearing in D.C., we heard from a lot of small farmers in the East who expressed their concerns about what they were going through. In El Paso we heard concerns about water treaties. In Los Angeles, we heard a lot of information from the urban side and what they are doing to conserve water. More public hearings will be held to give as many people as possible across the nation an opportunity to provide their concerns. We are looking at possibly having public hearings in January and February in Austin, Texas, Billings, Montana, Atlanta, Georgia, Ohio and the Northeast.

The focus of the review includes monitoring and prediction, preparedness and mitigation, and how we communicate with the public.

The Interagency Contact Group and staff, with input from Commission members, have been preparing a draft report. The draft report will be put on the Internet in the next couple of months on the Commission's web site, www.fsa.usda.gov/drought, which also has information about additional meetings and hearings. The Commission would like to give the public an opportunity for input before the report is finalized.

The Commission's vision is of a well-informed, involved U.S. citizenry and its governments prepared for and capable of lessening the impact of drought consistently and timely in the new millenium. The Commission's vision is based on the following principles:
1. Consideration of all affected entities and related issues including legal, economic, geographic, climate, religious and cultural difference, fairness and equity, and environmental concerns.
2. Comprehensive, long-term strategies that emphasize drought planning and measures to reduce the impacts of drought.
3. Federal role focused on appropriate coordination, technical assistance, education and incentives, while at all times respecting the rights of the state, local and tribal entities.
4. Self-reliance and self-determination
5. Lessons learned from the past.
6. Shared drought expertise and knowledge across international borders.

The Commission's key goals are:
1. Drought planning and impact-reduction measures that incorporate comprehensive, long-term strategies.
2. Effective drought monitoring and prediction as well as analysis, interpretation and dissemination of easily understood drought-related data and information.
3. Sustained, high-quality, drought-related research and innovation that stems from individual, local, state and regional drought planning needs and effective transfer and application of research results.
4. Coordinated, national approach to addressing drought.
5. A safety net of emergency response programs.
The Commission welcomes all public comments regarding drought issues and concerns for their consideration in making its recommendations to the President and Congress. A draft of the report will be available on the Commission's web site (www.fsa.usda.gov/drought) in a few months for public review and response. The Commission hopes to submit its final report in May or June. The web site contains information regarding my address and other information needed to contact the Commission. Please feel free to contact me if I can be of any assistance.

Texas Drought Response Legislation

Gary L. Walker
Texas House of Representatives

Where I live in Texas, we say we're right in the middle of the best fishing in the whole Southwest. It's only 250 miles to any lake in any direction. So, I guarantee you we don't have much water and what we've got is agricultural use. We are in the Ogallala. We deplete about a half a foot to a foot a year. We have very little recharge. So, precipitation enhancement is really our only hope for the near future for any water supplies.

In Texas, if you're alive, only two things are certain, because there is obviously a third thing that's evident in all of our lives. In Texas, it's taxes and drought. We are in our third out of four years in drought. Of course, that's relative. In 1998, we had 6.2 inches of rain in my county for the whole year. This year, we've had about 20 inches of rain for the whole year, but it has not rained since July. So, we've had four months of practically no rain. Our landmark legislation in 1997 was Senate Bill 1 and Lt. Governor Bullock, before he passed away, touted it to be the most important water legislation ever created in Texas. It was brought about primarily because of the drought in 1995, 1996 and 1997. They kid me in the legislature that we live in the drought all of the time.

There are two types of drought as most of you know, climatological and hydrological. We've taken the approach in Texas that the best drought prevention is a good long-term water supply - planning and subsequent implementation. The Palmer index shows you that Texas is in a drought today. My dad lives in Houston, where normally through this time of the year 45 inches of rain falls, they've had 25. On the Texas coast, we're 17 inches behind. In Corpus Christi on the lower coast, their two main water supply reservoirs are at less than 25 percent. They have just completed a pipeline for a contact with the Lower Colorado River for $750 an acre-foot for non-treated, non-delivered water. Water has some value in Texas, especially when it goes to municipalities.

Senate Bill 1 in 1997 during the 75th legislature was in response to the drought of 1996-97. We had estimated losses of $6 billion. After Senate Bill 1 was created, we in the legislature and Lt. Governor Bullock went around talking about it, and people said, "How is this gonna make any more water in Texas?" And we said, "It just is not." But what it really did is create the regional planning process, a bottom-up approach to water planning.
Senate Bill 1 created a regional planning mechanism made up of local people. Eleven regions were mandated in the bill, but we fought for almost a year just defining the lines for the different regions. Once we finally got that done, we ended up with 16 regions. Boy people squabbled over that - whether we did it by river basins, by county lines, by municipalities. Nobody wanted to be with San Antonio, because they are considered the gorilla of Texas. They have no surface water supply; they are strictly dependent on the Edwards Aquifer. It's the largest city in the world that has a sole source aquifer. We finally got these rascals in place, and the original statute called for the regional plans to be submitted to the State of Texas September 1, 2000, which is less than a year away.

The next step was that the state would take these regional plans and mold them into a state plan. We've had state plans before, lots of them. But they were all done by the state, and most of the time, they didn't know what was going on out in the "real" areas of Texas. When I talk about real areas, I tell them that the "R" in my name stands for "rural" not "Republican." It's a huge fight. In Texas, in our four large metropolitan areas, we have over 66 percent of our representation. Out of 150 members in the legislature, over 100 of them live east of I-35. So, representation in the Texas legislature is quite rural and municipal, not so much Democrat and Republican, and it's going to get worse for rural Texas east and west when we re-district in the next legislative session. This is the cornerstone of Senate Bill 1 water planning.

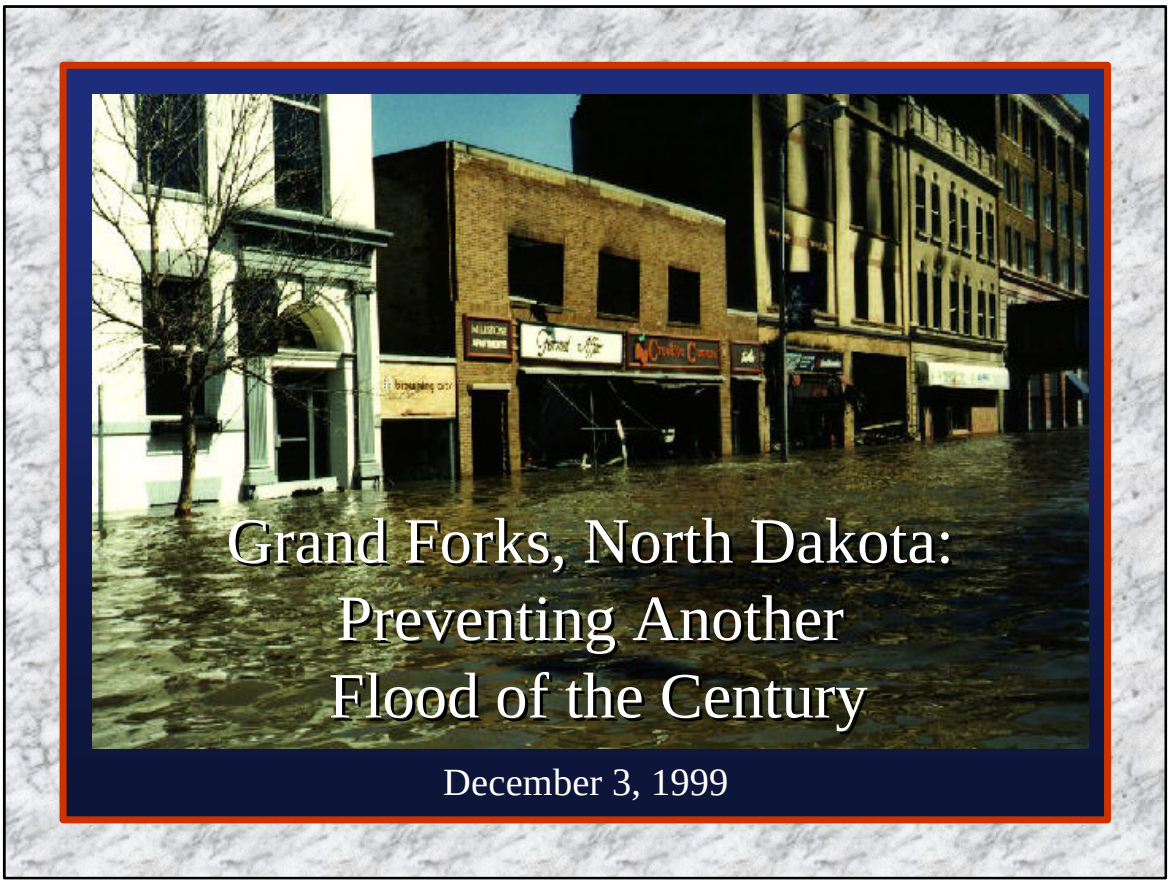
What we hope is that this plan will represent regional issues. It's an opportunity to collect data and develop strategies to meet 30 years of needs, even though we are actually going to plan for 50. We're going to update these plans every five years. That means the regional planning groups are still going to stay together over the course of the next 20 or 30 years and update to the state every five years. For a city or entity to be eligible for monetary assistance from the State of Texas, it has to be included in these regional water plans. There are provisions, if you are a city or county or rural water district, not to be included in a regional plan. But down the line, we hope that we've made it to where it would be very detrimental.

So, the water regional plan has the 50-year planning. The projections for population, water demands and supplies are the three things that are really important. I manage a water conservation district. In Texas, we have a convoluted water structure. We have right of capture, which most people talk about as private ownership of water, but it's not actually an ownership issue, but it is the right of capture. We pretty much know what we use based on center pivot hourly counts, water-well timers and those kinds of things. But in many areas you'd be surprised how a city or a county doesn't really know the projections for population or uses. This has really created an awareness around the state where all these regional planning groups have to post notice. They have regular monthly meetings. They have lots of folks who show up to complain about different things as you would imagine. We are going to evaluate our water management strategies in these plans.

We're going to get to these long-term water supply planning issues through these regional groups. I might add

that the State of Texas funded these regional groups in 1997 and we have a two-year budget. The first budget, I think, was about $7-9 million. In the 76th legislature, which we just finished in May, for the next two-year cycle as these plans are due in January 2001, we put about another $6-8 million into the planning. This actually winds up to be a total of $16 million. That's not a million for each planning group, it just so happened that the numbers worked out to be $16 million. The area where I live has a lot better handle on our water use and water supply, because some of our water conservation districts out there have been in existence since the mid-1950s. As you get into the central part of Texas, they haven't got that.

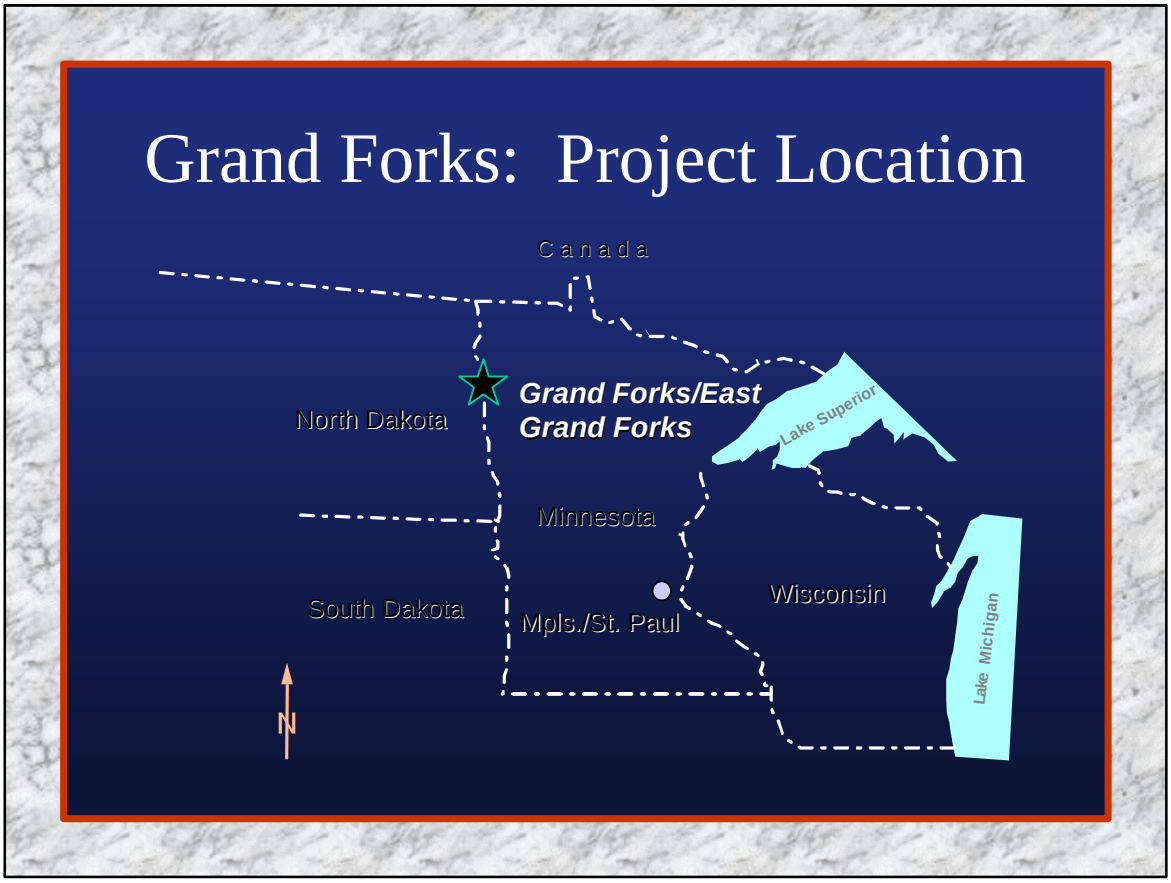
In terms of water use efficiency, education and awareness, the Governor's Drought Preparedness Council is going to start having regular drought planning workshops around our state starting in January. The Drought Preparedness Council was really a lot larger piece of the puzzle in our Senate Bill 1 issue, even though we did not create the Council statutorily until our last session in 1999. The Drought Preparedness Council is a combination of 12 agencies under the direction of the Governor with the Texas Department of Public Safety as the lead agency. The Council does the drought response planning. For example, I read in the paper that airplanes and helicopters have been moved into the Waco-Abilene area because, if you've been to Texas lately especially the central part, they are really dry and ugly, the deer are skinny and all those things. Many of those central Texas cities depend on reservoir water, and the grass fires are a real problem when we get into the drier areas of Texas.



Grand Forks: Preventing Another Flood of the Century

Presenter: Kenneth A. Vein, Director of Public Works/City Engineer

* Thanks to Gov. Owens and Conference Organizers for the opportunity to speak to you today. It is an honor to be a part of a conference such as this - where the focus is on preparedness.
* Photo shows our downtown area at the flood crest and after our fire in April of 1997.
* We learned a great deal about disaster recovery and preparedness after our 210 year flood in 1997. Today, however, I will be sharing with you the specific things we are doing to prevent a similar event from occurring in our community again.

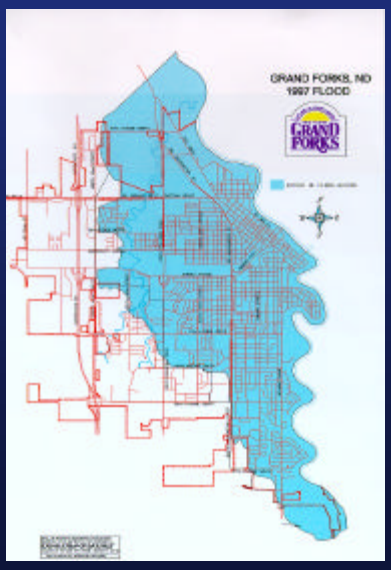


* Just to give you some background, Grand Forks is located in the northeastern part of North Dakota, approximately 70 miles south of the Canadian border, at the confluence of the Red Lake and Red Rivers. East Grand Forks, Minnesota is located directly across the Red River from us. Grand Forks is the third largest city in North Dakota with a population of 50,000. East Grand Forks has a population of approximately 8,000.

* The Red River of the North, which flows north, is the largest river basin in the continental United States that drains into the Arctic Ocean. The Red River Valley is very flat, and the entire area used to be the bottom of Lake Agassiz, which existed in the glacial periods. Because of this combination - a north-flowing river and a flat basin - our entire region has been extremely susceptible to flooding for years.

* There are several problems with a river that flows north:
  - significant floods to date are a result of snowmelt with a combination of spring rain.
  - melting snow run-off drains north into areas not melting, creating a delayed movement of water downstream
  - Ice in the channel - sometimes 2 feet thick breaks up late causing ice jams

The Flood of 1997



* The Flood of 1997 was a defining event for our communities. Although predictions called for a crest of 49 feet and we prepared for 52, the Red River of the North eventually overtopped both cities' dikes and crested at 54 feet. As a comparison, our normal flow is 13 to 16 feet and flood stage is 28 feet. Virtually everyone was evacuated and damage estimates ranged as high as $2 billion. Actual costs are coming in just under a billion dollars. Luckily, there were no lives lost.

Quick Facts:

Residential Units in GF: 10,885 (single family, approx. same # of multi-family)

# of units sustaining damage = 9,001 (83%) which varied from basement/1st floor/2nd floor/complete inundation

Commercial units in GF = 1,444

# of units sustaining damage = 751 (62%)

Number of Businesses Downtown: 385 (all affected)

# of Buildings Destroyed by Fire: 11 (no water distribution system)

# of Apartment Units Affected by Fire: 60

# of Sandbags Used to Fight Flood: 3.5 million/ .5 million yards of dirt

Water Treatment Plant was inundated.

# of Days Without Running Water: 13

# of Days Without Drinkable Water: 23

Quantity of Debris Hauled Away: 60,000 tons

River was over flood stage for 45 days.

# of porta-potties brought in: 1000

Schools: 15 of 17 damaged, 3 totally destroyed

County Office Building inundated, including Register of Deeds office

* Even before the flood waters receded, assistance began arriving to our ravaged community. Volunteers, touched by the images of drowning homes and fire, came from miles away to help us clean up. Because of the national and international media attention, donations came from all over to help the city rebuild. The State helped us manage donations and had large warehouses across the state.
* The federal and state governments also stepped in to assist in the recovery efforts. The most notable assistance came from FEMA, Corps of Engineers, and a disaster relief bill from Congress, which eventually brought $171 million of Community Development Block Grants to Grand Forks. In total, the city and residents received about $500 million of assistance, which has been used in hundreds of different repair projects and recovery programs.
* It has been a long, exhausting recovery period for our communities, but we are starting to see the fruits of our labors
* Foremost in our minds, however, as we put our communities back together, was the very real fear that this could happen again. Although we had been investigating flood protection projects in the past and had an elaborate flood fight plan, the flood of 1997 made us much more aware of our intense vulnerability and we immediately stepped up efforts to ensure that we would not face this kind of catastrophic devastation again.

Hazard Mitigation: Preventing Another Disaster

- Reducing the Damage a Future Flood Could Cause
- Reducing the Possibility of Another Flood Inundating our Community

* In Grand Forks, our hazard mitigation programs can be divided into 2 main categories: 1.) those things we did to reduce the damage the another flood could cause, and 2.) those projects that would reduce the possibility of another flood inundating our community. These projects included both structural and non-structural alternatives. In all, I will review 5 different programs with you that we have undertaken. Most of these programs are things that you can initiate now, prior to a flood, although it is easier to undertake these projects and find funding for them after your community has experienced a disaster.

* The first thing we did was as much a flood recovery project as it was hazard mitigation. Although floodwaters reached almost 75% of our community, several low-lying areas close to the river were completely inundated. Almost immediately, we began to identify properties that were destroyed by the flood and began the process to acquire them and demolish them. We used a combination of FEMA's 404 Hazard Mitigation Grant Program dollars for this project, as well as some of the Community Development Block Grant funds we were given. 100 properties were demolished immediately, before we had officially purchased them, because their severe structural damage posed a threat to human health and safety.
* When FEMA 404 funds were used to purchase a propery, they carried with them a "green clause" which required that the land be left vacant for eternity, thus reducing the possibility of future damages on future development there.
* Those homes that were considered salvageable were moved to higher ground. Unfortunately, the vast number of properties could not be saved.
* The Historical Mitigation that we were required to do slowed the process considerably, since most of the homes in low-lying areas were older and special care had to be taken to try and preserve them
* We had actually started a much smaller scale version of this buyout program earlier, but participation was weak, as residents did not see an immediate need or benefit of selling their home to the City. So you may have some difficulty in convincing people in vulnerable areas of their vulnerability

* In all, we purchased over 800 homes and 42 commercial properties through our acquisition programs. Not only does this reduce the amount of damage that another flood could cause, it eases our flood-fighting efforts, since we no longer have to use valuable resources to protect these difficult areas. In total, we spent $50 million on our acquisition program - $38.5 million of CDBG funds and $11.5 million of FEMA funds. One of the major problems we encountered was that the County Register of Deeds office had flooded and much of their paperwork was destroyed.
* This map shows those properties we have bought. The largest areas were Riverside, Central and Lincoln Parks. Lincoln Park itself is a very low area of town and we bought almost 400 homes in this neighbrohood alone.
* As a part of removing properties from vulnerable areas, it is important for communities to carefully monitor their growth and development. Be aware of highly flood-prone areas and consider how those areas will be zoned and developed. We have restricted some development along the river.

2. Modify Existing Structures

* The second part of reducing future damage involves the changes we made to existing structures to make them more flood-proof. A quick example of this is what we did in our City Hall building, which received 3-4 feet of water on its first floor and completely flooded the basement in '97. When we replaced the furnace and other utilities, we relocated them up to the second floor. Our Information Services Department also relocated up to our 3rd floor, taking with them all of their computer equipment.

Our Water Treatment Plant is a special story in floodproofing that I'd like to share. We have a sophisticated lime, soda ash treatment plant with a 25 year old sludge plant adjacent to it. Located right on the river, the Plant went down in the 1997 flood. We sustained over $10 million in damage and the distribution system was completely depressurized. We were without water for 13 days and without potable water for 23 days. This had a major impact on our community. We decided we had to better protect this vital piece of our infrastructure and put together a special flood protection plan for this building.

Raised utilities (e.g. transformers raised outside, 3 motor control centers from ground or below ground levels moved up)

Changed to submersible components for those flow meters that could not be moved.

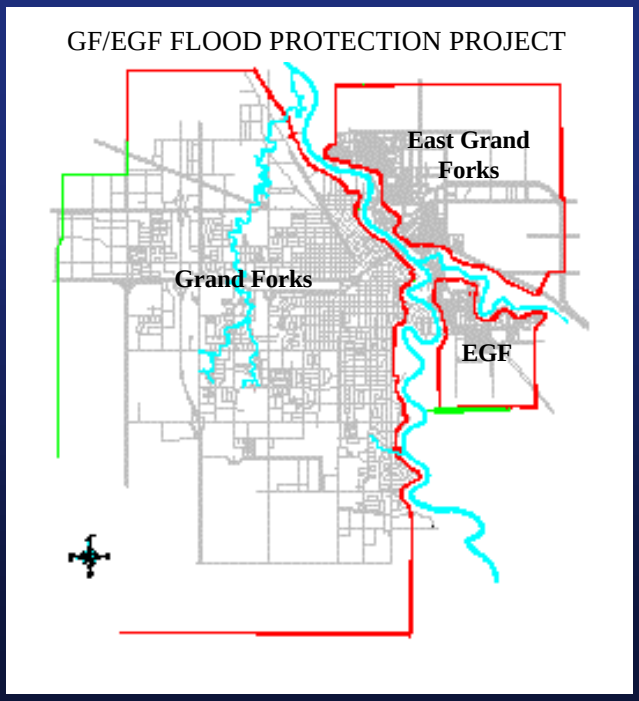
Special levee system designed to surround plant during flood times (instability of soil doesn't allow it to be built now).

20 Flood shields installed along all openings – doors & windows - at time of emergency to secure building.

* Other entities also undertook hazard mitigation work. The new schools that the school district built were raised above the new 100 year flood plain that FEMA is developing or they were relocated outside the 100 year flood plain. The County did the same for some of their buildings.

* In addition to limiting the damage that another flood could cause, we have also taken steps to improve our protection systems and reduce the possibility of another flood inundating our community. There are three main areas that we have worked on: 1.) a permanent long-term flood protection project, 2.) an interim plan to improve our existing system, and 3.) longer term basin-wide water management.

3. Pursue Permanent Flood Protection



This map shows the current design of our permanent flood protection project, which we are pursuing with the City of East Grand Forks and the St. Paul District of the US Army Corps of Engineers.

Designed to protect us from the same volume of water as the 1997 flood: 136,900 cfs (210 year flood event)

Includes a total of about 30 miles of levees and floodwalls and 2 coulee diversions - one on each side of the river. This will require the acquisition of 150 more properties.

Levees will be about 10 feet high (higher in East Grand Forks because they are slightly lower than us) and will have a 10 foot top width with 3 to 1 side slopes. This will allow us to raise the levee, if necessary, to fight higher floods. There is some thought that we might be able to contain a 500 year flood with this system.

Total cost of the project is estimated at $350 million - $230 million for the ND side and $120 million for the MN side. Federal government will be paying approximately 50%. The remaining Grand Forks share is $115 million, of

Getting to this point - of actually designing a project - has been a long process. Have been working with the Corps for decades because they knew our communities were vulnerable.
1984: Corps completed EGF flood control study, received favorable federal benefit/cost ratio. Project shelved because of low local support (would have required the demolition of several downtown city blocks.)
1987: City requested Congressional approval to study flooding in GF.
1990: GF started the process of getting a federally-funded project by initiating a Reconnaissance study with the Corps, which determined that there would be a federal interest in protecting our city
1993: Feasibility study (next step in process) was started.
1997: We were in the middle of the Feasibility Study when the 1997 flood hit and drastically changed all of the historical data that the Corps had. It also brought a lot of national attention to our communities and the Corps immediately began working on a new plan.
1998: The Corps took the old EGF project off the shelf, updated it for the 1997 flood data, added the GF portion and completed the study by the end of 1998. The new, combined project had a benefit/cost ratio of approximately 1.1 and was authorized by the federal government in December of 1998. This study process normally takes 4 years, the Corps did ours in 18 months.
We have been focusing on securing our first federal funding, which we received in the FY 2000 budget - $10 million - and the state support. We will begin construction this coming summer and hope to be done by 2007.
Worked very closely with our Congressional Delegation throughout, which helped us overcome a number of obstacles: e.g. WRDA (Water Resources Development Act) was held up in Congress and our project was pulled and included in Omnibus Spending bill to ensure its passage in ‘98.

4. Improve the Existing Flood Protection System

While we were pursuing our permanent protection system, we were also considering how to better protect our community until the project was complete. We are in a “wet cycle”, according to some experts and can expect higher than normal floods for the next several years.

This photo is from the April 1999 flood crest - 2 years after our catastrophic flood. Although the river stayed in its banks, it crested 16 feet above flood stage. We spent about $500,000 in our emergency flood fight that spring.

We have been declared a federal disaster area 6 times in the last 10 years because of our flooding problems.

4. Improve the Existing Flood Protection System

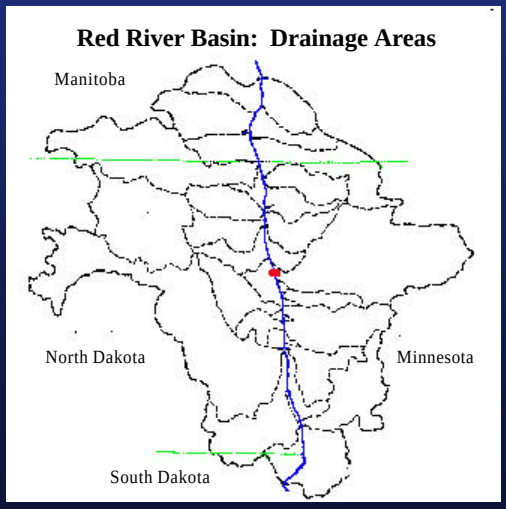
Immediately after the flood of 1997, we developed a back-up plan for another disastrous flood. Perhaps the biggest mistake we made in '97 was failing to have a backup plan in case our first line of defense fell. It never had before and we just didn't consider that it might. The new plan showed the best places to build a secondary line of defense - often times several blocks away from the river on higher ground - if we needed to. This would mean sacrificing hundreds of homes to save the city, but at least we had a plan. Once this line was established, some property owners wanted compensation, even though we have not yet had to use it.

Since then we have also started improving our first line of defense. Our existing levees were raised and new ones were built to raise our entire level of protection to about 52 feet. (The flood of 1997 was 54 feet). The red lines on the map show those areas where levee improvements were undertaken.

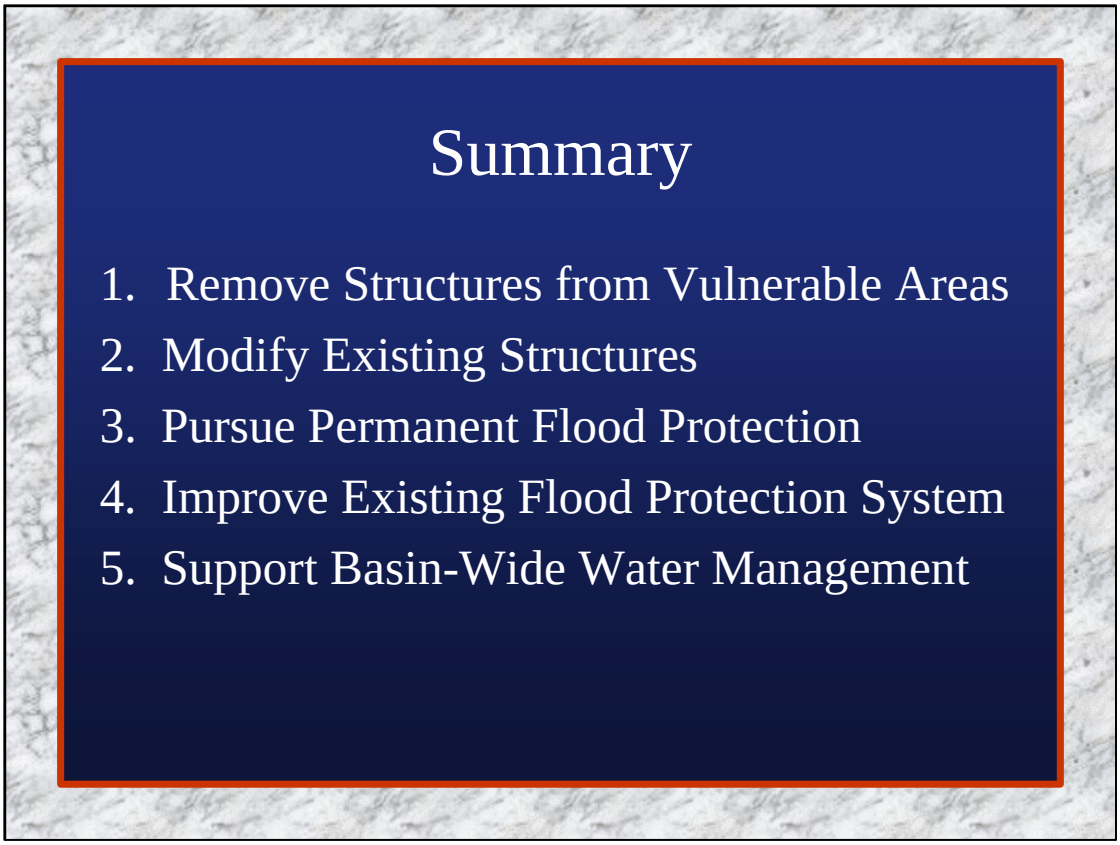
The photo shows the highest levee we have built. In the past, we built a levee on the road during the emergency. Now, we have built a higher, more stable levee that can exist until the Corps project is built. All of this work will better protect our community, as well as save money in our flood fight.

The estimated cost of this plan is between $2.5 and $3 million.

5. Support Basin-Wide Water Management Strategies



Finally, we are also supporting basin-wide solutions to our flooding problems.
Map shows the drainage area of our basin. Very large and very flat, making one singly solution unlikely, if not impossible. The total drainage area for our basin in 30,100 square miles.
Several different studies going on now that are investigating smaller projects - impoundments upstream to control the water, different land uses to avoid runoff problems, etc.
Basin covers 3 different states and 2 countries, as well as numerous counties and cities.
Politically, these solutions will be difficult to implement and are considered very long-term solutions, which is why we are pursuing our own levees project while supporting this process. There are literally hundreds of water entities that exist for this basin, including watershed boards, county water resource districts, the International Joint Commission, the FEMA Initiative Committee, the The International Coalition, the Red River Basin Board, and grassroots groups.
Benefits here will be to the entire basin and could help manage water in times of drought as well as floods.



Thank you again for your time today. If you have any questions, I would be happy to answer them during the panel discussion or anytime later in the conference.

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Case Study: Tulsa, Oklahoma

M. Susan Savage
Mayor
City of Tulsa

It's always difficult being the last speaker on a panel, but I'll try to bring different elements together. I will talk about the flood side, not drought. We occasionally have droughts in our part of the State of Oklahoma, but generally if the weather gets dry, our problems come from the fact that we have issues with our supply and distribution system rather than the supply of water. So, I come to you from a floodplain management perspective.
I think as you have listened to the speakers this morning, there are some central themes that are emerging, which really speak to those of us who are practitioners on the local level, brings to the heart of the matter the issue of forming partnerships, doing long-range planning, looking at something beyond just your immediate need and ensuring that whatever you do is sustainable.

With those general principles in mind, let me give you a little bit of background. In Tulsa, we have learned and put into practice these principles the hard way. But we have learned. Tulsa has a long history of flooding and other natural disasters. We are a city of 385,000 that covers about 200 square miles. We're described as a geographical crossroads and a weather junction. That may be an interesting description, but let me tell you what it means. We are often the point at which the warm moist air collides with the cool northern fronts, so we can get in the course of 24 hours tornadoes, thunderstorms and ice storms. We have everything. We get 37 inches of rain. We can get as much as 15 inches in a few hours. We have thunderstorms, tornadoes, floods, lightening strikes, high winds, and in the winter, ice and hail storms. Tulsa has the fifth highest tornado risk in the nation. We also get earthquakes, which was a little bit of an unknown anomaly to me, but occasionally we do get tremors. We have had, by virtue of experience, to move beyond just the response mode into the long-range planning, hazard mitigation mode. There was a time when the federal insurance administrators came to Tulsa frequently. Back in the 70s and the 80s, parts of Tulsa were washing away every year in floods that cost our citizens more than $300 million in damages over a 15-year period of time, and I didn't bring that up to 1999 dollars. Tulsa was declared a flood disaster nine times between 1970 and 1985. Scores of our citizens lost their lives or were injured. The property market was destroyed. Entire sectors of the city were tainted by being flood prone. It's not exactly on your Chamber of Commerce roster when you have the fifth highest tornado likelihood in the nation and you flood on a regular basis. Those are some issues eventually you have to address. A Tulsa writer said not long ago that the fundamental lesson that nature teaches and will repeat patiently for the slow learner is that rivers and creeks own the floodplains. I'm proud to say that we finally got the message.

For us the turning point was the devastating Memorial Day flood in 1984 that killed 14 people, injured 288, damaged or destroyed 7,000 buildings and cost in today's dollars nearly $300 million in direct damages. Our response to this devastation was finally to say we're going to stop rebuilding in these areas that we know will continue to flood. Today, Tulsa's floodplain program is based on, we believe, respect for natural systems. It includes comprehensive watershed management. It includes dedicated funds for maintenance and operation. We created multi-use facilities. We have a prototype alert system and a $200 million capital improvements program that are all part of our floodplain management effort. Our citizens have not rejected a sales tax or a bond issue initiative, which are our means of generating capital improvements for flood projects, since we committed to do this in 1984. Tulsa has physically removed by voluntary acquisition more than 1,000 buildings from the floodplain. Various improvements have reduced flooding so significantly for more than 2,500 citizens that we have removed them from the 100-year Federal Emergency Management Agency (FEMA) floodplain maps. This enables our citizens to enjoy the lowest flood insurance rates in the nation, 25 percent below the national rates.

