Colorado Drought Conference

Managing Water Supply and Demand in the Time of Drought

Conference Proceedings, December 4, 2002

Co-Sponsored by: Colorado Water Resources Research Institute
Colorado Water Conservation Board

CWRRI Information Series Report No. 96

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Colorado Water Congress
Water Resources Division of the Colorado Department of Natural Resources
Colorado State University's DroughtLab
U.S. Geological Survey
CSU Western Center for Integrated Resource Management

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Foreword

Colorado is in the midst of a particularly dry period in its history. The flows of 2002, in many parts of the state, are the lowest on record. These record low flows follow two below normal water years. Colorado has not had to cope with a multi-year drought of this magnitude for almost 50 years. During this time, considerable shifts have taken place in Colorado's economic base as well as in its corresponding use of water.

'Drought' is a difficult term to define, particularly when the wide range of water shortage ramifications, to both human and natural systems, is considered. As a result, it is difficult to develop an in-depth discussion of 'drought'. With that as a qualifier, this drought conference narrows its focus to the efforts, and related lessons learned, of our water management system in providing water during the drought of 2002.

At this time (December 4, 2002), there is great uncertainty about the water supply of 2003 and beyond. The purpose of this conference is to focus on the thinking, actions and plans of Colorado's professional water managers as they attempt to guide Colorado through the uncertainties of the current drought. The published proceedings of the conference, it is hoped, capture the uncertainties, challenges, critical decisions, options, and immediate, as well as long-term, plans of Colorado's water managers. It is hoped that by preserving the thoughts and coping strategies of water managers, at the height of uncertainty, future citizens and water managers will better understand the need to constantly prepare for drought in a semi-arid climate.

Robert C. Ward, Director
Colorado Water Resources Research Institute and CSU Water Center

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CALL TO ORDER:

Professor Jose Salas, DroughtLab, Co-Director

I would like to welcome all of you to our CSU campus and to our drought conference. Two weeks ago, exactly, on November 20th, the president of our university Dr. Al Yates, sent a letter to the CSU faculty where he summarized the state of our funding situation and the state of the budget, which is well known by now and he advised the faculty on the challenges, actions and measures that all of us will take to cope with the situation. Dr. Yates also stated in his letter, and I quote, "I have often said the people of Colorado State University show their true mettle in times of adversity and I know in the weeks and months ahead we will rise to the challenges before us . . . " and so on . . .

What has this to do with drought? Well, I believe it does at least in the concept and the spirit. I believe in times of severe drought the people of Colorado will truly show their imagination and effort to cope with many of the impacts and consequences that this drought has brought before us. As a step in this direction, our university, through the Drought Analysis and Management Laboratory, decided to organize this conference to provide an opportunity to describe our experiences, interchange ideas on what the current drought means and what can we do about it.

In the summer of this year (2002), the Colorado State University, through CSU's Water Center and through the Colorado Climate Center, created the Drought Analysis and Management Laboratory, DroughtLab, to bring together multidisciplinary faculty, researchers and students from several departments and colleges across the University campus, to focus research and studies on the complex issues relate to drought. This Drought Conference is one of the several activities that the DroughtLab has been undertaking and I would like to take this opportunity on behalf of Dr. Roger Pielke, co-director of the lab, and myself to thank Dr. Robert Ward, the director of the Water Center, for taking the lead in organizing this conference. And also, at the same time, this Conference would not have been possible without the support of the Colorado Water Congress, the Colorado Water Conservation Board, the State Engineer's Office and the USGS Colorado District. And we thank them very much for their support. Now what will this conference produce? We will publish a well documented meeting proceedings which will include all oral and written presentations and posters and a summary of the discussions and comments and recommendation that will emerge from this meeting today.

And now, it is my pleasure to introduce Dr. Tony Frank, CSU Vice President of Research and Information Technology.

WELCOME

Tony Frank
Vice President for Research and Information Technology
Colorado State University

Good Morning.

It is my pleasure to welcome you to our campus, although, on behalf of Colorado State University, I have to admit I wish we were all here to talk about something other than the drought. I think for anyone who has been even remotely engaged in our region, we all know large numbers of people who have been impacted by the drought. From our urban areas to our farms, from fields to golf courses and lawns, from ski areas to the capitol and our court houses, the drought has continued to have a marked impact across our state and across our region. And yet, just as the drought is here, so are we – and as I look across this room from the perspective of someone who is not an expert in water, I see in you and the organizations that you represent a tremendous asset of expertise, of experience, of vision, and, simply, of the ability to get things done. Many of you have a long history of accomplishing things for Colorado and the region in the area of water.

I believe that as we look down the road, whether we're talking about water science, social implications of drought, water policy, or economic impact; we're going to be able to call upon that experience and that energy and that expertise to step up and really make an impact for the citizens of our state and for our region. And if you think about it, society makes a tremendous investment not only in our research universities, but in all the different organizations and institutions you represent. And in times like this we have the opportunity and, I believe, the responsibility to step forward and deliver to society a return on the investment that they've been making. I'm confident, as I look at the expertise assembled around this room, that we'll be able to do that.

Colorado State has a long history and pride – with, I think, some justification – in its involvement with water and water research issues. And yet, clearly, we're very thankful to have the expertise of a wide array of people far beyond our institution, who have agreed to participate in this conference. We'll be better off because of your participation. So again, whether we're talking about immediate response issues, or longer term, proactive planning for the next drought (because I suspect we all know that just as this drought will pass, there will be another one down the road, and we need to plan for it as well); your activities here will be valuable. So, on behalf of the DroughtLab, the Colorado Water Resources Research Institute, and the University as a whole, welcome to our campus, best wishes for a productive conference and thanks in advance for all your efforts in these challenging times.

OPENING REMARKS

Representative Diane Hoppe
Co-chair of the Colorado Legislature's Water Resources Review Committee

Good Morning ladies and gentlemen. And Dr. Ward, I want to thank you for putting this entire conference together because this, I think, will be a quite historical conference in that this will actually record what is happening with this current drought, and hopefully for the future, provide some information for future droughts.

As we know in Colorado, droughts are cyclical. And certainly, we're in the midst of one of the deepest cycles that we've had in the history of our state.

Looking from the legislative aspect, we have many challenges facing us this year. We have the challenges of budgets that are in a declining state. We still are experiencing revenues that are declining in the state; we're in the midst of the worst drought in the history of the state; and I think that the economic impacts of this drought will be felt for many years. I recently had an opportunity to speak to some local school administrators out in my district and as you're probably aware K through 12 receives the bulk of their funding from state government and this legislature and governor are committed to fully funding K-12 education, but the remaining portion of their funding comes from a local level, from the property taxes that people pay and I think that that's where the impacts of this drought are really going to show up.

Looking at all the different scenarios that might happen, I live in an area where irrigated agriculture produces a lot of income for our counties. If that income is reduced, the farmers may have to change their operations to become dry land farmers. If they are indeed able to stay in business – I think that the impact felt by the counties in the reduction of their assessed property values are going to have a significant impact on the schools, too.

So we've tried to prepare the school administrators in our district. I advised them, "Do your cuts now. Anticipate that there is going to be a declining budget, and even though the state may maintain its funding level, you probably better be aware that there is a likelihood that there will be a decline at the county level."

I don't really want to be all that pessimistic, but as a legislator I represent 66, 000 people and under the new reapportionment, all of the state representatives represent that many people. One of the frequently asked questions that I receive is, "What are you going to do about the drought this year?" Well, what I plan to do is introduce legislation to make it rain!

But in seriousness, I try and get people to divide that question into three parts: the immediate term, the intermediate term and the long term. And I think that that's the way that the legislature needs to look at the current drought situation. I think that the legislature needs to realize that our system of water administration is not broken; it's just simply out of water right now. We have a good system in place, but we have a severe shortage of water. So for the immediate term I think what we need to do is to add some flexibility to the existing statutes; try and encourage cooperation between municipalities and rural areas; try and find some ways to encourage either dry year leasing, which probably will mean some infrastructure. And dry year leasing could work much on the same principle as water banking, if only we had those facilities and the infrastructure in place within a given area to make those exchanges happen on an available need basis. I think the legislature needs to use some common sense, and I don't know if that's possible, but we'll try.

We all need to do what's reasonable. I don't think we [the General Assembly] should go out on a limb and really take some far reaching ideas that don't have any basis of fact. As Dr. Ward and I were talking a little bit earlier, I wish we had the results of some of the studies that his institute is conducting at this time. I think they would be invaluable in terms of how we might be able to stretch our existing water resources to more efficiently use the water and save some water that possibly could be used, leased or sold to other areas. But we have to remember that we can't negatively impact return flows, because that water is someone else's water right and we can't negatively impact our compact agreements. So, those are two things that I'm going to insist that the legislature this year always keep in mind: that we can't negatively impact the return flows or the compact agreements.

Looking at the next term, which I call the intermediate term, before we get to the future solutions, I think we need to look at some things that are not new to us; one is improving forest management to improve water yields. And you have to realize that improved forest management won't work in every single area; that in certain drainage basins we certainly can do a better job of managing the forest and increasing water yields.

The next thing we need to consider is weather modification options and I think you have on your agenda this afternoon some opportunity to hear some experts talk about weather modifications. We also need to consider conservation. But as we consider conservation, again, we have to keep in mind the return flows that make our whole system work here and the compact agreements.

In the long term, we've got to be looking at more storage. You know the storage we have now is providing for us. Our forefathers had the insight to look into the future and say, "We've got to provide this storage." In the climate that Colorado's in; in the geographic location in being a headwater state, we have to capture the water as snowmelt and use it all year around. That's a given in this state and we need to do a little better job at that.

You know, I think during these extreme drought times, cooperation is the key. I'm quite distraught on my end of the river, at seeing the number of law suits that have been filed and I want to remind my constituents that law suits don't make any more water. Farmers that have very little expendable cash right now are paying their money to attorneys and won't have any more water to show for that. If we can pass that bill that says we're going to make it rain, that would help.

I don't want to go on too long here, but I don't want to end on a pessimistic note, either. I think this drought is the catalyst for change and the changes, I think, are going to be good. We do need to do some things in the state of Colorado to make our system more efficient, to really stretch our existing resources. And, as was noted earlier, we have a lot of good minds in this room – a lot of good ideas. And I hope that you will communicate those to me and to others in the legislature, as we go through this legislative session. We need all the help we can get.

I have to tell you, it's kind of ironic that we're going into this worst budget year, this worst drought cycle and the legislature, when we have the greatest turnover that we've had in the legislature because of term limits. We have the most inexperienced people making these decisions this year when we need the most experience. So, those of us who are returning to the legislature, I think, need to provide the leadership. We need to ask our colleagues to educate themselves, especially in water issues. We've provided a number of opportunities for legislators to get some education really quickly.

Today as a matter of fact, the legislative council is going through orientation for new members and has on their agenda today, a briefing on the basics of water law. There will be several other opportunities through the Colorado Water Congress, through the Colorado Foundation for Water Education, and also Senator Nets and myself are sponsoring a briefing the day before the session starts for legislators. So I'm optimistic that the opportunities are there for them, but they need to reach out and grab those opportunities.

Again, Dr. Ward, I want to commend you for the efforts that you've made in putting this program together. I know that in looking at the agenda, you have some great speakers lined up and I think it will be very informative for all of us. Thank You.

"WE'VE BEEN HERE BEFORE!" HISTORIC RESPONSES TO DROUGHT IN COLORADO

Michael Welsh
History Department, University of Northern Colorado

The year 2002 will go down in history as the driest twelve-month sequence since records have been kept on Colorado's precipitation (a period that stretches back 150 years to the days of the famed gold rush). Public attention has focused upon the subject of water in ways not seen for six decades and more (at least as far back as the "Dust Bowl" of the 1930s), while the potential for stunting the urban and industrial growth of the Centennial state has worried political and civic leaders as much as the impact upon Colorado's multi-billion-dollar agricultural sector. Streams like the Arkansas River flowed at levels last witnessed in the early 1700s, when the only travelers upon it were Spaniards and Plains Indians. Early winter snows in the high country augured well for the ski industry, but water managers and scientists alike warned that much more moisture needed to fall from the skies to replenish the vast network of reservoirs and lakes from which Colorado's good fortune emanates.