Our program has as its foundation the national flood insurance program. However, we made a very conscious decision to go beyond their minimum requirements. As a result we have had no record of any building flooding that was built in accordance with our local floodplain management or stormwater management regulations since they were strengthened. Our regulatory systems are based on a 100-percent fully urbanized floodplain. That's important as to be distinguished from just a 100-year floodplain. This is fully urbanized. We have projected what we anticipate the growth could be, and we've based those floodplain regulations on that. As each of us knows, in a community, the more the concrete you put down or asphalt or hard surface, the more you reduce the area available for natural flood control. The floodplain uses cannot reduce, restrict or impeded channel conveyance capacity or increase downstream velocities. No change can take place in the floodplain that decreases or reduces storage. If filling is allowed, compensatory storage must be provided in the floodplain.

What does all of that mean on a practical basis? I can tell you that the developers don't always love these regulations. They think they are onerous. They think they are costly. The homeowners downstream from development love them, because in fact, you can physically see the increases in runoff. When we undertake a stormwater or floodplain management project and our largest single project was in partnership with the Corps of Engineers over a 10-15 year period where they paid 50 percent of the cost, all along the area that flooded the worst in 1984, we built a

whole series of what we called detention facilities. What is important about those, rather than just being large caverns in the earth that collect and hold water until such time as it can be released, is we've also turned them into multi-use facilities. We have, in effect, tripled the amount of land we now have available for recreational purposes by acquiring these properties and turning these detention facilities into recreational facilities. We have trails. We have soccer fields. We have baseball fields. We have tennis courts. We have frisbee courses. And I will tell you in your communities, when you begin to feel the pressure from those who have interests who wish to develop or stop the construction of an element of your floodplain management program, these recreational enthusiasts become your greatest constituents to ensure safety in the community. Because if we develop in those lands, it takes away from the activities they enjoy. I'm not sure we started out with that deliberate thought in mind, but we quickly realized that we had a community asset in addition to providing public safety.

The City of Tulsa charges a stormwater fee of $3.16 per month for single family residents or $3.16 per month for every 2,600 square feet of impervious area for multi-family, commercial or industrial accounts. The stormwater fee brings in about $12 million per year, which is spent about 70 percent on operations and maintenance (and this is cleaning out the channels and all of the facilities that we have), 5 percent on small drainage projects, 10 percent for planning and engineering, 5 percent for customer services and 5 percent for general administration and another 5 percent for a transfer to our general fund for the support services. What this enables us to do is to maintain those facilities we have constructed and to bring in the development community as a partner with us in the overall construction of those.

In summary, I wear my Project Impact pin with pride, because we really lobbied FEMA to become a Project Impact city. They were looking at cities who were in the midst of making changes in hazard mitigation, and we said we have spent the last 15 years trying to do it. You ought to look at us and we'll champion your cause. We have really changed the way we do business with respect to floodplain management and now as a Project Impact city, we are moving into everything from building saferooms in our schools, our homebuilders are working with us to deal with issues of tornadoes in new construction, a variety of issues from hazard mitigation that really transcend floodplain management. What has been helpful to us has been the partnerships that we have formed with the federal government, the state government and other communities. Denver was a city that gave us some early expertise as we began our floodplain management development. We have worked with other cities all across the nation. As we have worked to address our flood problem, we have also created for our community great assets not only in terms of public safety but also in terms of trails and parks and open space. It requires a tremendous amount of political will, good expertise and partnerships, and as you look to balance the growth with the needs of the development community and public safety you find that you will have conflicts. But if you stand firm on the long-range impact of what your community can save in terms of dollars and lives and property, then you will find that, even if it's grudgingly, eventually the development community will come along.

It has been a 15-year progression for us. We continue to work on these issues. We know that we will flood again in Tulsa. But I will tell you, the last substantial rainfall we had that was comparable to the 1984 flood was on Mother's Day 1993. And when my husband and children asked me what I wanted to do, I said I want to drive around and see how the detention ponds were doing. So we drove along the Mingo Creek basin into west Tulsa. At a variety of areas, we did have flooding and we continued our voluntary acquisition into the western part of our city where we are now doing some additional floodplain management work. But it has been a community effort. It has required the commitment of people who far proceeded me and who will follow me. And it requires partnerships.

Summary of Interest Group Discussions

Transcribed and Edited by the Water Resources Research Institute Robert Ward, Catherine J. Shrier and Shirley Miller

Working luncheons on the second day of the conference provided attendees with an opportunity to express their own ideas on how to improve Colorado's preparation for and response to floods and droughts. Participants divided into six interest groups: environmental, business, water management, agricultural, county, and municipal. The groups were asked to discuss the following questions from their own interest group perspectives:

· Define strategies for the Governor's Action Agenda for Reducing Colorado's Vulnerability to Floods and Droughts, including consideration of infrastructure, administrative, statutory, and funding issues.

· Define the Roles and Responsibilities of Federal Agencies, State Government, Local Governments, Businesses and Individuals in the reduction of Colorado's flood and drought vulnerability.

In each group, there was a facilitator for the discussion as well as an assistant facilitator who took notes. The conference attendees then re-assembled and the facilitator for each group presented a summary and recommendations from their discussions. Presented below are edited notes from the assistant facilitator in each group, as well as the transcribed recommendations presented to the conference by the facilitator for each group.

Environmental Interests

Facilitator: Jo Evans, Evans Environmental Consulting Assistant Facilitator: Bob Zebroski, Soil Conservation Board

Governor's Action Plan

· Infrastructure Issues. The group recommended consideration of non-structural solutions as an alternative to structural solutions, such as letting the public know that buying in a floodplain is their risk and responsibility. Recreational use of floodplains should be considered. Reservoir operations should consider natural risks and realize that drought, fire, and flood do not recognize jurisdictional boundaries.

· Administrative Issues. Local governments should be considered the starting points in policy-making. Counties should be encouraged to adopt zoning to protect wetlands. Implement cooperative planning by multi-interests - similar to the Texas process. Develop outreach to recreational users. Concerns should be dealt with on a watershed basis. Planning is critical, but implementation is the bottom line.

· Statutory Issues. Incentives (e.g., a tax break) should be provided for planning studies on a basinwide, factual basis; and/or creation of a central point to facilitate a common information base. Management must be based on a valid understanding of the natural system or it will fail.

· Funding Issues. Could the Colorado Water Conservation Board Construction Fund be a source of funding? Funding purposes should be directed at particular goals, including: protection of all aspects of the environment; promotion of water demand management; addressing issues from a watershed basis; and integrated uses of water.

Responsibilities

· Federal. There should be good dialogue. Federal agencies need to be good neighbors and manage federal lands as a part of Colorado, not as a separate entity. Also, is flood insurance a good thing - or a bad thing?

· State. Should provide a catalyst for communication, facilitate watershed planning, and fund collaborative efforts and a database.

· Local. The local land use and planning role should be recognized. Look to local solutions.

· Private Sector. Include everyone - get everybody to the table.

· Individuals: What does the public want? Need to be at the table.

Conclusions/ Recommendations

Presented by Jo Evans

The Environmental Group met and the first and foremost thing that we decided was that the complexity of the issues surrounding strategies for drought and flood preparedness preclude any simplistic band-aid solutions, and we came up with none in that category.

We did decide that our function would be to look at protection of all aspects of the environment from the broadest possible perspective, and that after a good and very thorough discussion of a whole raft of issues, ultimately we decided that we would recommend as a group six goals to be the first step in trying to improve where we are today relative to our preparedness in Colorado for both flood and drought from an environmental perspective.

The first goal we recommended was to get the word out to the general public - an educational role. There are a great many people in Colorado now who don't know what it is like to live in a semi-arid state; who don't believe that there is any difference in lifestyle based on what they might have

enjoyed in New York or the Midwest. We need to educate them about what it is like to deal with drought and flood here in the arid West and to consider water demand management in all of the solutions that are being offered.
The second goal we recommended was consideration of non-structural alternatives as a starting point.
The third goal was that, in order to do one and two above, the state has a role to facilitate watershed planning in a way that is consistent with both educating the public and considering non-structural as well as structural alternatives.

We need to provide resources from the state, which would be our fourth goal. The state needs to be in a position to provide resources for funding these collaborative management solutions, being a repository of factual information, so that we make decisions in the planning process based on the reality of the environment that we are dealing with, not just preconceptions of what the problem is.

Any strategies need to be implemented at the local level - a local implementation with a focus on local planning with state support for funding a database and coordination. When we deal with these planning needs everybody needs to be at the table, and that includes our federal neighbors as well. The federal government needs to be part of the solution and part of discussing what as a good neighbor they are doing. All the interests need to be at the table at the local level for planning.

Integrating the uses within a watershed approach requires that degree of collaborative participation if we are going to take the next steps down the road. Our recommendation is that from these six goals we move forward to do watershed planning starting where we are now, incorporating what we already know, and that the state role needs to be primarily one of supporting and funding this coordinated effort and providing the database on which to go forward and facilitating that kind of collaborative management approach.

This needs to be a bottom-up as opposed to a top-down approach.

Business Interests

Facilitator: J.J. Ament, Denver Chamber of Commerce
Assistant Facilitator: Heidi Heltzer, Colorado Association of Commerce and Industry

Governor's Action Plan

· Infrastructure Issues. Public Service Co. has 30 jurisdictional dams to generate electricity. There is a need for more high-mountain storage - no cushion for shortage of water/hydroelectric capacity in drought situations. Without Two Forks, we will see an impact in the next 10-20 years. Develop partnerships of local governments and state government with business.

· Administrative Issues. Colorado water law is cumbersome, lengthy and expensive; even so, that may not be bad. An easier and more streamlined permitting process for zoning is needed, with forms made to be computer compatible - use Internet or web-based forms - and uniform. Cost is excessive due to studies, reports, etc. Some environmental permit regulations are more stringent than at the federal level. Generally supportive of state oversight to help move projects along, i.e., dam inspection.
· Statutory Issues. Encourage state agencies to present proposed statutory changes to business community ahead of time for input. Have computer compatibility for forms at one source which fits into the Governor's plan for New Century Colorado.

· Funding Issues. We need public/private partnerships. Gravel extraction facilities create holes that can be used for lakes - water storage, recreational purposes. Would like funding from GOCO.

Responsibilities
· Federal. Process is too complicated at both federal and state levels. You have to go to the federal level for dollars, but state needs to have the right programs in place to access (be eligible for) federal funds.

· State. State needs to know what mechanisms must be in place to have access to federal dollars, particularly in the event of an emergency. State should work to engage private sector in why flood and drought preparedness is important. Don't rely on federal government. If you want federal money, you have to go get it. First priority for the future rests at state level. Need a state plan. Educate business on the importance of water issues. Set example for local governments. State's dam safety program is good. Need public/private partnerships re: water storage. Permitting/study process costs millions and takes years. Special use permits are too difficult to obtain. If agencies are going to propose statutory changes, they should actively seek input from trade associations. May be incumbent upon state to set the example for level of importance.

· Local. Work through planning and zoning. Zoning departments need to look at geography of their community, particularly in regard to climate variability across the state. Educate communities on potential for emergencies to build awareness.

· Private Sector. Develop partnerships with governments. Develop internal company efficiencies. Educate consumers. Develop entrepreneurial innovations. Give water credits for saving water - the credits are an incentive (water banking) for saving consumptive use.

Conclusions/ Recommendations

Presented by Heidi Heltzer

The business community had an interesting challenge by looking at how do flood and drought impact businesses. I think it was more how do we play a role in impacting the likelihood of drought and flood.

I will run down the list of what we came up with from the administrative, statutory perspectives that we felt might need to be addressed.

Overall, there was a general concern that there needs to be more high-mountain water storage. That was based on the fact that there is no real cushion for a drought situation, because the generation of electricity relies upon water. If we run out of water, we run out of electricity, which will impact businesses throughout the state, potentially, depending upon the severity of the drought.

The permitting process was discussed as being somewhat cumbersome and time-consuming. There was a desire to see that streamlined. There was general support for state oversight to help projects move along. When there are checks and reporting requirements, it keeps the process moving, which results in better efficiencies for development and production in business.

We would also encourage state agencies to present proposed statutory changes to the business community so we can work together in finding solutions that work for all interests and to be able to go to the legislature hand-in-hand. We would also like to develop public-private partnerships; for example, one situation that was discussed was gravel extraction facilities. Once the minerals are extracted, this leaves a big hole in the ground. There is an opportunity for the local government to work with that business in developing that into a recreational area. If there may be a way of providing some dollars from the state, whether it is from GOCO or another source, there was discussion about pursuing that as an option. It was considered to be a real win-win situation for the business, the local community, and the state overall.

When it comes to the role of the state, there was concern to make sure that the state knows what mechanisms need to be in place to have access to federal dollars, particularly in the event of an emergency. There was some discussion that there needs to be certain roads and programs that link the state level to the federal level in order to be able to access those dollars. That should be looked into to make sure that it has been done accurately and won't leave us in a fix someday.

We would like to see a state plan, and feel it is incumbent upon the state to set an example for local governments, like zoning departments, because of the diversity of geography throughout Colorado and the climate variability which was discussed yesterday throughout the state. Local governments really need to step up to the plate and educate their own communities about the likelihood of drought or flood situations based upon their geography, particularly certain areas such as homes that are in floodplains or businesses.

As a business community, we would like to work at developing partnerships with the governments to look at internal company efficiencies and educating consumers about water issues to the best of our ability.

Water Interests

Facilitator: Dick MacRavey, Colorado Water Congress
Assistant Facilitator: Kent Holsinger, Department of Natural Resources

Governor's Action Plan

Monitoring gages, with satellite links, are essential for flood warning and management of water. The Feds say we have ten years to replace 300 stations, costing $2.8 million over 10 years, with better transmitters. Can that funding be provided by the legislature, with water data published on the Internet? Some funding from the CWCB construction fund has been used, but should get funding from general fund. The gaging stations were designed for low flows - can they be re-designed to function during high flows?

Who is responsible for stream restoration and floodplain management - conservation districts? CWCB? We have varying political jurisdictions with different levels of responsibility, many of whom look at the issues differently. We do not have an umbrella organization to hold everyone together, although there is talk of forming a stormwater authority through state legislation.

How to request funding for gaging stations? As a means of water quality monitoring or for flood alert? Should there be a cost share, and with whom? TABOR spending limits will be an issue, creating more pressure as productivity in Colorado increases. The size of state government is actually getting smaller, while the population, inflation, and infrastructure requirements increase. Money is going to get tighter. To exempt water development from TABOR restrictions would take a vote by the people. Water management requirements need to be prioritized and presented for budget considerations. EPA may be a source of cost-share, as well as local entities for urban drainage. Farm Bureau may also get involved to deal with TABOR restrictions.

Presenting water issues on public ballot initiatives is difficult because of the awareness problem; it works for transportation initiatives because people can see highway prob-

lems every day. Also the Highway Commission puts out a list of highway problems, and that list of priorities is distributed throughout the communities. There is no similar list of priorities and backlogs in the water community. We need to clearly identify problems basinwide, and what it takes to fix them. If it is hard to find $280,000 a year for gages, imagine what it will take for our water problems. We need $200 million for additional storage alone on the Arkansas. Transportation worked because Governor Romer convened a blue-ribbon panel on intrastate transportation issues. There has been no blue-ribbon panel on water. We rely on the courts to make the decisions. The Farm Bureau study is a step in the right direction.

Risk-based assessments of our water systems by basin are needed - people need to know the risks so they can see storage as something other than an environmental catastrophe. CWCB may help communities with planning by providing a model drought plan, and by preparing an atlas based on Dr. McKee's study to help them determine the drought risks in their basin. Drought triggers such as those used by Denver Water and drought response plans at a local level are also needed.

Should there be a flood and drought response fund, separate from the CWCB construction fund? Funding for water conservation education? Is weather modification a viable technology? More research is needed. Should GOCO funding be used to support more high mountain storage of water for flood and drought mitigation? High-altitude storage is the solution to floods and droughts - off-river storage. Establishment of a state commission or blue-ribbon panel is needed.

Roles and Responsibilities
California provides a model for aggressive pursuit of federal funds, state incentives for local planning (drought plans, risk assessment), the existence of a state water commission. State needs to be more aggressive in seeking federal funding. Corps can provide 35/65 cost share and has responsibility for flood control. State is responsible for funding and coordination. Local governments need to call state attention to problems, ask state permission. Locals don't like the idea of a state plan, so the state needs to provide incentives to the local governments to get things done (e.g., drought plans).

Conclusions/ Recommendations

Presented by Dick MacRavey

It is typical that anytime you get the water community or interests together, they certainly come forth and live up to the quote by Mark Twain, which was, "Whiskey is for drinking and water is for fighting over." We went off into a number of areas, some very interesting - certainly weather modification - John Shawcroft did a good job in getting that stirred up. There were other things that were touched on in terms of the satellite system, the retrofit requirements by the feds (which is a serious situation), responsibilities regarding rivers, modeling, the Farm Bureau study that was mentioned several times, and other subjects that were touched on.

In terms of what you might say in delineating four general areas, if you can come up with that, nothing necessarily would be described as a consensus, but certainly general areas in which the group could focus on in the future.

One area was the need for a state commission or blue-ribbon body to examine floods, drought and water-related issues, or you might say, the big picture approach to things. This would include members of the Executive Branch, the General Assembly and the public. That is one general area.

Another area, the most difficult area of all, is funding. We are certainly aware in this state of the problems that we have with funding and the requirements that have been imposed by the TABOR Amendment. I might note, parenthetically, that something you need to be aware of is that there are now 226 initiatives proposed, and three-fourths of them by the author of that TABOR amendment. Consequently, that gets to be one of the big problems we have out there - this whole business of funding and the constraints that we have to deal with.

Again, there was a more aggressive pursuit of federal funding, and lifting, if possible, the TABOR limits regarding water projects or water-related needs and looking at more seriously the GOCO funds, particularly from the standpoint of recreation, because water is a big aspect of recreation. Pueblo Reservoir, as you well know, is one of the most popular recreational facilities in this state.

In terms of other things that were suggested, there was the need for state incentives for local drought and flood planning - risk-based assessments, etc.

And finally, we always get back to one of the areas that we all talk about - the need in terms of education. We are all well aware of how many more new people have come into the state and the differences in the environment or area they came from in terms of rainfall is entirely different than, say, the 14.7 inches of rainfall that you have in the Denver area or the 6.9 inches that you have in the San Luis Valley. Consequently, we have an enormous job to acquaint those new citizens of the state with a better understanding of the kinds of issues that we have related to water, whether sometimes too much or not enough.

There is need in the research area. There was quite a discussion in terms of the weather modification issue and the needs there.

In terms of delineating between the different levels of government, the private sector, and individuals, to be very

frank we didn't get into that in terms of doing a definitive job of addressing those issues.

Agricultural Interests

Facilitator: Ray Christensen, Colorado Farm Bureau
Assistant Facilitator: Bob McLavey, Colorado Department of Agriculture

Governor's Action Plan

· Infrastructure Issues. The Eastern Plains need a long-term water supply plan. The Colorado River Basin is an untapped source for all water problems if we had the structures to handle it. We need more water storage for both flood control and drought mitigation.

· Administrative Issues. Texas has a good precipitation enhancement and brush control program. A "statewide" water plan is impossible because of the diversity of the state. We should convene a stakeholder's group to address water issues, including conservation. We should look at the Texas "District Planning Process." In Colorado, it could be done on a "River Basin" concept, or Geographical Area of Interest, with plans submitted to the state for coordination. We need to review all state, local and federal regulations to decide when there is too much and where there is not enough.

· Statutory Issues. We need to control growth. We need legislation to force locals to enforce floodplain restrictions.
· Funding Issues. We need increased funding for more data collection. Water planning cannot take place without data.

Roles and Responsibilities

Provide education programs and get the private sector involved. Develop consensus for new storage, because water conservation alone won't cut it. Federal land use planning. Increase profitability for agriculture.

Conclusions/ Recommendations

Presented by Ray Christensen

We had a very good group. I think all the farmers and ranchers ditched us and went over to the other groups, but we had a lot of good people who are very interested in agriculture. Many of the themes that Dick MacRavey talked about we mentioned as well - the group felt education was very important, especially getting the private sector more involved in understanding what is going on with both floods and drought throughout Colorado.

They would like to at the least a review of all regulations at the local, state and federal levels. For example, some felt that there are too many regulations in some places and not enough in others. Another example is local floodplains - there has been some development in floodplains throughout Colorado that there shouldn't be, so why aren't local governments doing more to prevent that development in the designated floodplains? There could also be some review of federal laws that deal with the environmental side.

There was agreement, I believe, that we need to keep the current water structure that we have, meaning our water rights system that we have developed over the past 100 years, albeit not perfect, but it is important that we keep the system in place so we protect the senior water rights. With that in mind. the group was very excited about the plan that Representative Gary Walker from Texas brought up regarding the Texas Water Plan. We had a lot of good discussion about that, and there seemed to be consensus that Colorado should look at that, at least look at some level of statewide planning where you have local groups that pull together. Does it have to be on a basin-by-basin structure? Not necessarily. There was some support for perhaps not just doing it by the basin but by the geographic area of interest. We often think, here in Colorado, of basin-by-basin, which is good, but perhaps we should think of another way to do that at the local level. That is why the group thought it was important to get all the interest groups involved, whether agriculture, environmental, business, local, municipalities - get everyone involved at the local level so they can review what is going on with flood and drought in their particular areas.

There is a big need for data collection, which Colorado is beginning to be more aggressive in, but group members felt we need more data as well.

Yes, there was consensus for more storage in Colorado, not only for flood prevention and flood control, but also to meet the state's water needs into the next century with our growing population, both structural and non-structural. Water conservation of course comes up, and everybody agrees that we probably need more water conservation, but at the same time they know that conservation, in and of itself, will not help us meet our water needs in the future.

Better land use planning would be helpful. Also, look at energy needs and how that affects the water supplies and timing.

Finally, I managed to get this agreement out of them which I was very please to hear - that we need more profitability in agriculture. That is how you keep farmers farming, and ranchers ranching. What a novel idea.

County Interests

Facilitator: Commissioner Jake Klein, Otero County
Assistant Facilitator: Dave Noe, Colorado Geological Survey

Governor's Action Plan

· Infrastructure Issues. Planning must be broad enough so as to not affect downstream users. Streambank erosion, bed degradation, and sedimentation are three big impacts…not covered under Corps of Engineers (COE) General Investigations policy -- need states to influence COE's ability to do this by approaching CSB. Local groups (e.g., Fountain Creek) could help push this. Problems are complicated and there are cross jurisdictions: state, provide funding and technical support; local, provide leadership and direction. Funding (lack of) is a big drawback for doing real project work. Can't hire person-power to do projects. Communities may not have resources to pay back loans (e.g., state CWCB loans). Siltation of reservoirs occurs sometimes twice as fast as planned. River beds are building up (so flooding caused by less water). Should new subdivisions be allowed on floodplains? 100-year floodplain may not really be valid. Floods can erode banks and cut new courses in the geologic floodplain, which is much broader. Newer homes threatened in Douglas County. "Prudent lines" have been invoked where bank erosion is anticipated. Negative effects for agriculture (lost land). Need to consider using "build-out" floodplain scenario instead of current land use. Need technical information in order to create more stringent detention requirements. Dillon's flows in mountain or plateau areas. Are they "legal" floods? Are they insured?

· Administrative Issues. COE's work is limited to studies, not action. Need more federal support for improvement work. Let the locals do the work. Revisit existing plans and update them. Use updates from recently affected communities, since they learned lessons the hard way. Cooperation of agencies is essential - interagency (state) mitigation team. More floodplain regulations needed at local level. More mapping needed (revisions and new mapping).

· Statutory Issues. Need to get more appropriations for funding sources (e.g., CWCB construction funds) for flood mitigation projects (CWCB Severance Tax funds, too).

· Funding Issues. CWCB has Severance Tax funding for water availability studies … not nearly enough. Mineral industries "stunned." CWCB has $200 million Construction Fund … water supply. Also used for grants (under legislative approval). There is broad, statewide local support for creating a revolving loan program from CWCB for flood planning or infrastructure projects. Funds to buy/destroy or move flood-damaged properties. Coordination of funds, funding agencies difficult because it is not a constant function. State hazards committee can help (M. Matulik) - has one page "quick hits" reference handouts. Project impact. State bridge fund is essentially gone (FEMA has funding for bridge renovations). List of available funding sources needed.

Responsibilities

· Federal. Need to approach Congress to increase appropriations for FEMA's Project Impact. Assess and potentially increase the role of Project Impact to include non-funding items (awards, media exposure, education). Need good river measurement systems (also State Government).

· State. Provide funding and technical expertise. Work with local governments on funding from Joint Budget Committee (JBC) and information needs (general and project-specific). Seek the intervention of the Governor of Colorado (and the Colorado delegation to the United States Congress) with the Senate Committee on Energy and Water Appropriations, as well as with the Office of Management and Budget and Assistant Secretary of the Army Corps of Engineers to adjust the policy constraints applicable to the federal government's General Investigation Program (Appropriation) for water resources studies. Specifically, the policy adjustment needs to embrace, as a high priority in the GI program, studies and projects that address: streambank erosion; streambed degradation; and sediment deposition.

· Local. Planning is okay, but local governments must follow through on unpopular activities (e.g., depopulating the floodplain area). Need to inform and educate JBC on these issues in order to gain support for new funds for flood mitigation. Preserve floodplains as open space. Provide leadership and direction. Play bigger role in bringing in funds for projects. More stringent detention requirements.

· Private Sector. Include in plans … resources can be tapped into. Private foundations can be money sources.
· Individuals. Need for more personal responsibility for those who live in floodplains. Encourage home owners associations, individuals in unincorporated areas to become informed or create plans. Water Board members should take information (e.g., basin fact sheets) to constituents and stimulate discussion and action.

Conclusions/ Recommendations

Presented by Jake Klein

We had some great people who have been through this process, the floods in the last year, from different counties and different aspects. We had the state, the feds, so we did get into some very good discussion on this. On the infrastructure piece, planning is probably one of the most

important things we need to do, but we need to do it with a broad enough look so as not to affect any of the down-stream people.

With stream bank erosion and sedimentation, the big impacts that happen with flooding, we need to get hold of this prior to. We need to look at it from how all of the agencies view this, and come together in coordination to get the infrastructure completed. We should look at the administration, the Corps of Engineers work and how they can help you with studies. They are very slow at implementation and getting the actual action done. What we would like to see and what was discussed was to let them help you with the studies, get some of this done (in some cases many studies already have been completed), get their okay, see if we can get them to help us, and let us do the work at the state and local level.

We need to get quite a bit more cooperation between agencies. The interagency mitigation team is a great start, and I know the Water Conservation Board has that going. They need to bring others in. We also are looking at what we need, as a group, to do locally to help the state and statutorily to get funds increased. That will be an education piece - we need to help educate our legislators as to the devastation and what can happen with the floods and who is affected. We also need to take that a little further. We need to educate the people at the local level and across the state as to what happens to the farmer we heard about just a minute ago when half his land washes down the river to someone else and he has lost part of his livelihood. There are a lot of things we need to do in education. That came up over and over in quite a few of the different areas that we talked about.

I have about five pages on the funding piece, so we won't get into all of that because you will get a report on it, but we could talk about funding for a full day. It is very important, because at the local level most of the rural areas, where a lot of this is taking place, don't have the funds to really do something. They need help from either the state or the federal government. We need to help the state and the feds get more money, and that is a cooperative effort that should be made throughout the whole system. Not one of us can do it on our own; we must help each other.

We need good river measurement systems. I know we have some out there, but the problem is if it is a flood, once the water leaves the bank of that particular waterway those measurement systems do not work anymore. They can't give you the data that you need.

There is a need to approach Congress again to increase appropriations for FEMA's Project Impact. We need to help with that. It was suggested that they do some awards, media exposure education (there, education comes up again). At the state level, we need funding and technical expertise. Expertise is very vital to many of the smaller rural areas and even to some of our cities.

Work with local governments in funding - we need to go to the General Assembly to have things done. If it has any money attached to it, we better let the Joint Budget Committee know and get them educated quickly so maybe we can get some dollars. There again, we need the cooperation of the local governments to help the state and to help our legislators to get something passed.

The private sector is a very important piece in some of the things we talked about, because this is an untapped resource in many areas, and it is a very good resource. Through private business and industry in many areas, even rural areas, you can get a lot of volunteers to help. Many have good equipment - heavy equipment - that can be used to help out in local situations. They have private foundations that can help you with some of the money problems and funding. You need to bring these people to the table when you are doing your management assessment for emergencies and risk. Bring them to the table so they know what is going on and they can help.

With individuals, having just come through this and still going through it, it is not very popular, but the individual needs to take more personal responsibility for what is going on, because they chose to live in that floodplain. They know about what the chances are of getting flooded, so they have to take some responsibility for that. We need their help and we need their understanding.

Water board members should take information and fact sheets to their constituents and stimulate discussion and action. That we can do with the individuals and that is the education piece again. It comes down to everybody working together to get something done and educating people as to what is going on and what can happen. Education is it.

Municipal Interests

Facilitator: Doug Kemper, City of Aurora
Assistant Facilitator; Jack Kirtland

Governor's Action Plan

· Encourage basin-wide planning. Fountain Creek Watershed Forum is an example for regional basin planning (enabling legislation to form a river basin planning district - for waterway improvements and maintenance). There is need for coordination and probably for legislation (should be generic). Other examples: Firestone - Weld County, ditch companies.

· Need legal mechanism to fund $20 million in improved, urban drainage and flood control districts - fully built-out vs. river basins (look at existing condition). Need to have one entity collect the dollars and spend revenues. There is an issue with detention/release and the effect on other entities. El Paso County: different entities have land-use

authority and water resources interests. Mitigation doesn't work independently - need to have coordination.

Stormwater runoff related to pollution (based on permitting requirements) could be coordinated with the basin planning effort. Urban drainage and flood control district may be a good prototype. Downstream users are affected, so you have to get the whole area included in the district. Need for uniform standards. Funding capability (utility fees?).

· Operations/maintenance. State can help - Army Corps of Engineers -streambed degradation, erosion, sediment deposition - Secretary of Army has to rule that this is an area of interest - has to be a high priority. Need pressure from U.S. Congressional representatives. All entities have to be aligned with this policy.

· Limit how closely structures are to the stream. FEMA flood maps are outdated. What does floodplain-floodway mean? Is 100-year flood standard still appropriate?
· Need for better weather/climate information: monitoring system; education system; Internet access. Open-space acquisition is a hot topic - floodplain area and flooding, building in floodplain. Regulatory - set development standards - too simplistic view because of dynamics of flood event. Stream shifts are critical too, and trees along river.
· Development community - planning/vested rights, takings. These don't allow for good development that is flood-resistant to occur. Small communities don't have legal capability to fight developers. Incentives - don't build or if you are affected, no bailouts for change again.

Federal relief encourages development in stupid areas.
· Role of education - drought (water conservation) and flood danger.
· Legislature needs to fully fund State Engineer's Office functions. CWCB - needs to support operations as well as construction. Need more storage. Have to get more efficient with how we use water. Better ag. uses requiring low water volume. Use technology. State - education (e.g. by CSU, water conservancy districts) for people moving in that water is a limited commodity.
· Waterbank - non-tributary water in underground reservoir (aquifer) should be evaluated. Runoff of reservoirs used for recharging of groundwater.
· Conservation is a value - put financial resources into it. Must have conservation plans or no state funds. Balance between conservation and storage.
· Planning process - Corps (?) plan discourages development in floodplain fringes. Low interest loan funds to purchase lots in floodplain. Basin-wide planning and implementation - could state cost-share?
· GIS system development - who is responsible? Only five people at CWCB to coordinate between FEMA and locals, hazard mitigation, floodplain management.

Conclusions/ Recommendations

Presented by Doug Kemper

We had a great group, about 20 people, in our group. I tried to encourage the group to look at getting beyond the Appropriation Doctrine and looking at the Alphabetical Doctrine, where we feel we might be better off allocating water based on alphabetical order as opposed to appropriation. About that time, we lost our representative from Waverly, who couldn't see the wisdom of that.

The discussion opened with Representative Vince saying at the statehouse water really isn't a top issue. I think one only needs to walk into the offices of the Water Conservation Board or the State Engineer's Office to see that it really hasn't been from a funding standpoint - just look at their office space on up. So, funding was a key issue. I tried to get the group to focus on identifying the number one thing in both flood and drought issues that we would like to get on the Governor's agenda. The background discussion centered around the floods that had occurred in the lower Arkansas this year on Fountain Creek and in the area of Colorado Springs and Pueblo and on down, and also issues related to small communities such as Firestone.

One of the issues that came up with is that communities have different standards for flood protection. The number one thing that we would like to see on the Governor's agenda is the encouragement of basinwide planning to facilitate intergovernmental cooperation. There are instances where there may be 20 to 30 different individual small governments that have influence over flood control and standards of development in communities. The thinking was that if we could do something like what is done with the Urban Drainage and Flood Control District here in the Metro area, that would be a good model. Basically, we decided that we would like to have, ultimately, from this basinwide planning is the facilitation of creation of these kinds of special districts like the UDFCD to carry things from planning through funding through implementation and then ultimately management.

In the planning area, we felt the need for more climatic data, more monitoring for both real-time and long-term data, and more education. From the funding aspects, there seemed to be more need for funding things that were referred to earlier in the conference - GIS projects and some mechanism to acquire low-interest loans for acquisition of properties. As you heard from representatives from Grand Forks and Tulsa, quite a few homes had to be acquired there.

Hal Simpson sent the message that funding for gages and real-time data acquisition was important, and again for acquiring general information. Another issue on funding

that we talked about from the federal perspective, is that the Corps of Engineers does not seem to think they have the authority or even the priority for issues related to streambed degradation, streambank erosion, or sediment deposition. The message came loud and clear that we need to put more pressure on our U.S. representatives to put pressure on the Corps to make this a larger issue. It certainly was in the flooding of the Arkansas Basin.

From the standpoint also of funding, it was pointed out that the Colorado Water Conservation Board only has five people there that deal statewide with issues related to flood. Some additional FTEs there would be of benefit.

In the area of drought, four words - "conservation as a value." We had Liz Gardener of Denver Water in our group, and there was a strong feeling throughout the entire group that it has been a long time since we have experience in drought-related issues. People need to keep that on their radar screens - wise use of water is extremely important. We are not seeing any long-term climatic changes from what Tom McKee says, and we have had a very wet period here for the last 18 to 20 years. We need to keep reminding people of that, because we have a whole generation of people who have grown up not having really experienced drought.

Education was deemed extremely important, and implementation of education programs. There was some feeling that there could be some revitalization of the Office of Water Conservation within the Water Conservation Board, and continue to do more things to get education out at the state level and also implemented at the local level.

The other issue that came up was water storage - the more typical concept of high-altitude water storage, and perhaps more encouragement of development of local storage that might be able to be worked in with flood control, through retention ponds, perhaps using those and continuing to work those into water supply. Also, the idea of aquifer recharge was brought up, and the conjunctive use concept of taking in water during the wetter periods and/or perhaps acquiring on an interruptible basis from the farmers and recharging some of the aquifers that are being overdrafted. Our discussion concluded with this - we need to have a balance between conservation and storage.

Where Do We Go From Here?

Russell George
Speaker of the Colorado House of Representatives

There is an old adage that says that 90 percent of winning in politics is showing up. I would say for this group 90 percent of winning is sticking it out. You are the tough ones. I wish I could say we have saved the best for last, but that would be a little self-serving on my part.

A weather report for those of you who want to know what is going on outside - if you live in downtown Denver, you would say that it is snowing. If you live in Douglas County you would say we are recharging groundwater. If you live in Western Colorado, you would say we are refilling the reservoirs. There is always a silver lining in the cloud, and the moisture is very welcome.

It is probably a little presumptuous of me to come up here toward the end of a two-day conference, not having sat in on very much of it, and presume that I have something to say that you haven't already thought of or haven't already said. It probably is right that everything that should have been said in Colorado today about droughts and floods has been said in one form or another, and that is good. So I am not going repeat or summarize, but just give a little different perspective, focus a little differently on some points and put things in a different context. My context is partly where I think we are. Wherever we are, it is a result of where we have been and what we have done, not just this moment in time.

Many of you know that I started in this business as a kid carrying an irrigation shovel on an irrigated farm on the Colorado River, and understood drought more than flood. The Colorado does flood, but not to the extent that we have seen in some other parts of Colorado. But we certainly experienced drought, and I oftentimes will find that my thinking is more along the lines of, "What are we going to do about drought?"

I have in my mind some rules of play, some of the basic underlying principles that we ought to keep in our hearts as we talk about changing the way we react to the legal context of droughts and floods in Colorado.

The first rule that you must never forget is that Mother Nature is totally in charge. Here I am trying to say that we should not overestimate what we are capable of doing in this subject area as a state government. Much of what we talk about here, much of what we wish to respond to, is in the end uncontrollable. That is certainly true on the margins. There is not a whole lot we can do as a government to handle the worst of the floods - to do anything to stop what Mother Nature will do.

Likewise, I am not sure there is a whole lot we can do, even at our best, when we get into the 50-year drought cycle. We have been lucky in that respect, but we won't always be. As lawmakers and policy makers, we have an obligation to look as far into the future as we can. As we try to imagine how we are going to change our legal system to deal with this, let's not be too proud of what we are doing in anticipating that we are doing a lot, because Mother Nature will probably fool us. Whatever we do, we need to recognize that vulnerability.

Another rule that I like to think about is that, when we plan for floods and drought, we are caught by one of our more dominant human traits. It goes something like this: we probably don't really appreciate or understand the value of water until we either have too much or too little. Most of the time we are okay, and we have a tendency to be like the guy who has a leaky roof. When it is raining, it's too inconvenient to go out and fix it, and when it is not raining, he doesn't need to fix it. I think in many ways that is the way we have been dealing with drought and floods from a state standpoint.

Locally, it is different. Our water districts, whether they are conservancy or conservation or other special districts dealing with either water quality or water quantity, form their priorities based upon a need and then try to respond to that need. The comment earlier was, "It is pretty clear that from a state standpoint there has been a lot of neglect. It has not been a high priority." I think that is true. Part of what I want to talk about today is, if that is true, is it good or is that bad?

What we have done in Colorado, for the most part over these years, is develop what I would say is a pretty good plan to deal with the way we use water. It has been with us since Colorado became a state, and it is called the Prior Appropriation Doctrine. Again, that was driven by Mother Nature. When people came here and tried to live, they realized that Mother Nature was expecting them to use a little ingenuity to survive, our first look into history, to the extent that it is an accurate window, is a number of years ago, when our brothers, the Anasazi Indians, tried to settle in the southwest part of the state. Why they picked the driest, most desert-like part of Colorado is a mystery to us, but we know they did and we also know that they survived.

We devised perhaps a much more elaborate legal scheme. We don't know exactly what the social structure of the Anasazi was, but we know what our legal scheme is - and that is the Prior Appropriation Doctrine. I would say, by most measures, this doctrine has worked very well as an allocation system. Because it works so well, we rely on it; we strengthen it; and we protect it. We do that because it works. When we hit a drought period, we discover both the strengths and the weaknesses of this doctrine. Its strengths are obvious to those who have senior decrees,

because it protects those decrees and provides the water that the owners of those decrees have anticipated. Those owners and users have planned for the drought. They have anticipated the drought. They have spent capital. They have done all the things they should do, as best one can anticipate, to be able to have the water when they need it. To the extent that the Prior Appropriation Doctrine protects them, it is a strong and powerful tool.

The weakness is the other side of that coin, isn't it? That is the people who have junior decrees or no decrees at all. There isn't anything in the Prior Appropriation Doctrine to protect those people. What we discover as we talk about the future and about what the state's role ought to be, we begin to understand that the Prior Appropriation Doctrine is not a very good social planning tool. My point is, it was never designed to be - it was designed to be a property rights tool. Where the conflict is likely to come is, as we recognize drought as a crisis, we then say, "But one of the reasons we have government is so that together we can respond to crisis as a matter of public policy to protect our citizens." We really believe that as a matter of public policy it is not good to let some of our citizens suffer, and in this context, not good to let them suffer in time of drought. Or, don't let some people be without water when they need it. So, what happens in the drought is that the people without - and to some extent these are people who didn't plan, didn't spend money, didn't anticipate, decided they didn't need to fix the roof because it wasn't raining - are saying, "Wait a minute. This isn't what my government is supposed to do for me. How come they have water and I don't? Use my government to take it from them and give it to me."

We really have a different crisis there, because we now in effect have a constitutional crisis on our hands. On the one hand, we have a government that is designed to help the public health, welfare, and safety; yet, on the other hand, we have the Constitution that is going to protect the water property rights of our citizens. What do we do with that conflict? I don't know altogether what the answer is, except that the context within which we need to look for solutions is to not try and solve the crisis of drought by precipitating a constitutional crisis. Where should we go with our anticipation and planning? It is all right to use your state government, but we shouldn't be using the police power part of state government. We should be using the other tools that we have.

The discussion for two days has been money, I am sure. We need funds; we need money to do this; we need money to do that. That is good! That is one of the things we do with government. We accumulate taxes from all of us and then your legislature tries to respond to the needs of the day and apply those common dollars to those purposes. Colorado has done that, I think, to a fairly successful but limited degree over the years. I think our revolving loan fund that is administered through the Water Conservation Board is wonderfully successful. We can continue to do things like that. I think it also makes some sense for the state to be putting dollars aside for unknown water expenditures in the future. I happen to believe that the state ought to be anticipating building some reservoirs for both purposes - storage for time of drought, for capacity when we have floods, and for exchanges and other things you can do when you have the storage to work from. I think all of that is good, but what wouldn't be good is if we took the state and said, "We will lay an umbrella over the top, and we will simply decide that a drought is an emergency, and therefore, using the police power, say, 'You have to give up your water' and 'You may receive this water.'" That would not be a good result, and we need to resist that wherever we can.

We have that happening to us a little now, and it highlights how destructive this can be to our sense of community. People who like to use reservoirs for recreation, for example, have not contributed to the planning and the cost of construction and do not contribute to the operation of an irrigation reservoir. Rifle Gap is the one that comes to mind - that is an irrigation reservoir, and people get pretty unhappy when we draw it down in August, because it makes the recreation experience less desirable. So there is political pressure to try and change the operating plan of that reservoir. I think such examples can be found all over the state.

Another place we see this is an irrigation reservoir that we want to fill early so that we have the water later in the year; yet, you have other people downstream who are worrying about floods. They say, "Why don't you manage that reservoir just the reverse? Leave it empty so that you can avoid flooding for me." Those are the kinds of problems that we are seeing today. We want to really resist the urge and temptation to let that be the model for the future.
I don't know if we have any friends here from the U.S. Forest Service, but may I suggest that the attempt by the Forest Service to dictate bypass flows is also in the same context. That is not respecting the property rights aspect of the people who have spent a lot of money over the years trying to develop, preserve, protect, and use that water right. A bypass flow is an exercise of police power that does not respect those property rights, and I think we need to resist that kind of effort wherever we can.

Let me finish by trying to respond to the charge I have been given, and that is to comment on, "Where do we go from here? What can we do?" A lot of times this planning really needs to come from local governments. That has been historical, whether it is counties, cities, or more likely, our special districts and water districts. That is good, because we are talking about on-the-ground issues; and we are talking, I hope, about on-the-ground solutions. Frankly, I think we have a lot of people of good will across the state who really do want to anticipate solutions. We can do that on a voluntary basis with each other.

As I understand it, there is a consortium developing here in the South Metro area with a lot of water users coming together by intergovernmental agreement saying, "Let's

work together and try to anticipate some of our water supply needs in the future." That is all by willing, voluntary agreement. It is happening, and I think it will continue to happen. Any way the state can encourage that, assist it, and provide incentives for it, that is what we ought to do.

We do, after all, have the best revenue-generating government machine in the state. There is more money coming into the state than we have need for, but that is not true for local governments, necessarily. So, we have the revenue to some extent. We have a little problem called "TABOR" about the extra, but neverthess, the money is there. We are likely, as far as we can see into the future, going to have the state revenue generator probably being better than the local generators, and I think that money ought to be made available in appropriate ways - grants, construction projects - all of those things are appropriate ,but they need to be done on a voluntary, by-agreement basis and no other way.

In the end, I want to comment about conservation and storage in this context. In all my years dealing in the water business, I have accepted the discussion that conservation is a good thing. When you are raised on a farm in a semi-arid area, you learn conservation as a natural way of doing things. I have carried that into my law practice and have thought about it in the same context in my public service. But I think there is another side to conservation when we think about drought that we really must not forget. That is, if you are as successful in conservation as the philosophy would allow you to be during times of plenty, you will create a drought-hardening result when you hit the drought. If you have conserved all you can conserve when you don't need to, you don't have anything to help you in the drought. In some respects, I am rethinking all of this, and instead of thinking that something not conserved is wasted, I need to think of it as something not conserved may help me when I really need it. That is a different approach, and I have to think about it. I think there is merit to it - that we may be doing ourselves a disservice by pushing for too much water conservation in times of plenty, because it could dramatize and deepen the crisis when we are actually in drought. You know, Colorado is kind of an odd place - everything runs down and out. So, if we have done everything we can to let all the extra run down and out when we don't need it, what will we have when we do need it? It is a thought that I want all of us to keep in context as we work on these issues as time goes by.

It wouldn't be appropriate if I didn't get on my soapbox about storage. I cannot envision a water problem in Colorado that cannot be helped to some degree by a good reservoir in the right place. I know that is not what everyone wants to hear, but I am trying to think about these things in the long-term, as we all should. I just still am not convinced that a reservoir is a bad thing. Yes, reservoirs change some environmental values. Everything we do in life does that. The question is mitigation - balancing - and protecting values by adjustment and mitigation. I think in the long term the state does have a role in encouraging storage. I don't know that I mean high-altitude, huge reservoirs. There are probably not that many opportunities left. It may be that the cost of those, the various environmental costs of those kinds of reservoirs, are too high for the values and benefits. That may well be true, but there are other kinds and places of reservoirs and storage structures that we can use. I would like us to think in terms of where can we most benefit from storage, not whether or not we should be doing storage.

Finally, let me finish with one other adage of mine, and that is, "In politics, it seems like all we ever do is talk, talk, talk." May I say that a conference like this is designed for talk, talk, talk, and let me say, "Thank you for doing that," because the point that I want to make was alluded to earlier, and that is: communicate and educate. In the water business, some of the best cooperative solutions have occurred only after the warring sides stepped back and tried to understand what the other guy's problem was.

They did have a need to accomplish their individual goals. But once each side figured that out, instead of saying, "I have to have this, and therefore, you are in my way," and they began saying, "I understand you have to have that." Then they began to figure out how they could help each other. In the sentence that I am living over here in the gold dome these years, I have understood that this is important for us. I come from a rural district. Most of my colleagues come from urban and suburban districts. It finally dawned on me that, if I could get them to come over and see me and just visit with my folks a little bit, they would begin to understand why it is that I vote the goofy way that I do. Also, last year when I decided to try and become speaker, I decided maybe I better go into their communities and listen to their constituents. It opened up a whole new world for me. What we learn, of course, is that we are not all that different. Our issues seem to be different, but it is perception as much as anything. We just need to talk to each other, to truly communicate. It is one of the ironies of the modern days, isn't it? We have more good, communicative tools than we have ever known in history, and one of the biggest problems in self-government is that we cannot communicate with each other. In this business, we have to. This is what we are trying to accomplish here.

The other part of communicating is educating. Most of my colleagues, your representatives and senators, don't know very much about the technical side of water - water law, drought and floods, or the engineering that is involved. We can't let them make decisions that affect your lives until they have been educated. We are busy folks, so we are not likely to go out and educate ourselves. That means that you must take on the role to ensure that each of us is educated to the extent that we need to be. Talk, talk, talk, please. It is critical. It is the way we will solve our problems in the future.

Owens Administration Response

Greg Walcher
Executive Director
Department of Natural Resources

I want to tell you that this conference was also sponsored by the Department of Agriculture, and Commissioner Don Ament is another state fighting on our behalf on another issue today. I want you to know that he is here with us in sponsorship and spirit, and to some degree money.

I want to introduce Bob Brooks and Jane Norton. I can't tell you how much I enjoy working with the two of them. We want to do a quick wrap-up, and thank you all for coming. Let me first introduce the Director of the Department of Local Affairs, Bob Brooks.

Bob Brooks
Executive Director
Department of Local Affairs

For those of you who don't know the Speaker of the House, the more I get to know this man the more respect I have for him. It is a pleasure to work with you. I did offer a time-saving idea, I thought, to Greg Walcher. He rejected it. I thought being as there are plenty of microphones up here, all three of us could speak at the same time and we would get this over with quicker.

With a lot of the ideas that were discussed today, there is some political will involved. The solutions are difficult, and solutions are always more apparent to people that don't have to make the decisions. Let me just mention quickly that what we mainly do at the Department of Local Affairs is work with local governments. With a number of the things that were discussed today and some of the goals and solutions that were discussed in the wrap-up, I think there is perhaps a place for the Department of Local Affairs (DOLA) to involve itself to some degree. I spent 15 or so years in local government, and of all the issues that local governments deal with, and I think it is true for state government as well, dealing with some of the crisis situations and planning for things like drought and flood, I shudder to think how little time is actually spent on those. Most counties and many of the municipalities probably have some kind of a plan in place. They have given some thought to it; but as far as updating it, it has probably been years since most of them have. They probably dedicate very little if any staff at most levels - maybe one or two at most - to be prepared for those kinds of issues. So while these crises are devastating when they hit, such little thought and preparation many times goes into preparing ourselves, that I think we end up spending more of our time and effort and funding on the response and recovery from those kinds of things. Perhaps it might be a little cheaper and more efficient if we gave some forethought up front.

As far as educating the public goes, for local government elected officials, for example, maybe there is a place that DOLA can assist in that, along with Colorado Counties, Inc., (CCI) and the Colorado Municipal League (CML). They are the spokespeople for and to local governments many times. A focus on planning was something that was mentioned. I notice, at least as far as flooding and to a degree droughts are concerned, the Office of Economic Development, which is in the Department of Local Affairs, does work with local governments to prepare for those things, do planning, and assist them with some of the data collection as well. It provides technical assistance along those lines.

A couple of things were mentioned that I found very interesting. One was data collection. It is interesting and I am sure you aware that Colorado has an organization that monitors droughts and things of that nature - the Water Availability Task Force. They have some real experts in climatology that do a very good job. But I thought it was interesting last April, I believe, that they did an estimate that we might be in a position to have one of the most serious droughts we have had in perhaps years and years.

As it turns out, we had one of the wettest springs and early summers that we have seen. I guess the reason I would like to bring that out is, while data is important, particularly in snowpack, it provides extremely valuable information, the fact of the matter is back in the early '60s a certain fellow (I can't remember his name) was convinced that, with a large enough computer and enough data, it would be possible to accurately predict the weather. This fellow spent about 30 years getting bigger and bigger computers, and he had sources from literally all over the world - airplanes, ships, base stations around the country - that sent data by satellite to his massive computer, and after 30 years of doing that his predictions were accurate up to about two days. The fact of the matter is, it was some of his early work that later in his life actually produced the theory of chaos. There are some things that are just so complicated that when you miscalculate even small parts of the formula the results are terribly inaccurate. So, while data is important and useful, I don't think we would want to design our whole summer based on what we estimated we were going to have in the way of precipitation. What we need to do instead is use the data we can to plan, but then have an emergency plan and a back-up plan as well, in case those projections are not accurate.

Another comment was made about reviewing local and probably other regulations. I agree with that. Again, I think that if you follow around elected officials at the local level and other levels, their days are full. They have a number of issues that the have to deal with on a weekly and daily basis, so when they start looking at things like the floodplain, it just doesn't work its way up to the top of

their agenda often enough. There are a number of things, not only with regard to changes in the floodplain - through satellite technology, GIS, and other things - where we can now get more accurate in those floodplain estimates.

There are also now ways to build within the floodplain that are safer. There are things you can do to get out of avalanche zones and still utilize your property. I saw a television show on one of the educational channels a few years ago about California. They went through section after section where development had been allowed to occur where the Santa Ana winds had been causing fires for 200 years. And yet, they let neighborhoods go in there, and now the neighborhoods burn every few years. Where there were constant rockslides and hillsides were falling away, they let homes be built there, and now they are falling off the hillsides. Everyone knew that would happen, and yet they did it anyway. It takes a lot of political will to take away someone's property rights. At the local level to put that kind of responsibility on them, they will need a lot of support and a lot of education. That is something we need to work on, and reviewing those regulations is something we need to push for at the local level, so we can start those kinds of discussions among our department and CCI and CML.

Finally, I would like to mention that, at least philosophically on my part, government is here to help protect our public. The safety, welfare and health of the public are our main responsibilities, particularly when it comes to things like floods, droughts, and other few-times-in-a-lifetime events. On the other hand, this is Colorado. You don't have to live here too many years to figure out that we are going to have floods, droughts, and we need to be prepared for those not just at the governmental level, but at the private-sector level. I have always found that during emergencies the private sector has resources out there. I am not talking necessarily about asking them for things for free, but the fact of the matter is you can double your efforts in responding to any kind of event if you remember that the private sector is out there to help.

The other thing is that people need to be responsible for themselves to a degree as well. Obviously, government is there to help, but I echo what the Speaker said: If you are going to live in Colorado, you need to be prepared for just a few things to deal with on the individual level. I hope and believe that this conference has been very helpful. It has brought out some good ideas, and I feel that I have gained some direction from it. Now, our challenge is to put those ideas to use as well as talk, talk, talk.

Greg Walcher
Executive Director
Department of Natural Resources

Jane Norton is also a sponsor and co-host of this conference, because, as many of you know, when we have these disastrous events at the local community level, very commonly the first state people on the front lines are employees of her department.

Jane Norton
Executive Director
Department of Public Health and Environment

I fear that the order of our presentations will set us up for a very anti-climatic finish here, but nonetheless, I want to thank Greg Walcher and the folks at the Department of Natural Resources, the Department of Local Affairs and Bob Brooks, and the Department of Agriculture with Don Ament, for convening this very important conference. I have to tell you that I think we have the West Slope well-represented here at the podium. We have Palisade, Grand Junction, Durango and Rifle. We don't often get together like this. I do want to thank the Speaker for his leadership in this important issue. We appreciate your partnership at the state level and the local levels as well. I know the Governor is very pleased to have your attendance here as well.

Obviously, flood and drought preparedness is a very important issue to the State of Colorado. I have very vivid memories of the flood of 1965. Greg, however, was not born.; he just had to watch the pictures. I can remember going through Centennial Racetrack. (my father was with the race commissioner in the summers) and walking through the stables that were just decimated in 1965 -- as a child, how horrifying that was -- then, to be on the CSU campus a couple of days after Spring Creek flooded through Fort Collins, and just having these memories as a reminder that not only is emergency planning important, but preparedness is as well. These are cycles, and we know we will have a drought; we know we will have floods in the future.

I also want to very much thank each and every one of you for your participation here today. We cannot do these types of conferences and these types of proactive planning without you. You bring very important expertise to the table, and I want to thank you on behalf of all of us for your participation here today.

We cannot overestimate how very important a proactive planning approach is, so that when we do get in a situation we can sit down together prior to an emergency happening and have a well-thought-out plan in front of us. I cannot overestimate the value of that.

I would like to talk a little about the historical context of the involvement of the Health Department. Historically, we at the Health Department have focused on the aspect of emergency - whether it be drought or flood - as opposed to being a part of a core team designing management and other structural options to minimize the impacts of flood and drought to our people and to our economy. But now, I would like to take just a few minutes to briefly outline the

roles and responsibilities of the Health Department, specifically in a flood situation.

Obviously, our first and foremost concern at the Health Department is for the human health of the citizens of our Colorado, actual and potential health threats. We have a Water Quality Control Division, and with them and the assistance of our chief medical officer, we have primary responsibility for assessing health threats and assisting communities impacted by floods. In the case of a flood, the State Health Department would immediately launch an assessment process for impacted drinking water and wastewater facilities systems such as treatment plants, water distribution systems, and sewage collection systems. Through this close communication with the facility operators and close coordination with our local elected officials and Health Department officials, our water quality experts determine if drinking water has been contaminated. If it has been contaminated, we need to immediately target the problem to determine what we need to do to protect human health and get us back on track.

The department's work includes immediate visits to impacted sites by our staff, who offer to provide technical assistance to operators and involved local officials. I think Commissioner Klein spoke to the value of technical assistance and expertise in these types of situations. That would include offering to inspect and evaluate damaged facilities. It also means assistance on issues such as facility and equipment repairs and proper re-start procedures. We talked a little about financial assistance as well, and also we can be of help directing impacted communities to the Department of Local Affairs or FEMA, if financial assistance is deemed necessary. Again, Commissioner Klein alluded to that in his summary report.

Also, to the extent that we determine that there is a health threat, we need to immediately notify the public. This is a very important aspect of what we do. In the case of a threat to drinking water, we could issue boil orders, floodwater safety advisories, and any other type of public communications that were determined to be necessary. If we were to take such action, we would work closely with plant operators and local officials in the area, making final decisions and preparing public notices. Even when the floodwaters recede, I think it is important to remember that the Health Department is certainly still vigilant in those days and months after the floods. We would continue to follow up with impacted facilities to be sure that operators were quickly and properly repairing any damage that might happen to the facilities. If a facility were negligent in taking action to protect human health, we could issue an enforcement action as well. Also, as needs dictate, we would do follow-up studies to determine what actions are necessary to protect critical infrastructure in the future.

I want to briefly describe to you a project that we have going that we think is going to be very important for local communities, and that is at our Water Quality Control Division. It is compiling important information that is necessary for communities to be able to respond in an emergency such as a flood. The information will include how to obtain safe drinking water during a flood and the hazards of reentry into a flood zone. I hope to have these recommendations from the work group in front of me within the next couple of weeks, and we will get those out to the communities involved. We are very pleased about that. This came about actually when our folks sat down with the environmental health officers in Otero, El Paso, and Pueblo counties after the floods there last spring. We were very pleased to have a tangible action item come out of that, and we think it will be very helpful for the communities.

That is our traditional role, but I wanted to be here especially today to offer my pledge that our participation will be on the planning side as well as the emergency side, and we want to work closely with Greg and other staffs in order to do that. Our activities certainly have ramifications in a number of different areas: water quality, obviously; flood zones; air quality in wildfire areas; best management practices for facility locations; and public health in flooded areas where there is contamination. These are all elements of solutions that you are beginning to craft today, and we certainly want to be a part of those. We want to be of assistance in those planning efforts as well as the emergency efforts. I look forward to working with you in the years to come, and I want to thank you again for your participation.

Greg Walcher
Executive Director
Department of Natural Resources

I would like to thank about eight people in the Department of Natural Resources staff who worked overtime for several weeks on the logistic details of this conference, particularly, our conference coordinator Kathy Kanda and all of the others in my office who worked so hard to put this together. We very much appreciate their help on it. Also, I want to acknowledge again Henz Meteorological Services and CH2M Hill for sponsoring the reception last night. We appreciate that very much.

Mr. Speaker, thank you again for being with us today. We already warned, just before you came in the room earlier, that those who stay to the bitter end clearly had more influence with you in the next session than those who have left already. I know you will keep that in mind. We look forward to working with you during the next session on these issues and a wide range of others as well.

Finally, I cannot thank all of you enough for being here. Ideas on what to do and how to get it done especially have to come, as the speakers said, from the ground up and can't be dictated by the state. Those of you who took time to spend a couple of days here with us, we very much appreciate it. We will publish the results of this. You will all get a copy, and that will create several ongoing processes which you will be hearing more about in the coming weeks. With that, thank you all for coming.

Governor's Flood and Drought Preparedness Conference

Speaker Biographies

Don Ament

Commissioner of Agriculture
Colorado Department of Agriculture

Don Ament was appointed Commissioner of Agriculture in January 1999 by Governor Bill Owens after completing 12 distinguished years in the Colorado General Assembly – four years in the House of Representatives and eight years in the Senate. He served as Chairman of the Agriculture, Natural Resources and Energy Committee; Chairman of the Capital Development Committee; and as a member on the State, Veterans and Military Affairs Committee, and the Transportation Committee.

He also chaired the national American Legislative Exchange Council's Task Force on Agriculture and is considered an expert on water and property rights.

At the conclusion of his first term in the House, Ament was named the "Most Promising Legislator." He has been named four times as "Legislator of the Year" by the National Federation of Independent Business and has received "Legislator of the Year" awards from 20 associations including the Colorado Association of Commerce and Industry, Ducks Unlimited, the Consulting Engineers of Colorado, the Colorado Cattlefeeders Association, the University of Colorado and the Colorado Green Industries.

Ament served five years on the State Board of Education, four of them as chairman. He also served 14 years on the RE-1 Valley School Board in Sterling and is a former president of the Colorado Association of School Boards.

Ament is a farmer and rancher in Northeast Colorado. He and his wife, Patty, have three grown children.

Ann Azari

Consultant
Ann Azari Consulting

Ann Azari recently served three terms as Mayor of Fort Collins. She is the owner of Ann Azari Consulting, which she has operated for the past 10 years. In addition to serving in local elected office, Azari has held national leadership roles through the National League of Cities, the U.S. Conference of Mayors and the Department of Commerce. Presently, she is concentrating on service to communities and business through her consulting work.

Prior to serving as an elected official, Azari was a public official in county and state government. Her special focus is the practice of building community.
She has broad-based experience that brings the down-to-earth perspective of a community leader practitioner to help with problem solving, facilitation and community participation, as well as community and governmental relations. She is an advocate for the use of geographic information technology to help create the common understandings needed for successful interaction in community life and for efficiency in responding to community problems. She believes that community engagement and cooperation from local to national to international levels can be enhanced to better resolve issues.

Maryanne Bach

Regional Director
Great Plains Region
U.S. Bureau of Reclamation

Maryanne Bach was named Regional Director in November 1988. Prior to that she was Assistant Director of Reclamation's Program Analysis Office in Denver. She served as Deputy Regional Director for the Great Plains Region from 1994 to 1996. She has also served as Director of Reclamation's Organization and Management Analysis Office in Denver.

Before working for the Bureau of Reclamation, Bach served as Director of the Department of the Interior's Office of Policy Analysis and as Deputy Assistant Secretary for Fish, Wildlife and Parks in Washington, D.C. She also fulfilled a special one-year assignment as Assistant Director in the White House Office of Science and Technology Policy.

Prior to moving into federal service, Bach was Science Coordinator for the U.S. House of Representatives Committee on Science, Space and Technology and technical consultant to the House Subcommittee on Natural Resources, Agriculture Research and Environment, and the Subcommittee on Science, Research and Technology.

Bach has a bachelor's degree in biology from Providence College, Providence, Rhode Island, and a master's degree in ecology from Iowa State University, Ames, Iowa. In 1998, she received an honorary Doctorate of Public Service Degree from Providence College.

Duncan S. Bremer

Commissioner
El Paso County

Duncan S. Bremer has served as El Paso County Commissioner for District 1 since 1994. He is on several Colorado Counties, Inc., committees, including serving as Chairman of Health and Human Services and President of the Front Range District. Additionally, he serves on the Human

Services and Education Steering Committee of the National Association of Counties, the Board of Directors of the Pikes Peak Area Council of Governments and as President of the Baptist Road Rural Transportation Authority.

Bremer was active in developing Colorado's welfare reform legislation and has been on the boards of directors for various non-profit organizations. He has published books and articles on diverse subjects ranging from welfare reform to solar energy and the law of condominium financing.

An attorney who specializes in small business and real estate law, Bremer earned bachelor of arts and master of architecture degrees from Yale University and a juris doctorate from the University of Connecticut. He and his wife of 30 years, Michele, founded Wings Like Eagles, a non-profit Christian ministry to families with special needs children. They have three grown sons.

Bob Brooks

Executive Director
Colorado Department of Local Affairs

Bob Brooks was appointed Executive Director of the Department of Local Affairs by Governor Bill Owens in January 1999. As Executive Director, his responsibilities span a wide range of services to communities and local governments to help build capacity. These services include training, technical and financial assistance and emergency management.

Brooks has more than 21 years of local government experience. Prior to his appointment at Local Affairs, he served as the County Manager of La Plata County since 1992, as County Commissioner for Arapahoe County from 1982-89, as well as City Manager of Goodland, Kansas, and Monte Vista, Colorado.

Brooks also spent 12 years working in the private sector, three as director of Construction Services for the Colorado Contractors Association and nine as president of Cambridge Construction Corporation, a residential and commercial construction and development company.

Throughout his career, he has been active in numerous civic and business organizations including Rotary International, Jaycees and the International City/County Managers Association. He is a found member of the E-470 Authority Board of Directors, past president of the Colorado Association of County Administrators, and a former member of the Board of Directors of the Municipal Energy Association of Nebraska. He has been honored by many business and professional organizations, the most recent of which was the first "County Administrator of the Year" award conferred by the Association of Colorado County Administrators.

Brooks earned his bachelor's degree in business administration from McMurry College in Texas and a master's in business administration from Abilene Christian University. He is also a graduate of the John F. Kennedy School of Government's Program for Senior Executives in State and Local Government at Harvard University.

Brooks and his wife, Jan, have two children.

Hank Brown

President
University of Northern Colorado

Hank Brown became the 11th President of the University of Northern Colorado in July 1998. Before becoming UNC's President, he served Colorado in the United States Senate. Before the Senate, he served five consecutive terms in Congress (1980-90), representing Colorado's 4th Congressional District. He also served in the Colorado Senate from 1972-76.

Brown was Vice President of Monfort of Colorado from 1968-80. He is both an attorney and a certified public accountant. While in the Senate, Brown taught graduate-level public policy courses at Georgetown University and political science courses at Catholic University in Washington, D.C.

Brown earned a bachelor's degree in accounting from the University of Colorado in 1961 and served as CU's Student Body President. He earned a juris doctorate degree from the University of Colorado Law School in 1969. While in Washington, D.C., Brown earned a master of law degree in 1986 from George Washington University. In 1988, he passed the exam to become a certified public accountant.

Brown served in the U.S. Navy from 1962-66 and was decorated for service in Vietnam. The Colorado native was born February 12, 1940, in Denver. He and his wife, Nan, have lived in Greeley since 1969. They have three adult children.

Ray C. Christensen

Executive Vice President
Colorado Farm Bureau

Ray Christensen is Executive Vice President of the Colorado Farm Bureau, where he has worked since 1983 as Director of Public Affairs and Director of Legislative and Governmental Services. He served as Chairman of the Colorado Agricultural Council from 1985-89.

Before working for the Colorado Farm Bureau, Christensen worked as an agricultural and land use consultant for Engineering Science, Inc., in Denver. He has also worked for the Missouri River Basin Commission in Helena, Montana, and the South Dakota Department of Agriculture's Division of Conservation, as well as on his family's grain and livestock farm in Veblen, South Dakota.

Christensen has served in the U.S. Army and U.S. Army Reserve from which he retired in 1982 as a Captain.

He earned a bachelor of science in geography from South Dakota State University, where he also attended graduate school for geography and environmental studies. He is married to wife, Cindy.

Leona C. Dittus

Executive Director
National Drought Policy Commission

Leona C. Dittus was designated Executive Director of the National Drought Policy Commission in September 1998. The 16-member commission was established when President

Clinton signed the National Drought Policy Act of 1998. The commission has been tasked to provide advice and recommendations to the President and Congress on the creation of an integrated, coordinated federal policy designed to prepare for and respond to serious drought emergencies.

Dittus previously served as Emergency Programs Coordinator for the Farm Service Agency from May 1997. She also served as FSA's contact with state governors, Indian tribes and organizations, low-income and minority producers, and federal, state and private relief agencies.

She served as Director of the Emergency and Noninsured Assistance Program Division from 1995-97; as Deputy Director of the Emergency Operations and Livestock Programs Division from 1991-95; as an Agricultural Program Specialist in the Livestock Programs Branch of the Emergency Management Operations and Livestock Programs Division from 1988-91; and as an Agricultural Program Specialist in the Price Support Branch of the Cotton, Grain and Rice Division from 1985-88. From 1977-84, Dittus was a Program Assistant in the Grant County Agricultural Stabilization and Conservation office in Carson, North Dakota.

Dittus was born and raised on a farm near Elgin, North Dakota, and was self-employed in farming and ranching in North Dakota for more than 20 years. She has receive numerous awards and honors including selection for the ASCS Career Development Program for Women and the Administrator's Award for Service to Agriculture Individual Award.

Jo Evans

Consultant and Lobbyist
Evans Environmental Consulting

Jo Evans is an environmental consultant and independent contract lobbyist specializing in natural resource issues. She has been a registered professional lobbyist at the Colorado General Assembly since 1984. Organizations she represents include Northwest Council of Governments Water Quality and Quantity Committee, the Audubon Society, the Environmental Defense Fund, Colorado Trout Unlimited and Clean Water Action. Evans is a recognized environmental authority on Colorado resource issues. She is a frequent lecturer on environmental matters to varied state groups and serves on numerous environmental advisory councils and ad hoc issues task forces.

She has served on the Arapahoe Community College Council, the Colorado Emergency Preparedness and Community Right to Know Commission, the State Water Task Force, the Colorado Water Quality Forum, the Mining Water Quality Task Force and the Inter-regional Committee on Property Rights and Takings.

Evans coordinated the Governor's Wildlife Conference in 1993 and served as a consultant for the Wildlife and Outdoor Parks and Recreation divisions' public outreach for the proposed collaborative management plan for the Mount Evans Corridor.

She holds a bachelor of science degree from the University of Southern California and a master's degree from the University of California.

John R. Fetcher

Secretary-Manager
Upper Yampa Water Conservancy District

John R. Fetcher is Secretary-Manager of the Upper Yampa Water Conservancy District and has been responsible for the construction of Stagecoach and Yamcolo reservoirs.

Fetcher has served on the Colorado Water Conservation Board, the Colorado Water Quality Control Commission, and the Colorado Water Resources and Power Development Authority. He served one term as President of the Colorado Water Congress and in 1992 was named the Wayne Aspinall Water Leader of the Year by Congress.

He was one of four founding principals of the Steamboat Ski Area and was its President from 1962-70. To provide water for the growing resort, he formed the Mount Warner Water and Sanitation District in 1966, which he managed until December 1997.

In 1949, he purchased a cattle ranch on the Elk River, which he operates today in partnership with his son Jay.

Prior to moving to Colorado, he was employed by the Budd Company from 1936-49, including two years as the company's representative in France. As Chief Plant Engineer at the Philadelphia Plant, he was involved in the production of stainless steel railway passenger cars.

Besides his activities within the water and agricultural communities, Fetcher is active in skiing and ski jumping. In 1983, he was elected to the Colorado Ski Hall of Fame.

Fetcher was born and raised in Winnetka, Illinois. He earned graduate degrees from Harvard in electrical engineering and business administration.

Marilyn S. Gally

State Hazard Mitigation Officer
Colorado Office of Emergency Management

Marilyn S. Gally is the State Mitigation Officer with the Office of Emergency Management in the Department of Local Affairs Local Government Division.

Prior to working with the Office of Emergency Management, Gally worked with the Colorado Department of Transportation in the Metropolitan Transportation Planning Unit.

She holds a bachelor's degree in geological sciences from the State University of New York and master's degrees in urban and regional planning and in public administration from Florida State University.

Russell George

Speaker of the House
Colorado House of Representatives

Russell George is Speaker of the Colorado House of Representatives. He has represented the 57th House District since 1993. He has served on the following committees: Judiciary; Local Government; Agriculture, Livestock and Natural Resources; and Capital Development. His district

encompasses Moffat, Rio Blanco, Garfield and Pitkin counties.

He earned a bachelor of science in economics from Colorado State University and a juris doctorate degree from Harvard Law School. He is a native of Rifle and operates a private law practice in his "spare time."

Charles M. Hess

Operations Division Chief
U.S. Army Corps of Engineers

Charles M. Hess is Chief of the Operations Division of the Civil Works Directorate in the Headquarters of the U.S. Army Corps of Engineers. In this capacity, he oversees the national program for Operations and Maintenance of Navigation, Hydropower, Environmental Stewardship, Readiness and Regulatory. The annual budget for these activities exceeds $2 billion.