If crises are the trigger for public policy in America, drought in Colorado certainly qualifies as an important feature of historical life. The story of the highest state in the nation is replete with examples of cultures finding opportunity amidst the aridity and harshness of nature, only to face challenges and hardships when nature turned on them and forced them to leave. All of these examples, ironically enough, had links to the cycles of abundance and scarcity of moisture now plaguing the first years of the 21st century. The ancient cultures of what came to be called the "Four Corners" area of southwestern Colorado were attracted to its high mesas and deep canyons in the first millennium because of what scientists claim was a 400-year "wet cycle" (roughly the years 800-1200AD). Their civilizations flourished throughout the interior deserts, only to be devastated with the onset in the 13th century of a prolonged "dry cycle" that raised levels of anxiety and stress. This culminated in violence, death, and the departure of the people whom later generations of archaeologists would call the Anasazi (translated for decades as "the ancient ones," or "those who have vanished").

Not until the return of the 400-year wet cycle in the 17th century would today's Colorado draw renewed attention from outside groups seeking opportunity and stability in a harsh land. The four centuries of European and American control of Colorado (beginning with the early Spanish explorations of the mid-1500s) relied upon a general pattern of moisture that would come and go in 20 to 25-year wet and dry cycles within the larger domain of abundance. The Spanish, seekers of gold and large civilizations to conquer and convert, found neither in the far northern reaches of their empire. Their words for the Great Plains (El Llano Estacado, or the "Staked Plains"), and for the semi-nomadic cultures that inhabited them (Los Indios Bravos, or the "wild and uncontrollable Indians") reflected the ways that nature shaped human existence.

Old Spanish maps showed their preference for the green valleys and Pueblo Indian cultures of northern New Mexico, and the only Spanish reference to Colorado in the years prior to American entry was the term El Cuartelejo (the "far quarter"). Not until the American army moved northward into the San Luis valley in 1851 would a Spanish-speaking settlement appear in today's Colorado (the farming community of San Luis), and the population of southern Colorado remained small because of the high altitude, short growing seasons, and geographic isolation from the Front Range communities spawned by the 1858 gold rush.

It would be the Americans who would find the means to mitigate (if not overcome) the persistence of drought in Colorado, and it would be they who left the most permanent human mark upon the land. Yet even Yankee ingenuity met its match in the years before gold-seekers poured across the Plains. Lieutenant Zebulon Pike, sent by President Thomas Jefferson in 1806 to follow the course of the Arkansas River to its headwaters (much as Jefferson had ordered the more famous party of Lewis and Clark to do for the Missouri and Columbia basins), reported that the landscape of southern Colorado reminded him of "the sands of Africa."

More telling were the comments of Lieutenant Stephen H. Long, who in 1819 journeyed westward along the South Platte River, named a mountain peak for himself, and declared that the 700-mile stretch between Westport Landing, Missouri (outside of today's Kansas City) and the Rockies was the "Great American Desert." The name endured on maps for decades, and the perils of crossing the "dry line" of western Kansas affect people's consciousness today about the eastern plains of Colorado (where less than five percent of the population occupies 40 percent of the land).

Permanent settlement of Colorado's mountains and plains owed its existence to the fortunes of gold (and later silver) mining. The benefits of wealth overcame the limits of nature, abetted in the years 1865-1885 by a substantial wet cycle that led the nation's policy planners to think that it would never end. Communities like Greeley sprang up in the years after the Civil War to draw water from the copious streams of the central Rocky Mountain range, and the "Greeley model" of private irrigation districts became an international standard (emulated from the Central and Imperial valleys of California to the Middle East and Asia). Flattening out the cycles of abundance and scarcity with high-mountain storage, long canals, and divisions of water rights based upon seniority allowed farmers and ranchers to plan for a future that previous generations of Coloradoans had never known.

Then came a cycle of aridity in the 1890s and early 1900s that nearly wiped out the gains of a generation shaped by "wet-cycle consciousness." From the violent blizzards of 1887-1888 that killed over five million head of cattle wandering the open range from Montana to Texas, to the searing heat of the 1890s that gave rise to the radical political movement known as "Populism," climate and weather threatened to restore Stephen Long's "Great American Desert" moniker to maps of Colorado and the interior West.

A senator from the new state of Wyoming, Joseph Carey, convinced his colleagues in 1894 to pass the "Carey Act," which called for funding of irrigation reservoirs with money collected from the sale of public lands in the West. The grip of drought, however, kept many farmers from moving into the region, and the collapse of the silver mining business in the mid-1890s emptied Colorado's mountain towns (and removed the consumers of Colorado agricultural production). Not surprisingly, pressure on political leaders in Washington led in 1902 to the establishment of the U.S. Reclamation Service (later renamed the U.S. Bureau of Reclamation), in which the federal government provided the capital, technology, and engineering expertise to sustain agriculture throughout the interior West.

As would happen so often in Colorado's history of drought and abundance, the return after 1905 of the wet cycle coincided with major gains in population (this time to the urban corridor of the Front Range and also the vast expanses of the eastern plains). Farm prices soared to their highest levels ever in the years preceding and including World War I (1914-1918), as the federal government negotiated contracts with America's farmers to "plant fence to fence for national defense," as posters proclaimed on the walls of post offices and feed and grain stores in farm country.

At the same time, the federal government opened lands on the plains heretofore ignored by homesteaders, including the South Platte River valley. There a group of black residents of Denver followed the call of the Reverend O.T. Jackson in 1909 and started the utopian colony that they named "Dearfield." With profits like farmers had never seen, railroads ran lines across the plains, banks loaned money in record quantities, and communities built schools and other public institutions in hopes that stability and prosperity were there to stay.

If history meant anything to these 20th century pioneers, it was the boom mentality that came with wet-cycle consciousness. Perhaps that explains the shock and trauma visited upon the state when the dry cycle returned in the mid-1920s, aggravated by the end of federal farm contracts after the war's end, the shift of investment capital to the nation's growing cities (which also offered more attractions and amenities than rural America), and the collapse in 1929 of the stock market, which triggered the decade-long "Great Depression." By 1933, farm and ranch production in Colorado had declined by 50 percent (a statistic that mirrored national trends), unemployment stood at one-third of the adult work force, and the value of investments had sunk to a mere ten percent of their 1929 peak.

Making matters worse for Colorado and its neighbors was the added calamity of the Dust Bowl (1931-1940). W.D. Farr, a banker in Greeley during the Thirties, would witness first-hand the pain and suffering that drought could inflict on his friends and neighbors; a phenomenon that remained fresh in his mind six decades later in a 2002 interview on the history of drought in 20th century Colorado. Farr would recall how dust blew down the wide streets of Greeley (a town created to overcome the vagaries of nature on the plains), and how that broke

the resolve of people to endure the hardships all around them.

Community leaders like Farr would gather to contemplate radical solutions, among them the novel concept of transferring water from the abundant west-flowing streams of the Colorado River valley to the parched towns and farms of the South Platte drainage basin. Convincing West Slope interests to sign away their claims to water that they did not need was but one of the challenges in the path of the "Colorado-Big Thompson Project," known colloquially as the "C-BT" and "the Big T." Congress approved the project in 1937, and by 1954 water flowed from reservoirs in western Colorado through a 13-mile long pipeline under Rocky Mountain National Park and into the Cache la Poudre and Big Thompson rivers. Farr remarked that the stability and volume of the "Big T" had "created" the modern Front Range, and that its combination of storage reservoirs and supplies from the sparsely populated West Slope would help eastern Coloradoans survive most of the dry cycles that followed.

With the return of the wet cycle in the early 1940s, abundance of another sort came to Colorado: the urban growth associated with military spending in World War II (1941-1945). The population of Denver would expand from 330,000 in 1940 to 2.4 million in the 2000 census, with similar statistics for communities like Colorado Springs (40,000 to 550,000) and Fort Collins (12,000 to 100,000). Agriculture would benefit from these growing markets for food and fiber, just as wartime crop production again brought prosperity to farmers suffering from a decade of drought. The dualities of urban sprawl and increased farming would place a strain upon the state's water supply when the next dry cycle came (the mid-1950s), at which time the strategy of underground pumping for irrigation wells was introduced. The dry cycle of the early 1950s to the late 1970s only had one bad year (1954), and that was mitigated by the flow of C-BT water onto the plains.

Increased use of water in the dry cycle of mid-century would lead in 1969 to another change for water users: the adjudication of water rights. Water courts were established in each river basin of the state, with rural and urban interests competing for claims to stream-flows that fluctuated dramatically in periods of drought. Before this dry period ended, yet another feature of water management entered the Colorado landscape: snowmaking for the state's growing network of resorts. International fascination with Colorado (particularly its snow-covered mountains) had lured a new generation of pleasure-seekers in the 1960s and 1970s, and skiing became their venue for excitement and adventure.

A "year without snow" (the winter of 1976-77) kept many resorts from opening, and their owners responded in the same way that the irrigators of Greeley had done a century before. They applied technology to their operations, and drew water from mountain streams to spray upon their mountainsides. Additional technologies included "cloud-seeding," where airplanes flew into the heart of storms over the Rockies and dropped iodized pellets that would expand the water molecules (and increase the yields of snow).

The late 1970s also witnessed the first attempt to manage drought, rather than merely react to it with despair or public works facilities. Colorado governor Richard Lamm, who had risen to prominence in the early 1970s with his strident message of environmental protection, assembled the first "drought task force" in state history. Lamm had worked in 1972 to block Colorado's bid for the 1976 winter Olympics (the only state to have done so in the 20th century), and he stressed the need for careful stewardship of the state's natural resources. Len Boulas, director of Colorado's office of emergency preparedness, would chair the task force, and Fred Anderson, a state senator from Loveland, would serve as a senior member representing the state legislature.

In interviews in 2002, Boulas and Anderson recalled the many problems facing their committee: a lack of precedent not only in Colorado but nationwide in drought planning (only one state had a similar task force underway in 1979, said Boulas); the desire of urban residents to have green lawns in an arid climate (Denver would not have individual water meters for households until the early 1990s, and people would water their lawns daily to combat the drought); and the need to sustain agricultural production that consumed over 80 percent of all stream-flows in the state.

Confronting the drought task force was one additional feature not known to previous generations of Colorado water managers: the environmental movement. Fred Anderson recalled how representatives of major environmental groups practiced "single-issue" politics: speaking emphatically for their position, with little regard for the complexities of water management in the state. Anderson and his colleagues realized that water policies had to change, but the tensions caused by drought, demand, and environmental activism made their job no easier. Eventually the committee sent Governor Lamm a report offering suggestions for cutbacks (Denver temporarily

would restrict lawn-watering in the early 1980s), but their work stalled when the matter of water rights adjudication surfaced.

Then, remembered Boulas, the wet cycle returned, lasting for nearly two decades. Public awareness of the hazards of drought vaporized as easily as water does in desert heat, and the drought task force recommendations collected dust on library shelves. More critical questions consumed the attention of the state's leaders, such as recovery from the late 1980s energy bust, the reinvigoration of the state's economy with urban growth and high-tech industries in the 1990s, and new demands on water resources for commercial and recreational development.

When the latest round of abundant moisture ended in the mid- to late-1990s, much had changed in Colorado that threatened the state's water resources once more. Census data revealed that the Centennial state ranked third nationally in population growth, with three of the fastest-growing counties in America to be found along the Front Range and in the adjacent foothills. Prosperity had reshaped the economy, with Colorado seen as an attractive option for families and corporations fleeing the high costs and overcrowding of the nation's more-mature urban areas. Farmers also had reconfigured their operations to meet the international markets, and the decline of available water for irrigation made them only more dependent upon underground sources. The inevitable clash of uses that emerged at the turn of the 21st century, then, reminded Farr, Boulas, and Anderson that several lessons of the past needed repeating.

First, said W.D. Farr, water managers and urban planners alike needed to "be cautious" about their projections for water use. After nearly a century of observing the Colorado water scene, Farr concluded that one must respect the power of nature, and also "remember that people forget the past" as they seek a better future. Fred Anderson then noted how a "balance" must be struck between growth and environmental protection. He and Len Boulas remarked about the visceral distrust of environmentalists regarding multi-purpose water storage facilities, which both individuals claimed would affect the landscape far less than persistent drought.

Boulas closed with the admonition that water managers must learn to work together (a plea echoed by former state senator Anderson) rather than focus upon their particular region of the state or river basin. Finally, said Boulas, water managers needed to remember that they were servants of a public in need of explanations of the complexity of western water. Its history and future would shape the plans and dreams of four million Coloradoans, not to mention the generations to come.