Previous positions included Director of Engineering and Technical Services in the Ohio River Division and Deputy Commander for Programs and Technical Management at the Corps Hunstville Engineering Center in Alabama. Hess also served as the Corps Baltimore District's Deputy District Engineer for Project Management. His career with the Corps spans 29 years, beginning in the New York District in 1969, and duty in Saudi Arabia and the Charleston District.

Hess is a graduate of Rutgers University where he received a bachelor's of science degree in civil engineering. He also has a master's in engineering management from George Washington University with a major in construction management. He is a registered engineer in the State of New Hampshire and is a member of the Society of American Military Engineers.

Noel Hobbs

Water Resources Consultant
Camp Dresser & McKee, Inc.

Noel Hobbs is a Water Resources Consultant for Camp Dresser & McKee, Inc. He worked for Denver Water from 1957-94, where he was Assistant Manager of Marketing, Chief Planner and last held the position of Manager of Resource Planning.

For the past 25 years, Hobbs has been a private consultant. He has been the project director and project manager of many regional and community-specific water resource and water supply planning studies in Colorado. He has conducted numerous studies for the transfer of water rights and represented clients as an expert witness.

Doug Kemper

Manager of Water Resources
City of Aurora

Doug Kemper is the Manager of Water Resources for the City of Aurora. The Water Resources Division is responsible for daily management of Aurora's raw water supplies, water resources planning and the acquisition of new water supplies. He has worked on a variety of projects in the South Platte, Arkansas and Colorado River watersheds during his 13 years with the city. His key area of interest is working with a variety of entities to find more productive resolutions of water resources conflicts.

Prior to working with Aurora, Doug worked as a water resources engineer for four years with Rocky Mountain Consultants. He is a graduate of the University of Colorado with a master's degree in civil engineering/water resources. He serves on the Board of Directors for the Colorado Water Congress. He also teaches water resources management at the University of Denver.

Barbara Kirkmeyer

Commissioner
Weld County

Barbara Kirkmeyer has served as a Weld County Commissioner since 1993 and was Chairman of the Board of Commissioners in 1996. Kirkmeyer co-owned and operated a floral and gift shop from 1982-97 and currently is co-owner of a working 264-acre farm in southwest Weld County.

She has served on numerous boards and commissions including the Energy and Mineral Impact Assistance Advisory Committee since 1994, the Governor's Smart Growth Inter-Regional Council, leadership positions in Colorado Counties, Inc., and the Colorado Water Congress. She has also been appointed to many committees and task forces focused on transportation issues and on human services issues, often in leadership roles. These include the Governor's Blue Ribbon Panel on Transportation, Upper Front Range Transportation Planning Region, National Association of Counties Transportation and Telecommunications Steering Committee, State Board of Human Services, Child Welfare Allocations Committee, Governor Owens Transition Team Human Services Subcommittee and the Farm Labor Housing Board.

She is active in the Republican Party, including serving as Republican Precinct Committee Chair for Weld County and Republican Chair for House District 31.

In 1993, Kirkmeyer was honored as "Freshman Commissioner of the Year" and in 1997 as "Commissioner of the Year."

Kirkmeyer holds a bachelor of science degree from the University of Colorado at Boulder. She also coaches girls softball and basketball. She and her husband, Duane, have three children.

Harold "Jake" Klein

Commissioner
Otero County

Harold "Jake" Klein has served on the Otero Board of County Commissioners for 11 years. He is past President of Colorado Counties, Inc., Chairman of Action 22 and a member of the National Association of Counties Board of Directors and the State Board of Human Services.

Larry F. Lang

Flood Control and Floodplain Management Section Chief
Colorado Water Conservation Board

Larry F. Lang, who has worked for the Colorado Water Conservation Board for 28 years, is Chief of the agency's Flood Control and Floodplain Management Section. In that capacity, he has been active in creating, implementing and managing Colorado's floodplain management programs and flood mitigation projects. He also chairs the Colorado Flood Task Force and the Flood Committee of the Colorado Natural Hazards Mitigation Council. Lang is active in the Colorado Association of Stormwater and Floodplain Managers and the National Association of State Floodplain Managers, Inc.

Lang is a graduate of South Dakota State University.

David Little

Manager of Water Resources
Denver Water

David Little has worked for Denver Water for more than 18 years. He is the Manager of Water Resources and is responsible for assuring that Denver's customers have sufficient water supplies now and in the future. Based upon his knowledge of Denver's water collection system, Colorado water law, environmental issues and hydrology modeling, Little has been involved in numerous negotiations and planning efforts. These include: Denver's Integrated Resource Plan; Denver's Drought Management Plan; the Platte River endangered species program; Clinton Reservoir/Fraser River agreement; Metropolitan Water Supply Investigation; Wolford Mountain Reservoir; and Colorado River Endangered Species Recovery Program.

Little graduated from Colorado State University with a bachelor of science degree in earth resources. Since graduation from CSU, he has completed numerous classes in engineering, environmental planning and negotiations.

Richard D. "Dick" MacRavey

Secretary and Executive Director
Colorado Water Congress

Richard D. "Dick" MacRavey is in his 20th year as Secretary and Executive Director of the Colorado Water Congress. Previously, he served three years as Executive Director to the Larimer-Weld Council of Governments and seven years as Executive Director of the Colorado Municipal League. During his tenure with Larimer-Weld COG, he was responsible for developing and guiding the early stages of the Larimer-Weld "208" Water Quality Management Planning effort.

In 1970, MacRavey served as Chairman of the Colorado Good Government Committee for the promotion of the State Constitutional Amendments One (Governor's Cabinet), Two (State Civil Service Reorganization) and Three (Local Government Modernization). All three amendments were approved overwhelmingly by the people of Colorado. In 1988, legislative leadership appointed him to serve on Colorado Vision 2000 and on the Legislative Council Subcommittee on Long-Range Planning for State Government in 1989.

During 1969-71, MacRavey served on the National League of Cities Board of Directors. He also served on the Boards for Colorado Water PAC and the Colorado Water Education Foundation. He is a member of the American Society of Association Executives, Colorado Society of Association Executives, Colorado Water Congress, American Water Works Association and International City Management Association. In 1999, MacRavey was named the 19th recipient of the "Wayne N. Aspinall Water Leader of the Year Award."

MacRavey has a bachelor of science degree from the University of Wisconsin, Madison, and a master of science degree in public administration from the University of Colorado at Boulder. MacRavey and his wife, Mary, are the parents of six adult children, one grandson and two step-grandchildren.

Nancy J. McCallin, Ph.D.

Director
Office of State Planning and Budgeting

Nancy J. McCallin is Director of the Governor's Office of State Planning and Budgeting. Her responsibilities include developing the Governor's budget proposal and financial plan for the state and executing Colorado's $10.9 billion budget. Additionally, she is responsible for analyzing the national and state economies and advises the Governor on tax policy and TABOR issues.

Prior to joining OSPB, she was the chief economist for 10 years for the Legislative Council Staff, the nonpartisan research arm of the Colorado General Assembly. In that capacity, she was responsible for analyzing the Colorado and national economies, particularly as they related to legislative issues, state tax revenues and budgetary items. She also worked as an economist with United Banks of Colorado for seven years.

A graduate of Claremont McKenna College in California, McCallin's special fields of study include public finance, regional economics and monetary policy. She received her master's and Ph.D. degrees in economics from the University of Colorado at Boulder.

McCallin is active in a number of professional organizations. She served on the Board of Directors of the National Association of Business Economists and is past President of the Denver Association of Business Economists. She is a member of the Women's Forum of Colorado, the Governor's Task Force on Year 2000 Readiness and the Advisory Committee on Intergovernmental Relations.

John H. McClow

Partner
Bratton & McClow, LLC

John H. McClow, partner in the firm of Bratton & McClow, LLC, has practiced law for 26 years and is counsel for the Upper Gunnison River Water Conservancy District.

McClow moved his general litigation practice from Boulder and Denver to Gunnison in 1991 and formed the partnership with Dick Bratton. His practice includes real estate and water matters, and litigation in the state and federal courts at the trial and appellate levels.

McClow has represented the Upper Gunnison River Water Conservancy District as an intervenor before the Federal Energy Regulatory Commission opposing the proposed Rocky Point Project and the Upper Gunnison Project, both pump-back hydroelectric generating facilities involving the Taylor River and Taylor Park Reservoir. He was the lead trial counsel in the recent trial of Arapahoe County's claims for water rights in the Gunnison River and its tributaries. He has handled a wide variety of water, commercial litigation and appellate litigation, including several water rights cases before the Colorado Supreme Court.

McClow is active in the Colorado and 7th Judicial District Bar Associations. He has a bachelor of arts degree from the University of Colorado and a juris doctorate degree from the University of Colorado School of Law.

Thomas B. McKee, Ph.D.

Colorado State Climatologist (retired)
Colorado State University

Thomas B. McKee served as Colorado State Climatologist from 1974 until his retirement in May 1999. He continues to work as a faculty member at Colorado State University where his research for the past 10 years has focused on problems in regional and local climate, mountain meteorology and atmospheric radiation. His current research projects include a temperature, precipitation and wind continuity study for the National Oceanic and Atmospheric Administration and development of new methods for determining extreme precipitation for the Colorado Department of Natural Resources.

Before joining the CSU faculty, McKee taught at the University of Virginia and worked for the National Aeronautics and Space Administration.

McKee has been involved in numerous professional organizations and published extensively in his field of expertise. He has served on the Colorado Governor's Drought Council and the Colorado Water Availability Task Force. He has been honored as an American Meteorological Society Fellow and received the Deans Council and Abell Teaching Awards from CSU.

McKee holds bachelor's and master's degrees in physics from North Carolina University and William and Mary College, respectively, and a Ph.D. in atmospheric science from Colorado State University.

Mary Fran Myers

Co-Director
Natural Hazards Research and Applications Information Center

Mary Fran Myers is Co-Director of the Natural Hazards Research and Applications Information Center at the University of Colorado at Boulder. For 25 years, the center has served as a national clearinghouse for research data and information on the social, political, economic and behavioral aspects of all natural disasters, including floods and drought, and programs to reduce damage from them.

Before joining the center in 1988, Myers worked in the water resource agencies of both Illinois and North Dakota, helping to coordinate the National Flood Insurance Program.

She has authored and co-authored several articles on policy challenges facing the flood management community and recently completed an assessment of how recovery assistance provided in the wake of the 1997 Red River floods has affected the long-term flood resiliency of communities in the basin. Since 1991, Myers has served on the Executive Committee of the Colorado Natural Hazards Mitigation Council.

In 1997, Myers was bestowed the Association of State Floodplain Managers' highest individual honor, the "Goddard-White Award," in recognition of her many contributions to improving floodplain management policy in the country. She holds a master's degree in public administration from the University of Illinois.

Jane E. Norton

Executive Director
ColoradoDepartment of Public Health and Environment

Jane E. Norton was appointed executive director of the Colorado Department of Public Health and Environment by Governor Bill Owens in January 1999 after a decade of service in government, public policy and health care.

Immeditately prior to her appointment to CDPHE, Norton worked in several capacities for the Medical Group Management Association, which is a national trade association for medical group practices and medical practice executives.

From April 1988 to January 1993, she served as the regional director for the six-state Region VIII Office of the U.S. Department of Health and Human Services.

From mid-1986 through January 1987, she served as a member of the Colorado House of Representatives, filling out the remainder of an unexpired term.

She earned a bachelor's degree from Colorado State University and a master's in management from Regis University.

Bill Owens

Governor
State of Colorado

Governor Bill Owens was elected Governor of Colorado on November 3, 1998, becoming the first Republican elected to the office in 28 years. Prior to his election as Governor, he was elected as State Treasurer in 1994 after serving in the Colorado House of Representatives and the Colorado Senate.

Owens earned a bachelor's degree in political science at Austin State University. He was awarded a two-year fellowship to the Lyndon B. Johnson School of Public Affairs at the University of Texas where he received a master's degree in pub-

lic administration.

Owens then joined the accounting firm of Touche Ross & Company in Washington, D.C., as a management consultant. He moved to Colorado in 1977 to work with the management at the Gates Corporation in Denver. Later he served as the Executive Director of the statewide trade association and chaired the Aurora Planning Commission.

M. Susan Savage

Mayor
City of Tulsa, Oklahoma

M. Susan Savage has served as Mayor of her native city since 1992. She oversees myriad services and capital projects made possible by a $479 million budge.

She has implemented numerous operating efficiencies, expanded and improved public safety services, promoted neighborhood and citizen participation in planning the community's future, worked to redevelop older neighborhoods and the central business district, led community initiatives to improve educational opportunities and worked at all levels of government to ensure Tulsa has clean air and drinking water.

She serves on the President's Council on Sustainable Development and the National Recreational Lakes Commission. She is a member of the Executive Board of the U.S. Conference of Mayors, where she chaired the Energy and Environment Committee. She serves as a Director of the Oklahoma Municipal League.

Prior to her work at City Hall, Savage served 10 years as Executive Director of the Metropolitan Tulsa Citizens Crime Commission.

Her undergraduate degree is in criminal justice and economics, and she has studied and worked with courts and prison systems in the United States and England. She is the mother of two children and is married to a Vice President of a Tulsa-based oil company. She volunteers at Booker T. Washington High School and has served on several community non-profit boards. She is the granddaughter of the late U.S. District Judge Royce Savage, appointed by Franklin Roosevelt.

Hal D. Simpson

State Engineer
Colorado Division of Water Resources

Hal D. Simpson was appointed State Engineer on August 7, 1992. Simpson is responsible for managing the Division of Water Resources, which has a staff of 250 and a budget of about $16 million. As State Engineer, he also serves as Colorado's Commissioner on five interstate compacts and is responsible for assuring compliance with these compacts. The State Engineer is also the Executive Director of the Colorado Ground Water Commission and is Secretary of the Board of Examiners for Water Well and Pump Installation Contractors.

Prior to his appointment as State Engineer, Simpson served as Deputy State Engineer, headed the Engineer Section and worked as Chief of the Water Management Branch.

Before coming to the Division of Water Resources, Simpson was employed as a Water Resources Engineer by Wright-McLaughlin and served as an officer in the U.S. Army Corps of Engineers at the Omaha District, where he supervised construction by civilian contractors at Fort Carson, Ent Air Force Base and the Air Force Academy.

He holds a bachelor of science degree and a master's degree in civil engineering from Colorado State University. The master's degree specialized in water resources and ground water hydrology. Simpson has also completed post-graduate work in water resources at the University of Colorado.

Simpson is a registered professional engineer in Colorado and a member of Chi Epsilon. He is a second generation native from the Greeley area and grew up on a dryland wheat farm with a small dairy.

Donald P. Smith, Jr.

Judge (retired)
The Crisis Committee – Buffalo Creek

Donald P. Smith, Jr., was appointed as a Judge to the Colorado Court of Appeals in 1972 after serving as Chief Judge for the 18th Judicial District, to which he was elected in 1964.

Previously, he had served as Assistant Attorney General for the State of Colorado, Assistant City Attorney for the City of Englewood and City Attorney for the City of Sheridan. He was a founding partner of the law firm Myrick, Smith, Criswell & Branney.

Elected to Senior Status in 1993 when he retired from the bench, Smith now directs the Multi-Door Courthouse Project in Arapahoe County and a post-decree mediation program for Denver District Court. He performs mediation and arbitration services throughout the state, both privately and for the Judicial Branch's Office of Dispute Resolution. He also teaches at the University of Denver College of Law.

His numerous community service activities include: co-founder and past Chairman of the Board of the Inter-Faith Task Force; co-founder and past President of the Arapahoe Institute for Community Development; co-founder and Executive Board Member for Court House, Inc., a residential treatment center for "at-risk" youth; past Chairman of the Arapahoe Community College Citizens Advisory Committee; Trustee for the Public Employees Retirement Association; President of the Colorado Masonic Foundation for Children; and President of Colorado Demolay Foundation.

Smith earned his bachelor of science degree from Colorado A & M College (now Colorado State University) and his juris doctorate degree from the University of Denver College of Law. He is a graduate of the National Judicial College and the New York University Judges Resident Seminar. He and his wife, Marjorie, have two children.

William P. Stanton

Conservation Planning Section Chief
Colorado Water Conservation Board

William P. Stanton was appointed in 1999 as Chief of the Conservation Planning Section, including the Office of Water

Conservation, of the Colorado Water Conservation Board. His duties include drought planning, water efficiency planning, and public information and education about water conservation. He is also responsible for managing Colorado's Weather Modification Program.

Stanton began working for the CWCB in 1997 in the Flood Control and Floodplain Management Section. In 1991, he was reassigned as Assistant to the Director and worked on special projects including the feasibility of developing a Colorado River Decision Support System. He became Chief of the Project Planning and Construction Section in 1993 with responsibility for managing the CWCB Construction Fund and the Water Project Construction Loan Program.

Previously, he worked for Morcan Engineering Company as an Assistant Engineer in Delta, Colorado.

Stanton earned bachelor of science and master of science degrees in civil engineering from the Worcester Polytechnic Institute in Massachusetts. He has been a registered professional engineer in Colorado since 1976. He is a member of the American Water Works Association and the Colorado Chapter of the American Water Resources Association. A native of Winnetka, Illinois, Stanton is married and has two sons.

Jack Truby, Ph.D.

Planner
Office of Emergency Management

Jack Truby is the principal author of Colorado's drought and other plans. He recently served as the state's Individual Assistance Officer in the Fort Collins and Colorado Springs recovery efforts. He is a member of the drought plan's Water Availability Task Force and has been a volunteer planner for the Western Governor's Association.

Truby is a graduate of the U.S. Military Academy with a master's degree in geography from Northwestern University and a Ph.D. in international relations from the University of South Carolina. His service with the U.S. Army included troop command, the Army General Staff and the faculty of the Army War College.

Truby is currently managing seminars on the history of the Soviet Union, Latin America and Economics 101 in the University of Denver's "Viva" program. Truby is also a nationally ranked competitive swimmer.

Kenneth A. Vein

City Engineer and Director of Public Works
City of Grand Forks, North Dakota

Kenneth A. Vein is the City Engineer and Director of Public Works for the City of Grand Forks, North Dakota. Vein plays a major role in the city's flood recovery process. He has facilitated a number of neighborhood meetings on both the long-term flood protection project and the short-term flood fight plans, and has worked with the U.S. Army Corps of Engineers on the long-term flood protection plan for the City of Grand Forks. Vein continues to be involved in securing state and federal funds for the permanent flood protection project.

Vein has also held the positions of Acting Director of Public Works/City Engineer, Assistant City Engineer and Project Engineer for KBM, Inc.

Greg Walcher

Executive Director
Colorado Department of Natural Resources

Greg Walcher was appointed Executive Director of the Department of Natural Resources by Governor Bill Owens in January 1999. He brings to the position 20 years experience in natural resource issues.

From 1989-99, Walcher served as President of CLUB 20, the Western Slope promotional organization. During his tenure, CLUB 20 nearly tripled the size of its membership and budget, and Walcher was credited with bringing a new level of activity, visibility and effectiveness to the Western Slope.

Walcher also spent 10 years in Washington, D.C., on U.S. Senator Bill Armstrong's staff, including five years as Executive Director. He handled issues as diverse as transportation, agriculture, governmental affairs and natural resources.

A fifth-generation native of Colorado, Walcher was born and raised in Grand Junction and received his degree from Mesa State College, where he served as Student Body President and became a national college debate champion. He and his wife, Diana, operate a 15-acre peach orchard in Palisade.

Gary L. Walker

Representative
Texas House of Representatives

Gary L. Walker has served in the Texas House of Representatives during its 74th, 75th and 76th sessions. He chairs the Land and Resource Management Committee and serves on the Natural Resource Committee. He is a member of the Texas Conservative Coalition and the Rural Caucus.

A native Texan, Walker has been actively involved in ranching and water conservation since 1978. He directed the construction of the new Subtitle D. Landfill in Yoakum County and is presently employed as a groundwater consultant with the Sandy Land Underground Water Conservation District.

His public service activities include involvement in the Lions Club, the Plains Chamber of Commerce and Yoakum County Junior Livestock Association. Walker also served as a Navy pilot. He holds a bachelor of science degree from Texas A&M University and has completed graduate course work at West Texas A&M University. He and his wife, Frankie, have two children and five grandchildren.

Dave E. Wattenberg

Senator
Colorado Senate

Dave E. Wattenberg has served in the Colorado Senate representing Senate District 8 since 1984. He is Chairman of the Agriculture, Natural Resources and Energy Committee, and

also serves on the Business Affairs and Labor, and Legal Services committees. His district encompasses Jackson, Eagle, Garfield, Grand, Moffat, Rio Blanco and Routt counties.

Prior to serving in the Senate, Wattenberg was elected to the House of Representatives. He also served for 14 years on the North Park Board of Education.

A native of Walden, Colorado, Wattenberg owns and operates a ranch in North Park and studied agriculture at Iowa State University.

Richard P. Weiland

Regional Director, Region VIII
Federal Emergency Management Agency

Richard P. Weiland was appointed Regional Director of FEMA Region VIII by President Clinton in July 1997. As Regional Director, he coordinates FEMA's prevention, preparedness and disaster response and recovery activities in Colorado, Montana, North and South Dakota, Utah and Wyoming.

Prior to his appointment, Weiland held an executive-level position on the staff of Senator Thomas A. Daschle, where he had risen from a variety of staff positions over the span of 15 years. His responsibilities included developing community relations, economic development initiatives, intergovernmental affairs, constituent services, tribal relations and state outreach programs.

Weiland is a former board member of the Carroll Institute, a non-profit organization that administers drug and alcohol abuse prevention and dependency programs. He also served on the Rural Development Commission, a Presidential initiative to help rural states, was active in Rotary International and the Sioux Falls Chamber of Commerce.

A native of South Dakota, Weiland holds a bachelor of science in communications and political science from the University of South Dakota, Vermillion, South Dakota. He has also completed work toward a master's in public administration at the University of South Dakota. He and his wife, Stacy Newcomb, reside in Evergreen, Colorado, and have five children.

Connie Woodhouse, Ph.D.

Research Scientist
University of Colorado/National Oceanic and Atmospheric Administration

Connie Woodhouse is a Research Scientist at the Institute of Arctic and Alpine Research, University of Colorado at Boulder. She is also a Visiting Scientist with the National Oceanic and Atmospheric Administration Paleoclimatology Program, National Geophysical Data Center.

Her research interests include climate variability over time scales of decades to centuries to determine the range of variability under naturally varying climate conditions. Another research focus is dendrochronological (tree ring) reconstructions of climate for the Western and Central United States, specifically, precipitation-related variables, such as rainfall, streamflow and snowpack.

Woodhouse holds a master's in geography from the University of Utah and a Ph.D. in geosciences from the University of Arizona.

Bradley J. "Brad" Young

Representative
Colorado House of Representatives

Bradley J. "Brad" Young has represented House District 63 since February 1996, representing a portion of Arapahoe County and Cheyenne, Kiowa, Kit Carson, Elbert, Yuma and Prowers counties. His primary legislative interests include water, education, rural economic development and telecommunications. He is currently Chairman of the Agriculture, Livestock and Natural Resources Committee and also serves on the Audit Committee and the Appropriations Committee.

While out of session, Young is a certified well tester, performing power co- efficient tests and water meter verifications under the Arkansas River Rules.

Young received an undergraduate degree and a master's degree in agricultural engineering from Colorado State University, where he studied irrigation engineering.

Colorado Water Development Study – 1999 Update

Project Goals

In 1996 the Colorado Farm Bureau initiated the Colorado Water Development Study to provide an overview of current and projected water resources conditions in the State of Colorado. The information provided in this study will assist Colorado water interests and the public in evaluating proposed Colorado water projects, prioritizing those projects, and formulating recommendations and strategies for funding and implementing preferred projects. This 1999 Update reflects current population trends and emerging water development issues.

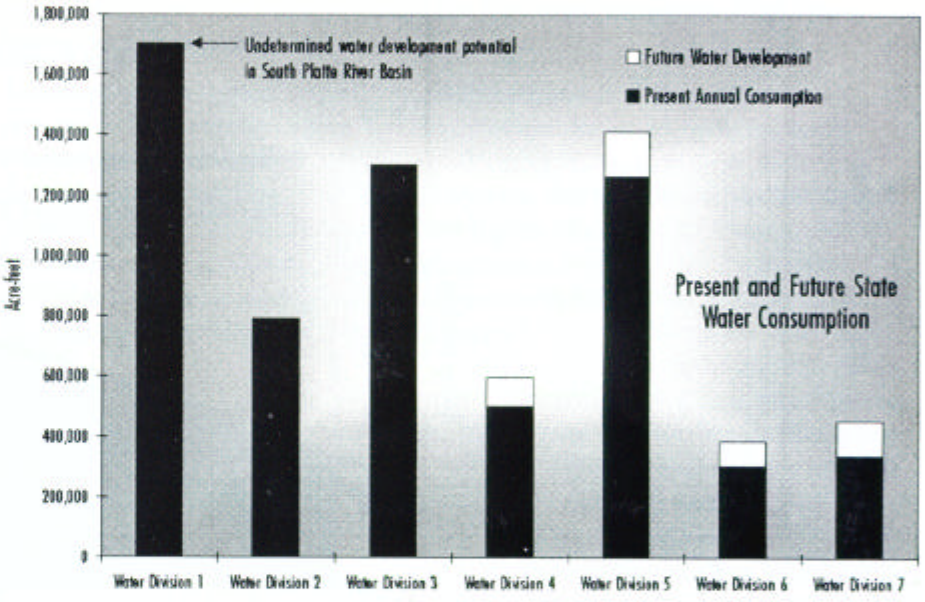
The project scope included:

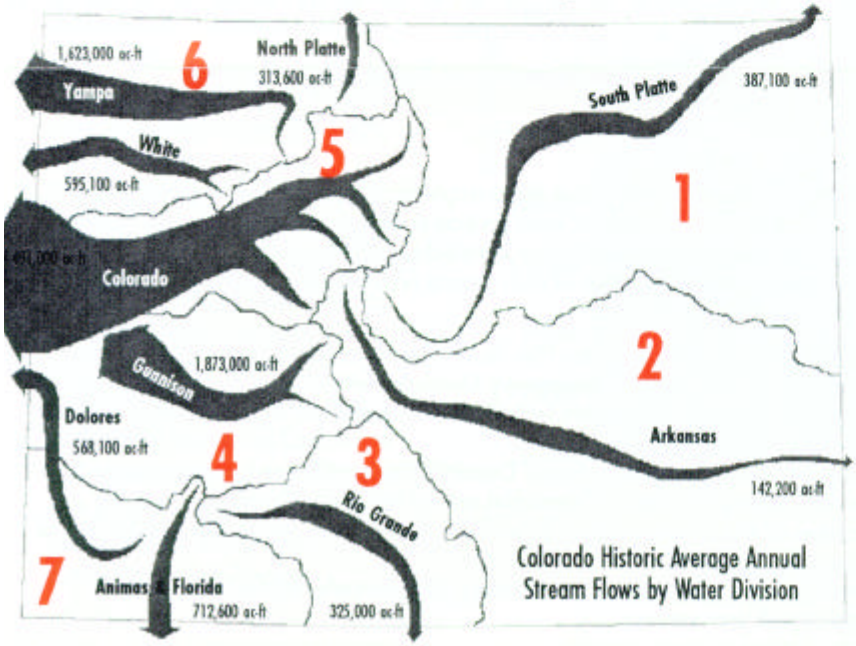
- Project Colorado water supply needs and uses to the year 2100.
- Prepare an overview of existing Colorado water supply.
- Inventory water development agencies, growth projections and water supply projections.
- Inventory proposed water development and storage projects.
- Prepare a report summarizing the findings of the study.

Existing Colorado Water Supplies

An overview of existing Colorado water supplies was prepared based on the best information available from State water resources agencies. Most evaluations are based on 1970 and 1985 data.

The Colorado Water Conservation Board has estimated the total available state water supply to be 15.6 million acre-feet. Current annual consumptive use is about 6.1 million acre-feet in an average year. Interstate compacts may limit increases in future consumptive use to as little as 450,000 acre-feet.





Seven basins are currently near the limits of depletions or consumptive use on the basis of in-state use or interstate compacts:

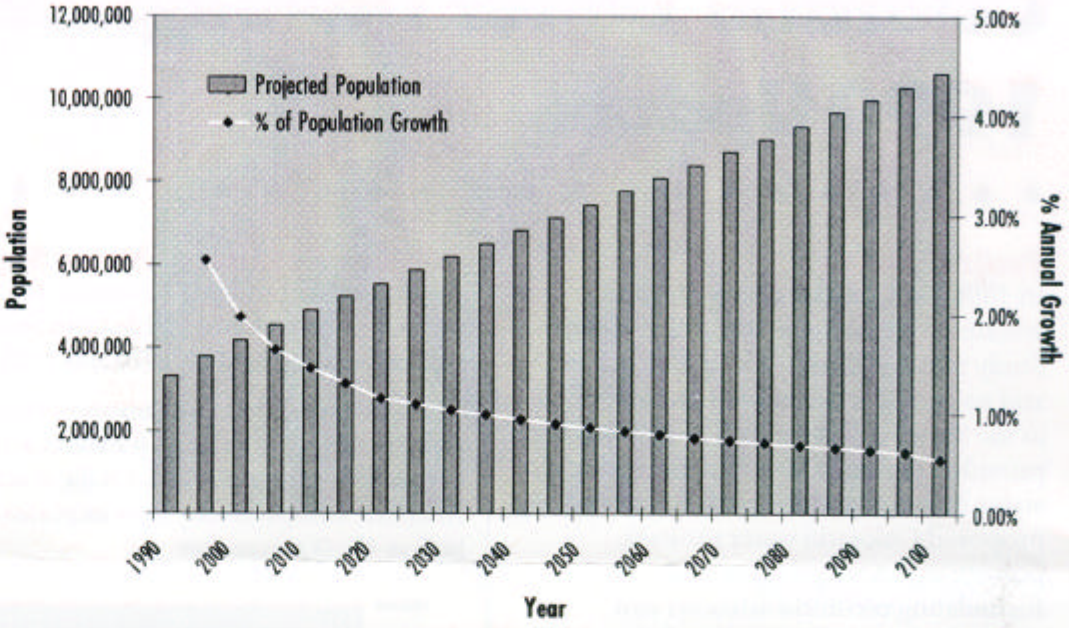
- Arkansas River Basin
- La Plata River Basin
- Republican River Basin
- Laramie River Basin
- Rio Grande River Basin
- Costilla Creek Basin
- North Platte River Basin

The Colorado River Basin and South Platte River Basin have the potential for additional depletions based on estimates of current use under the compacts. However, future water requirements for endangered species recovery programs mandated by the Department of the Interior in both basins may affect when new water development in these basins can occur. Water requirements for these environmental programs are currently being negotiated by a consortium of affected interests.

Population Projections

Population projections have been updated for the state and for the seven Water Divisions using current data from the State Demography Section.

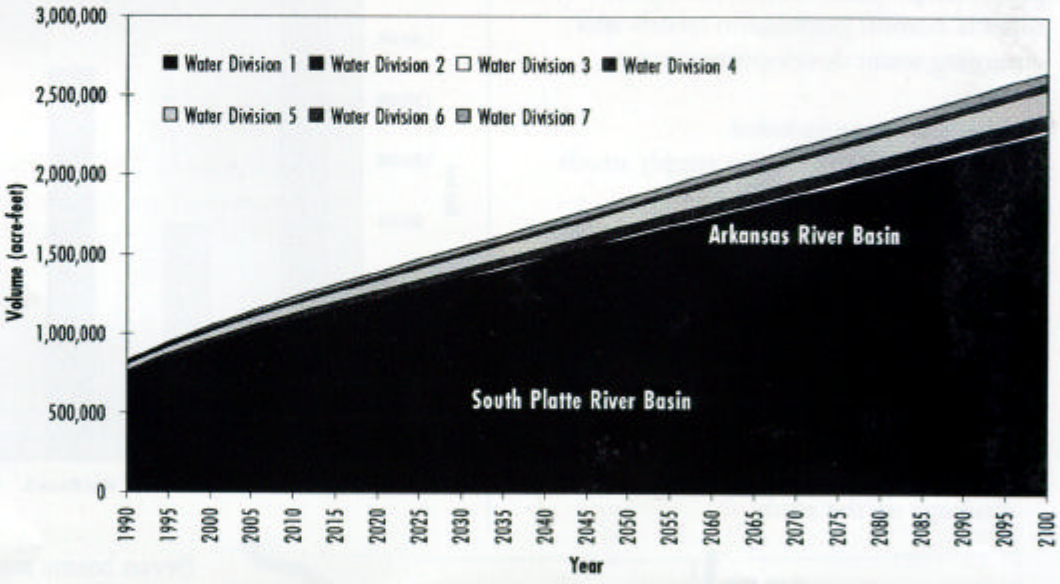
Statewide population is projected to increase from 4.0 million in 1998 to 10.6 million in 2100, with the largest growth to occur in the Front Range communities located in Water Division 1. ❖



Statewide Projected Population and Percent Annual Growth

Municipal & Industrial Water Use Trends

Population projections were used to project future municipal and industrial (M&I) water requirements. M&I water usage was estimated based on the assumption that 1 acre-foot of water will support 4 persons for one year. Statewide M&I use is projected to increase from 1.0 million acre-feet in 1998 to 2.7 million acre-feet in 2100 if present per capita use factors continue. ❖



Projected M&I Water Requirements to Support Colorado Population

Agricultural Water Use Trends

Acreage of irrigated land has remained fairly constant in Colorado since the mid-1970s. Nonetheless, irrigation water use has declined by about 15 percent over the past 15 years due to a combination of generally favorable climatic conditions and improved irrigation practices. Statewide agricultural water use is not expected to increase through the year 2100. ❖

Need for Statewide Water Development Programs Continuation

The population and water use trends shown above emphasize the need for the continuation of a statewide process for the development of water projects to increase the water resources available. Over fifty projects in the planning process were identified in the 1996 Colorado Water Development Study. Excellent examples of such projects both completed and in the development process include:

- Denver Water's Integrated Resource Plan that evaluates its future water supply options
- Southeastern Colorado Water Conservancy District's Future Water Storage and Needs Assessment process to develop firm agricultural and municipal supplies through the year 2040
- Northern Colorado Water Conservancy District's Southern Water Supply Project which provides Big Thompson water to municipal entities within the District
- Continuation of the planning efforts by a wide consortium to ensure the construction of the Animas La Plata Project
- The development of projects such as Wolford Mountain which benefit diverse geographical and user interests ❖

Requirements for Additional Water Supplies

Requirements for additional statewide water supplies will be primarily generated from the following: M&I demands from an increasing instate population and increased agricultural use and M&I demands in downstream compact states utilizing Colorado River, South Platte River and Arkansas River flows. Impacts on future Colorado water development potential under interstate compacts and environmental programs currently being negotiated can not be estimated at present, but could prove to be significant constraints on water development in the next century.

The need for additional M&I water was estimated by State Water Divisions based on the projected population, water demands, and the 1996 Colorado Water Needs Survey results. A range of dry-year yields for existing water supply projects was developed based on low- and high-yield estimates for water agencies not providing this information in returned surveys.

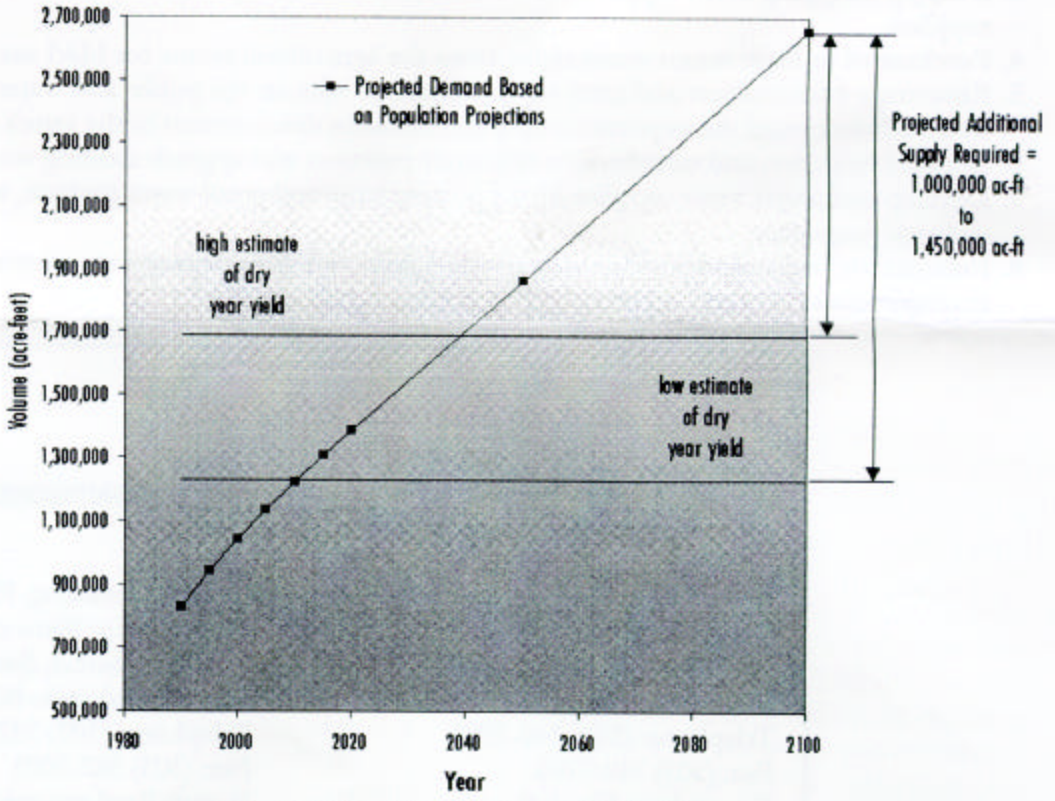
Although it is not possible to develop precise projections of future regional or statewide water requirements, the following observations can safely be made.

1. An additional 1,000,000 to 1,450,000 acre-feet will be needed to meet growing M&I demands in Colorado by the year 2100.
2. Agricultural demands are not expected to increase through the year 2100.
3. Demands for environmental programs (e.g., endangered fish recovery programs) may impact when and where future water development can occur.
4. Increasing demands in downstream states may put additional stress on Colorado water resources, particularly in the Upper Colorado River, South Platte River and Arkansas River Basins.
5. Water conservation practices, while important, are not expected to satisfy future water supply needs alone.
6. Projected demand will exceed currently developed supplies in some regions in the next 20 years. Given the time required to implement water development projects, efforts are warranted to expedite currently proposed projects and encourage planning of new projects.

The Colorado Water Needs Survey identified over 50 significant water development projects or strategies which are currently being considered by the state's water agencies. These include options from constructing new reservoirs to enhancing wastewater reclamation opportunities. The majority of these projects will require inter-agency and often inter-regional coordination, planning and funding to become a reality.

The current trend is toward developing multiple smaller projects for meeting future demands rather than a few large projects (such as Two Forks Dam). Further research into specific projects is recommended to assess which have the most potential for furthering the goals of the Farm Bureau and its constituents.

Another trend is toward developing databases and decision support systems to better understand and manage resources on a watershed basis. State agencies are currently using or developing these tools now, including the Colorado River Decision Support System, the Rio Grande Decision Support System, the South Platte Water Rights Management System, and HydroBase. The Colorado Water Conservation Board and the Division of Water Resources plan to integrate these tools into one statewide "Colorado Water Decision Support System."



Statewide Projected M&I Demand versus Dry-Year Yield

Threats to Water Supply Development

Several threats to existing water supplies or developing new supplies were identified by water providers in the 1996 Colorado Water Needs Survey. A factor which is seen as a threat to one agency may be perceived as an opportunity to another.

- Unpredictability of weather-related or catastrophic events
- Additional federal and state environmental regulations
- Degradation of water source quality
- Drawdown of aquifer water levels
- Lack of reservoir storage space
- Restrictions on water use due to interstate compact requirements
- Exportation of water from the Western Slope to the Front Range
- Unsustainable growth
- Reduction of return flows due to conversion of irrigation use to domestic use ❖

Colorado Farm Bureau Recommendations for Water Development Polices

In the development of Colorado's water resources certain policies should be followed as a guide when pursuing the water development opportunities.

1. The State of Colorado should take aggressive action in developing its water sources.
2. Protect the prior appropriation system.
3. Protect Colorado's interstate water compact entitlements.
4. Protection of existing water rights when interbasin water transfers occur.
5. Allow the free market system to work in the pricing of water. ❖

Potential Statewide Water Development Opportunities

In order for the State of Colorado to meet future water demands, water policy makers, users and managers should consider a mix of several potential opportunities.

1. Develop cooperative water resource planning processes for local, regional and state agencies.
2. Develop alternatives for further funding, both private and public, for water project development.
3. Develop unappropriated supplies. At least 450,000 acre-feet have been identified as new developable surface water supplies.
4. Purchase of or lease senior water rights from the agricultural sector for M&I use.
5. Encourage conservation and carry out programs to educate the public and water user entities about the importance of water efficiency and the importance of water resource development to the state's economy.
6. Improve irrigation and transmission efficiency practices and upgrade existing water collection and delivery systems.
7. Develop additional water supplies by supporting large and small water projects, wastewater reuse, and groundwater recharge programs.
8. Enhance and expand statewide computer databases and decision support systems to improve development and management of existing supplies. ❖

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Cascading or Secondary Effects of Disasters

HAZARDS / Primary Event	Avalanche	Drought	Earthquake	Flood	Landslide	Tornado	Wildfire	Winter Storm	Civil Disorder	Dam Failure	Haz Mat	Power Failure	Rad Incident	Transportation	Urban Fire
Avalanche										✔	✔	✔	✔	✔	
Drought							✔								
Earthquake	✔			✔	✔					✔	✔	✔	✔	✔	✔
Flood					✔					✔	✔	✔	✔	✔	
Landslide				✔						✔	✔	✔	✔	✔	
Tornado											✔	✔	✔	✔	
Wildfire				✔	✔						✔	✔	✔	✔	
Winter Storm	✔			✔	✔					✔	✔	✔	✔	✔	
Civil Disorder							✔				✔	✔	✔		✔
Dam Failure				✔							✔	✔	✔	✔	
Haz Mat									✔						
Power Failure									✔		✔				
Rad Incident									✔						
Transportation							✔				✔		✔		
Urban Fire											✔				

✔ = Types of secondary or cascading events that can be triggered by the primary event

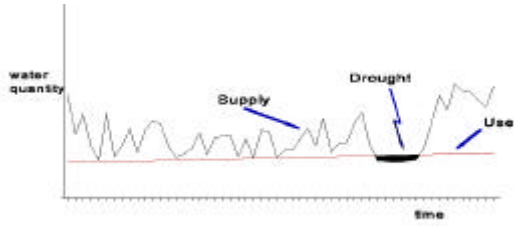
Colorado Drought Facts

Colorado Water Conservation Board

Drought is a shortage of water, usually associated with a deficiency of precipitation.

· The severity of drought depends on the magnitude of the deficiencies compared to historic averages, the aerial extent or size of the area impacted, and the duration.
· Drought is relative to "normal" for a particular region and time of year.
· Drought occurs when the demand for water exceeds the supply of water.

Drought



Source: National Study of Water Management During Drought, The Report to the U.S.Congress, 1995.

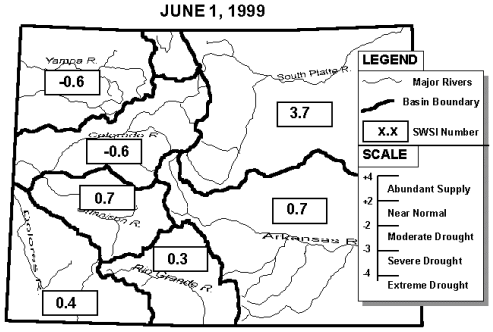
Drought is a unique natural hazard.

· Drought differs from other natural hazards in that it has a slow onset, evolves over months or even years, affects a large spatial region, and causes little structural damage.
· Drought follows no path like tornadoes or floods.
· Drought usually has no clear beginning or end.
· The impacts of drought span economic, environmental, and social sectors. However, like other natural hazards, drought's impacts can be reduced through mitigation and preparedness.
· Further study of weather patterns such as La Nina, El Nino, and the jet stream might be used to predict drought in some areas of the world.

Several indexes have been developed to better monitor emerging drought.

· Palmer Drought Severity Index (PDSI) - a complex calculation based on soil moisture used to determine when to provide federal drought assistance.
· U.S. Drought Monitor - a recently developed weekly assessment of drought conditions across the nation for agricultural, wildfire, and water impacts prepared by USDA, NOAA, DOC and the National Drought Mitigation Center.
· Standard Precipitation Index (SPI) - compares current and historical precipitation to indicate emerging drought.
· Surface Water Supply Index (SWSI) - a weighted index by river basin considering snow pack, stream flow, precipitation, and reservoir storage.

SURFACE WATER SUPPLY INDEX
JUNE 1, 1999



Dry periods have occurred several times in Colorado's recent history.

· Five dry periods have been identified from the instrumental record over the last century.
· Colorado's climate is extremely variable. A severe, sustained drought could occur again. The question is when, not if.

Dry Periods by River Basin from 24-month SPI

Lower South Platte	1889-1905	1931-1941	1953-1957	1964-1965	1976-1979
Upper South Platte	1893-1896	1931-1941	1953-1957	1963-1965	1977-1979
Lower Arkansas	1893-1898	1931-1941	1953-1957	1963-1965	1975-1978
Upper Arkansas	1888-1895	1931-1941	1950-1957	1963-1965	1975-1979
Rio Grande	1897-1906	1926-1935	1950-1952	1963-1965	1971-1978
San Juan, Animas, Dolores	1899-1905	1931-1936	1951-1957	1960-1964	1976-1978
Gunnison	1889-1905	1931-1938	1951-1957	1960-1964	1975-1978
Colorado Mainstem	1889-1905		1951-1957	1960-1965	1976-1978
Yampa, White	1901-1905	1934-1937		1963-1965	1976-1978

Source: McKee, Doesken, and Kleist, Historical Dry and Wet Periods in Colorado, 1999.

Baca County, Colorado, about 1936

Photo by D. L. Kernodle

Drought can significantly impact Colorado's water dependent economy.

· Tourism, agriculture, hydropower generation, municipal government, manufacturing, and mining all depend to some degree on a firm supply of water.
· The potential impact of drought on the economy depends on how much water is demanded by each sector and how much is consumed, when and where it is consumed, and if it can be stored before use.
· Tourism, generally a non-consumptive water use that demands water for recreation (skiing, rafting, fishing and boating) and the environment (in-stream flows and forests), would be heavily impacted by drought.
· Agriculture and livestock, the state's 3rd largest economic sector, has the state's greatest water demand and would be heavily impacted.
· Hydropower generation in Western Colorado does not "consume" water, but it is the second most significant water demand and would be heavily impacted.
· Municipal, domestic, and commercial water demands, while less significant, could be seriously impacted depending on the degree of drought planning in each community.
· Other sectors of the economy, such as manufacturing and mining, demand less than 1% of the total water demand and might only be impacted through secondary impacts to the economy.

Reservoir storage has been a critical element of western drought management strategy.

· Most of the surface water supply in Colorado comes during the 4 month snowmelt runoff months of April, May, June, and July.
· Reservoir storage grew tremendously after drought in the 1930's and 1950's.
· By about 1970, active reservoir storage in Colorado peaked at about 1.5 acre-feet per person and has been steadily declining ever since.
· By about 1990, total statewide active reservoir storage capacity exceeded 4 million acre-feet.
· But the population is growing faster than new surface water supplies and reservoirs are being developed.

The next drought in Colorado will pose a significant water management challenge.

· The growth of our population is resulting in the need for more water for municipal and industrial (M&I) use. Assuming one acre-foot per 4 persons per year, the need for M&I water is projected to increase from 1.0 million acre-feet in the year 2000 to 2.2 million acre-feet in 2100.
· There is a growing desire for water based recreational and environmental use. The patterns of water use are changing from a seasonal demand to a year round demand, from a diversion from a stream to an in-stream flow.
· Not only is there competition to change water use patterns, but we are faced with challenges from downstream states and the influence of national laws and changing perspectives.
· Considering Colorado's growing population, demand management will play a huge role in reducing the future impact of drought.

"And it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It was always like that."
John Steinbeck
East of Eden

Checklist of Historical, Current, and Potential Drought Impacts

This checklist of drought's effects can help planners anticipate problems that might arise in future droughts. Many planners find it useful to identify the "drought of record," that is, the worst ever recorded, examining its actual effects, and projecting what the effects would be if the same drought were to occur under current conditions and in the future.

If enough time, money, and personnel are available, it might be useful to conduct impact studies based on common droughts, extreme drought(s), and the "drought of record" for your region. This would yield a range of impacts related to different degrees of severity.

H = Historical Drought
C = Current Drought
P = Potential Drought

H	C	P	**Economic**
			Costs and losses to agricultural producers
☐	☐	☐	Annual and perennial crop losses
☐	☐	☐	Damage to crop quality
☐	☐	☐	Income loss for farmers due to reduced crop yields
☐	☐	☐	Reduced productivity of cropland (wind erosion, long-term loss of organic matter, etc.)
☐	☐	☐	Insect infestation
☐	☐	☐	Plant disease
☐	☐	☐	Wildlife damage to crops
☐	☐	☐	Increased irrigation costs
☐	☐	☐	Cost of new or supplemental water resource development (wells, dams, pipelines)
			Costs and losses to livestock producers
☐	☐	☐	Reduced productivity of rangeland
☐	☐	☐	Reduced milk production
☐	☐	☐	Forced reduction of foundation stock
☐	☐	☐	Closure/limitation of public lands to grazing
☐	☐	☐	High cost/unavailability of water for livestock
☐	☐	☐	Cost of new or supplemental water resource development (wells, dams, pipelines)
☐	☐	☐	High cost/unavailability of feed for livestock
☐	☐	☐	Increased feed transportation costs
☐	☐	☐	High livestock mortality rates
☐	☐	☐	Disruption of reproduction cycles (delayed breeding, more miscarriages)
☐	☐	☐	Decreased stock weights
☐	☐	☐	Increased predation
☐	☐	☐	Range fires

H	C	P	Economic (continued)
			Loss from timber production
☐	☐	☐	Wildland fires
☐	☐	☐	Tree disease
☐	☐	☐	Insect infestation
☐	☐	☐	Impaired productivity of forest land
☐	☐	☐	Direct loss of trees, especially young ones
			Loss from fishery production
☐	☐	☐	Damage to fish habitat
☐	☐	☐	Loss of fish and other aquatic organisms due to decreased flows
			General economic effects
☐	☐	☐	Decreased land prices
☐	☐	☐	Loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, dairies, etc.)
☐	☐	☐	Unemployment from drought-related declines in production
☐	☐	☐	Strain on financial institutions (foreclosures, more credit risk, capital shortfalls)
☐	☐	☐	Revenue losses to federal, state, and local governments (from reduced tax base)
☐	☐	☐	Reduction of economic development
☐	☐	☐	Fewer agricultural producers (due to bankruptcies, new occupations)
☐	☐	☐	Rural population loss
			Loss to recreation and tourism industry
☐	☐	☐	Loss to manufacturers and sellers of recreational equipment
☐	☐	☐	Losses related to curtailed activities: hunting and fishing, bird watching, boating, etc.
			Energy-related effects
☐	☐	☐	Increased energy demand and reduced supply because of drought-related power curtailments
☐	☐	☐	Costs to energy industry and consumers associated with substituting more expensive fuels (oil) for hydroelectric power
			Water Suppliers
☐	☐	☐	Revenue shortfalls and/or windfall profits
☐	☐	☐	Cost of water transport or transfer
☐	☐	☐	Cost of new or supplemental water resource development
			Transportation Industry
☐	☐	☐	Loss from impaired navigability of streams, rivers and canals
			Decline in food production/disrupted food supply
☐	☐	☐	Increase in food prices
☐	☐	☐	Increased importation of food (higher costs)

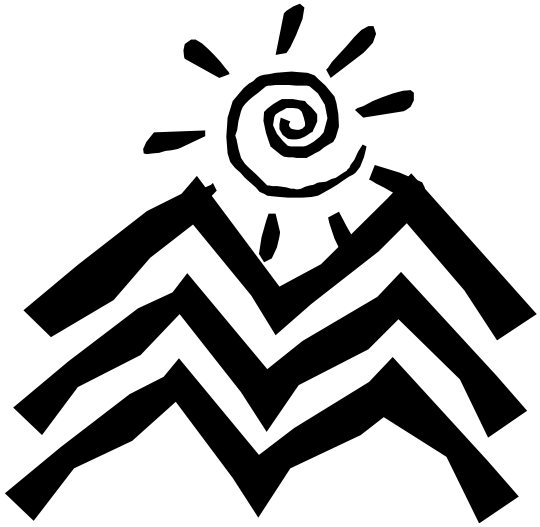
H	C	P	Environmental
			Damage to animal species
☐	☐	☐	Reduction and degradation of fish and wildlife habitat
☐	☐	☐	Lack of feed and drinking water
☐	☐	☐	Greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant
☐	☐	☐	Disease
☐	☐	☐	Increased vulnerability to predation (from species concentrated near water)
☐	☐	☐	Migration and concentration (loss of wildlife in some areas and too many in others)
☐	☐	☐	Increased stress to endangered species
☐	☐	☐	Loss of biodiversity
			Hydrological effects
☐	☐	☐	Lower water levels in reservoirs, lakes and ponds
☐	☐	☐	Reduced flow from springs
☐	☐	☐	Reduced streamflow
☐	☐	☐	Loss of wetlands
☐	☐	☐	Estuarine impacts (e.g., changes in salinity levels)
☐	☐	☐	Increased ground water depletion, land subsidence, reduced recharge
☐	☐	☐	Water quality effects (e.g., salt concentration, increased water temperature, pH, dissolved oxygen, turbidity)
☐	☐	☐	Damage to plant communities
☐	☐	☐	Loss of biodiversity
☐	☐	☐	Loss of trees from urban landscapes, shelterbelts, wooded conservation areas
☐	☐	☐	Increased number and severity of fires
☐	☐	☐	Wind and water erosion of soils, reduced soil quality
☐	☐	☐	Air quality effects (e.g., dust, pollutants)
☐	☐	☐	Visual and landscape quality (e.g., dust, vegetative cover, etc.)

H	C	P	Social Impacts
			Health
☐	☐	☐	Mental and physical stress (e.g., anxiety, depression, loss of security, domestic violence)
☐	☐	☐	Health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations, reduced fire fighting capability, etc.)
☐	☐	☐	Reductions in nutrition (e.g., high-cost food limitations, stress-related dietary deficiencies)
☐	☐	☐	Loss of human life (e.g., from heat stress, suicides)
☐	☐	☐	Public safety from forest and range fires
☐	☐	☐	Increased respiratory ailments
☐	☐	☐	Increased disease caused by wildlife concentrations
			Increased conflicts
☐	☐	☐	Water user conflicts
☐	☐	☐	Political conflicts

☐	☐	☐	Management conflicts
☐	☐	☐	Other social conflicts (e.g., scientific, media-based)
			Reduced quality of life, changes in lifestyle
☐	☐	☐	in rural areas
☐	☐	☐	in specific urban areas
☐	☐	☐	increased poverty in general
☐	☐	☐	population migrations (rural to urban areas, migrants into the U.S.)
☐	☐	☐	loss of aesthetic values
☐	☐	☐	reduction or modification of recreational activities
☐	☐	☐	Disruption of cultural belief systems (e.g., religious and scientific views of natural hazards)
☐	☐	☐	Reevaluation of social values (e.g., priorities, needs, rights)
☐	☐	☐	Public dissatisfaction with government drought response
☐	☐	☐	Perceptions of inequity in relief, possibly related to socioeconomic status, ethnicity, age, gender, seniority
☐	☐	☐	Loss of cultural sites
☐	☐	☐	Increased data/information needs, coordination of dissemination activities
☐	☐	☐	Recognition of institutional restraints on water use

A History of
DROUGHT IN COLORADO

LESSONS LEARNED AND WHAT LIES AHEAD



No. 9 - Second Edition
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"When drought returns to Colorado, as it surely will, it will be challenging to see just how far we can stretch our water."

by
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in collaboration with

William P. Stanton
Colorado Water Conservation Board

Open Letter on Drought in Colorado

Dear Reader:

Over 20 years ago, the severe winter drought of 1976-77 sent shock waves through Colorado's economy and state government. Bare ski slopes, empty reservoirs, and drifts of topsoil left many of us in government feeling helpless and ill prepared. At that time, Governor Richard Lamm convened a special council of experts who assessed the crisis and proposed ideas for lessening the impacts on recreation-based industries and agriculture.

The greatest frustration expressed by decision makers then was the lack of timely and integrated information on which to make plans and base actions. How severe and how widespread were the drought conditions? Who was affected and what were the current and emerging impacts? The state needed better information.

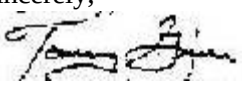
The crisis motivated actions, but by 1978 heavy snows and spring rains were falling again. As is often the case, when the immediate crisis passed, proposed actions were tabled. Then came the winter of 1980-81 with another round of severe snow shortages. Governor Lamm, who was still in office, brought back many of the same experts. Within a matter of months the "Colorado Drought Response Plan" was approved and implemented. While it is arguable that this plan could immediately reduce drought impacts, what the plan did accomplish was to identify drought as a major natural hazard in Colorado and to establish clear mechanisms for monitoring drought conditions and impacts, and communicate water supply and drought impact information to decision makers. Colorado was one of the first states to institutionalize drought monitoring and response, and has been very active ever since in promoting research and encouraging drought mitigation efforts.

This report describes some of the new techniques for drought monitoring that have been developed in Colorado, and presents results of drought studies which have been supported by the Colorado Office of Emergency Management, the Colorado Water Resources Research Institute and the Colorado Agricultural Experiment Station.

Since the "Colorado Drought Response Plan" was implemented in 1981, Colorado has enjoyed the longest period free from widespread multi-year droughts since before the 1930s "Dustbowl." Yes, we now have better information about drought and improved data on the frequency and severity of droughts from the past. But with the very generous precipitation for the period 1982-1999, are we ready and able to deal with drought and its consequences?

Please take the time to read this report. At the very least, I hope this will remind us all how real the threat of drought is here in Colorado so that we can be better prepared when the next drought threatens.

Sincerely,



Tommy Grier, Director
Colorado Office of Emergency Management

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Colorado is a dry state.

Annual precipitation in Colorado averages only 17 inches statewide. The majority of the state is considerably drier with only 12-16 inches of precipitation annually. The San Luis Valley in south-central Colorado is the driest region, averaging only seven inches in the center of the valley. In comparison to the large majority of the area of the United States, these precipitation totals are meager — less than half of the precipitation that falls over the U.S. corn belt, for example. But Colorado benefits from much higher precipitation amounts on the ranges of the Rocky Mountains that cover the state from north to south. Most of the areas above 10,000 feet in elevation average more than 25 inches of moisture annually, with more than 50 inches in a few isolated high-mountain locations.

With great effort, some planning, and a history of diligence and creativity, Colorado has adapted to this dry climate such that the state successfully maintains a large agricultural industry, large and growing urban population centers, a vast and diverse recreational industry and a high quality of life for the citizens of the state, while still sending large volumes of water to downstream states on the major rivers.

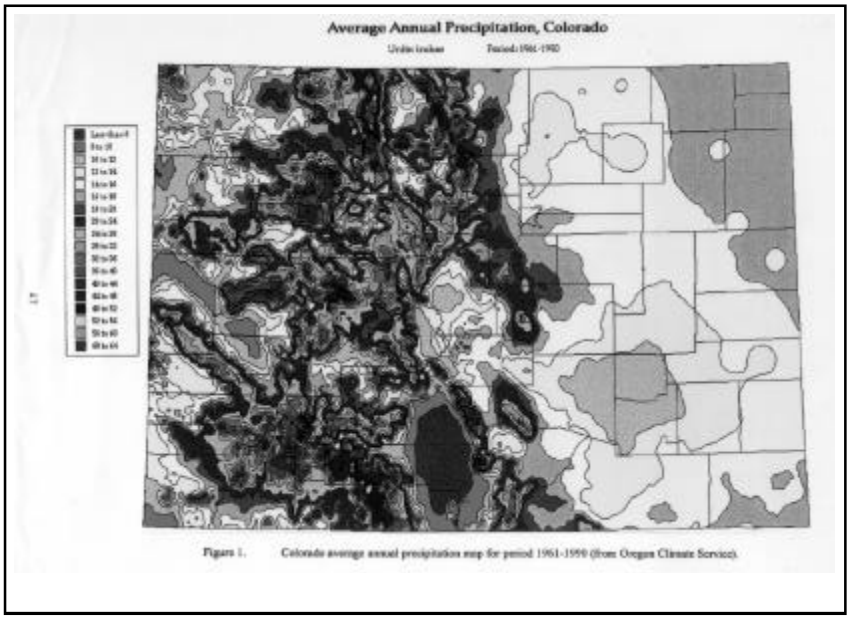
But a threat looms over Colorado and its vibrant economy. It is the threat that is with us nearly every year but which often goes unnoticed or ignored. It is the threat of drought -- and the social, economic, and environmental impacts that come with drought.

Colorado's population continues to grow rapidly. Much of this population growth has occured since the last major statewide drought in 1981. In recent decades, there has also been an introduction of several newer uses of water in the state. Water is now needed to support populations of endangered species, mountain snow making, and river and reservoir recreationists as well as more traditional uses for farmers, for hydropower generation, and for rapidly growing thirsty cities.

So far, we have done a fairly good job meeting these diverse demands while still delivering the water to downstream states as prescribed by interstate compacts. We have been able to meet these demands in part through changes in water management, but also (and perhaps most importantly) through the abundance of water availability that we have enjoyed. The last multi-year drought in Colorado ended in 1978. The last two decades have brought Colorado the most reliable precipitation since before the "dust bowl" drought of the 1930s. When drought returns to Colorado, as it surely will, it will be challenging to see just how far we can stretch our water.

A study of historical dry and wet periods in Colorado was recently completed by the Colorado Climate Center at Colorado State University. This study, which is summarized in this report, analyzed precipitation, snowpack, and streamflow data over the last 100 years or so, and provides some important insights into the nature of drought in Colorado.

Before we can understand dry, or "below normal", and wet, or "above normal" precipitation, we need to understand what is considered "normal" in Colorado, a state that experiences a wide range of climate patterns in different parts of the state and at different times of the year. We also discuss how and when water is used in Colorado, since this gives us an understanding of who will be impacted by "single season" droughts. We consider some implications of the new uses of water and new demands for water availability that have developed in Colorado. Finally, we look at Colorado's drought history and what that history can tell us about droughts in Colorado's future.



What is drought?

Drought is unique among natural hazards because it is not a clear event, like a flood, earthquake, hurricane or tornado. These events strike, leave their mark, and are gone. A drought, however, sneaks up on us quietly disguised as lovely, sunny weather. Unlike a hurricane, we cannot follow its course on a map. We are never sure when a drought began until after it is already well underway, and we are often unsure when it ends. Any day when it doesn't rain or snow (which describes the majority of days here in Colorado) could be the beginning of the next drought.

Which still does not answer our question: what is drought?

Drought is a concept that is both simple and complex. Drought is a shortage of water, usually associated with a deficiency of precipitation. Drought occurs when the demand for water exceeds the supply of water.

Simple, right?

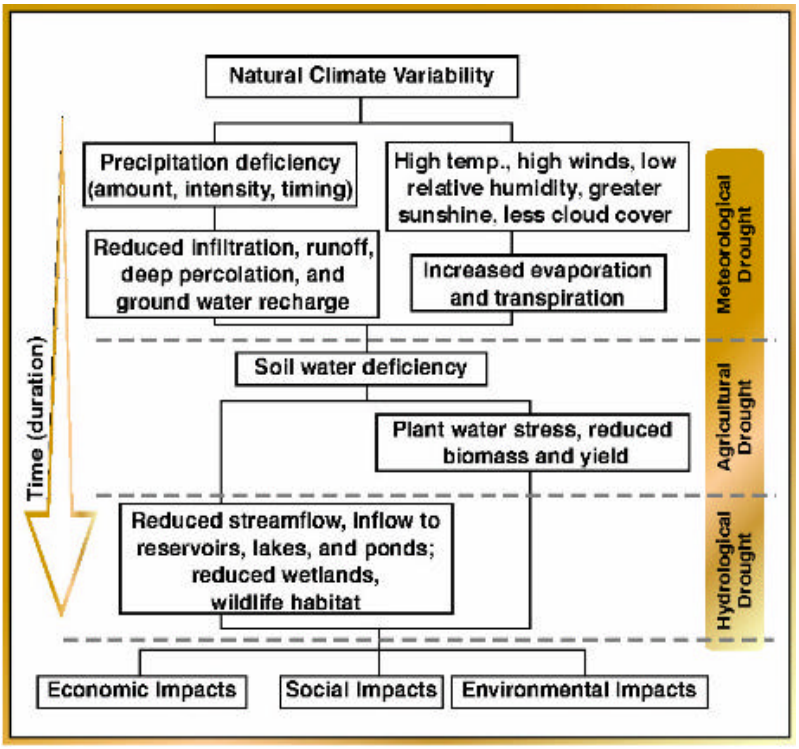
Yes, except that different types of demands require different amounts of water in different forms at different times of the year. Droughts are often defined by their impacts, e.g. on crops or on reservoir water levels and power availability. Thus, there is no universal definition of a drought. The more diverse the economy and the climate of a region are, the harder it is to define drought. Drought means different things to different people; one person's drought can be another person's "sunny day."

Drought is also "relative" and must be defined in terms of what is "normal" for a particular region or time of year. To someone who has lived in Nevada or Arizona, Colorado looks mighty green and lush. Folks who just moved here from the eastern half of the United States, however, may think that Colorado experiences perpetual drought. In fact, for most locations east of Omaha or Kansas City, the driest year on record may still be wetter than the wettest year on record for most of Colorado's lower elevations. Coloradoans have adapted to this dry regime.

One important measure of drought is the impacts of water shortage on nature and society. These impacts may change over time as new mitigation measures are developed. For example, many water users in Colorado are able to store water over time, or transport water from other parts of the state, or use groundwater recharge to re-regulate streamflows, or make artificial "snow" for ski areas. Since Colorado receives new water supplies only one way – as rain, snow, or other precipitation – some form of precipitation is necessary to provide water to Colorado's population and economy. That precipitation, however, does not necessarily fall on the populations that use the water most or at the times when it is most needed.

Understanding – and thus preparing for – a severe drought in Colorado requires an appreciation of how Colorado receives its water supply and how different water demands use that supply. This paper presents a discussion of Colorado's water supplies and demands, and an analysis of the history of wet and dry periods in Colorado.

Several definitions of drought have been proposed by various agencies. The figure, which is from a publication by the National Drought Mitigation Center (http://enso.unl.edu/ndmc/), illustrates a set of definitions that show both causes and impacts of drought over time, namely: meteorological drought, agricultural drought, hydrological drought, and socioeconomic (and environmental) drought. Another important definition of drought concerns wildfire risk. This paper deals primarily with meteorological drought and the history of wet and dry periods in Colorado. However, the impacts of droughts of different durations, levels of severity, and areal extent, are also discussed.



Measuring and Assessing Drought

Because drought can be defined in so many ways, based on both the causes (lack of supply) and the effects (adverse impacts to water users), several methods have evolved to measure and assess drought. A variety of monitoring and analytical tools are available to help track precipitation and current water supply anomalies, and to identify and describe droughts that have occurred in the past. In particular, several indices are used to help simplify complex data to provide information for planners and decision makers. Paleoclimatic techniques, such as measurement of tree rings, ice cores, pollens, and ancient lake levels, are also employed to study drought patterns and frequencies over the past several centuries.

Instrumental data are used extensively for monitoring precipitation, snowpack, streamflow, and reservoir levels. **Precipitation** is measured daily at several hundred locations across Colorado. Some National Weather Service stations have data collected for 100 years or more, and are used extensively by the Colorado Climate Center at Colorado State University for drought research. **Snowpack** data, critical for predicting runoff and surface water supplies, are collected at higher elevations by the Natural Resources Conservation Service, U.S. Department of Agriculture. A few of these sites date back more than 60 years. Precipitation and snowpack data have been analyzed in a recent study (summarized in this report) to determine the patterns of wet and dry periods and their hydroclimatic impacts in Colorado over the last 100 years. Monitoring this data is very important to predict near-future drought potential. **Streamflow** is the net result of precipitation, snowmelt, evapotranspiration, infiltration and groundwater recharge, as well as man-made influences such as irrigation diversions and reservoir storage and releases. The combination of streamflow readings and reservoir levels provides the best direct indication of available surface water supplies in each of our river basins.

These climate observation networks provide important data to analyze current and historic droughts and relate water availability to the observed impacts. Years of experience, along with common sense, have shown that the types and levels of drought impacts are directly related to the following drought characteristics:

- **Magnitude** (how large the water deficits are in comparison with historic averages)
- **Duration** (how long the drought lasts)
- **Areal Extent** (what area is impacted by the drought)

Severity, the most commonly used term for measuring drought, is a combination of the magnitude or "dryness" and the duration of the drought. This combination can be linked to actual impacts from a drought. Traditional maps and graphs of precipitation, snowpack, and streamflow patterns continue to be used extensively for identifying drought. The following set of indices are also used in Colorado:

The **Palmer Drought Severity Index** is a complex soil moisture calculation that is used by federal agricultural agencies to determine when to provide drought assistance. Since this index was developed for areas of the country with more homogeneous climates, Colorado adapted the index by separating the state into 25 climatically similar regions.

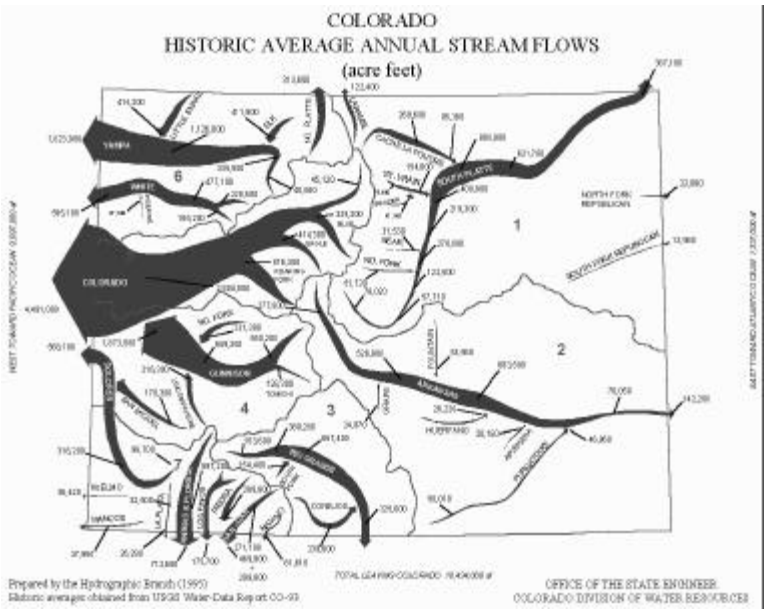
The **Crop Moisture Index** was developed from the Palmer Index, and was designed to evaluate short-term moisture conditions across major crop producing regions. It uses the average temperature and total precipitation for each week and compares the calculated index with the previous week. This is a better index to measure rapidly changing conditions and for comparing different locations.

The **Surface Water Supply Index** (SWSI, pronounced "swazee") was developed in Colorado, and is used in many Western states to provide a weighted index of snowpack, streamflow, precipitation, and reservoir storage. The SWSI is calculated independently for each basin due to differences in climate and reservoir capacities. The weighting factors for this index change from winter to summer.

The **Standardized Precipitation Index** (SPI), also developed in Colorado, appears to be the simplest yet most robust index for describing drought patterns. The SPI is based on current and historical precipitation data for a particular location. The SPI is proportional to precipitation deviation from the "average" (surplus or deficit) for that location, and has a unique probability that the deviation would occur at that location. The SPI can be computed for different time scales, can provide early warning of drought and help assess drought severity, and is less complex than the Palmer Index. The SPI identifies a beginning and end for each drought, as well as an intensity level for each month in which the drought occurs. The following table shows the values for the SPI index.