Their understanding of the centrality of water would echo that of a former Coloradoan, James A. Michener, whose five-year stint as a professor of history education at Colorado State Teachers College in Greeley (today's University of Northern Colorado) affected his thinking many years later when he returned to write the definitive novel of Colorado's history, Centennial (1974). Coming in 1936 from the humid East in the worst year of the Dust Bowl (Weld County had seen summers with over 100 days of temperatures above 90 degrees, winters with little or no snow, and dust clouds billowing 60,000 feet into the atmosphere), Michener marveled at how nature resisted the efforts of farmers and ranchers lured onto the plains in times of abundance.

Towns like Keota, which became a favorite haunt of Michener's (and the site of his "Line Camp" in Centennial), lost their best and brightest to the wind, drought, and bad markets of the 1930s. By the 1970s, the only reminders of the experiment of the plains were the creaking windmills, sagging structures, and empty town-sites where hopes had risen as rains had fallen, and Michener's gift to Colorado was to reiterate the old lesson that water makes us what we are.

DROUGHT: A RECURRING ATMOSPHERIC AND HYDROLOGICAL EVENT

Session Moderator:

Martyn Clark
Western Water Assessment
CIRES-NOAA
Boulder, Colorado

CLIMATE HISTORY LEADING UP TO 2002 DROUGHT

Roger Pielke, Sr. – Director, and
Nolan Doesken, Research Associate,
Colorado Climate Center, Colorado State University

I'm going to go through a little bit of history. This is a joint talk with Nolan Doesken and myself. And the first thing I want to do is put the concept of drought in Colorado in a perspective in terms of three month dry periods, if you want; and the fraction of the state of Colorado that's in drought in that time period; and what you see is that there are periods in the last one hundred years – one hundred and ten years, where significant fraction of the state is in drought. So clearly, as we've seen Michael's presentation discuss, that there are periods of drought of different lengths, different intensities and the drought we're in now we'd heard earlier that this was the worst drought in Colorado history. Actually, I don't think that true and I'll give you some examples of that in a minute, which is kind of a scary scenario.

But first, let's talk about some types of droughts. One of them is when we don't have any snowfall in the mountains until late January, then maybe it dumps for the rest of the season; but if you're a ski industry, that's not too good. It could be dry in April and July, but you get good rains in August; but if you're a dry land farmer, that's not very favorable. Another type of drought we've had this past one year; would occur for the next five years, and then, if we had a situation where the mountains received 90% of average snow for the next twenty years; all of these would have different impacts in the state.

An example of a recent drought we've heard, the 1970s drought – can be illustrated by this figure – this is the Palmer Drought Index, showing much of the western United States in severe and extreme drought – the upper Midwest, also in extreme drought. In a few minutes I'll show you the drought coverage for this past event, and you'll see that the current event is not out of the ordinary in terms of it's aerial extent. But, let's get to the backdrop of where we started from.

First of all, we've been drought free, for the most part, since the late 70s, then we had some very wet years – we had extreme record stream flows in 1983 and 1984. We had 1999, where we had a low snowpack but we had good precipitation in the spring, and so by September 30, 1999 the state reservoir storage was about 130% of average. So, it was fun to go the state drought task force meetings during those times, because there was really no concern, other than the fact that we knew that drought was going to come again.

And it did come again this past winter. We got to April 1st with record low, or near record low, snowpack statewide after, as you can see, some abundant years back in the mid '90s. So we entered with poor snowpack, but there was lots of optimism because we weren't as bad as 1977 and we had some optimism for a wet spring and that's what we'd normally expect. But that's not that way it worked out, as you're all aware. We got into April, it was very warm and very dry, we had rapid snow melt and even worse, we had lots of sublimation and evaporation from the snowpack so it didn't even get into the rivers, so there was very little runoff. Then we get into May – May is usually quite wet, in much of the state. We had only had one significant storm, continued high evaporation – the severe drought arrived and it came suddenly, no one predicted it – not at this intensity. We get into June, we did have some rain, but a lot of it was heavy rain, it ran off, evaporation rates were high; extreme drought in the mountains; the forest fires started to occur in the state and the biggest example of that was the Hayman fire, which was the largest in the state's history, over 100,000 acres burned. So we had raging wild fires, low stream flow, rapidly depleted reservoirs, severe agricultural impacts, hot weather and we started to see urban water restrictions imposed.

So again, this came on suddenly. You can look at the temperature anomaly for June, much of the state or all the state, was well above average, some places in the southeast were six degrees above average. And we get into July – July also is often a wet period, the monsoon typical starts as you go through July starting in the southwest and working farther Northeast. It didn't start as expected, so the hot and dry weather continued, crops withered, urban water concerns continued. But later in July we started to get a little more humid; we had some lighter winds, so we had a little bit less evaporative loss

of whatever water was left. But we still were well above average in terms of temperature running up to four degrees or so above average; so, hot and dry – a bad combination.

If you look at the US drought monitor for late July, you can see the aerial coverage of drought in the West. You can see, Colorado was near the epicenter of the drought, so it was serious. We get into August, and we had some extreme heat early, some more wildfire flare-ups, that one near Steamboat Springs, but we started to get some storms in late August, the monsoon finally did kick in some, so here was some relief, some moisture recharge, but we're still far from out of the drought.

You look at the temperature anomaly, we were still above average, but not quite as far above average, about two-degrees above average, but it continued, this very, very hot summer. Looking at it in a national perspective; looking at the fraction of the U.S. that's in extreme drought conditions, which is the top figure you can see on the right hand side, that almost forty-percent of the country was in extreme drought conditions. But then you contrast that to what occurred in the 1930s for example and you can see that this drought was not the worst nationally in history, it's just sort of a run-of-the-mill drought, in fact, it's still rather a short-term drought, so it puts it in a perspective that really should wake us up, that things could get a lot worse then they already are.

We did an analysis of September 1, 2001 to the end of August 2002, using climate divisions that Klaus Wolter has developed and this shows the rank of these long term climate observing stations for the period of record for the precipitation for that 12 month time period. And it does show the extreme severity of this one-year drought in the State of Colorado, but the message here is also that some locations didn't have the most extreme drought; for example, Grand Junction was the eighth driest in that 120 year time period; Cheyenne-Wells, it was the fourth; Leroy was third; Kassler was the eighth; but a number of the sites did have their worst one-year period – from September first to the end of August – on record. It doesn't mean the driest one-year on record; but that time period which is close to the water year.

But then we get into September, and some good news comes; much of the state had good water – not everyone did – up northeast around Fort Morgan they didn't, but lots of areas had over 200% of average in September, so the message of, is the drought over?, of course the answer obviously, is no. But it was a good signal; it did well for the soil recharge, for example, in some of the eastern areas of the state. This is the precipitation percentage for the water year, from October to the end of September, and even with the rains that did occur in September, you can see that statewide, every one is below average. Some areas did get up to 90%, but in general, it's below 70% and in a lot of location, below 50% of average, so an extremely dry year, as you can see looking at the reservoirs around the state.

Now, put this a little bit into a global context just to make this clear that this is a regional issue – this happens to be temperature. It's a September map of the global temperature in the lower part of the atmosphere and when it's blue, it's below average; and when it's red, it's above average. You can see the cooler weather that came to Colorado in September, where the hot anomaly shifted farther east. But you can see in a global context, that there are areas that are wet, and there are areas that are dry, areas that are warm, and areas that are cool and it varies. The pattern we got into last winter was one where we missed the winter storms – they didn't come into the mountains, but we also missed the spring storms, which typically wet the Front Range. So we had a combination of weather patterns that caused the state, as a whole to become dry.

Just to illustrate that not everyone had the driest one-year on record, this is the data for Fort Collins. The blue line shows the wettest year which is '22-'23, the driest year in Fort Collins, was 1953-'54 and you can see where 2001 and 2002 fall into that range. What's different between now and 1953 and 1954, as we've already heard, is that the use of water is different. There's more urban demand on water so the impacts are quite different. And the reason we need, I think, to focus more on the impacts is that the predictive skill of these kinds of events is very poor.

The American Association of State Climatologists has a policy statement that concludes that perhaps at best under some situations, we have some seasonal skill. And you'll hear more about that in a little bit. Beyond that time period, we think there's no skill, so the statements you hear in the media, that the West is going to become warmer and dryer – I don't think there's any scientific foundation for making that prediction. And what our proposal is, and our direction is, is to focus on vulnerability. And the idea is that you assess the risk for example, to water resources, of variability due to climate and other environmental issues. And that's a much more valuable tool to present to policy makers than trying to say we can predict what will happen 10 years in the future, or even next summer. We think that we should explore that as a

research issue, but to base policy completely on those tools, we think is a mistake.

I'll give you an example of some of the needs that we have here in Colorado, and what we can do to study this vulnerability to drought. What would be the impact today of historical droughts, for example; a reoccurrence of the '50s drought, the '30s drought, or the 1890s drought? What would be the impact today of the pale droughts that Connie Woodhouse will talk about in a little bit? And what if the 2001-2002 pattern reoccurred this coming winter? As I said, we had a very serious one-year drought, but there are longer time droughts of longer duration and more serious dry conditions, and so if they reoccurred with today's infrastructure, what would be the consequences? Another question is how we can make Colorado more resilient to droughts, since they're part of our system. And what are the definitions of the multi-dimensional character of droughts (because there are different droughts for different impacts)?

And finally, I'd like to alert you to a magazine that we publish through the Colorado Climate Center where we talk about issues such as drought and climate and so forth; past issues are available on our website at http://climate.atmos.colostate.edu/. We are trying to communicate four times per year what has happened in terms of the Colorado climate in the past and some of the issues related to the Colorado climate. There are several articles that Tom McKee, former State Climatologist, and Nolan Doesken have put together for the magazine, and I would suggest you take a look at those. They were written before the current drought, but they're very applicable for the pattern we're in now. With that, I'll conclude. Thank you.

THE TREE-RING RECORD OF DROUGHT IN COLORADO OVER THE PAST 300-460 YEARS

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INTRODUCTION

Colorado is fortunate to have a relative wealth of old trees (300 to over 800 years old) that are also sensitive to year-to-year variations in soil moisture from rain and snow. This sensitivity, manifested in the widths of annual tree rings, makes trees a useful proxy, or surrogate, for instrumental hydroclimatic (e.g., precipitation, drought, streamflow, snowpack) records. The tree species in Colorado that best reflect variations in moisture are pinyon pine, ponderosa pine, and Douglas-fir. These species tend to grow at lower elevations where tree growth is limited by moisture availability. Trees that are growing on particularly water-stressed sites (e.g., dry, rocky, south-facing slopes) can record an especially good record of past hydroclimatic conditions in their ring widths.

Over the past four years, a collaborative research effort of dendrochronologists from Boulder and Fort Collins has resulted in tree-ring collections for over 50 sites in Colorado, mostly from the Upper Colorado and South Platte River basins (Figure 1).