SPI Values	
2.0 +	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

An excellent discussion of different drought indices is available on the National Drought Mitigation Center web site at http://enso.unl.edu/ndmc/enigma/indices.htm



How Colorado Gets its Water

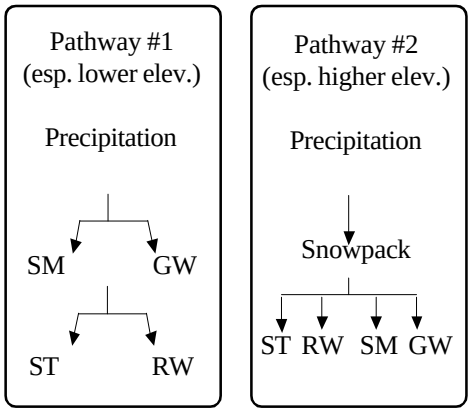
Colorado gets new water supplies[1] from only one source: precipitation, in the form of rain, hail, or snow. Colorado gets all of its water from precipitation because there are no major rivers that flow INTO Colorado.[2] There are several major river basins, originating in the Colorado Rockies, that flow OUT of the state, providing water to much of the southwestern United States, and contributing to the Missouri and Mississippi rivers as well. Thus, Colorado earns its title as "the Mother of Rivers."

Although the main source of Colorado's water supplies is precipitation, Coloradoans typically do not use water directly in the form of precipitation. Usually, water comes to Colorado as precipitation but is then stored in one of five forms of usable water:

- snowpack (SN), used directly for recreation, although it also serves as a storage of water supplies;
- streamflow (ST), used for recreation, habitat, irrigation and municipal water supplies, as well as to meet interstate compact obligations;
- reservoir water (RW), used similarly to streamflow;
- soil moisture (SM), used for natural vegetation and agriculture; and
- groundwater (GW), used for irrigation and municipal water supplies.

The amount of time it takes for precipitation to turn into a usable form of water can vary greatly. Precipitation can add to soil moisture or snowpack almost immediately. However, there can be delays of several days or weeks before precipitation adds to the water levels in streams, reservoirs, or groundwater aquifers. During those time delays, some precipitation can be lost to evaporation. Thus, some of the brief summer rains that fall in Colorado will add little or no water to the usable water supply. Water can also be stored as snowpack for months before melting to become streamflow, then reservoir water or groundwater.

There are two natural pathways by which water from precipitation become a usable source of water supply:



The first pathway is that precipitation falls on the ground and becomes soil moisture (SM) and groundwater (GW) to support vegetation and other uses locally where it occurs. A portion may also become streamflow (ST) and reservoir water (RW). This is the dominant pathway for all lower elevations of the state and for the higher elevations in the summer season.

The second pathway is that precipitation falls as snow at higher elevations in the winter season to become snowpack (SN), and later becomes available as streamflow (ST), reservoir water (RW), soil moisture (SM) and groundwater (GW) during the following spring and summer. This is the primary pathway by which mountain snows provide surface water resources for the state, and results in peak streamflows occuring from April through July.

[1] Not including ancient aquifers, such as in the Denver basin, which receive little or no recharge and are being "mined."

[2] Well, OK, there's Little Snake River, which starts in Wyoming, enters Colorado briefly to join the Yampa before leaving for Utah. The Green River also starts in Wyoming, flows to Utah, then comes into Colorado briefly to join the Yampa before leaving the state again.

Precipitation: Colorado's Direct Source of Water

Of all the elements that make up our climate, precipitation – how it forms and when and where it falls — is perhaps the most interesting and significant. Here are a few important traits of precipitation.

1) Unlike temperature, humidity and wind, which are continuous variables, **precipitation comes in episodes.** Depending on where you are in Colorado, precipitation falls only two to six percent of the time, on average.

2) **Precipitation is highly variable both in time and space.** No two years are ever alike. Within the state boundaries, it is extremely rare to have all parts of the state experiencing above or below average precipitation at the same time, even for a month. There is always diversity with some areas wet while others are dry. At any given point, annual precipitation totals can vary from only about half of the long term average in a very dry year to close to double the average in a very wet year. In relative terms, the variability is even greater for seasons or single months.

3) **Rain versus snow** – the fraction of annual precipitation that falls as snow varies greatly across Colorado from less than 15% over southeast Colorado to more than 70% at high elevations in Colorado's northern mountains. This has a major bearing on our water balance and helps determines how much moisture evaporates, soaks into the ground, or runs off to become stream flow and reservoir supplies.

4) **A few big storms contribute the majority of the precipitation that falls each year.** More than half of the total annual precipitation falls in only 20% of the days when precipitaiton occurs. The other half of annual precipitation comes from the remaining 80% of days when it rains, snows, or hails. What this means is that the difference between a very wet and a very dry year may come down to the presence or absence of just a few major storm systems.

5) **Precipitation is highly seasonal.** Most areas have well defined times of year that are distinctly wetter than others. This is not unusual as is typical for many parts of the world to have pronounced and repeatable wet and dry seasons. For example, throughout all of California most precipitation falls during the winter with very little precipitation falling during the summer. What is unique about Colorado, however, is the amazing diversity of seasonality. Some parts of the state experience their annual wet season at the identical time that others are in their dry season. Depending on location in Colorado, any of the four seasons are "the wettest time of year" in some part of the state. Just the short distance from a mountain peak to a nearby valley bottom can result in wet and dry seasons being out of phase. For example, Denver's wettest period is in the spring, but just 30 miles to the west, Berthoud Pass has its maximum precipitation in mid winter. This complexity is very important for understanding drought development in Colorado.

6) **Long range prediction (weeks, months, or seasons in advance) is very difficult.** While considerable progress is being made in long-term climate prediction, it remains extremely difficult to accurately predict when and where precipitation will fall with confidence and reliability.

To help understand drought history and potential for future drought, a brief discussion of precipitation mechanisms and moisture sources is appropriate.

There are two essential ingredients for precipitation anywhere in the world:

- **Water vapor in the atmosphere**
- **Upward vertical motion, which cools the air so that the water vapor condenses.**

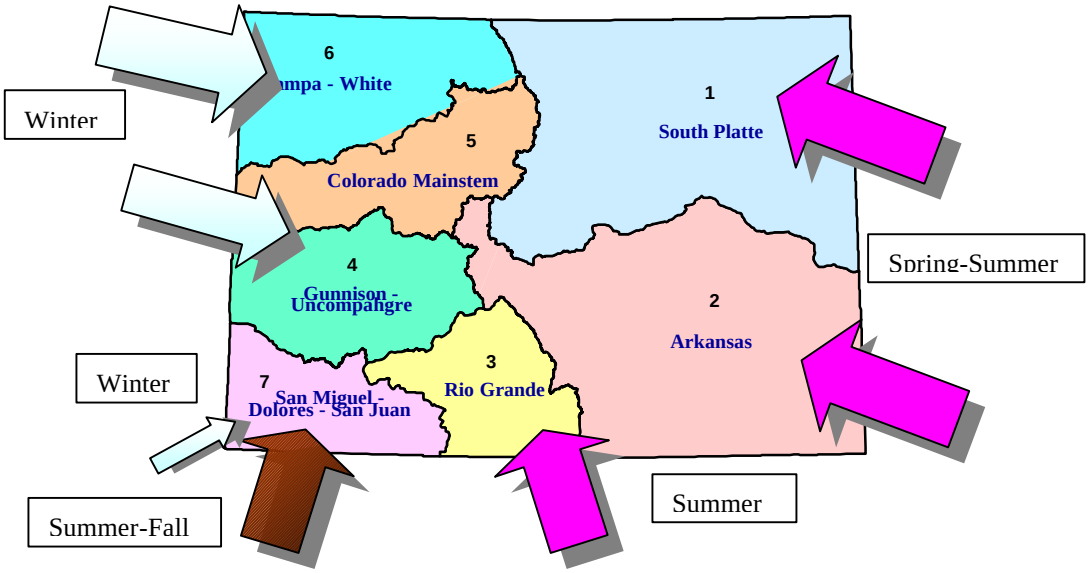
The complexities of precipitation patterns and seasonality in Colorado are largely a result of our interior continental location, far removed from primary oceanic moisture sources, in combination with Colorado's high elevation and rugged terrain. Three quarters of all land in the continental U.S. at elevations exceeding 10,000 feet is found here in Colorado. The Continental Divide that follows the crest of the Rockies through Colorado acts as an effective barrier to moisture transport, most of which occurs in the lower few thousand feet of the atmosphere.

In Colorado, the primary sources of water vapor in the atmosphere are:

- the Pacific Ocean
- Gulf of Mexico and recirculated Gulf moisture from evapotranspiration off of the land and vegetation throughout the Mississippi Valley
- Gulf of California and Gulf of Mexico moisture that reaches Colorado after first crossing Mexico

Mechanisms for producing rising air (upward vertical motion) in Colorado include convection (warm air rising), orographic (mountain-induced) lifting and large-scale storm systems that produce colliding air masses (storm-induced).

Figure: Sources of Atmospheric Moisture in Colorado



Although Colorado is far removed from oceanic moisture sources, moist air masses are carried to the state by global atmospheric circulations. These circulations migrate through the year, changing the sources of moisture that enter Colorado (as shown in the figure). The mechanisms to lift and cool air to saturation (when condensation and precipitation can occur) also change with the seasons.

During the late fall, winter, and early spring, the winds aloft are strongest over the mid latitudes of the northern hemisphere resulting from the very strong temperature gradients between the polar region and the equator. The great river of air known as "the jet stream" directs air masses and migrating storm systems approximately from west to east. During this time of year the Pacific Ocean is the primary source for moisture reaching Colorado. This is the time of year when storm systems are very strong and fast moving. This is also the time of year when orographic (mountain-related) air motions are most dramatic as rapidly moving air is lifted on the upwind side of each mountain barrier and then descends and warms on the leeward side of the mountains. Because of cold temperatures, however, total water vapor in the atmosphere is limited.

What this means for Colorado is that frequent snows near and immediately west of the each mountain range occur when enough Pacific moisture is present. Because of persisting cold temperatures in the mountains, most of the precipitation falls as snow and remains as snowpack that accumulates for several months until finally melting in the spring and summer. As the air moves east of the mountains, it descends, bringing very little winter moisture and periodic strong, dry winds. On occasion, a very strong winter storm will draw moisture northward from the Gulf of Mexico and for a matter of hours drop widespread "upslope" precipitation east of the Rockies. However, subsequent warmer days and sunshine will rapidly melt and evaporate much of this precipitation.

During the spring months, the westerly winds aloft begin to slow a bit and the air begins to warm. Storm systems are still present but move slower. This allows more moisture from the Gulf of Mexico to move northward and westward in advance of these storms. As a result, a few spring storms typically bring widespread precipitation along and east of the mountains. A single spring storm can deposit as much precipitation in eastern Colorado as most winter storms combined. This period of episodic widespread storms lasts from early March into early June. This is the wettest time of year for much of the Front Range and northeastern Colorado. At the same time, storms from the west diminish and contribute ever less Pacific moisture. June is the driest month of the year for much of western Colorado, while the last half of June is frequently hot, sunny and dry over most of the state.

During the summer months, winds aloft tend to be very light, and moist Pacific air masses no longer reach Colorado. The primary mechanism for lifting and cooling air to saturation becomes convective updrafts from the heating of air near the ground. Thunderheads (cumulonimbus clouds) become the primary cloud responsible for precipitation whenever sufficient moisture is present in the air. Occasionally, humid air from the Gulf of Mexico and the Mississippi Valley will drift into eastern Colorado. A few weak cold fronts will also drop southward from Canada to help trigger some local thunderstorms on the plains. Thunderstorms also become more frequent during July over the mountains and Western Slope of Colorado as air from the Gulf of California and/or Gulf of Mexico drifts slowly northward across Mexico and the Southwest U.S. This wind circulation associated with the "Southwest Monsoon" is responsible for an important wet season over portions of southern and western Colorado from July into September. July and August are the wettest months of the year for much of southern Colorado and many mountain valleys. When sufficient moisture is present, thunderstorms will develop every day in and near the mountains.

(continued on page 12)

Colorado's Typical Wet and Dry Seasons by Basin

It is common and necessary practice in watershed management to combine data from an entire basin including both high and low elevations. It is important to recognize, however, that the seasonality of precipitation may vary greatly within each basin, and that precipitation at different times of year across the basin may not be well correlated.

For many water management and planning applications, Colorado is divided into seven water divisions (see figure). Each of these basins originate in high mountain environments and descend through mountain valleys and eventually drop to much lower elevations. Thus, we can roughly divide each basin into an upper and lower basin based on approximate elevation and mountain proximity. The table below is not definitive, but is meant to give a general picture of the typical wet and dry periods experienced across Colorado.

Water Division I

South Platte, Upper: Wet Dec.-Apr., Dry June and again in Aug.-Oct.

South Platte, Lower: Dry Nov.-Feb., Wet Apr.-Jul.

Water Division II

Arkansas, Upper: Wet Dec.-Mar., Jul.-Aug., Dry (at the highest mountains) May-Jun.

Arkansas, Lower: Dry Nov.-Feb., Wet May-Aug.

Water Division III

Rio Grande, Upper: Wet Dec.-Mar. and mid-Jul.-early Oct., Dry May-mid-July.

Rio Grande, Lower: Dry Nov.-Apr., Wet mid-Jul-Sep. (NOTE: The San Luis Valley, which includes Great Sand Dunes National Monument, receives the least precipitation in the state, with an annual average of less than eight inches of precipitation.)

Water Division IV

Gunnison, Upper: Wet mid-Nov.-Mar., Dry mid-May-mid-Jun.

Gunnison, Lower: No significant wet season. Dry late May-Jun, slightly wet mid-Jul-Aug

Water Division V

Colorado, Upper: Wet late Nov.-Apr., Dry Jun-mid-Jul.

Colorado, Lower: On average, there is no clear wet or dry season in the lower portion of the Colorado River basin.

Water Division VI

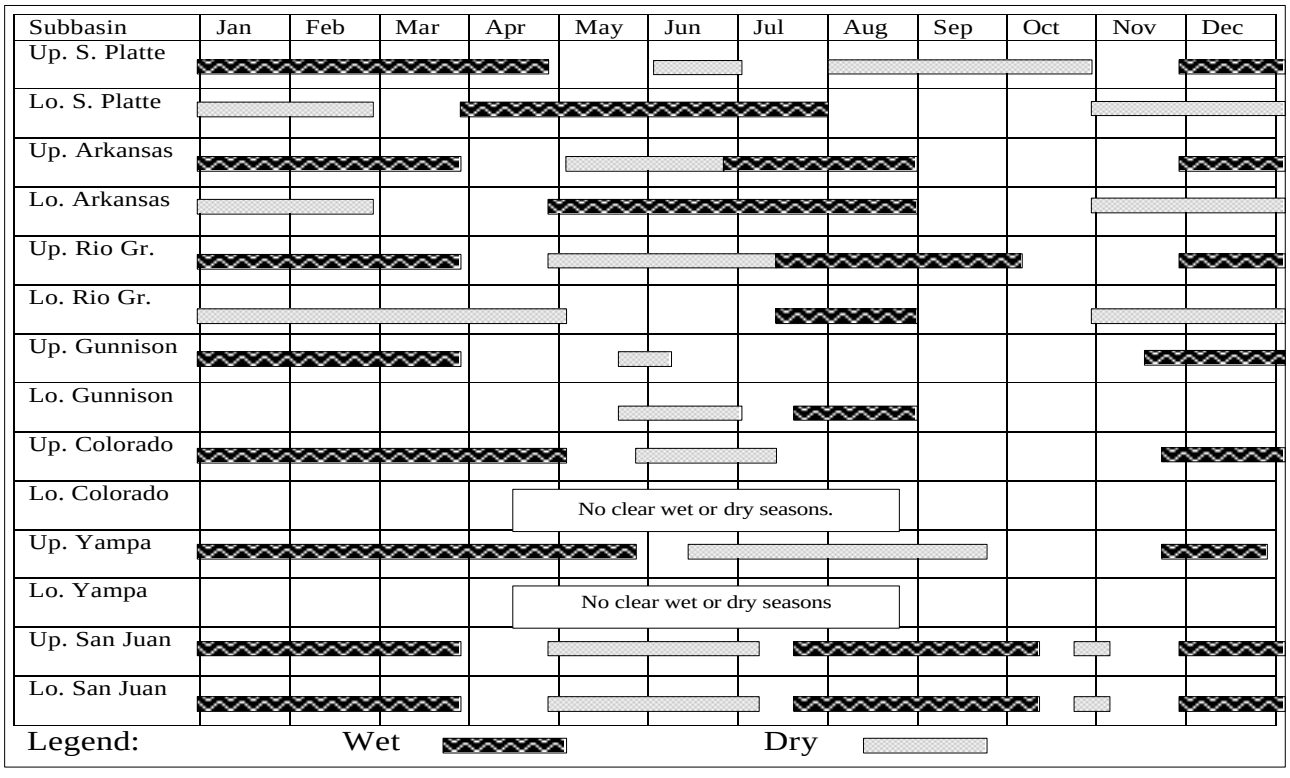
Yampa-White, Upper: Wet late Nov.-May, Dry mid-Jun.-Sep. (NOTE: The high mountains of this basin include some of the wettest areas of the state, receiving an average of more than 50 in/yr of precipitation.)

Yampa-White, Lower: Similar to the lower portion of the Colorado River Basin, with no clear seasons, and less likelihood of receiving rain from the summer monsoon.

Water Division VII

San Juan, Upper: Wet Dec.-Mar. and late Jul-early-Oct., Dry May-early Jul. and mid-Oct-mid-Nov. (NOTE: The high mountains of this basin are also among the wettest in the state, receiving more than 50 in/yr average annual precipitation.)

San Juan, Lower, Wet Dec.-Mar. and late Jul-early-Oct., Dry May-early Jul. and mid-Oct-mid-Nov. (NOTE: similar to the upper basin, but less wet in the wet seasons.)



Water Demands in Colorado: How and when we use our water

Before we continue our discussion of the history of wet and dry periods in Colorado, and considering drought and drought preparedness, we should remember that precipitation — our source of water supply — is only half of the drought picture. The impacts of a lack of precipitation on humans and nature depend on several factors including: how water is used; when water is needed; how much water is needed; and how long water can be stored before use.

Although this paper is based on research regarding the history of wet and dry periods in Colorado, some discussion is provided here of some of the major uses of water in Colorado to put these historic precipitation patterns in perspective. This is particularly important since the types and locations of water demands in Colorado have undergone some dramatic changes, particularly in the last 20 years. In many cases, important uses of water in Colorado are "non-consumptive", such as water in the form of snow for skiing or water in streams for recreation or habitat. Water is used multiple times between the time it enters Colorado as precipitation and the time it leaves the state as streamflow or evaporation. This discussion addresses the timing of water use and relative amount of water required for different demands in Colorado. As we have seen from the ski season of '76-'77 or any of several droughts that have impacted important crops in Colorado, major impacts to any of the economic sectors dependant upon these water uses have serious impacts on the economy of the **entire** state. In addition to these in-state uses of water, we also have several interstate compacts or agreements requiring water to flow from Colorado to other states.

Agricultural water supplies. This remains the number one water demand in Colorado. However, Colorado agriculture has undergone recent changes, including the introduction of new types of crops, new irrigation techniques, renewed interest in non-irrigated agriculture, and more drought resistant strains of traditional crops. Agricultural users have four sources of water: direct precipitation, streamflow diversions, reservoir storage and releases, and groundwater withdrawals. Storage of water in reservoirs is one form of drought mitigation. When more precipitation is available, however, farmers can rely less on their stored water supplies, and withdraw less water from streams and aquifers as well. Information on snowpack and precipitation that has fallen by early April is used to determine how the irrigation reservoirs are managed. Examples of **irrigated agriculture** in Colorado include corn, sorghum, dry beans, barley, potatoes, sugar beets, and vegetables. Water demands for most irrigated agriculture begin increasing in late April, peak in early July, and drop off into late October. **Non-irrigated or "dryland" crops** are more susceptible to damage by droughts, especially "single season" droughts. Major dryland crops, which include the largest acreage of crops in Colorado, include winter wheat and beans, as well as pastureland. Winter wheat crops are successful if they have some precipitation in the fall to start germination of the plants, and some precipitation in spring to develop the grains. Pastureland is particularly important for livestock. Newer non-irrigated crops include sorghum, corn, canola, and sunflowers, which are more drought resistant but still need adequate soil moisture and timely precipitation for a successful yield.

Municipal and industrial water supplies. Municipalities typically develop extensive storage facilities to ensure reliability of water supplies. For example, some cities have storage facilities in several different river basins, which allows them to use different sources of water in situations where one or more area has below normal precipitation. Water demands for industrial and many municipal uses are fairly constant throughout the year. However, about 50% of municipal water is used for watering of lawns and landscapes (e.g. parks and golf courses); these demands occur mainly in the summer.

Recreation. There are many uses of water in the state for recreation. Typically, recreational industries require that precipitation falls or has fallen by a certain time of year. For example, **ski resorts** must have water available for snow making in October and November, and snow direct from snow precipitation by November and continuing through April to ensure a successful season. The most profitable period, however, is during the December/January holiday season, so earlier snows are critical. **White-water rafting** is also dependant upon winter snows, although the timing of the snowfall is less important. Water for rafting comes from melted snow in the spring. Peak streamflows from snowmelt occur in May and June, and decreases later in the summer. **Summer recreation**, particularly in lakes (e.g. fishing and boating) requires water available in May through September.

Forests and Environmental Uses. National forests and parks are important for Colorado's economy both for timber resources and for tourism. Forest fire is also a major safety concern during droughts. In-stream uses of water to support animal and plant life and provide habitats is one of the more recent water demands of concern in Colorado. Water requirements to support critical habitat for different species vary throughout the year. Water planning and the management of water facilities now often include some consideration of these demands.

Hydropower A measurable amount of Colorado's power is generated in the form of hydroelectric energy, which can be provided when reservoir storage is high. If reservoir levels drop, the amount of energy that can be generated is reduced, and greater power demands by Colorado may impact "the Western Power Grid". Our peak power demands occur at the time when our water levels are falling, in the heat of the summer.

As summer comes to an end, the westerly winds aloft gradually increase again and low level moisture from the south and east retreat. The fall is often characterized by long periods of sunny, dry weather. Occasionally, however, Pacific moisture reaches western Colorado, sometimes in dramatic fashion as moisture from dissipated Pacific hurricanes sweeps northeastward. Infrequent but occasionally very heavy fall rains are an important part of the climate of western Colorado. A few storms will also harvest Gulf of Mexico moisture over eastern Colorado.

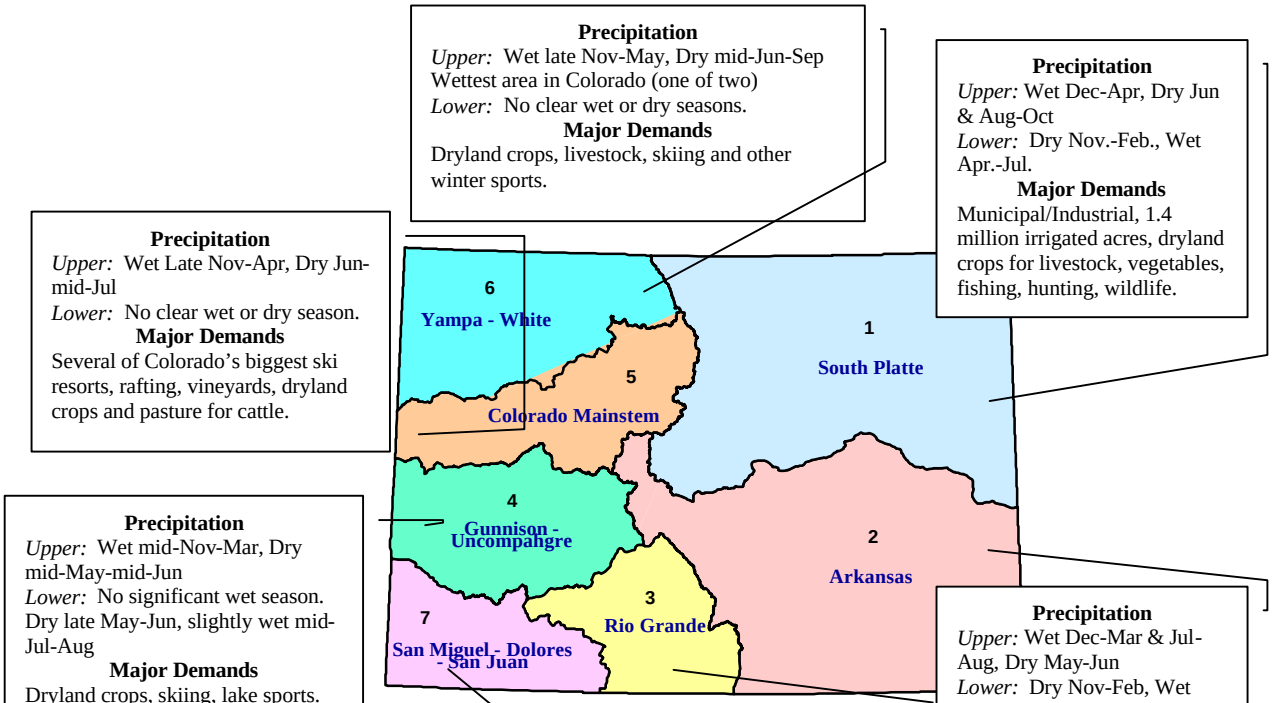
These seasonal weather patterns and the shifting of moisture sources through the year are a natural part of Colorado's variable climate. In combination with the topography of the state, the result is seasonal precipitation patterns that differ from north to south, from west to east and also locally as a function of elevation.

Drought can be initiated by either a lack of moisture from one or more of these predominant supplies, or a lack of upward vertical motion to harvest the water vapor from the atmosphere. Due to natural variations in our climate, single season droughts over some portion of the state are quite common. However, with so much climatic diversity and with such a variety of moisture sources and precipitation mechanisms, it is historically rare for all areas to be deficient at the same time. For example, in any given year, winter snowpack accumulation may be subpar in some portion of the mountains, but summer storms may compensate. Likewise, it is very common to have very dry winters east of the mountains, but a few spring storms can make up for winter deficits.

Multiple season and widespread droughts do happen, however, and we must be aware of their potential.

Major Water Demands in the Seven Colorado Water Divisions

The figure below shows the State of Colorado divided into the seven Water Divisions that are used for water right administration and management purposes by the Colorado Division of Water Resources. These Water Divisions correspond with the major river basins in the state, with some of the smaller river basins lumped together into a single division (e.g. the San Juan and Delores Rivers in the southwestern corner of the state, and the North Platte with the Yampe-White). Additional information on major water demands by basin available in *Water, Colorado's Precious Resource, 2nd Edition*.



Precipitation
Upper: Wet late Nov-May, Dry mid-Jun-Sep Wettest area in Colorado (one of two)
Lower: No clear wet or dry seasons.
Major Demands
Dryland crops, livestock, skiing and other winter sports.

Precipitation
Upper: Wet Dec-Apr, Dry Jun & Aug-Oct
Lower: Dry Nov.-Feb., Wet Apr.-Jul.
Major Demands
Municipal/Industrial, 1.4 million irrigated acres, dryland crops for livestock, vegetables, fishing, hunting, wildlife.

Precipitation
Upper: Wet Late Nov-Apr, Dry Jun-mid-Jul
Lower: No clear wet or dry season.
Major Demands
Several of Colorado's biggest ski resorts, rafting, vineyards, dryland crops and pasture for cattle.

Precipitation
Upper: Wet mid-Nov-Mar, Dry mid-May-mid-Jun
Lower: No significant wet season. Dry late May-Jun, slightly wet mid-Jul-Aug
Major Demands
Dryland crops, skiing, lake sports.

Precipitation
Upper: Wet Dec-Mar & Jul-Aug, Dry May-Jun
Lower: Dry Nov-Feb, Wet May-Aug
Major Demands
Some municipal/industrial, dryland crops including corn, alfalfa, and pasture, and vegetables and melons.

Precipitation
Upper: Wet Dec-Mar & late Jul-early-Oct, Dry May-early Jul & mid-Oct-mid-Nov Wettest area of Colorado (one of two).
Lower: Wet Dec-Mar & late Jul-early-Oct, Dry May-early Jul & mid-Oct-mid-Nov
Major Demands
Dryland crops, corn, apples, national parks, rafting, skiing.

Precipitation
Upper: Wet Dec-Mar & mid-Jul-early Oct, Dry May-mid-Jul.
Lower: Dry Nov-Apr, Wet mid-Jul-Sep (Driest area of Colorado)
Major Demands
Mostly crops irrigated with groundwater from San Luis Valley aquifer.

The Colorado Drought Response Plan

The State of Colorado has responded to and prepared for drought in several ways during this century. For example, state agencies have supported improvements in agricultural management, establishment of insurance programs, promotion of water conservation, and diversification of the regional economy. As the State responded to two short but intense droughts in 1976-1977 and again in 1980-1981, it became apparent that better coordination was required in the assessment of the development and impacts of drought, in the dissemination of information on developing droughts and on alternate responses available to decisions makers, and in the determination of when the State would act to request actions at the federal or local level. These concerns led to the development and implementation of Colorado's first Drought Response Plan in 1981. The purpose of the Plan is "**to provide an effective and systematic means for the State of Colorado to deal with emergency drought problems which may occur over the short or long term.**" The Plan was initially developed and implemented in 1981. It was revised in 1986 and again in 1990. As of December1999, the Plan is under review for a 2000 revision.

The Plan did not create a new government entity to deal with drought. Rather, the Plan provided a means for coordinating the efforts of those state agencies and related organizations (e.g. local government agencies, academic research centers and similar public and private organizations) that would be called upon to deal with drought, typically from the perspective of a particular economic sector (e.g. agriculture).

The Plan is organized into an **Assessment System** and a **Response System**. The Assessment System is organized into ten task forces: the Water Availability Task Force (TF#1), eight Impact Assessment Task Forces (TFs #2-9), and the Review and Reporting Task Force (TF #10). Of these task forces, only the Water Availability Task Force (WATF) meets continuously. The WATF has met at least quarterly since 1981, or more often if drought conditions are developing. The WATF consists of state, federal, local, and academic experts on drought analysis. This Task Force makes assessments and projections (in comparison with the historical norm) on:

- snowpack
- reservoir levels
- precipitant
- streamflows
- soil moisture
- ground water levels
- temperatures

If the WATF determines — based on their evaluations, experience, and common sense, and on whether certain "trigger levels" of drought indices (including the Palmer Drought Severity Index and the Surface Water Supply Index) have been reached — that drought conditions are developing, the WATF Chairman will notify the Governor and recommend activation of the Colorado Drought Response Plan. WATF notification will include information on which areas of the state will be most affected.

The Governor then activates the Review and Reporting Task Force, as well as the appropriate impact task forces. The Review and Reporting Task Force reviews and oversees the activities of the WATF and Impact Task Forces and prepares timely reports to leadership, the media, and key elements of the Response System. Local governments and state agencies are called upon to designate a drought coordinator. Each Impact Task Force assesses the potential drought impact for a particular economic sector or concern, and consists of representatives from agencies that would normally be responsible for issues related to that sector. The Impact Task Forces are:

TF #2: Municipal Water
TF #3: Wildfire Protection
TF #4: Agricultural Industry
TF #5: Tourism
TF #6: Wildlife
TF #7: Economic (aggregate economic loss)
TF #8: Energy Loss
TF #9: Health

The Response System consists of several lead agencies as well as an Interagency Coordinating Group (IACG). The IACG designates specific agencies as lead agencies for responses in appropriate areas, and ensures coordination of response activities by the various agencies. The Drought Response Plan states which of the emergency lead agencies are responsible for what responses. The IACG also handles media releases, coordination with the Executive Branch and state legislature, and makes recommendations regarding the need for a federal drought declaration.

The Office of Emergency Management and other agencies are currently reviewing the Colorado Drought Response Plan for a 2000 revision. Changes under consideration for the updated plan include increased guidance on drought impact mitigation for long term drought, and greater public access to and education on the Colorado Drought Response Plan and the state's current water availability status. Comments and suggestions on the Colorado Drought Response Plan would be welcomed by:

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15075 South Golden Road
Golden, CO 80401
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jeff.brislawn@state.co.us

Analysis of Historical Dry and Wet Periods in Colorado

Now that we have an understanding of how we define and assess droughts, how precipitation falls in different parts of Colorado, and how Coloradoans use that precipitation to supply water for different sorts of demands, we can look at the historical dry and wet periods in Colorado with a better understanding of the significance of those periods, and how similar dry or wet periods would impact Colorado today.

The historical record of precipitation, snowpack, and streamflow data wereanalyzed for each river basin in Colorado. The periods of above or below average precipitation were identified both for individual basins and for a majority of the state as a whole. The table on the following page shows the periods during which at least 60% of Colorado was wet or dry, as determined by the Standardized Precipitation Index (SPI) values for 24-month periods.

The analysis performed in this study revealed several important facts about dry and wet periods in Colorado:

1) Drought is a very frequent visitor to Colorado

- Single season droughts with precipitation of 75% or less of average for one to three months in a row occur nearly every year in Colorado.

- Based on the Standardized Precipitation Index, 3-month droughts with an index value of –1 or lower (equivalent to a moderate precipitation deficit with a probability of occurrence of no more than 16% for any consecutive 3-month period), occur approximately 90 in 100 years at any given location (see graph below).

- 93% of time at least 5% of state (based on percent of long term weather stations) is experiencing drought at either a 3-, 6-, 12- or 24-month time scale.

What this means is that Colorado is almost always in drought or near drought somewhere in the state.

2) Drought rarely encompasses the entire state.

- Only about five percent of the time (or approximately one year in twenty) does moderate or greater drought encompass at least half of the state at the same time.

- During recorded history, moderate drought (as defined by a standardized precipitation index value of –1 or lower) has never covered the entire state at the same time.

- Short-term droughts (3-month duration) have covered as much as 80 percent of the state. Longer-duration droughts (2-4 years) have reached to about 70 percent of the state.

What this means is that precipitation shortages rarely occur in the entire state at the same time. Economic and social impacts tied to a more "local" drought, however, can in turn affect the economy of whole state.

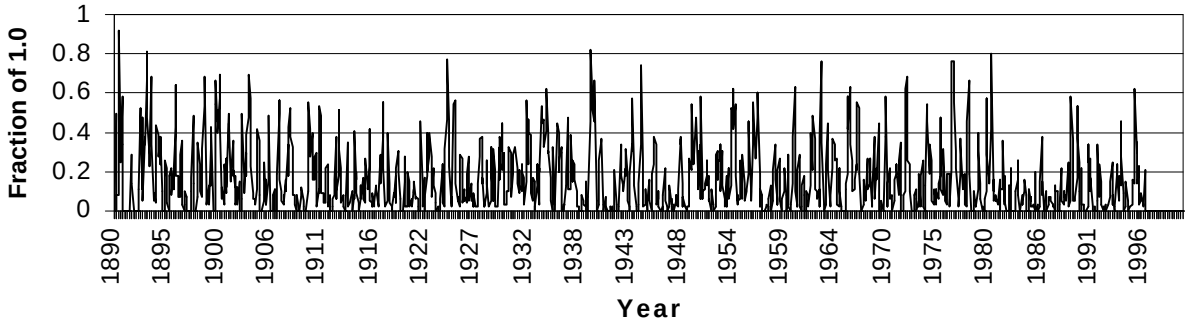
3) The most common droughts are short duration (6 months or less). They may be quite localized (especially during the growing season) or more widespread (especially during the fall, winter, and early spring). Depending on where and when they occur, they may have little or no impact on our lives. More widespread droughts do not necessarily have a tendency to become more long lasting.

4) Multi-year droughts occur infrequently.

- Precipitation time series for weather stations across Colorado show that periods of two or more consecutive years with much below average precipitation (less than 80% of average) have occurred a few times during the 20th Century at most Colorado stations. Below average precipitation lasting three years in a row, however, is quite rare. Many locations have never had three consecutive very dry years, particularly over the

(continued on page 16)

Fraction of Colorado in Drought
3-month SPI values



Summary of Colorado's droughts and prominent wet periods, 1890-1999.