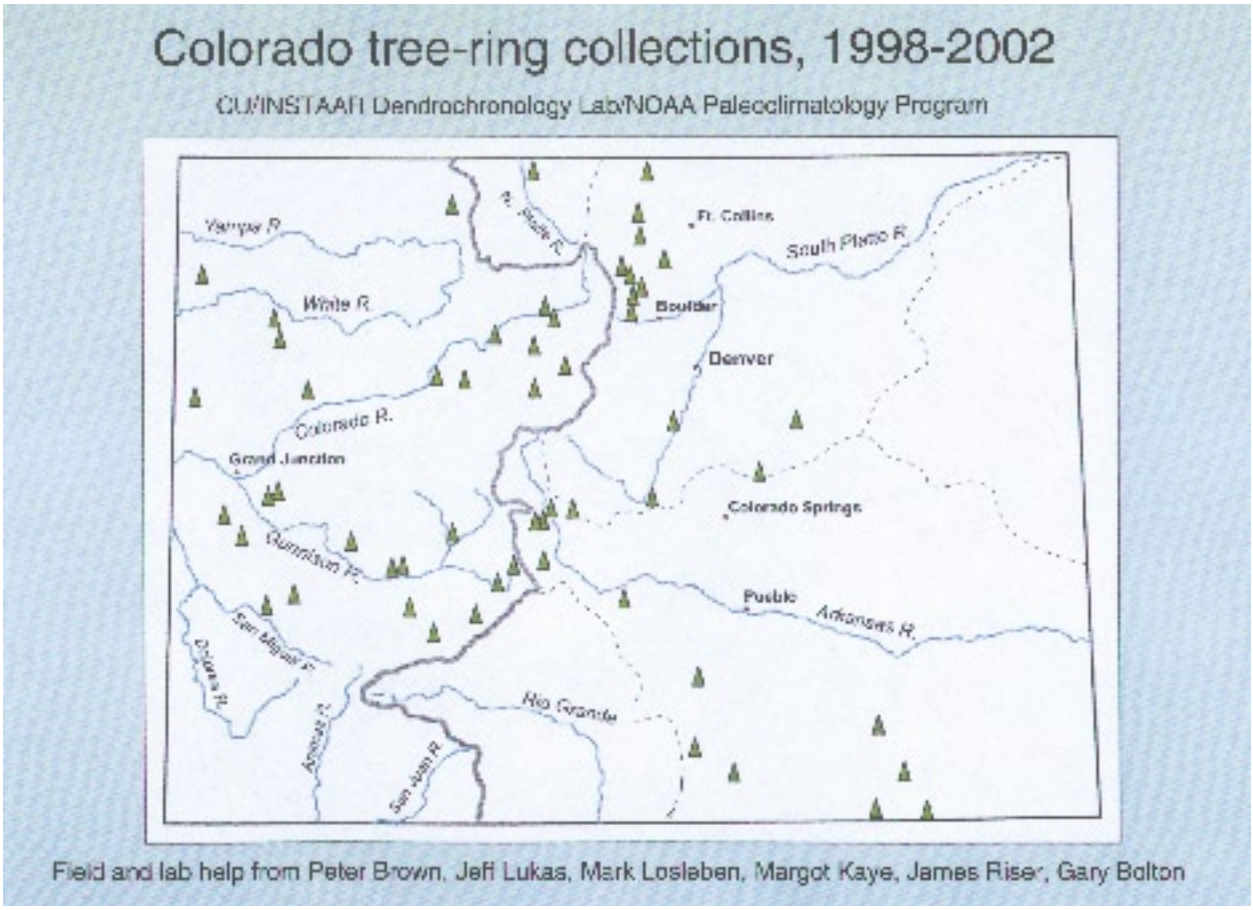

Figure 1. Locations of tree-ring chronology sites (triangles) in Colorado, collected from 1998 to 2002.

At each site, we sample two cores per tree from about 20 trees, using an increment borer to extract 1/4" diameter cores. After dating and measuring each core, all the dated measurements for each year are averaged together to create a site tree-ring chronology. The chronologies are used to generate reconstructions of precipitation, drought, streamflow, or snowpack. In addition to our collections, there are tree-ring collections made by researchers over past decades, including quite a good collection in the Front Range that we are working to update to the present, but are using in the meantime.

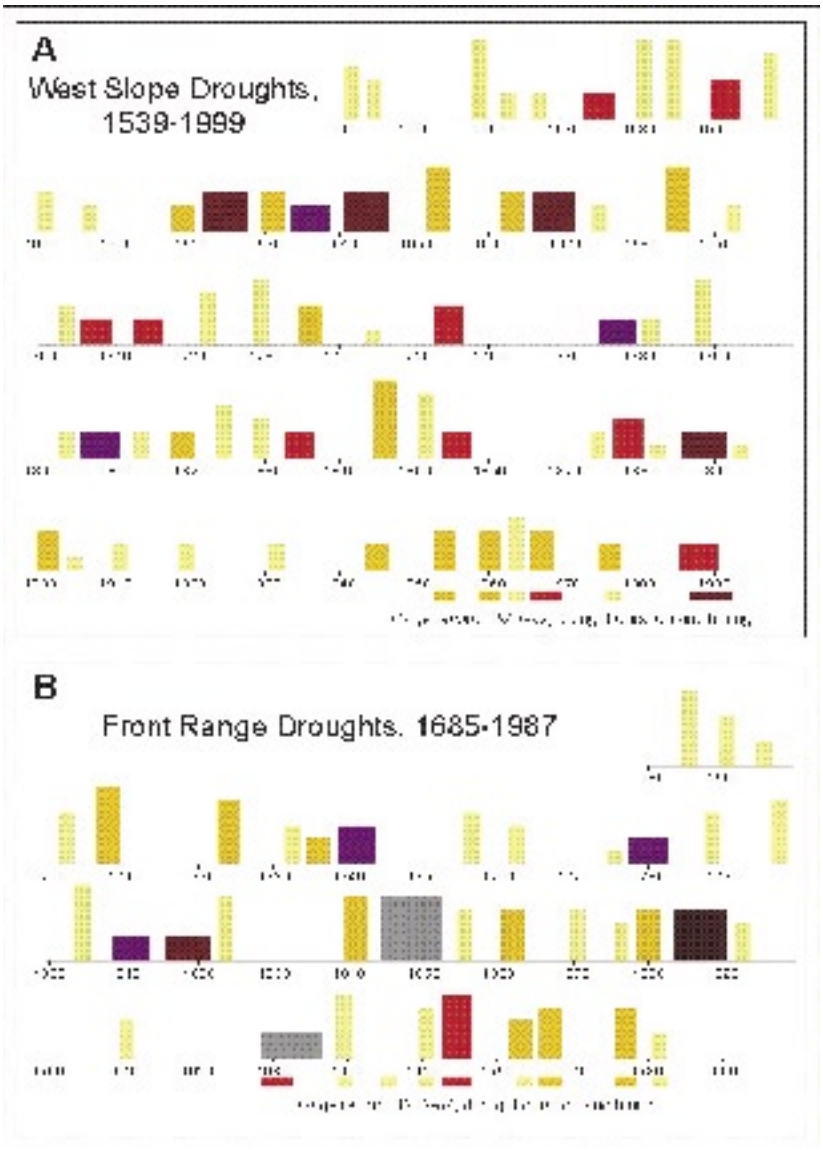

Figure 2a. Droughts in West Slope reconstructed flow, 1539-1999. Each row represents a century. The rectangles show when each drought occurred, and indicate the duration (shade and width of the rectangle) and relative magnitude (rectangle height) of each. At the bottom, the duration and timing of the droughts in the gage record are shown for comparison. The two records are quite similar.

Figure 2b. Droughts in Front Range reconstructed flow, 1685-1987, as for Figure 2a.

Tree-ring reconstructions of streamflow for the West Slope and the Front Range

Tree-ring widths can be used to reconstruct a history of past streamflow because moisture-sensitive trees in this area tend to integrate the effects of regional climate – including precipitation, snowpack, temperature, soil moisture, evapotranspiration, and sublimation – over the course of a year, much the same way an annual streamflow measurement is a cumulative measure of the climate affecting streamflow over the course of a year. When calibrated with streamflow, tree rings widths closely track the year-to-year variations in streamflow. We use statistical methods to generate a numerical model in which tree-ring widths estimate annual streamflow, and then use that model to reconstruct streamflow back in time for the length of the tree-ring record. As proxies for streamflow gages, tree rings do not exactly duplicate the gage record but they can explain about 70%-75% of the variance in the gage records in the Upper Colorado, and slightly less in the Front Range gages.

We have developed a set tree-ring reconstructions of streamflow for gages east and west of the Continental Divide in collaboration with water managers and consultants from a number of municipalities and water utilities (to date, Denver Water, Cities of Boulder (Hydrosphere Consultants) and Westminster, and Northern Colorado Water Conservancy District). In the current study, we averaged reconstructions for the Blue and Fraser Rivers (1539-1999) and Clear, South Boulder, and Boulder Creeks (1685-1987) to create composite flow reconstructions for the West Slope and Front Range. Both records show quite a lot of variability over the past few centuries, and most significantly, the 20th century part of the record does not contain the full range of variability seen in the longer records. The two composite flow reconstructions

show periods of drought shared by both watersheds (e.g., 1950s, 1880s, 1840s-1850s, 1770s, and 1710s) as well as unshared droughts (e.g., 1890s on the West Slope, 1820s on the Front Range). However, overlapping droughts, in which some years are shared and some are not, are the most common.

Drought characteristics

Drought can be measured in terms of duration, intensity, and overall magnitude. These characteristics can be assessed for each of the flow reconstructions. Here, drought is defined by two or more consecutive years of below-median flow. The reconstruction of drought for West Slope flow from 1539-1999 shows a high degree of variability in drought frequency and severity both within and between centuries (Figure 2a).

The early part of 20th century is notable for very few droughts and those that did occur were mostly two years in duration and mild. From the 1940s to the mid-1970s, droughts were more frequent and mostly three years in duration. The longest drought in this century occurred in the 1980s and into the early 1990s, and was a relatively mild four-year event. In contrast, the 17th century is characterized by a number of longer droughts (three six-year and one five-year droughts), and several relatively severe three droughts. The 16th century was characterized by a high frequency of two-year droughts, three of which were quite severe.

The reconstructed Front Range flow from 1685-1987 (Figure 2b) reveals a noticeable difference between this drought record and that for the West Slope: the Front Range flow record has droughts of longer duration than the West Slope. The longest droughts in the West Slope record are six years, but the Front Range record shows several droughts of seven and eight years in duration. The 20th century part of the Front Range record is similar to the West Slope record in that the first part of the century has few droughts – only one two-year drought until the 1930s. After the 1930s, droughts lasting two to five years are frequent. In the 19th century, droughts occur frequently except for a short break from the mid-1820s to 1840. This century also contains two long (seven and eight years) and severe droughts. One of these, the 1840s-1850s drought, was the length of the 1930s drought in the reconstruction, but the severity of the 1950s drought.

In general, both the West Slope and Front Range flow records show a high degree of variability in drought characteristics. This range of variability in the complete records is not well represented in the 20th century part of the record, or in any of the other individual centuries,

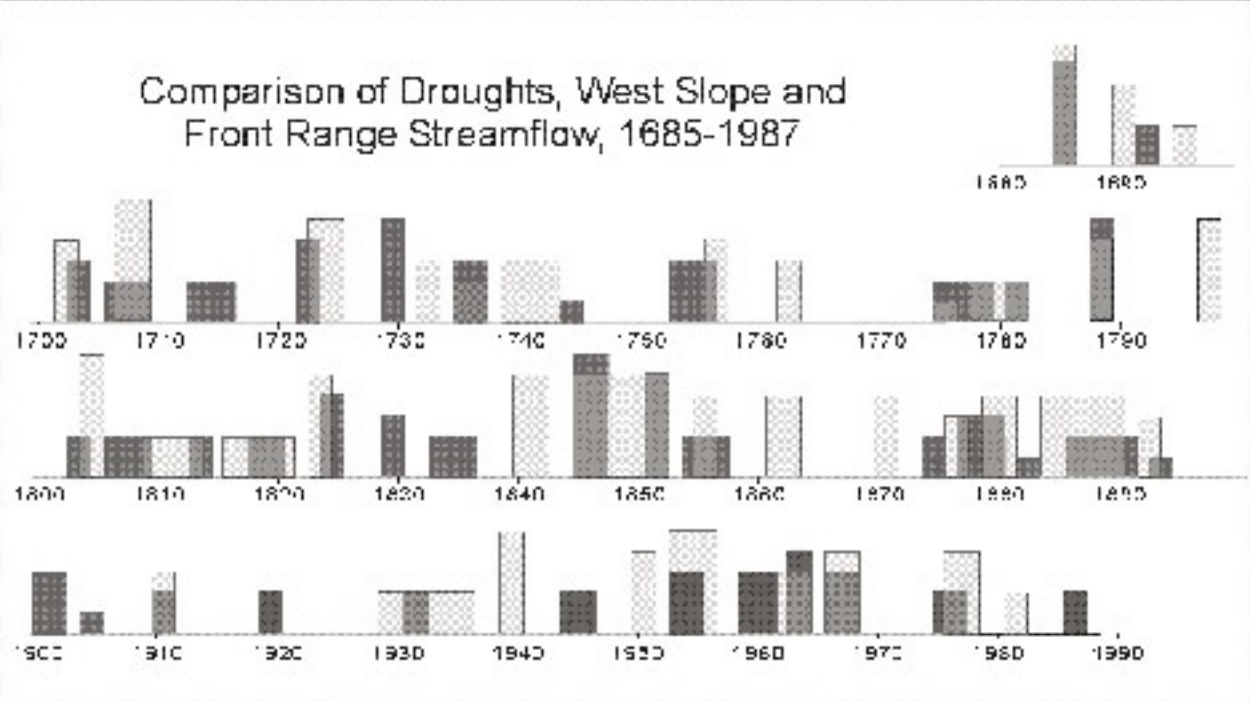

Figure 3. The drought record for the West Slope (dark gray) from Figure 2 superimposed over the drought record for the Front Range (light gray) from Figure 3, for the years 1685-1987.

for that matter. Each century has a different pattern of drought characteristics.