NOTE: The dates in this summary are based on 12-month water year (Oct-Sept) precipitation totals from individual weather stations and thus are not identical to the dates in the table for 24-month periods, at the bottom of the page:

- 1890-1894 DRY Severe but brief drought in 1890, particularly east of mountains, followed by a very wet 1891. Dry 1893 with severe drought 1894, again most pronounced over eastern Colorado.
- 1898-1904 DRY Sustained and very severe drought over southwestern Colorado. Worst drought on record in Durango area. Some dry years elsewhere in Colorado, but not as severe or sustained. Very wet 1900 northeast Colorado.
- 1905-1929 WET Longest recorded wet period in Colorado history with greatest areal extent in 1905-1906, 1914-15, 1921, 1923 and 1927. Significant but brief droughts did occur during this period, most notably 1910-11, and 1924-25
- 1930-1940 DRY Most widespread and longest lasting (and most famous) drought in Colorado recorded history. Severe drought developed in 1931 and peaked in 1934 and early 1935. Interrupted by heavy spring rains in 1935 and more widespread heavy rains in 1938. Culminated with one more extremely dry year in 1939 when several stations along the Front Range recorded their driest year in history
- 1941-1949 WET Widespread wet weather, especially 1941-42, 1947 and 1949. Wet period interrupted with dry mountain winters – 1944-45 and 1945-46 with very low snowpack accumulation
- 1950-1956 DRY Extremely dry period statewide except for one very snowy mountain winter 1951-52. Most of state affected, and drought worse than the 1930s in some areas such as the Front Range.
- 1957-1958 WET 1957 brought persistent widespread drought-breaking precipitation across nearly all of Colorado – wettest year in recorded history.
- 1959-1973 DRY/WET Interesting roller coaster ride with alternating very wet and fairly dry periods and large spatial variations. Local drought was prevalent in 1959, 1960, 1962, 1963, 1964, 1966 and 1972. Very wet weather was reported in 1961, 1965, 1969, 1970 and 1973 with episodes of flooding.
- 1974-1978 DRY Colorado's most recent period of sustained multi-year drought culminating in the record-breaking winter drought of 1976-1977, the driest winter in recorded history for much Colorado's high country and Western Slope.
- 1979-1980 WET Brief but pronounced wet period with heavy winter snows helped replenish reservoirs.
- 1981 DRY An extreme but brief drought period from the fall of 1980 into the summer of 1981. This drought again took aim at the Colorado high country and ski industry and initiated a huge investment in snow making equipment. It also stimulated the writing of the "Colorado Drought Response Plan" and the formation of the "Water Availability Task Force" which has been meeting at least once a quarter each year since 1981.
- 1982-1999 WET Colorado's second longest sustained wet period in recorded history and the most drought free period since 1890. Extremely abundant snowpack and surface water supplies 1982-1987 – largest annual streamflow volumes this century on several rivers. Interesting period, 1987-1994 with only modest snow pack accumulation and consistently below average streamflows, but with low elevation precipitation above average reducing demand for surface water. Significant but brief drought in 1989 to early 1990 in southwest Colorado. A brief growing season drought in 1994 in northeast Colorado, and another localized drought over SW Colorado from late 1995 into 1996. Very wet statewide in 1995, 1997 and 1999. The decade of the 1990s has been the wettest in recorded history over much of southeastern Colorado.

Table of Dry and Wet Periods for Colorado from the Fraction of Observing Sites. Precipitation for 24 month SPI.

Date	Dry	Duration	Date	Wet	Duration
1893-1905	X	12 years	1905-1931	X	26 years
1931-1941	X	10 years	1941-1951	X	10 years
1951-1957	X	6 years	1957-1959	X	2 years
1963-1965	X	2 years	1965-1975	X	10 years
1975-1978	X	3 years	1979-1996	X	17 years

northern half of Colorado. The only examples of four or more consecutive years with less than 80% of the long term average falling each year were found over southwestern Colorado near the turn of the last century (1899-1902), in southeastern Colorado during the dustbowl years (1933-1937), and over isolated areas of eastern Colorado 1952-1956.

- Based on SPI analyses, four droughts with a duration of at least four years (48 months) have occurred during the past century (see graph below).

- The significance and impacts of drought tend to increase with increasing duration (1930s, 1950s).

- Brief but extreme droughts can also have severe impacts. For example, extremely dry weather in eastern Colorado in April, May and June can ruin most of the winter wheat crop, even if the rest of the year is quite wet. Likewise, a very dry December, January and February can have very adverse financial impacts on Colorado's winter recreation industry, even if late season snows make up most of the precipitation deficit.

- Drought episodes have lasted as long as 10 years (1930s). However, these long-duration droughts are interspersed with periods of wet weather. For example, some of Colorado's wettest months on record (April 1900, May 1935, September 1938) were embedded in long-duration drought episodes.

5) Spatial patterns of drought.

- There appears to be no such thing as a "typical" drought pattern.

- Each of the largest and most severe droughts have had their own unique formation and spatial patterns.

- Each region of the state has its own drought history which may be similar or totally different from other regions of the state. Northern Colorado is sometimes wet when southern Colorado is dry and vice versa. The same is true for east versus west.

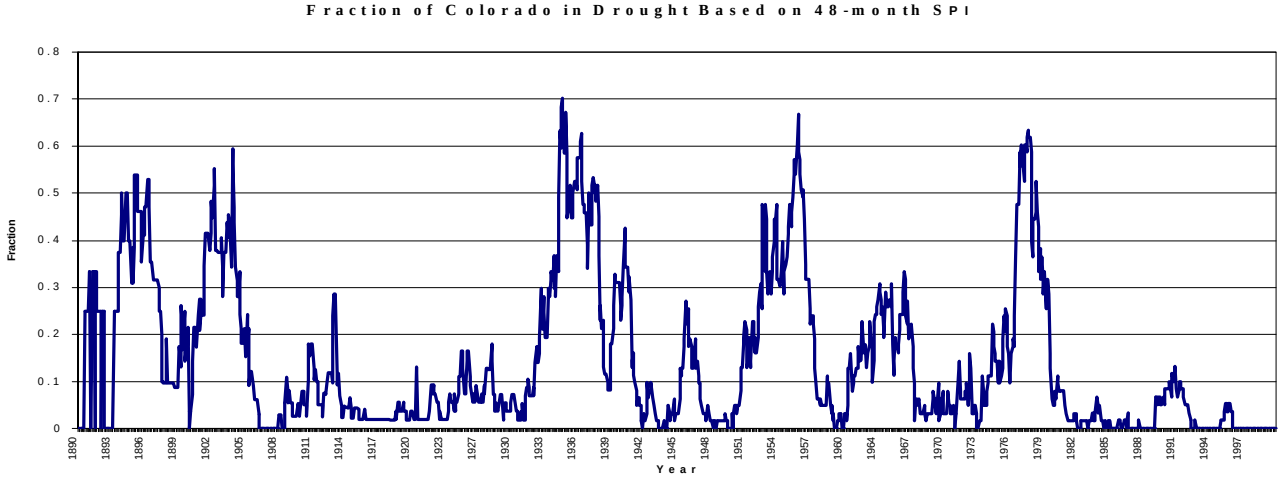
- It is rare for the entire state to exhibit similar precipitation patterns for more than a few months in a row.

6) Drought severity – how dry can it get?

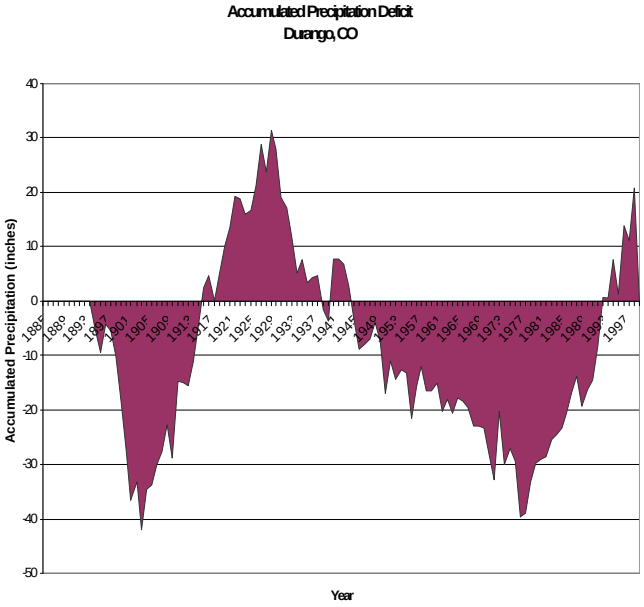
- Many areas of Colorado have gone without any measurable precipitation for up to 60 consecutive days. For a six-month winter season, 25-40% of the average accumulated precipitation represents an extremely dry winter (October-March). For an entire year, 50-60% of average represents an extreme drought year. Two to four months in a row with less precipitation than average is common. Five or more consecutive months with below average precipitation is very rare. Some weather stations have never had 6 or more consecutive dry months.

- Multiyear droughts of up to three consecutive years with less than 60% of average precipitation have occurred once or twice in the past 110 years at some locations in southeast and southwest Colorado. In Colorado's northern mountains, few sites have experienced two years in a row with less than 80% of average precipitation.

- Another way of looking at drought is by determining "accumulated deficits". For example, if your average annual precipitation is 16 inches, but you only received 12 inches, your accumulated deficit would be 4 inches for that year (see chart on the next page). When you accumulate deficits and surpluses year after year, you find that Colorado's worst droughts reach an equivalent deficit of about two full years of average precipitation. In Colorado's northern



mountains, and other areas with more reliable precipitation, accumulated deficits only reach about 1.2 years of average precipitation. For example, if Breckenridge averages 22 inches of precipitation per year, a very severe multi-year drought might result in an accumulated deficit of more than 22 inches over a few years time before above average precipitation reduces those deficits.



7) Timing of drought – When does it start? When does it end?

- Short duration droughts can begin and end in any season.

- Major droughts with durations of one year or longer tend to begin in and end in the season that is locally the wet season. This varies from place to place in the state. For example:

  Major droughts in the mountains tend to begin or end during the winter or spring months. In extreme southwestern Colorado, significant droughts have both begun and ended in the fall. The more dramatic the seasonal precipitation cycle is, the more difficult it is to end a major drought during the time of year that is the climatological dry season for that area. For example, over eastern Colorado, the months of December, January and February are typically dry. The three months combined produce, on average, less than 10% of the annual precipitation. Rarely does enough precipitation fall during this time of year to significantly alleviate longer-term moisture deficits. However, a week or two of very wet weather during late spring east of the mountains can bring a major drought to an end. For example, the spring of 1995 and the last few days of April 1999 delivered enough precipitation to compensate for large deficits.

- There are several examples of droughts ending abruptly with the appearance of widespread excess precipitation. For example, the severe 1950s drought was followed by the wettest year in Colorado's history in 1957. There are other examples of droughts that have ended more subtly, however.

8) Does a dry winter foretell a wet summer?

There is endless folklore concerning drought. Even before "El Nino" found its way into climatological jargon, people have talked ways to predict drought. Does the climate of one season foretell the next? Much folklore would suggest that. Our analyses, however, did not bear that out. We looked at a number of combinations. What happens after a very dry winter in the mountains? What happens after a very dry autumn at lower elevations (such as fall 1999 in Colorado)? Our analyses showed that sometimes dry winters in the mountains were followed by wet summers (like 1999), but other years they weren't. Sometimes dry springs along the Front Range were followed by hot dry summers (like 1954), but other years they weren't. Further analysis would be required to determine how and if preicpitation during one season helps foretell the next here in Colorado. Less than 10% of the variance in summer precipitation is explained anywhere in Colorado by the variations in winter precipitation.

9) Are there drought cycles?

People don't ask climatologists whether there are drought cycles in Colorado; most people are positive that there are. Some say there is a 3 year cycle, while others claim 7. The sunspot cycle of 11 years has caught some people's attention, while many strongly believe that a 22 year drought cycle (double sunspot cycle) controls Colorado's drought patterns.

We examined our rainfall records in Colorado in search of drought cycles. There is some evidence of a two to three year cycle over portions of southern and eastern Colorado. The dry periods in the 1890s, 1930s, 1950s and again in the 1970s have convinced some observers that the double sunspot cycle really does affect drought patterns in Colorado. That theory doesn't explain why the 1910s were so wet, why parts of the 1960s were very dry, and why we have been wet for the better part of 18 years in a row, but many still believe it. As for a seven or eleven-year cycle, there isn't much supporting evidence for that. It is true that dry periods are followed by wet, and wet followed by dry? That makes a cycle, doesn't it? The problem is that those cycles just aren't very reliable. As such, they don't help us much if at all in predicting what will happen next year or the year after that. Even throwing in the irregular cycle of the El Nino Southern Oscillation, we are still left with a great deal of unexplained variability in our precipitation.

Red Dawn II: What May Lie Ahead
(Colorado's "Worst Case Scenario" Drought)

Colorado has come a long way since the "dust bowl" years. We manage our crop and grasslands with soil and water conservation in mind. We store large volumes of water from wet years for use in dry years, and from wet seasons for use in dry seasons. We divert water from areas with lower demands to areas with higher demands. Still we know, history has a way of repeating itself.

Our study of past droughts has shown that the worst droughts are multi-year droughts. Vegetation dries up, soils blow, stored water reserves are gradually depleted, wells go dry. What begins as a minor inconvenience can, for many people, end in the loss of revenues, property, and livelihoods.

Sometime and somewhere in Colorado's future, a climatological scenario may unfold that goes something like this:

- *For two to four years, winter and spring precipitation in Colorado's mountains will fall far short of the average we have become accustomed to. Winter precipitation totals of 60 to 70 % of average in the high country will be followed by hot, dry summers on the Eastern Plains and Western Slope.*

- *The combination of diminished supplies along with heavy use of irrigation water will gradually deplete surface reserves and make ground water pumping more necessary. The Ogallala aquifer will again show signs of rapid depletion like it first did in the 1970s, and the cost of pumping groundwater will increase.*

- *Dryland vegetation will grow short and sparse. Bare patches will appear on sandy soils. Plant residue on unirrigated crop land will decrease each year. Despite efforts to retain soil moisture, crops will suffer and more topsoil will blow.*

- *Then along will come a winter like the winter of 1976-77 with snowpack accumulations less than 50% of average over most of the Colorado mountains, shutting down some ski areas.*

- *Spring will not bring its normal series of widespread rain and snow storms to the Front Range and Eastern Plains. A few storms will tease and appease us, but only a few. For the months of April through June, only about half of the average moisture will fall.*

- *Strong westerly and southwesterly winds will blow frequently, kicking up more and more dust as agriculture production falters. Giant dust clouds will blow through our cities and across fields.*

- *Water rights conflicts over municipal uses, agricultural uses, and instream flows will intensify, as will conflicts over interstate compacts and agreements.*

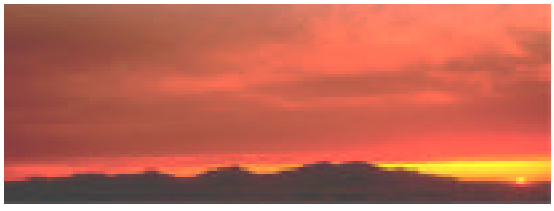
- *Finally, with reservoirs already very low, a long, hot summer will bring frequent temperatures near or above the 100 degree mark at lower elevations. Reservoirs will be too low to provide hydropower to meet demands for electricity to run air-conditioners and relieve us of the heat. Blackouts or brownouts will occur in some cities.*

- *Forest fires will race through thousands of acres of dry timber, and clouds of smoke will turn sunsets on the Front Range a deep blood red.*

Do you believe this? Will we be ready if it really does happen? Colorado's water planners think long and hard about drought. They know it is a part of life in the semiarid west. But most of us never give it a thought. Frankly, we haven't had to. The last multiyear Colorado drought ended in the late 1970s, and the last severe and widespread year-long drought Colorado ended in 1981. Yes, there have been local droughts since then, some quite severe, such as the drought southwestern Colorado experienced in 1989-1990 and again from the late summer of 1995 to early 1996. But droughts of that duration are not uncommon.

Overall, since 1982, Colorado has enjoyed the longest spell of wet (compared to historic averages) weather statewide since the favorably cool and wet period from 1905 through 1929 when so much of Colorado was settled and farmed. For portions of southeastern Colorado, the decade of the 1990s is the wettest decade since weather observations began in the late 19th century.

The heavy precipitation of the 1980s and 1990s does not guarantee that wet weather will continue into the 21st century. Neither does it assure us that drought is imminent. But one way or another, we know that drought will return. The longer we go without drought, the more likely we will be ill-prepared when drought makes its inevitable next visit to Colorado.



Are we ready?

Where to Learn More About Drought

This report in its entirety, with color graphics, can be found at the Colorado Water Resources Research Institute web site:

There are numerous publications on drought assessment, impacts, and mitigation, and on droughts in Colorado and United States history. Below are just a few state agency contacts, publication references, and web sites that are available to provide more information about drought:

A Few Agency and Organization Contacts:

Office of the State Climatologist
Colorado Climate Center (CCC)
Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523-1371
Ph.: (970) 491-8545

Office of Emergency Management (OEM)
Water Availability Task Force
15075 S. Golden Road
Golden, Colorado 80401-3979
Ph.: (303) 273-1622

Colorado Water Resources Research Institute (CWRRI)
410 N University Services Center
Fort Collins, CO 80523
Ph: (970) 491-6308

Colorado Water Conservation Board (CWCB)
Office of Water Conservation
1313 Sherman Street, Room 721
Denver, Colorado 80203
Ph: (303) 866-3441

A Few Publications:

1999. McKee, Thomas B, Nolan J. Doesken, and John Kleist. Historical Dry and Wet Periods in Colorado, Climatology Report 99-1, Part A: Technical Report, Part B: Appendices, Dept of Atmos Sci, CSU. Available from CCC.

1997. Edwards, Daniel C. and Thomas B. McKee. Characteristics of 20th century drought in the United States at multiple time scales. Climo Report 97-2, Dept of Atmos Sci, CSU, Fort Collins, CO, May, 155 pp. Available from CCC.

Colorado Drought Response Plan, 1990 revision. Division of Disaster Emergency Services (now the Office of Emergency Management). Available from OEM.

Water, Colorado's Precious Resource, Second Edition. Available for $2 each plus postage from: Metro Water Conservation, Inc. ,8739 West Coal Mine Avenue, Littleton, CO 80123, (303) 979-2359

Severe Sustained Drought: Managing the Colorado River System in Times of Water Shortage. The Powell Consortium, Issue No. 1, 1995. Available from CWRRI.

Colorado's Water, Climate, Supply, and Drought. CWRRI. 1990 Available from CWRRI.

Proceedings, Colorado Drought Workshops. Nov. 1977. Sponsored by CWCB and Colorado Drought Board. Available from CWRRI

1980. Howe, Charles W. Drought-Induced Problems and Responses of Small Towns and Rural Water Entities in Colorado: the 1976-1978 Drought. Available from CWRRI

A complete list of publications available from CWRRI can be found at: *http://cwrri.colostate.edu/*

A complete list of publications available from CCC can be found at: *http://ccc.atmos.colostate.edu/*

A Few Good Web Sites:

- Colorado Climate Center
  http://ccc.atmos.colostate.edu/
- Colorado Office of Emergency Management
  http://www.state.co.us/data2/oem/oemindex.htm
- Colorado Water Resources Research Institute
  http://cwrri.colostate.edu/
- Colorado Water Conservation Board
  http://www.dnr.state.co.us/cwcb/index.asp
- Western Drought Coordination Council
  http://enso.unl.edu/wdcc
- Western Regional Climate Center
  (especially for climate data)
  http://ww.wrcc.sage.dri.edu
- USDA Drought Information Page
  http://drought.fsa.usda.gov/
- National Weather Service (especially for maps and regional monitoring data on precipitation, temperature, indices, and related information)
  http://www.cpc.ncep.noaa.gov/products/analysis_monitoring
- National Drought Mitigation Center (especially good educational materials on drought indices and definitions)
  http://enso.unl.edu/ndmc/
- Natural Resources Conservation Service
  http://www.co.nrcs.usda.gov/ssps.htm

About the Colorado Water Resources Research Institute and *WATER IN THE BALANCE*

The Colorado Water Resources Research Institute (CWRRI) exists for the express purpose of focusing the water expertise of higher education on the evolving water concerns and problems faced by Colorado citizens. CWRRI strives to constantly bring the most current and scientifically sound knowledge to Colorado's water users and managers.

For more information about CWRRI and/or the water expertise available in the higher eduction institutions in Colorado, please contact CWRRI at the address below or by phone, fax, or email as follows:

Phone: 970/491-6308

FAX: 970/491-2293

E-mail: **cwrri@colostate.edu**

Colorado Water Resources
Research Institute
410 N University Services Center
Fort Collins, CO 80523

CWRRI went on-line with its web page in December of 1994. The CWRRI home page is located at the following URL:

http://cwrri.colostate.edu/

WATER IN THE BALANCE was created in the spirit of informing the public about complex water management issues.

The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the Colorado Water Resources Research Institute under Award Number 1434-HQ-96-GR-02660. The contents of this publication do not necessarily reflect the views and policies of the Department of the Interior, nor does the mention of trade names or commercial products constitute endorsement by the United States Government.

Colorado State University

National Drought Mitigation Center

Drought happens

A working definition of drought must be based on the regional climate.

What is Drought?

In general, drought is when a shortfall in precipitation creates a shortage of water, whether it's for crops, utilities, municipal water supplies, recreation, wildlife or other purposes.

It's very important to realize that each place needs its own operational definition of drought based on climate history. Twenty inches of precipitation would be a slightly wetter-than-normal year in Lubbock, Texas, but would be a severe drought in Nashville, Tennessee, with only 42 percent of normal precipitation.

Unlike other natural disasters, drought moves slowly. It takes months of below-normal precipitation to create a drought, and it takes more than one good rainfall to catch up.

Weather isn't the only cause of drought. Drought results from both natural events, such as a long dry spell, and from human activities that increase demand for water. Expanding populations, irrigation, and environmental awareness all put pressure on water supplies.

Drought differs from aridity. Drought is a temporary deviation from normal. Aridity is a permanent feature of some climates.

> *The Australian government has in recent years enacted a drought policy that emphasizes this distinction. Some Australian farmers, who were perhaps basing their idea of normal climate on England's, were claiming drought assistance as often as every three years. The new policy only grants assistance under circumstances of "extreme drought," defined as a degree of dryness that happens on average only once every 20 to 25 years.*

Although operational definitions of drought differ from place to place, drought is a normal part of virtually every climate on earth. We discuss normal weather patterns as though they usually happen, when in fact "normal" weather is a mathematical construction, and what's really normal is both long- and short-term variation from normal. Both droughts and floods are part of the continuum of the weather we must expect.

There are three physical kinds of drought: meteorological, agricultural and hydrological.

For more information, please contact:
National Drought Mitigation Center
University of Nebraska-Lincoln
P.O. Box 830749
Lincoln, NE 68583-0749
phone: 402/472-6707
fax: 402/472-6614
e-mail: ndmc@enso.unl.edu
URL: http://enso.unl.edu/ndmc

Operational Definitions of Drought

Operational definitions of drought vary from place to place, and are crucial for identifying the beginning, end and degree of drought. There are three main types of drought: **meteorological, agricultural** and **hydrological.** Some researchers, particularly economists, also look at drought in socioeconomic terms, measuring its impact on social and economic systems.

Meteorological drought

Meteorological drought is usually an expression of precipitation's departure from normal over some period of time. These definitions are usually region-specific, and presumably based on a thorough understanding of regional climatology. The variety of meteorological definitions collected from different countries at different times illustrates why it would be folly to apply a definition of drought developed in one part of the world to another:

United States (1942):
less than 2.5 mm of rainfall in 48 hours

Great Britain (1936):
fifteen consecutive days with daily precipitation totals of less than .25 mm.

Libya (1964):
when annual rainfall is less than 180 mm

India (1960):
actual seasonal rainfall is deficient by more than twice the mean deviation

Bali (1964):
a period of six days without rain

Normally, meteorological measurements are the first indicators of drought.

Agricultural drought

Agricultural drought occurs when there isn't enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.

Hydrological drought

Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as streamflow, and as lake, reservoir and ground water levels. There is a time lag between lack of rain or snow and less water in streams, rivers, lakes and reservoirs, so hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient for a long time, this storage if reflected in declining surface and subsurface water levels.

Socioeconomic drought

Socioeconomic drought is what happens when physical water shortage starts to affect people. Or, in more abstract terms, most socioeconomic definitions of drought associate it with the supply and demand of an economic good. One could argue that a physical water shortage with no socioeconomic impacts is a policy success. For more information on socioeconomic drought, please refer to the NDMC fact sheet, "The Devastation of Drought."

Drought happens

National Drought Mitigation Center

Our Mission

The National Drought Mitigation Center helps people and institutions develop and implement measures to reduce societal vulnerability to drought. The NDMC stresses prevention and risk management rather than crisis management. This approach promotes self-reliance to achieve greater resilience to drought.

The National Drought Mitigation Center, founded in spring 1995, builds on the accomplishments of the International Drought Information Center, established in 1988. Both centers are part of the Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln, and both are directed by Dr. Donald A. Wilhite.

Our Approach

We help planners bridge the gap between climatology and policy. Many of the worst effects of drought can be reduced or even eliminated when proper mitigation measures are introduced in advance of drought. This doesn't happen as often as it should because policy makers, climatologists and others involved in water and natural resource management often have radically different disciplinary perspectives.

How We Make a Difference

- The National Drought Mitigation Center maintains a continually growing archive of drought-monitoring and planning information, accessible via World Wide Web at **http://enso.unl.edu/ndmc**.
- Upon request, representatives of the NDMC advise policy makers, serve as special consultants to governments and agencies around the world, and conduct workshops and seminars at conferences and professional meetings.
- The NDMC conducts and fosters research on the best ways to monitor and mitigate drought.
- The NDMC can help with post-drought audits, to determine whether policy responses to drought were as effective as possible.
- Representatives of the NDMC are in touch with regional, state and federal drought planners to monitor information needs, innovations and current droughts.

Drought Planning

Key elements of a good drought plan are:

- ***a comprehensive climate-monitoring system*** to provide early warning of emerging droughts to decision makers.
- ***a network of people*** who can assess the evolving effects of water shortages on agriculture, recreation, hydropower, municipal water supplies, wildlife, and other areas that are sensitive to fluctuations in water supply.
- ***a policy/response committee*** that can implement short-term measures to reduce the immediate effects of drought and longer-term mitigation measures to reduce the effects of future droughts.

For more information, please contact:
National Drought Mitigation Center
University of Nebraska-Lincoln
P.O. Box 830749
Lincoln, NE 68583-0749
phone: 402/472-6707
fax: 402/472-6614
e-mail: ndmc@enso.unl.edu
URL: http://enso.unl.edu/ndmc

Please visit the National Drought Mitigation Center's site on the World Wide Web: **http://enso.unl.edu/ndmc**

About the NDMC

Here's where to find an overview of the National Drought Mitigation Center — its origins, staff, publications and services.

Drought Watch

Drought Watch features drought-monitoring indices and links to sites throughout the United States and around the world that provide data on precipitation and water availability, forecasts, and information on impacts of drought as it develops. Standardized Precipitation Index maps are jointly produced by the National Drought Mitigation Center, the Western Regional Climate Center, and the National Climatic Data Center.

Mitigating the Impacts of Drought

Drought Mitigation is constantly growing as we add new strategies and techniques that governments, agricultural producers and others have used to cope with drought.

Drought Climatology

Historic information about climate variability helps planners and policy makers put current and potential droughts in perspective. Drought Climatology includes climographs for various cities, links to other data products, maps and other ways to visualize and understand drought history.

Other Places To Go

Other Places to Go is a collection of links to web sites around the world with information about water supply and drought and its effects.

The Enigma of Drought

Drought is one of the most underestimated and least understood natural disasters. Operational definitions vary from one climate to another, and its impacts can be so widespread that they're hard to recognize. The Enigma of Drought provides in-depth information about the phenomenon.

Why Plan For Drought?

Newcomers to the idea of drought planning may find this information helpful. Why Plan for Drought? includes an overview of basic concepts — for example, drought happens just about everywhere — and a look at the institutions, assumptions, policies and doctrines that shape our society's ability to plan for drought.

What's New

Regular visitors to the NDMC's web site can check in here for pointers to the latest additions to our constantly growing collection of information.

Drought Planner's Handbook

There are several recognized methodologies for planning for drought, including a 10-step process that can be modified for a variety of circumstances and levels of government.

Directory of Drought Planners

The Directory of Drought Planners may be of use to state and federal officials who are looking for their counterparts in other states, regions and organizations, as well as to individuals who are looking for information or for a way to contribute to drought planning in their region.

National Drought Mitigation Center

Drought happens

The Devastation of Drought

Drought is slower and less dramatic than other natural disasters, but its effects are so long-lasting and widespread that it can cost more and cause more misery than hurricanes, earthquakes or other, more headline-grabbing disasters.

Direct physical effects of drought typically include poor crops and forage, increased fire danger, less water in soil, streams and reservoirs, and less water available for livestock and wildlife. These lead to indirect effects such as less farm income, reduced revenues for vendors and retailers who serve agricultural producers, foreclosures, and costly disaster relief programs. Drought also reduces water available for hydroelectric power, for recreation along lakes and rivers, and for barge traffic on major rivers.

In parts of the world with more vulnerable food supplies, drought can trigger malnutrition, famine and population migration.

The economic, social and environmental consequences of drought compound as it persists.

Drought's Winners

Not all of drought's effects are negative. Construction companies and airlines operate with fewer unscheduled delays when there is no rain.

In some cases, one person's loss is another's gain. Beneficiaries of the 1987-88 U.S. drought included:

- railroads, when Mississippi River flows were too low to support barge traffic.
- farmers with surpluses and those outside affected areas.
- non-hydroelectric power producers.

(over)

For more information, please contact:
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fax: 402/472-6614
e-mail: ndmc@enso.unl.edu
URL: http://enso.unl.edu/ndmc

The Costs Associated With Drought

Economic

- loss from crop production
  - *annual and perennial crop losses; damage to crop quality*
  - *wind erosion and other damage to cropland*
  - *insect infestation*
  - *plant disease*
  - *wildlife damage to crops*
- loss from dairy and livestock production
  - *reduced productivity of rangeland*
  - *forced reduction of foundation stock*
  - *public lands limited or closed to grazing*
  - *feed and water for livestock scarce or expensive*
  - *high livestock mortality rates*
  - *increased predation*
  - *range fires*
- loss from timber production
  - *forest fires*
  - *tree disease*
  - *insect infestation*
  - *decreased productivity of forestland*
- loss from fishery production
  - *damage to fish habitat*
  - *loss of young fish due to decreased flows*
- loss of national economic growth, slowed economic development
- loss from recreational businesses
- loss to manufacturers and sellers of recreational equipment
- increased energy demand and reduced supply because of drought-related power curtailment
- costs to energy industry and consumers from substituting more expensive fuels such as oil for hydroelectric power
- loss to industries, agricultural vendors and processors
- decline in food production or disrupted food suppy
  - *increase in food prices*
  - *increased food imports at higher costs*
- unemployment from drought-related production declines
- strain on financial institutions from foreclosures, greater credit risks, capital shortfalls, etc.
- revenue losses to federal, state, and local governments from reduced tax base
- revenues to water supply firms
- loss from impaired navigability of streams, rivers and canals
- cost of water transport or transfer
- cost of new or supplemental water resource development

Environmental

- damage to animal species
  - *wildlife habitat*
  - *lack of feed and drinking water*
  - *disease*
  - *increased vulnerability to predation, when animals cluster near limited water supplies*
- wind and water erosion of soils
- damage to fish
- damage to plants
- worse water quality, higher concentrations of salt and pollutants
- more dust and air pollution
- less aesthetically pleasing landscapes

Social

- food shortages, malnutrition, famine
- loss of human life from food shortages, heat
- public safety from forest and range fires
- conflicts between water users
- water sanitation problems such as higher concentrations of sewage and pollutants
- inequity in the distribution of drought relief
- decreased living conditions in rural areas
- increased poverty
- reduced quality of life
- social unrest, civil strife
- population migration from rural to urban areas

National
Drought
Mitigation
Center

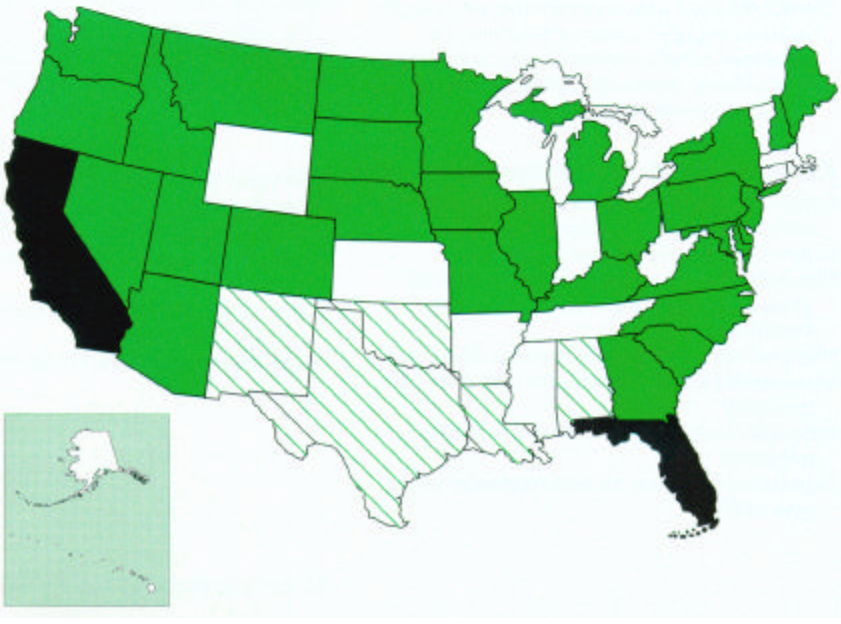
Drought happens

U.S. States Are Drought Policy Innovators

Because water shortfalls are first local and regional issues, and because of the lack of a cohesive U.S. water policy, states have emerged as important innovators in devising ways to reduce long-term vulnerability to drought. During the widespread U.S. drought of 1976-77, no state had a formal drought plan, and in 1982, only three states had drought plans. But as of mid-1996, 28 states had drought plans, five plans were in development, two states delegated responsibility to local water suppliers, and 15 states had no plans.

Research has shown that the frequency of drought in a state does not fully explain how committed a state is to drought planning. Trends in federal-state relations in the 1980s, as well as the drought of 1987-88, may be responsible for the surge in drought planning. During the 1980s, states' capabilities increased in conjunction with the Reagan administration's New Federalism and concurrent mandates to state and local governments, and states were concerned about federal intrusion into state-level water resource planning and water rights.

Drought preparedness plans promote a more preventive, risk management approach to drought. They contain three critical components: (1) a comprehensive early warning system; (2) assessment procedures for timely estimates of impact; and (3) response and mitigation strategies. After adopting a drought plan that provides for a better-coordinated and timely response, a state's next step is to work toward reducing long-term vulnerability to drought.



The Status of Drought Planning 1996

- States with plans
- States developing plans
- States delegating drought planning to local authorities
- States without drought plans

How States Mitigate Drought

The following grab bag of drought mitigation measures for state governments is based on two surveys, one published in 1993 and one that is ongoing. The 1993 survey was undertaken as part of a cooperative agreement with the U.S. Soil Conservation Service (now the Natural Resource Conservation Service). The current survey is part of the NDMC's ongoing communication with drought planners around the country. Many ideas naturally fit into more than one category, but each is only listed once.