A comparison of the two streamflow drought records is shown in Figure 3, with the drought record for the West Slope superimposed over the drought record for the Front Range. In a few cases, there are droughts that match year-for-year, although the magnitudes typically differ. These droughts occur roughly once a century, and are two to three years in duration. There are other instances when drought occurs in the west but not in the east (late 1820s- 1830s) and when it occurs in the east and not the west (1860s-70s). More often, the droughts overlap in time. This is especially true in the 19th century when there are long stretches of years with drought conditions in one or both regions (e.g., 1874-1895). The persistent droughts in the Front Range tend to be bracketed by or link shorter droughts in the west.

Do severe drought years (those in the driest 10th percentile) tend to be preceded by dry years, or wet years? Are they followed by dry years? These questions can be answered with the streamflow reconstructions by categorizing the years preceding and following drought years into five even classes; dry (< 20th percentile), moderately dry (20th to 40th percentile), near average (>40th and <60th percentile), moderately wet (>60th percentile), and wet (>80th percentile). In the case of the West Slope reconstruction, more years in the wet category immediately preceded extremely dry years than any other type of year. Combining categories, it appears that extremely dry years tend to be preceded by near average to wet years. In contrast, more moderately dry years follow extremely dry years in the West Slope record, and in general, there is a tendency for near average or dry years to follow extremely dry years. The Front Range record shows that years of near average and dry conditions tend to precede extremely dry years. Dry or near average years also tend to follow an extremely dry year in the Front Range record, but wet years also follow some extremely dry years, especially in the 19th and 20th centuries.

The 2002 drought in a long term perspective

Although we do not have tree-ring reconstructions that extend to 2002, we can evaluate 2002 flow in a long-term context by considering the percent of average flow value for 2002. For example, in 2002, Blue River was 31% of the 1947-2002 average. We examined the full reconstruction to identify years with flow values less than or equal to 31%, while taking into account the averaging period and the uncertainty in the reconstruction (i.e., only remember, about 60%-75% of the variance in the gage record is explained by the tree rings). Our results indicate a small handful of years have matched or exceeded the severity of the 2002 low flow in the Front Range (Poudre River and Middle Boulder Creek) over the past 300 years, and a slightly larger handful (due in part to the longer record) on the West Slope (Blue River) in the past 460 years. These reconstructions suggest that low flows similar in severity to 2002 occurred as recently as 100-120 years ago. Our analyses also indicate that 2002 levels were matched or exceeded as often as three times in a century (e.g., the 16th century). Treating the 2002 drought as part of a three-year event (2000-2002), the current drought appears to be much more common. Many three-year droughts of this magnitude are found in the Blue River reconstruction. A smaller number are found in the Front Range flow reconstructions, but at a number of gages, the 1954-1956 drought exceeded the magnitude of the 2000-2002 drought.

It should be noted that a different set of years matches or exceeds the low flow value of 2002 at each of the gages, and there are several reasons why this may be. Geographic differences in gage locations (especially east and west of the Continental Divide) are likely to contribute to differences. In addition, as well as there being uncertainty in the reconstructions, there is uncertainty in the gage records, as most of these are regenerated natural flows. One final reason for the differences may be due to the fact that the percent of average for 2002 has been calculated for a different average period in each case (Blue: 1947-2002, Middle Boulder: 1971-2000, Poudre: 1912-1983).

SUMMARY

Long-lived moisture-sensitive trees in Colorado provide the opportunity to generate high-quality reconstructions of streamflow for Colorado watersheds. These reconstructions can extend the gage records back 300-800 years. We are in the process of updating and expanding our set of streamflow reconstructions for other watersheds in Colorado besides the ones described here. It is also possible to reconstruct other hydroclimatic records such as for precipitation, drought (Standard Precipitation Index, Palmer Drought Severity Index), and snowpack (water content) from Colorado tree-ring chronologies.

The extended streamflow records from tree rings confirm that 2002 was a year of extremely low flow when viewed in the context of several hundred years, but its severity was not unprecedented. Conditions comparable to the 2000-2002 drought have been more frequent in the past.

In addition to using the tree-ring data to make a single year assessment of the 2002 drought, the streamflow reconstructions provide a broader context from which to evaluate drought characteristics of the 20th and 21st centuries. These reconstructions indicate that the 20th century instrumental record of drought, measured by duration, intensity, and frequency, reveals only a subset of the range of natural variability seen in the longer records. Our work also suggests that the climatic mechanisms that cause drought to persist are not the same in the West Slope and Front Range watersheds and in future work, we will use these and other records to explore causal mechanisms for drought.

ACKNOWLEDGMENTS

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PERSPECTIVES ON COLORADO DROUGHT

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Drought is an insidious hazard of nature. Unlike tornadoes, hurricanes, floods and fires, it sneaks up on the unsuspecting as a series of sunny, hot summer days or a period of mild, breezy weather during winter. Drought builds slowly on itself until it has a major impact on our very existence. Water supplies dry up, wells run dry and crops whither.

Frederic Remington, the artist and Western historian, understood the importance of water to the West. His famous painting, The Fight for the Waterhole, embodies the very essence of water's importance to the Western way of life.

Stephen Long, a U.S. Army lieutenant who passed through Colorado in 1822, giving his name to the most visible peak in Rocky Mountain National Park, wrote off the entire block of real estate that included Kansas, eastern Colorado and the Texas panhandle as "the great American desert." His assessment was much the same as Pike, who preceded him, even as to the limiting factor of the plains:

> The Great Plains region is almost wholly unfit for cultivation, and of course inhabitable by a people depending upon agriculture for their subsistence. Although tracts of fertile land considerably extensive are occasionally met with, yet the scarcity of wood and water, almost uniformly prevalent, will prove an insuperable obstacle in the way of settling the country.

If we are to plan water supplies of Colorado's future, a good place to start is in the understanding of Colorado drought: its history, its cycles, how we measure it, where it comes from and how we might plan for its occurrence in the future. The Drought of 1999-2002 in Colorado has provided a rude awakening to drought's impacts on modern life. A mandate to respond has been sounded. The time for decisive but meaningful action requires that we humbly appreciate and understand nature's power.

A look at the past

The history of drought in Colorado can be traced through the analysis of two important data records. First is the modern, or instrumentation, record consisting of actual measurements of climate variables at various locations throughout the state. This record generally dates from the present back to the late 19th century.

Second is the paleoclimatic record, primarily derived from the analysis of tree rings, and extending backwards through history for several hundred to over a thousand years. We will begin this section with a review of the major droughts of the 20th century, followed by a description of paleoclimatic, specifically tree ring, data analyses

and a summary of major drought periods throughout the past 2000 years.

Drought is clearly a common occurrence in Colorado, but droughts rarely encompass the entire state at any given time. Key points regarding Colorado drought are as follows:

- The most common droughts are of short duration (6 months or less) with aerial extents that vary with the seasons.
- Multi-year droughts occur infrequently.
- Precipitation data indicate that most weather stations across the state have experienced two or more consecutive years of precipitation less than 80% of average a few times during the 20th century.

The most significant droughts of the instrumented period, or since the turn of the past century, are listed in Table 1. Each drought period is characterized by when it occurred, the worst years of the drought and the portion of the state where the drought was worst.

TABLE 1. Significant drought periods of the modern or instrumented era

When	Worst	Major state impact areas
1890-1894	1890 and 1894	Severe drought east of mountains
1898-1904	1902-1904	Very severe drought over southwestern Colorado
1930-1940	1931-1934, 1939	Most widespread, severe and longest lasting drought in Colorado instrumented history
1950-1956	1950, 1954-1956	Statewide, worse than the 1930s in Front Range
1974-1978	1976-1977	Statewide, driest winter in recorded history for Colorado's high country and Western Slope
1980-1981	Winter 1980-1981	Mountains and West Slope; stimulated writing of the "Colorado Drought Response Plan" and the formation of the "Water Availability Task Force"
1999-2003	2001-2002	Significant multi-year state-wide drought

Early turn of the century drought

A severe but brief drought occurred in 1890, particularly east of the mountains, followed by a very wet year in 1891. Drought returned in 1893 with severe drought occurring in 1894, again most pronounced over eastern Colorado. This statewide drought produced a sustained and very severe drought over southwestern Colorado. Worst drought on record occurred in the Durango area during this time.

The Dust Bowl of the 1930s

This was the 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. The period culminated with one more extremely dry year in 1939 when several stations along the Front Range recorded the driest year in [20th century recorded] history.

The major drought of the 20th century, in terms of duration and spatial extent, is considered to be the 1930s Dust Bowl drought that lasted up to 7 years in some areas of the Great Plains. The 1930s Dust Bowl drought, memorialized in John Steinbeck's novel, The Grapes of Wrath, was so severe, widespread, and lengthy that it resulted in a mass migration of millions of people from the Great Plains to the western U.S. in search of jobs and better living conditions.

The Visionary Drought of the 1950s

With the Dust Bowl of the '30s a vivid memory, the statewide drought of the 1950s spurred major development of water storage facilities across the state. The development of the Front Range water supply system may have been a product of the fact that this drought was more severe along the Front Range than in the 1930s. Its severe impact on the Colorado Front Range and only light to moderate impact on mountain precipitation may have overly influenced water supply planners into using it as a model of sorts. Unfortunately, severe drought can simultaneously impact the entire state and negate a strategy based on plains drought but ample mountain snows.

The Severe Mountain Drought of the 1970s

Colorado's last period of sustained multi-year drought in the 20th century occurred from 1974-1981. The record-breaking winter drought of 1976-1977, the driest winter in recorded history for much of Colorado's high country and Western Slope, culminated this drought. Statewide weather modification activities were launched during the winter seasons with hopes of increasing the mountain snow pack. Only limited success was reported before snows briefly returned to the mountains for 1979-1980.

The Dust Bowl of the 1930s.

An extreme but brief drought period returned for 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.

Many of the drought dates presented in the preceding discussion and table are mirrored in the time series plot shown in Figure 1. The plot shows the fractional percent of Colorado immersed in at least moderate drought from 1890 to 2002. It is clear that the most prominent droughts in recorded history, those with the longest time-span and largest aerial extent, occurred at the turn of the twentieth century (1890s-early 1900s), the 1930s, the early- to mid-1950s, the mid- to late-1970s and the recent 1999-2002 drought.

Drought of 2002

Having considered the full extent of recorded droughts in the past 110 years, how does the Colorado drought of 2002 compare with past droughts? The severity of the 2002 drought eclipsed many of the records established during 20th century droughts, including those of the 1930s, 1950s, and late 1970s.

The comparative magnitude of this drought to other Colorado droughts is represented graphically in Figure 2. The 2002 drought produced the lowest Palmer Hydrologic Drought Index seen during the modern (instrumental) period of record.

During the drought of 2002, scientists at Hydrosphere and the National Atmospheric and Oceanic Administration collaborated to identify several tree ring records that correlate well with natural flows in Boulder Creek. From these tree ring records, they were able to generate estimates of stream flows in Boulder Creek that extend back as far as 1703.

The data, depicted in Figure 3, show that the 2002 stream flows are probably the lowest that have occurred since 1725. Not only that, but the data analyzed in the study suggest that droughts lasting more than 15 years have occurred several times within the past 300 years (Hydrosphere 2002).

Hydrosphere qualified the regional significance of the study, saying, "Boulder Creek is fairly representative of most of the northern Front Range and most of the tributaries into the Colorado-Big Thompson [system] as well" (Associated Press 2002).

More than half the state has been in moderate drought during the droughts of the 1890s, 1930s and the current drought of 1999-2003. However, short-term droughts (3-month duration) have previously covered as much as 80% of the state, and longer-duration droughts (2-4 years) have encompassed as much as 70% of the state.