For more information, please contact:
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URL: http://enso.unl.edu/ndmc

Assessment

Developed criteria — "triggers" — for drought-related actions
Developed an early warning system
Inventoried data
Inventoried water bank contracts to find new water supplies for drought-stricken areas
Evaluated use of ground water
Established new data collection networks
Studied public willingness to pay more for more reliable water supplies
Studied effectiveness of conservation measures
Monitored vulnerable public water suppliers

Legislation and Public Policy

Prepared position papers for legislature on public policy issues
Examined statutes governing water rights for possible modification during water shortages
Established a state water bank
Passed legislation to protect in-stream flows
Passed legislation to protect and manage ground water
Passed legislation providing guaranteed low-interest loans to farmers
Imposed limits on urban development
Developed a state water plan
Passed legislation requiring water agencies to develop contingency plans
Enacted legislation to facilitate water recycling

Increasing Water Supply/ Supply Augmentation

Issued emergency permits for water use
Provided pumps and pipes for distribution
Proposed and implemented program to rehabilitate reservoirs to operate at design capacity
Undertook water supply vulnerability assessments
Inventoried self-supplied industrial water users as a source of emergency public water supplies
Inventoried and reviewed reservoir operation plans
Provided funds for water recycling projects

Public Education

Organized drought information meetings for the public and the media
Implemented water conservation awareness programs
Published and distributed pamphlets on water conservation techniques and drought management strategies
Organized workshops on special drought-related topics
Prepared sample ordinances on water conservation
Established a drought information center
Set up a demonstration of on-site treatment technology at visitors center
Included media in state drought plan

Technical Assistance

Advised people on potential sources of water
Evaluated water quantity and quality from new sources
Advised water suppliers on assessing vulnerability of existing supply systems
Recommended adopting water conservation measures
Helped water agencies develop contingency plans
Formed a drought information center and distributed real-time weather data
Conducted workshops on crop survival during drought
Developed training materials in Spanish for agricultural and landscape irrigators
Conducted workshops on design and implementation of water rationing programs
Developed and marketed innovative technologies such as irrigation system improvements, waterless urinals, and monitoring technologies
Developed and distributed software for irrigators and urban water suppliers

Conservation/Demand Reduction

Established stronger economic incentives for private investment in water conservation
Encouraged voluntary water conservation
Required water users to decrease reliance on ground water and implement conservation measures
Improved water use and conveyance efficiencies
Implemented water metering and leak detection programs
Supported local development of conservation programs
Established standards for safe residential use of gray water

Emergency Response

Established alert procedures for water quality problems
Stockpiled pumps, pipes, water filters, and other equipment
Established water hauling programs for livestock
Listed livestock watering spots
Established hay hotline and provided emergency shipments
Funded water system improvements, new systems, and new wells
Funded drought recovery program
Lowered well intakes on reservoirs for rural water supplies
Extended boat ramps and docks for recreation
Issued emergency irrigation permits for using state waters for irrigation
Created low-interest loan and aid programs for agriculture
Created drought property tax credit program for farmers
Established tuition assistance so farmers could enroll in farm management classes
Informed farmers of sources of federal assistance

Conflict Resolution

Resolved emerging water use conflicts
Investigated complaints of irrigation wells interfering with domestic wells
Negotiated with irrigators to gain voluntary restrictions on irrigation in areas where domestic wells were likely to be affected
Clarified state law regarding sale of water
Clarified state law on changes in water rights
Suspended water use permits in watersheds with low water levels
Worked with community-based organizations to promote public participation in conservation programs

Drought Contingency Plans

Adopted an emergency water allocation strategy to be implemented during severe drought
Recommended water suppliers develop drought plans
Evaluated worst-case drought scenarios for possible further actions
Established natural hazard mitigation council

National Drought Mitigation Center

Drought happens

Why Drought Has Been Hard to Prepare For

1. Drought is a slow, insidious natural disaster, and people are natural optimists.

Fires, earthquakes, floods — we can pinpoint when and where they start, and they're over relatively quickly. Drought, in contrast, creeps up gradually. It's hard to pinpoint the moment when a prolonged dry spell becomes a drought. It's also hard to know when a drought is over.

Often people or governments are reluctant to admit that they are in a drought. No sane person would wait to react to a hurricane until 20 minutes after it hit, but people tend to wait until a drought is well-established before they react to it. By then, it's too late to take many of the most effective measures.

Many state governments and community water suppliers have established drought early warning systems that allow them to alert the public or to take various actions as water supplies get progressively lower over weeks or months. The next step is to create water systems and structure water use in ways that make us less vulnerable to drought — a step similar to implementing building codes designed to help buildings withstand earthquakes or hurricanes.

(over)

The Hydro-**Illogical** Cycle

2. We believe in "normal."

People assume there is such thing as normal weather, and that normal weather is what we should expect and plan for. In this way of thinking, droughts and floods are such rare events that there's no point trying to plan for them, and a bad year is bound to be followed by a better one. In reality, drought years often occur back-to-back, or several years in a row.

In fact, "normal" weather is really just an abstraction, a mathematical construct. Droughts, floods, and the kind of moderate weather fluctuations we think of as normal are all part of the same continuum of normal weather. Climatology shows us that over a given period of time, 30 years or 100 years, droughts of varying degrees of severity occur repeatedly in virtually all climates.

3. We don't have enough climate data

Weather records in the United States only go back 100 years, which isn't long enough to give us the big picture on climate. Indications are that more variation is possible than anyone has experienced in his or her lifetime. We know that our planet's climate has fluctuated over millennia to include ice ages and temperate epochs such as the one we're now enjoying, and recent research into tree-ring growth patterns reveals that within the past 1,200 years, western portions of the North American continent endured severe droughts of 100 years or more. Global warming may be playing a role in long-term climate patterns, too, perhaps heating our planet's surface temperatures into entirely new ranges and altering precipitation patterns and the frequency of extreme climate events, such as droughts.

4. Increasing demands for water increase vulnerability to drought.

Water supply planners often anticipate worst-case scenarios based on the "drought of record," the worst drought recorded for a given region. It's important for planners to ask themselves what would happen if the drought of record happened again now, realizing that the population and water use of many regions has grown dramatically since then, possibly increasing vulnerability to drought.

5. No one is in charge of drought planning.

No single governmental authority has responsibility for planning for drought or ensuring that U.S. citizens have safe and adequate water supplies. During the drought of 1977, for example, federal drought responses came down through 40 separate programs, administered by 16 different agencies. States are more likely to have assigned drought planning leadership to a single department, but there is great variation in the underlying philosophies and resources that states dedicate to the endeavor. In Nebraska, drought planning falls to the Department of Agriculture; in Colorado, it's the Office of Emergency Management; and in California, it's the Department of Water Resources.

For more information, please contact:

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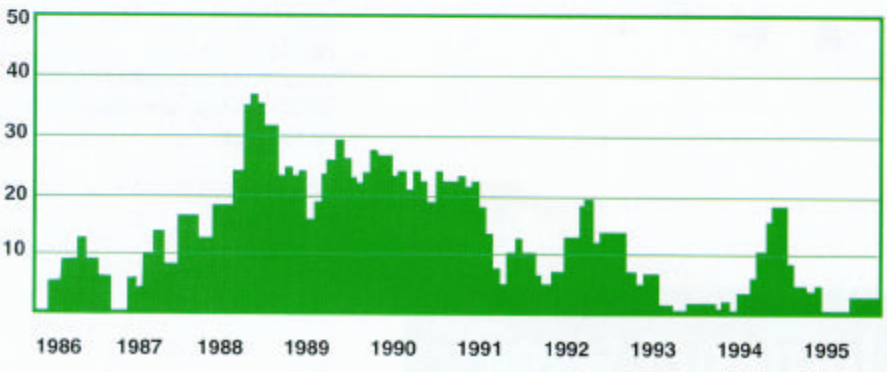
Percent Area of the U.S. In Severe to Extreme Drought

January 1986 - October 1995



From 1986 to 1995, 81% of the area of the 48 contiguous United States experienced severe or extreme drought at least once, with some states experiencing six consecutive years of drought.

Based on Palmer Drought Severity Index values of -3 or less, as calculated by the National Climatic Data Center.

National Drought Mitigation Center

Drought happens

What We Can Do About Drought

With a Few Months' Warning

- Urban water suppliers have found that by keeping the public informed as drought develops, most people observe voluntary water conservation guidelines, and emergency measures such as mandatory rationing can be avoided.

- Agricultural producers can use the information that the subsoil is dry at the start of the growing season as they decide which crops and which varieties to plant, how much seed to order, how much and which fertilizers, herbicides and pesticides to order, and when and how to till the soil.

- State and federal agencies can reserve funds and staff time for drought assistance programs such as emergency food and water for livestock, low-cost loans for emergency well-drilling, providing technical assistance to agricultural producers and urban suppliers, water conservation information campaigns, and resolving conflicts.

- Decision makers in all circumstances can take the time to respond to emerging drought with rational, considered measures, rather than panicking in crisis. Thoughtful, deliberate investment in long-term solutions is more cost-effective than crisis management.

To Reduce Long-Term Vulnerability

- State or regional authorities can develop drought early warning systems and contingency plans, implement policies such as water banking that add flexibility to water allocation systems, and work with water suppliers to implement incentives to use water efficiently.

- Municipal water suppliers can assess the vulnerability of their system, detect and repair leaks, charge customers according to how much water they use rather than charging a flat fee, charge proportionately more as customers use more water, and offer rebates for customers who install low-flow showerheads and toilets.

- Planning authorities, developers and agricultural producers can each play a role in land stewardship in ways that reduce vulnerability to drought. Overusing delicate soils can contribute to long-term desertification, reducing the productivity of marginal lands. Draining wetlands to accommodate agriculture or other development affects regional water supplies for both wildlife and people.

  Many communities in water-short areas require developers to secure water rights, typically by buying rights from farmers, before permitting new housing construction. Without securing additional water rights, growing urban populations would be at increasing risk from drought. However, transferring water rights from agricultural producers to urban suppliers to accommodate development further stretches existing water supplies, and may reduce the effectiveness of conservation measures as a response to drought.

- Homeowners can xeriscape (sometimes called "dry" or "conservation" landscaping") by selecting grass and flowers that require minimal water, fix leaky plumbing, install water-conserving showerheads and toilets, and reuse graywater from bathing and laundry.

- Agricultural producers can install efficient irrigation systems, and/or devise long-term crop rotation plans that include crops that require less water.

(over)

What is a Drought Early Warning System?

A drought early warning system has **two key components:**

- **a network of stations that monitor weather and water supply and report data regularly to state climatologists and other technical specialists who can interpret it.**
- **channels for communicating that information to decision makers.**

Depending on the sources of a region's water supply, early warning systems may incorporate data on precipitation, reservoir levels, streamflow, snowpack, and ground water levels. Water supply specialists may brief decision makers at regular intervals, or may only issue an alert when precipitation or another indicator of water supply falls below a certain threshold.

An early warning system can alert people that it's shaping up to be a dry year a few months before dry streambeds and parched crops make it obvious that a drought is underway. Those months of lead time enable policy makers, water suppliers, farmers, businesses and households to make better-informed decisions about water use. Sometimes policy makers use early warning systems to trigger pre-determined actions, such as requesting voluntary water conservation when the water in reservoirs falls below a specified level.

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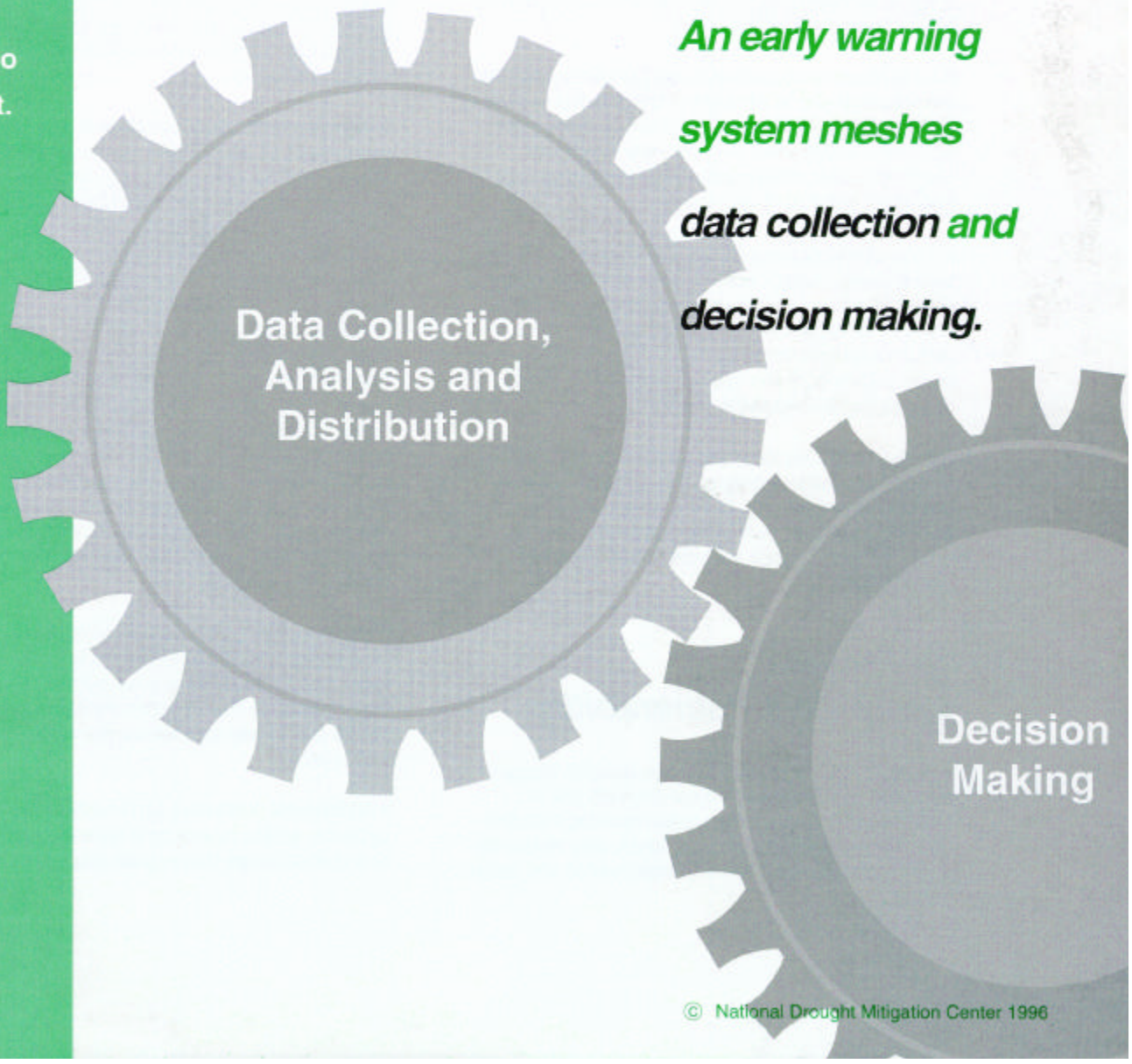
An early warning system meshes data collection and decision making.



NDPC National Drought Policy Commission

October 1999

Fact Sheet

Background

The National Drought Policy Act of 1998 (the Act), Public Law 105-199, was signed by the President on July 16, 1998. The Act establishes the National Drought Policy Commission (NDPC) to provide advice and recommendations on the creation of an integrated, coordinated Federal policy designed to prepare for and respond to serious drought emergencies.

Purpose

The NDPC is charged with making recommendations on:

- How to better integrate Federal drought laws and programs with ongoing State, local, and tribal programs;
- How to improve public awareness of the need for drought mitigation, prevention, and response;
- Whether all Federal drought preparation and response programs should be consolidated under one existing Federal agency, and if so, identify the agency.

The NDPC is to conduct a thorough study and, no later than eighteen months after the date of the enactment of the Act, submit a report to the President and Congress which contains a detailed statement of the findings and conclusions of the NDPC, together with its recommendations for such legislation and administrative actions as it considers appropriate.

Members

In addition to the Secretary of Agriculture, who will chair the committee, other members include:

- The Secretary of the Interior or a designee;
- The Secretary of the Army or a designee;
- The Secretary of Commerce or a designee;
- The Director of the Federal Emergency Management Agency or a designee;
- The Administrator of the Small Business Administration or a designee;
- Two persons nominated by the National Governors' Association and appointed by the President – one governor of a State east of the Mississippi River and one governor of a State west of the Mississippi River;
- A person nominated by the National Association of Counties and appointed by the President;
- A person nominated by the United States Conference of Mayors and appointed by the President; and
- Six persons, appointed by the Secretary of Agriculture in coordination with the Secretary of the Interior and the Secretary of the Army, representing groups acutely affected by drought emergencies. Such groups include the agricultural production community, credit community, rural and urban water associations, Native Americans, and fishing and environmental interests.

The public may send comments to:

USDA/FSA/AO
National Drought Policy Commission
STOP 0501
1400 Independence Ave., SW
Washington, DC 20250-0501

or e-mail: leona.dittus@usda.gov

A copy of the National Drought Policy Act and other related information is available on the NDPC website at www.fsa.usda.gov/drought

NATIONAL DROUGHT POLICY COMMISSION
COMMISSION MEMBERS

Dan Glickman
Secretary of Agriculture
U.S. Department of Agriculture
Washington, DC
Chair, NDPC

Ronald R. Morriss
Chairman of the **Santa Cruz County Board of Supervisors, NACo**
Nogales, AZ
Vice Chair, NDPC

Honorable Roy Barnes
Governor of Georgia
National Governors' Association
Representing states east of the Mississippi River
Atlanta, GA

Robert C. "Bob" Brown
Executive Vice President
Farm Credit Bank of Texas
Austin, TX

Brian Eliot Burke
Principal Deputy Assistant Secretary of the Army (Civil Works)
Department of the Army
Washington, DC

Sam Kathryn Campana
Mayor of Scottsdale, Arizona
U.S. Conference of Mayors
Scottsdale, AZ

Ane Deister
Executive Assistant to the General Manager
Metropolitan Water District of Southern California
Los Angeles, CA

John J. Kelly, Jr.
Assistant Administrator for Weather Services
Department of Commerce
Silver Spring, MD

Bernard Kulik
Associate Administrator for Disaster Assistance
U.S. Small Business Administration
Washington, DC

Eluid L. Martinez
Commissioner, Bureau of Reclamation
Department of the Interior
Washington, DC

Robert L. Miller
Ranch Owner
President, Intertribal Agriculture Council
Beggs, OK

Ernesto Rodriguez
State Director for Emergency Management
New Mexico Department of Public Safety
Santa Fe, NM

Brian Schweitzer
Farmer/Rancher, Soil Scientist
Former Member - Montana State Farm Service Agency Committee
Whitefish, MT

A. Leon Smothers
Manager, Water Resources Branch
Natural Resources and Environmental Protection Cabinet
Kentucky Department of Environmental Protection
Frankfort, KY

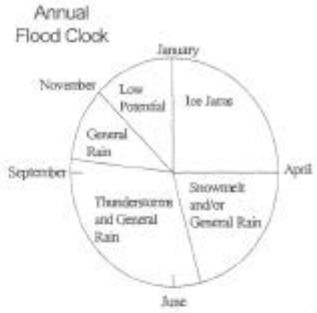
Larry Zensinger
Director, Human Services Division
Federal Emergency Management Agency
Washington, DC

Colorado Water Conservation Board
Flood Protection Program

Colorado Flood History

Introduction to Colorado floods

Every year, Colorado experiences at least one 100-year flood **somewhere in the state**. Floods in Colorado have caused damages worth over $4 billion (1999 $) and fatalities totaling more than 300 persons. Rapid population growth, unwise development in floodplain areas and the human nature to disregard warnings have all contributed to the loss of life and property during flooding events. Colorado has had flooding severe enough to warrant four Presidential Disaster declarations in the last twenty years: 1982, 1984, 1997, and 1999.



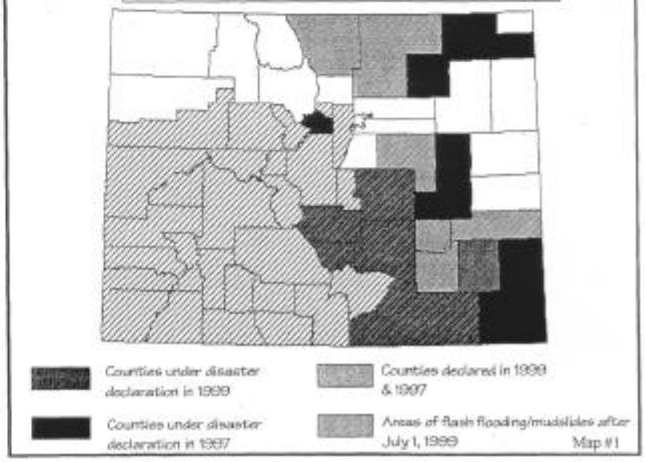
Major Floods in Colorado

Date	Major Stream or Location	Deaths	Damages (in 1999 $)
May 1864	Cherry Creek at Denver	?	6,000,000
July 1896	Bear Creek at Morrison	27	6,000,000
Oct. 1911	San Juan River near Pagosa Springs	2	6,000,000
July 1912	Cherry Creek at Denver	2	120,000,000
June 1921	Arkansas River at Pueblo	78	760,000,000
May 1935	Monument Creek at Colorado Springs	18	52,000,000
May 1935	Kiowa Creek near Kiowa	9	15,000,000
May 1942	South Platte River Basin	?	8,500,000
May 1955	Purgatorie River at Trinidad	2	36,000,000
June 1957	Western Colorado	?	18,000,000
June 1965	South Platte River at Denver	8	2,200,000,000
June 1965	Arkansas River Basin	16	205,480,000
May 1969	South Platte River Basin	0	21,500,000
Sept. 1970	Southwest Colorado	0	13,200,000
May 1973	South Platte River at Denver	10	388,800,000
July 1976	Big Thompson River in Canyon	144	85,200,000
July 1982	Fall River at Estes Park	3	49,080,000
June 1983	North Central Counties	10	26,250,000
May-June 1984	Western & Northwestern Counties	2	46,500,000
May-June 1993	Western Slope	0	2, 140,000
June 1995	Western Slope and South Platte River	21	51,266,000
July 1997	Ft. Collins & 13 Eastern Counties	6	169,367,000
May-June 1999	Colorado Springs & 12 Eastern Counties	0	100,000,000 (est)
TOTALS		**352**	**$4,486,577,000**

Colorado Flood Facts

Counties/Towns with Flood Prone Areas	268
Total flood insurance policies	15,203
Population in the 100-Year Floodplain	250,000
Homes in the 100-Year Floodplain	65,000
Commercial/Industrial/Businesses in the 100-Year Floodplain	15,000
Total Value of Property in the 100-Year Floodplain	16.5 Billion
Cumulative Flood Losses from the Turn of the Century to 1999	4.5 Billion
Miles of Delineated 100-Year Floodplains	8000

Recent Flood Events in Colorado



Colorado Water Conservation Board
Flood Protection Program

Designated 100-year Floodplains

The starting point of any floodplain management program is the identification of the 100-year floodplains and, if possible, the direct observation of actual flood events. The occurrence of a specific flood event is not predictable, however, the probability of its occurrence can be quantified. The State of Colorado, in cooperation with federal, state, and local governments, has adopted the 100-year flood (1% chance of occurrence in any year) as the recognized standard.

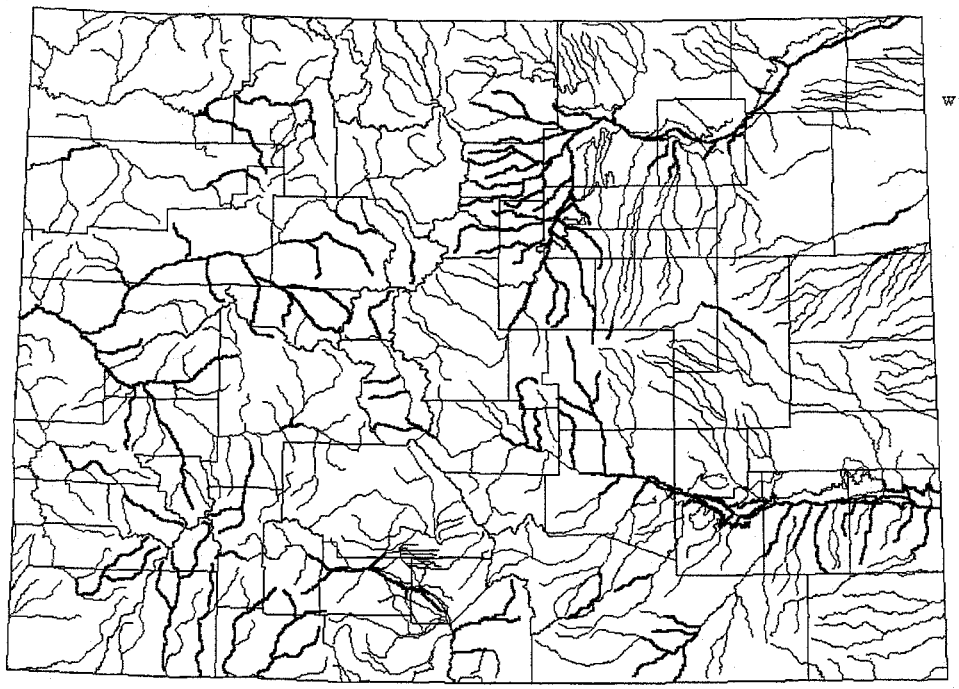
Many stream miles have already been studied and mapped for flood hazard areas, however, there are many more stream miles that will need to be mapped or re-mapped as Colorado continues to grow.

The CWCB has an active floodplain identification program which was initiated in 1967 following statewide flooding in 1965. The CWCB pursues the designation and approval of floodplain studies in the state, as required by State Statute.

Section 37-60-106 (1) (c) of the Colorado Revised Statutes directs the CWCB to designate and approve storm or floodwater runoff channels or basins and to make such designations available to legislative bodies of local jurisdictions.

The map below illustrates major stream reaches and identified floodplains.

Identified Floodplains in Colorado



For informational purposes only - not all streams shown.

100 0 100 200 Miles

8,000 Miles of Designated Floodplains
8,000 Miles to be considered for Designation

Designated Floodplains
Streams & Rivers
Counties

Colorado Water Conservation Board
Flood Protection Program

The Value of Stream Corridors

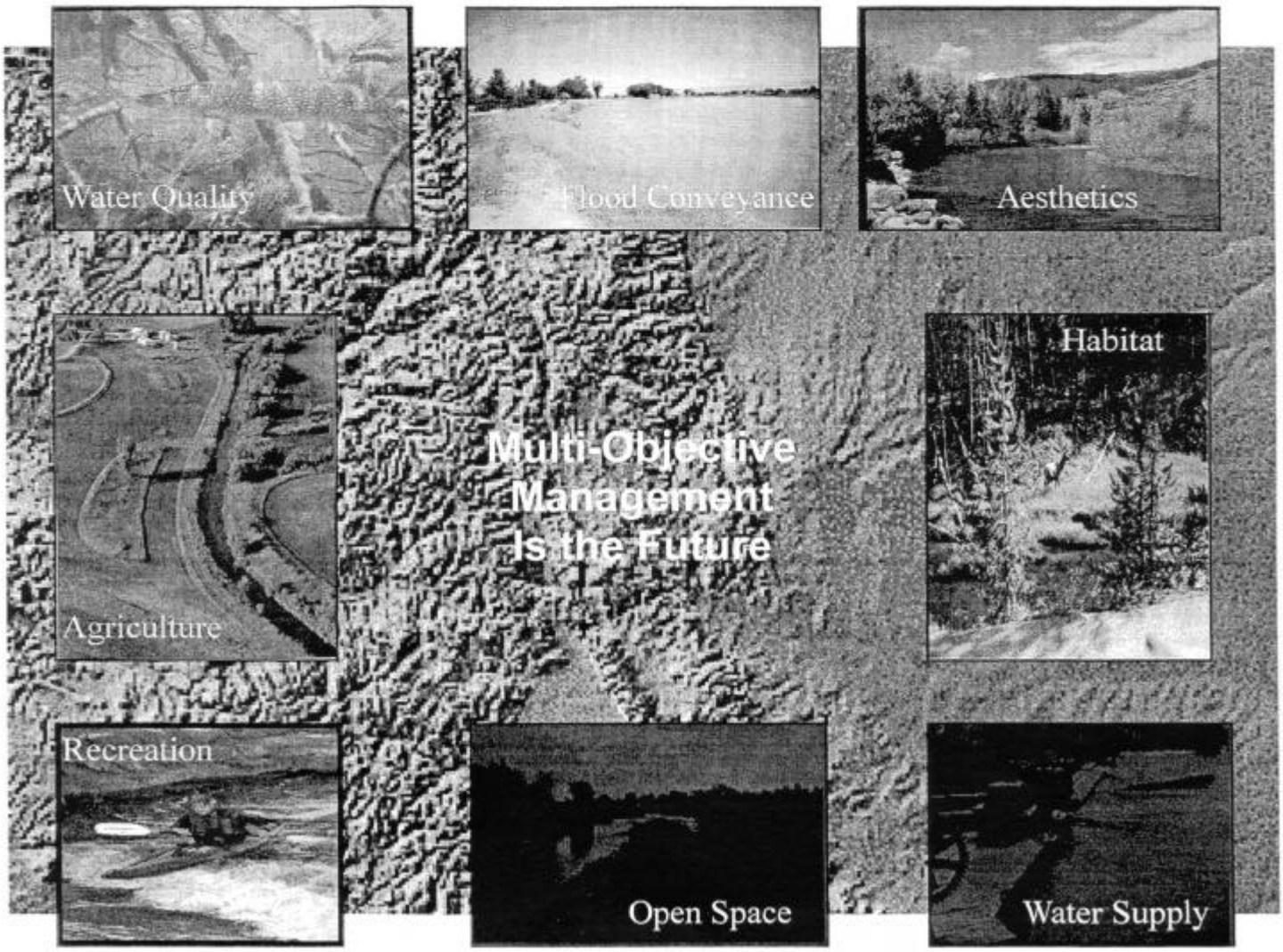
Colorado's stream corridors include channels, wetlands, natural floodplains, dams and reservoirs, and man-made water related structures. These corridors are important environmental and economic assets to the State. Healthy and natural corridors assist both in natural and in human processes vital to Colorado's well-being.

People and natural processes must team up to maintain acceptable standards for human activities in stream corridors and floodplains.

The CWCB Multi-Objective Management Studies program is a means to facilitate the wise usage of the State's floodplains and stream corridors.

Since 1995 the CWCB has responded to severe floods with Multi-Objective Management Studies:

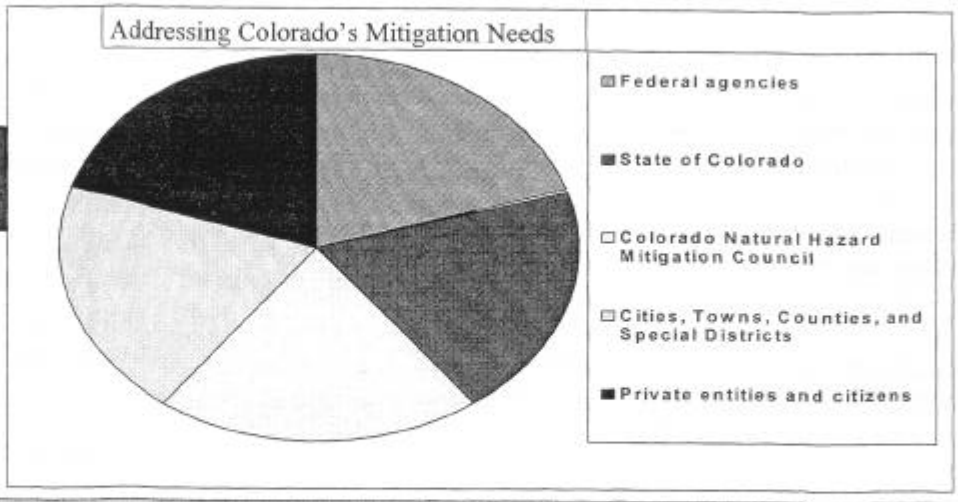
- **Arkansas River**
- **South Platte River**
- **Roaring Fork River**
- **Elk River**
- **Rio Grande**
- **Fountain Creek** (*proposed*)
- **North Fork of the Gunnison River** (*assisting local study initiative*)



Colorado Water Conservation Board
Flood Protection Program

Flood Hazard Mitigation

CWCB



CWCB mission statement: The floodplain section strives to reduce Colorado's vulnerability to property damages and loss of life caused by flooding, and to formulate and implement workable mitigation packages for Colorado.

CWCB Flood protection objectives:

- Flood risk identification
- Flood risk designations and regulations
- Flood response and recovery operations
- Federal and state flood related program coordination
- Customer service and water information

Planning:

- Delineate 100-year floodplains
- Develop community mitigation plan
- Design flood protection projects
- Encourage wise land use decisions
- Collect hydrology information and technical data
- Promote the sale of flood insurance
- Document flood events

Funding Sources:

The CWCB administers a number of programs which provide financial assistance to local governments in accomplishing flood hazard mitigation.

- **CWCB Construction Fund**

Annual grant and loan program designed to implement structural and non-structural flood reduction activities. Current funding level equals five percent (5%) of the annual revenue of the Construction Fund.

- **CWCB—Federal Emergency Management Agency**

One ongoing program, plus one additional program when a Presidential disaster declaration is made are described below.

- **Flood Mitigation Assistance Program**

75%/25% cost share small annual grant funds to 1) develop local flood hazard mitigation plans, and 2) implement structural and non-structural flood reduction activities.

- **Hazard Mitigation Grant Program**

75%/25% cost share ***disaster-related*** grant funds to implement structural and non-structural flood reduction activities. Utilized only twice in Colorado since passage of The Stafford Act in 1989.

- **CWCB—US Army Corps of Engineers**

Formulate study agreements and develop cost-sharing opportunities for flood related projects

Implementation:

- Disseminate 100-year flood information
- Perform site-specific investigations
- Build flood protection projects
- Provide technical assistance to NFIP communities
- Complete flood mitigation studies and reports
- Provide post-flood technical assistance
- Maintain statewide floodplain information support system

Colorado Water Conservation Board
Flood Protection Program

Needs Assessment

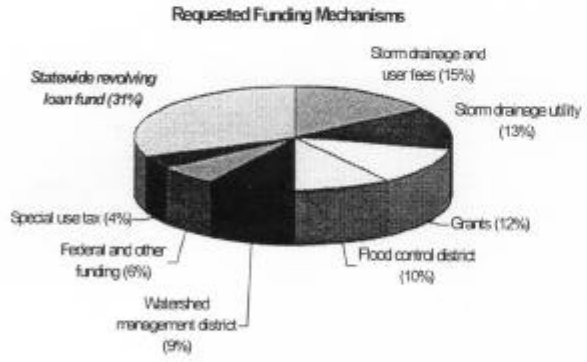
To meet the need for increased stewardship of Colorado's stream corridors and floodplains the Colorado State Legislature in 1996 directed the Colorado Water Conservation Board to conduct a statewide inventory of river channel restoration and floodplain management needs. The project is entitled ***"Stream Rehabilitation and Flood Protection Needs in Colorado"***

Statewide Needs

Many streams throughout Colorado experience erosion from natural processes and human activities and practices. Streambank erosion and channel degradation can change a stream's conveyance capacity, harm fish habitat, destroy agricultural land and damage private property. Rehabilitation measures are needed to stabilize threatened stream corridors, preserve the natural and beneficial functions of floodplain areas, and increase flood capacity. There is also a clear need for improved floodplain management to reduce the human vulnerability to flooding and prevent further encroachment into flood hazard zones. Additionally, there is a need to improve stream maintenance and implement flood protection measures to reduce annual flood losses.

Detailed Survey

To assess the floodplain management and stream rehabilitation problems and concerns across the state, the CWCB contracted with McLaughlin Water Engineers to conduct a statewide survey and needs inventory. A detailed questionnaire was sent to more than 400 entities soliciting feedback regarding flood hazards, floodplain management, multiple use of stream corridors, and other institutional issues. The CWCB received a 40% response.



The top 5 problems identified from the needs survey were:

- **Lack of funding mechanism**
- **Damages caused by flooding**
- **Mapping/development in floodplains**
- **Channel erosion**
- **Lack of management education.**

EXAMPLE OF BENEFITS

Blue River Rehabilitation Project Breckenridge, Colorado

Proposed Response to Needs

- Provide funding for multi-objective watershed planning
- Create a statewide revolving loan fund
- Establish a website to provide educational tools
- Expand the on-going program for floodplain mapping
- Prepare a statewide criteria manual
- Set minimum criteria for stormwater detention

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December 2-3, 1999
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- Department of Natural Resources
- Department of Agriculture
- Department of Local Affairs
- Department of Public Health and Environment

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