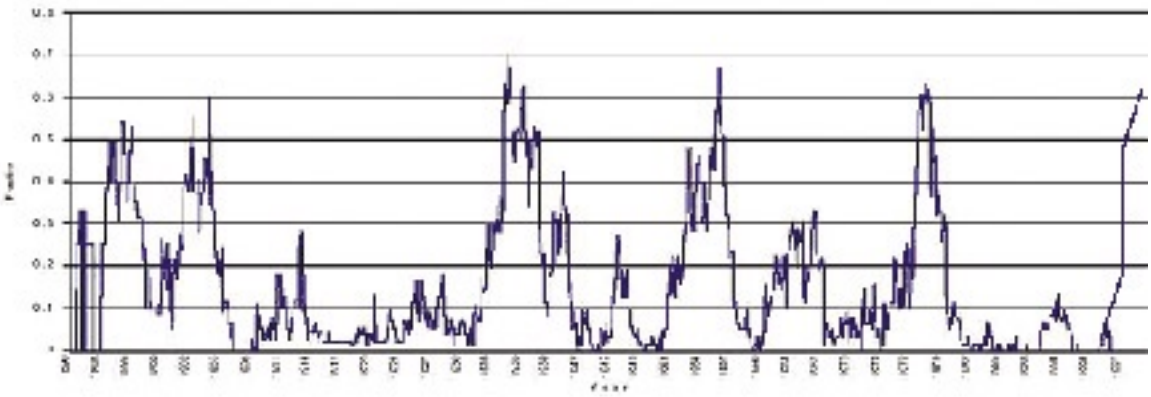


Figure 1. Fraction of Colorado in drought based (McKee et al. 2000) with est. 1999-2002.

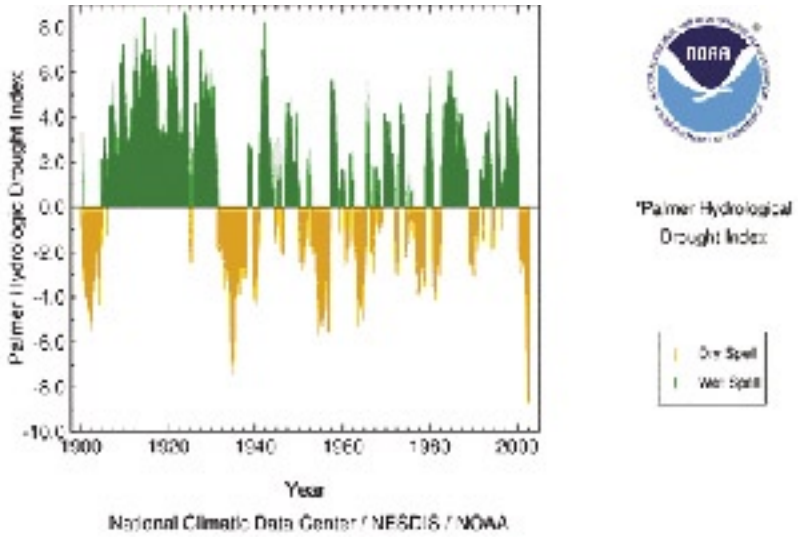


Figure 2. Colorado statewide PHDI*, January 1900-December 2002 (NCDC 2003).

TABLE 2. Dry periods in Colorado based on 24-month SPI

Date	Duration
1893-1905	12 years
1931-1941	10 years
1951-1957	6 years
1999-2002	4 years+
1963-1965	2 years
1975-1978	3 years

The data in Table 2, edited from a table in McKee et al. (2000), "shows the periods during which at least 60% of Colorado was dry, as determined by the Standardized Precipitation Index (SPI) values for 24-month periods." Note that the dates are not identical to those discussed above, as they were determined using a different methodology, namely the SPI instead of water year precipitation totals. However, it is clear that the 1999-2002 drought ranks as one of the most severe to affect the state during the instrumented period of record. The question remains how this drought compares to historical droughts of the past 300 to 500 years. Paleo-climatology may provide that insight.

Paleo-climatology of Colorado Droughts

Investigation of droughts that pre-date the instrumentation period falls within the realm of paleo-climatology. One of many options, tree rings can be utilized to recon-

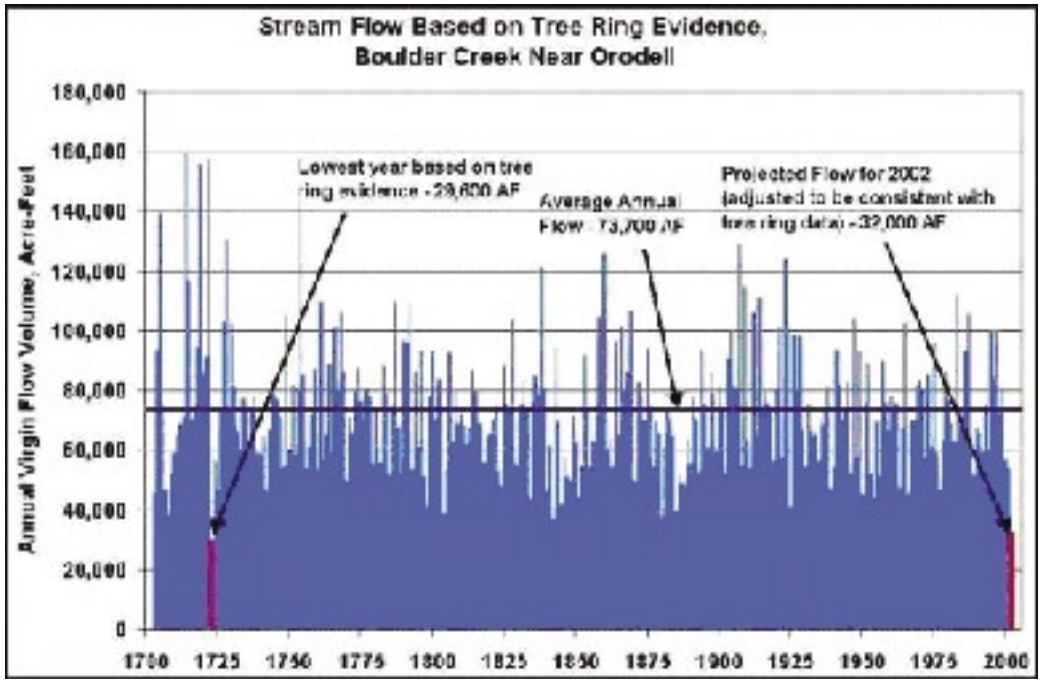


Figure 3. Streamflow on Boulder Creek based on tree ring analysis near Ordell, Colorado that shows the comparative impact of droughts since 1700.

struct records of past climate, including precipitation, drought, stream flow, and temperature. Trees at mid- to high-latitudes, such as those found in Colorado, grow one ring per year, and the most recent ring is formed inside the bark.

A wealth of long-lived, moisture-sensitive trees in this state make possible the generation of high-quality stream flow reconstructions that extend 300 to over 500 years into the past. Variations in ring widths that are common from tree to tree reflect droughts and other anomalies in climate (Woodhouse 2003).

Having established a general understanding of tree ring analysis, we can now look at some examples of the application of tree ring studies to determine historical drought periods in Colorado. Woodhouse et al. (2002) provide a detailed account of the impacts and implications of a drought in the western Great Plains from 1845-1856. Tree-ring based reconstructions of streamflow and Palmer Drought Severity Index (PDSI) have been developed and clearly show the extensive magnitude and duration of this mid-19th century drought. (See the Website http: //www.ngdc.noaa.gov/paleo/pubs/woodhouse2002/ woodhouse2002.html Drought in the Western Great Plains, 1845-56: Impacts and Implications Woodhouse et al. 2002)

As depicted in Figure 4, the identified core area (the shaded region) of the 1845-1856 Drought encompassed much of southeastern Colorado and the Front Range.

Were a drought of this severity and duration to occur here today or in the future, it would have, Woodhouse warns us, "considerable impacts now that the area now includes a major, rapidly expanding metropolitan area as well as large-scale crop and livestock production." These impacts would have widespread significance for Colorado's society, economy, and ecology. In their review of Great Plains droughts over the past 2000 years, Woodhouse and Overpeck (1998) summarize, saying ". . . the paleo-climatic data suggest a 1930s-magnitude Dust Bowl drought occurred once or twice a century over the past 300-400 years, and a decadal-length drought once every 500 years."

Elaborating on these conclusions, the authors report the following:

Historical documents, tree rings, archaeological remains, lake sediment, and geomorphic data make it clear that the droughts of the twentieth century, including those of the 1930s and 1950s, were eclipsed several

Figure 4. Core area of 1845-1856 drought (Woodhouse et al. 2002).

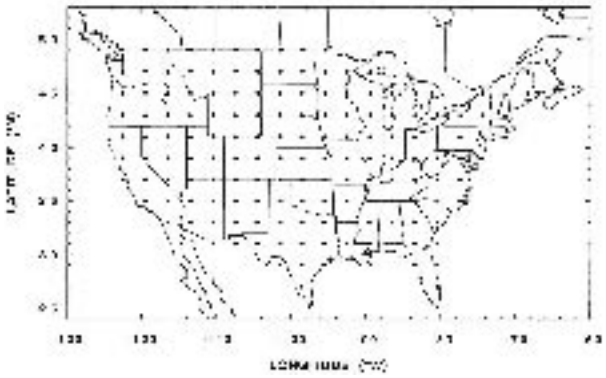


Figure 5. Locations of grid points for which there are PDSI reconstructions from tree rings.

times by droughts earlier in the last 2000 years, and as recently as the late sixteenth century. In general, some droughts prior to 1600 appear to be characterized by longer duration (i.e., multidecadal) and greater spatial extent than those of the twentieth century (Woodhouse and Overpeck 1998).

The United States map (Figure 5) was prepared by NOAA using a national tree ring data base that was used to prepare a standardized set of tree ring values of the Palmer Drought Severity Index (PDSI). Henz and Badini, 2002 prepared a detailed comparison of the tree-ring growth index at the four points shaded within Colorado. A comparison of tree ring-derived and instrumented SPI and PDSI values for the important Colorado drought periods during the past 100 years was developed. Special attention was given to recent period droughts of the

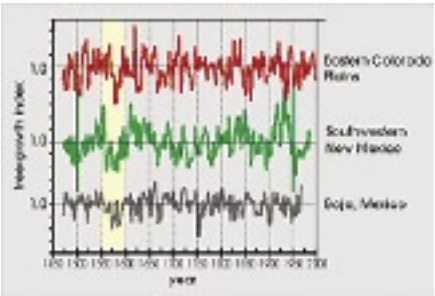
1930s and 1950s to insure that the drought periods correlation with tree ring derived drought periods.

The data in Table 3 is based on an analysis of the occurrence of wet and dry decades based on the tree-ring PDSI of four data points in Colorado shown in Figure 5. The four sites were used to analyze the occurrence historically of droughts in the northeastern, southeastern, southwestern and northwestern areas of the state. Analyses of the Colorado sites produced similar depictions of wet and dry decades. However, a number of dry decades that affected only the western or eastern half of the state were evident. It should be noted that at least one dry decade affects the entire state each millennia.

TABLE 3. Occurrences of wet/dry decades from 1500-1995 based on tree-ring growth index at Colorado data points in Figure 5.

Millennia	Wet	Decade	Very Dry	Decade	Total Events
1500s	3	20s, 60s, 90s	2	00s, 70s	5
1600s	3	20s, 40s, 60s	2	30s, 70s	5
1700s	2	10s, 50s	2	10s, 30s	4
1800s	2	20s, 30s	2	50s, 60s	4
1900s	2	10s, 20s	2	30s, 50s	4
Totals	12		10		22

From this historical perspective it appears that the current Drought of 1999-2002 likely has been exceeded in duration, intensity and coverage by historical droughts of the past. Consider the occurrence of coincident droughts such as the one apparent in the yellow bar on the graph. The eastern plains of Colorado, southwestern New Mexico and Baja, Mexico all experienced a multi-decade drought simultaneously. Winter and spring drought conditions appear to have been particularly severe in the Southwestern U.S. and northwestern Mexico, where this drought appeared to have lasted several decades (1625-1655). In other areas, drought conditions were milder, suggesting drought impacts may have been tempered by seasonal variations.



The non-traditional database of historic tree-ring analyses reported by Woodhouse, 2001, provides new opportunities for an in-depth look at the past that could open doors into the future of Colorado drought occurrence, while linking the information to state stream flow and water supply.

What is drought: not everyone agrees?

Drought has many different meanings. According to the Glossary of Meteorology, 2nd edition (American Meteorological Society 2000), drought is defined as "a period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance."

While this may sound like a simple textbook characterization, the definition continues with the following qualification:

> Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, there may be a shortage of precipitation during the growing season resulting in crop damage (agricultural drought), or during the winter runoff and percolation season affecting water supplies (hydrological drought).

Clearly, there is no singular expression of the meaning of the term drought. Not only does the meaning vary with the application context, but it is also subject to regional variation. Documents provided by the National Drought Mitigation Center (NDMC 2003) provide further insight into this multifaceted phenomenon.

Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration; it differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate.

Drought should not be viewed as merely a physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply. Recent droughts in both developing and developed countries have underscored the vulnerability of all societies to this "natural" hazard. Clearly defining drought is a multi-faceted problem.

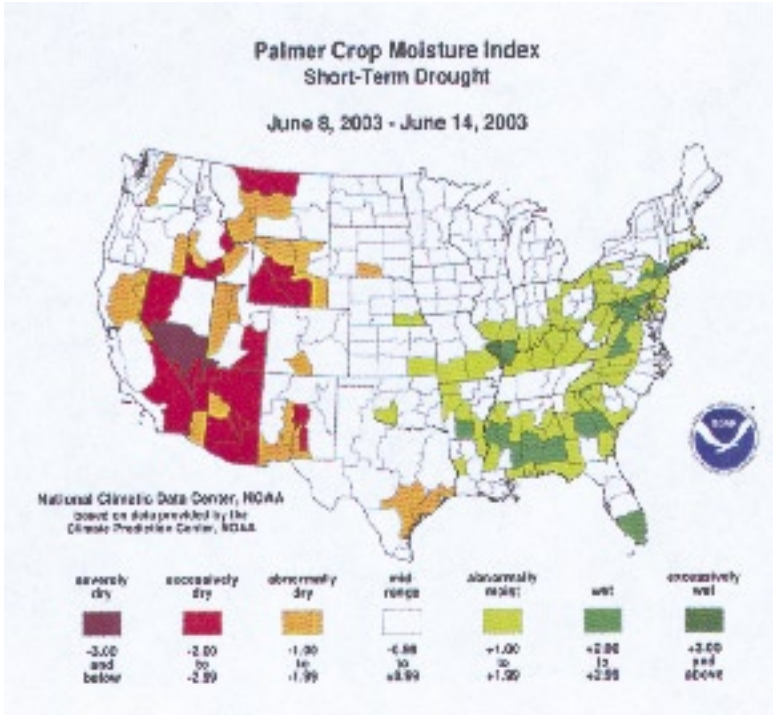


Figure 6. Map illustrating agricultural drought conditions (NOAA-NCDC 2003).

Meteorological measurements are the first indicators of drought.

Agricultural drought occurs when there is not 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 refers to deficiencies in surface and subsurface water supplies. It is measured as streamflow and as lake, reservoir, and groundwater levels. There is a time lag between lack of rain 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 over an extended period of time, this shortage will be reflected in declining surface and subsurface water levels.

How is drought classified? (Operational definitions)

The National Drought Mitigation Center classifies meteorological, agricultural and hydrological droughts as "operational definitions of drought." The NDMC (2003) proves to be an invaluable reference, providing four informative operational definitions of drought. Figures 6-8 illustrate the causes and effects associated with these definitions.

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 from different countries at different times illustrates why it is folly to apply a definition of drought developed in one part of the world to another:

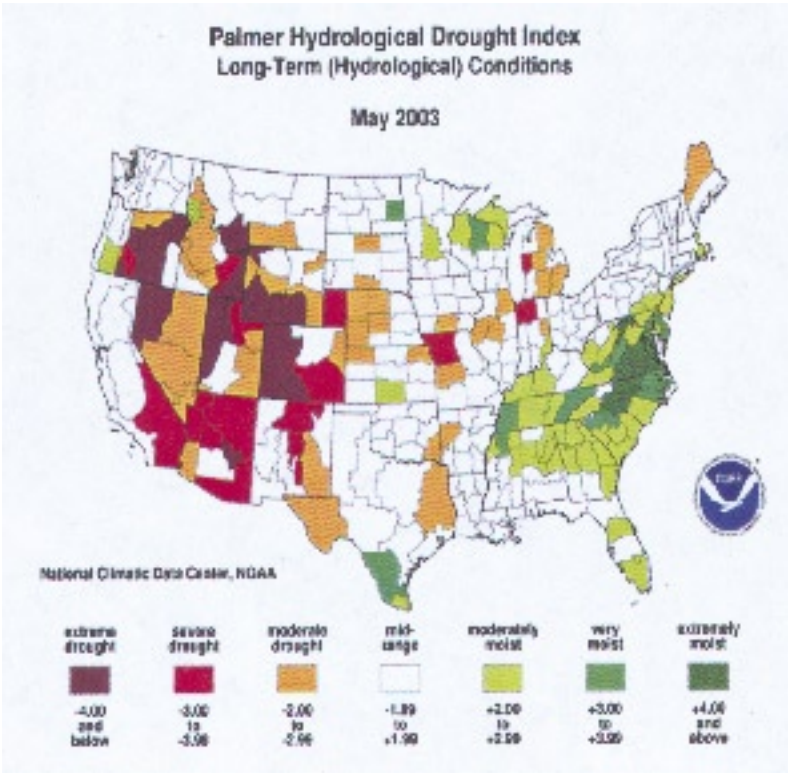


Figure 7. Map of hydrological drought conditions (NOAA-NCDC 2003).

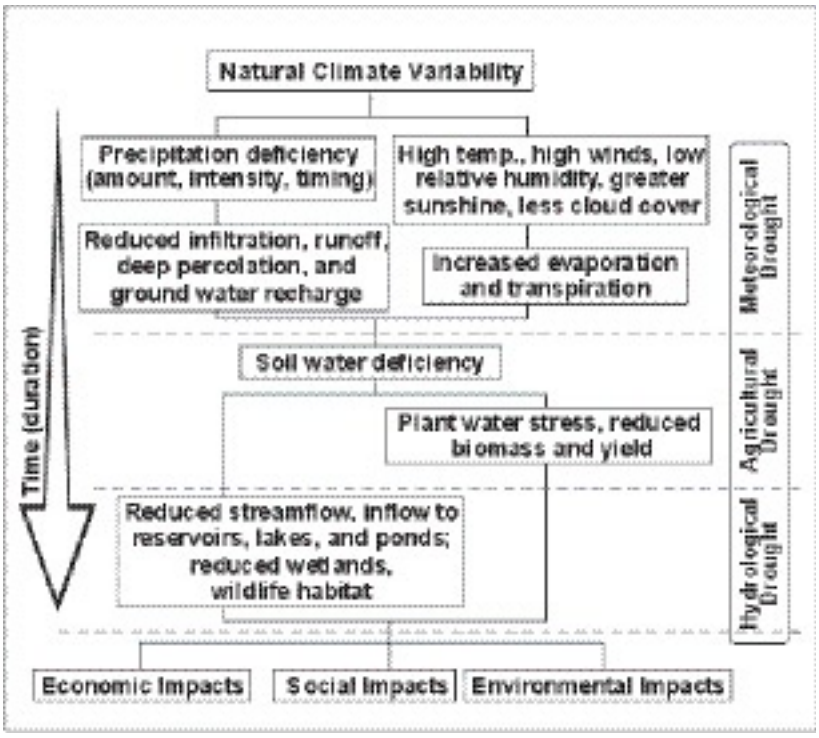


Figure 8. Illustration of operational drought definitions (NDMC 2003).

Socioeconomic drought occurs when physical water shortage starts to affect people, individually and collectively. Or, in more abstract terms, most socioeconomic definitions of drought associate it with the supply and demand of an economic good.

Figure 8 illustrates the time lag between meteorological, agricultural, and hydrological drought.

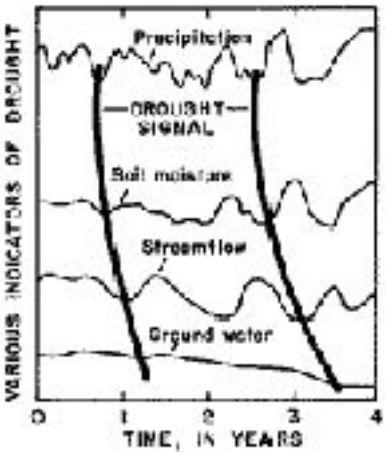


Figure 9. Time lag in hydrologic drought response (USGS 2003).

Further, the lag between different components of the hydrology is shown in comparing streamflow and groundwater responses. (Figure 9).

Each of the definitions provided above has important contextual implications for the state of Colorado. Taken as a collective whole, this account of the meaning of drought will serve as the cornerstone that completes the foundation of our understanding of Colorado's drought history.

Water Availability: where does the precipitation come from?

To better appreciate the forces at work during a period of drought, we first must take a brief look at the variability in precipitation across the state from both the perspective of location and time. Figure 10 depicts the annual precipitation found across the state; observe that annual precipitation and elevation are well correlated. By simply examining this figure and Figure 11 immediately below it, one can infer the locations of the highest terrain in Colorado. The topography of Colorado has a major influence on the distribution of precipitation across the state.

Wind, topography and precipitation

The sources of atmospheric moisture are depicted in Figure 12. Clearly the mountainous areas of the state are affected by moisture bearing winter winds from the west to northwest. The southwestern mountains favor wet winds from the southwest from summer into fall and winter. Upslope easterly winds from spring into summer bring green fields to the eastern half of the state and the southern mountains. Thus weather factors that influence the seasonal frequency and moisture content of these winds have a major impact on Colorado's precipitation.

A majority of the seasonal snowpack that accumulates across the higher mountain ranges of Colorado is produced between late fall and early spring. This time period is of particular interest because it is estimated that up to 80% of Colorado's surface streamflow originates from snowpack that accumulates during this period before melting in the April to July time frame.

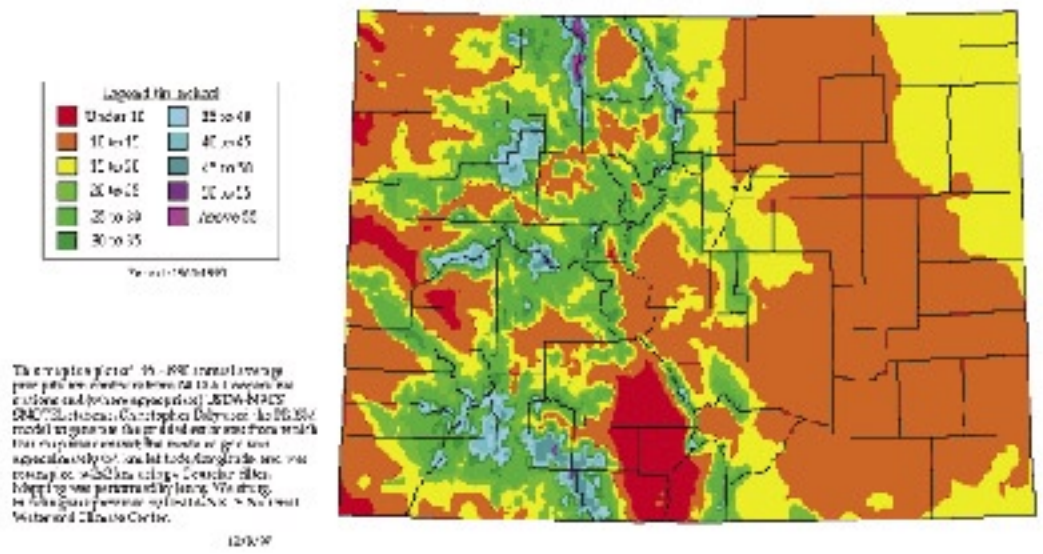


Figure 10. Colorado average annual precipitation (WRCC 2003).

During the summer and early fall, the jet stream becomes notably weaker, if not absent, and convective (i.e., thunderstorm) activity becomes the primary source of precipitation. The moisture for this thunderstorm activity derives largely from the pattern commonly referred to as the Southwestern Monsoon. The monsoon pattern is defined by a general area of high pressure, or ridge, in the mid levels (~7,000-20,000 ft. above sea level) of the atmosphere develops over southern New Mexico/ western Texas (see Figure 13). The inflow of monsoon moisture is determined by this flow. The clockwise flow of moisture around this area of high pressure introduces moisture into Colorado from both the Gulf of California and the Gulf of Mexico.

The data in the preceding figure is analogous to an area of high pressure at approximately 18,000 ft. above sea level. Droughts that have occurred during the summer and early Fall period are typically associated with an unseasonable northward migration of this area of high pressure resulting in two physical impacts.

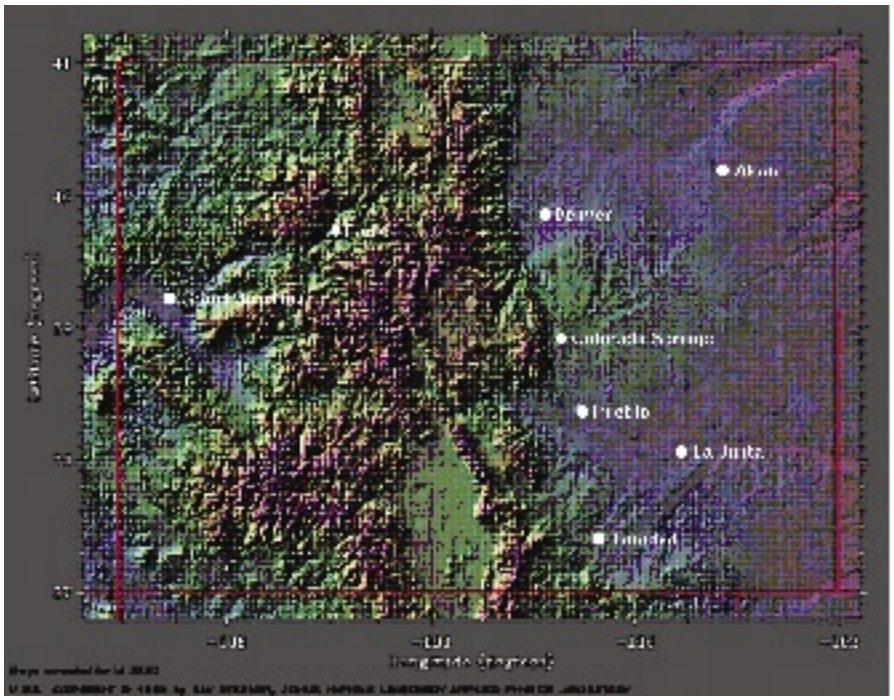


Figure 11. Colorado topography.

The first impact would effectively funnel the rich sub-tropical moisture to areas further west of Colorado in the direction of California, Arizona, and Utah. The second impact is that a more local presence of this mid-level ridge over the state can result in relatively warmer temperatures at these levels. Unseasonably warm air (between 10,000 and 20,000 ft above sea level) can act as “a lid on the atmosphere”, acting to suppress the strength of convective activity across the region which reduces the

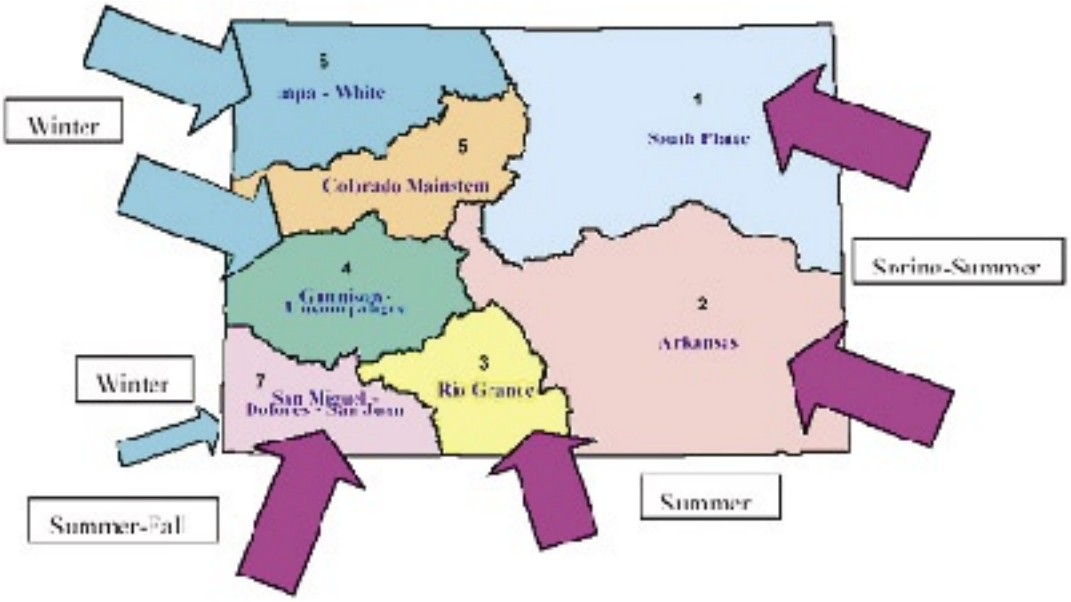


Figure 12. Sources of atmospheric moisture in Colorado (McKee et al. 2000).

occurrences of summer thunderstorms. The longer-term persistence of this ridge over Colorado can result in below-normal amounts of precipitation on a more widespread basis.

Jet streams, storm tracks, El Niño's and La Niña's

The production of precipitation across the state is attributed to the general positioning and strength of the jet stream, which typically traverses the state in a west-to-

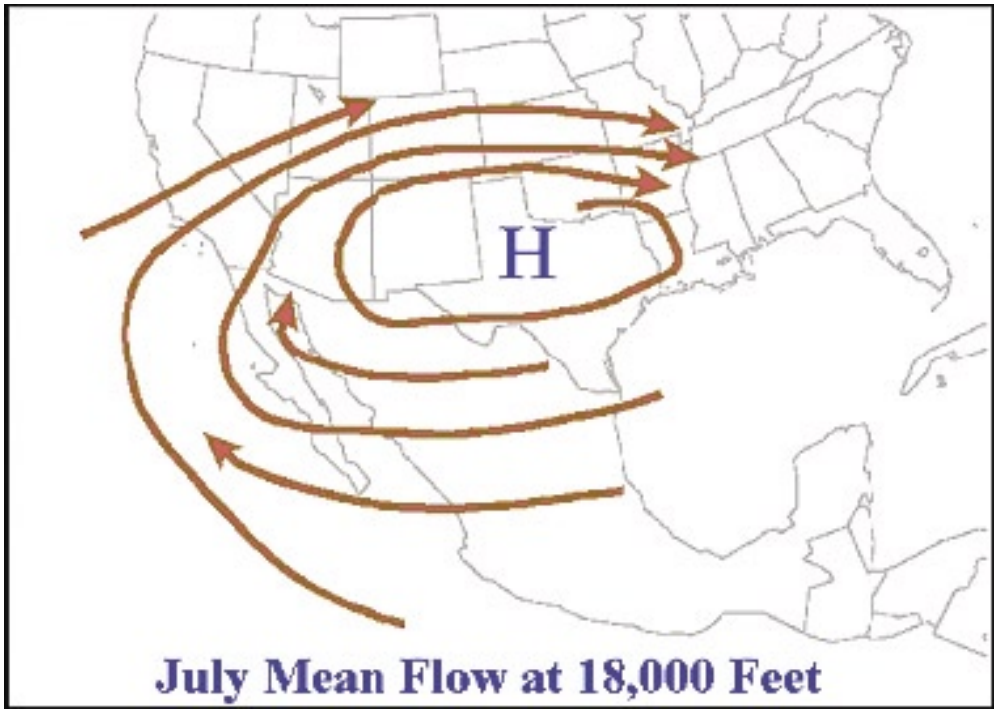


Figure 13. Long-term average of the 500 MB height field for July (from Douglas 1993).

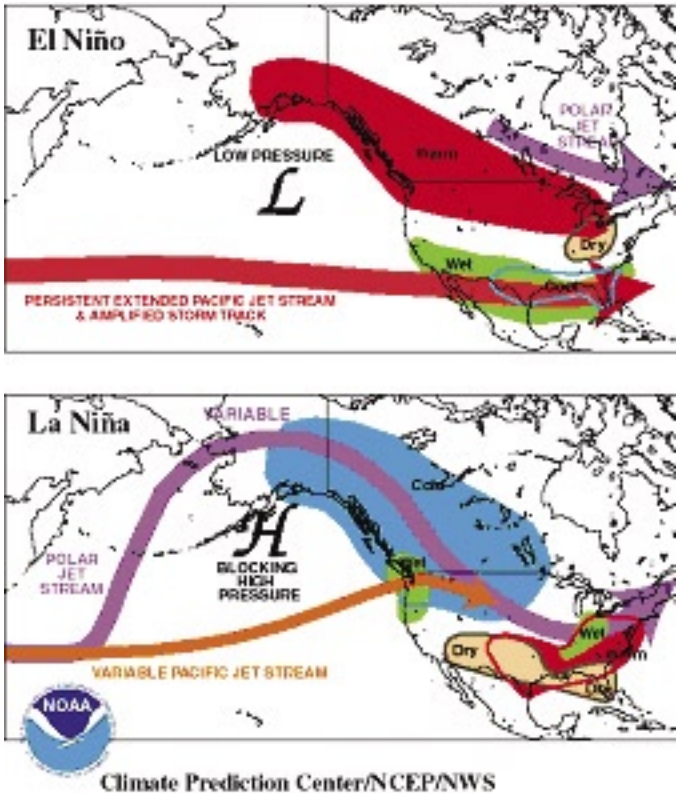


Figure 14. Typical January-March weather anomalies and atmospheric circulation during moderate to strong El Niño & La Niña (CPC 2001).

east manner during winter and spring. A majority of the moisture that falls across the state originates from the Pacific Ocean. This moisture is essentially transformed into precipitation by the following mechanisms, either singularly or in combination:

1) strong lifting by individual storms traveling along the jet stream; and

2) forcing of air across the mountains barriers, which also provides the lift needed to cool and condense water vapor in the air and produce precipitation.

In early spring, Pacific-based storm systems can effectively draw in low-level moisture from the Gulf of Mexico and generate exceptionally high amounts of precipitation east of the Continental Divide (a fine example of this scenario is the mid-March blizzard of 2003 across the northern Front Range).

To assess the impacts of drought during the late fall to early spring period, one should look at the longer-term positioning of the jet stream at this time of year and the factors that may influence it. The dominant cause of wintertime jet stream variability over western and central North America is the El Niño/Southern Oscillation (ENSO), which is essentially a shifting of relatively warm and cold surface waters and subsequent wind patterns across the equatorial Pacific Ocean. The general effects of El Niño and its counterpart La Niña can be found in Figure 14.

In general, El Niños are typically associated with conditions of higher moisture over Colorado while La Niñas have been typically associated with drier than average conditions over the state during winter. These relationships tend to be more robust in the southern regions of the state. However, it should be noted that the extreme, nearly statewide drought during the winter of 2001-2002 ENSO was not in a conclusive El Niño or La Niña state. Regardless of the state of ENSO or other climatic factors that are currently being examined, either a lack of Pacific moisture, a lack of storms with the jet stream (in strength or numbers), or both can be linked to periods of wintertime drought.

In La Niña years, the Pacific storm track tends to migrate further to the north and is already in a less-than-ideal position to bring an adequate amount of storms in terms of numbers and intensity for precipitation generation. La Niña years have had a greater tendency to produce drier-than-normal springs across the Front Range. Impacts of El Niño and La Niña on monthly precipitation at Denver and Grand Junction can be seen in Figures 15 and 16.

Note that in Grand Junction and Denver, El Niño years tend to produce more precipitation than in La Niña years. In Grand Junction the impact is more noticeable as a reduction of late summer and fall precipitation during La Niña years with lesser winter and spring impacts noticeable. In Denver, both winter and summer precipitation are higher during El Niño periods. The heaviest El Niño precipitation in Denver is evident from late February into early June. The recent Saint Patrick's Day snowstorm of March 17-20 is an excellent example of an El Niño-assisted major precipitation event. From these four figures it is quite evident that the El Niño and La Niña patterns influence seasonal precipitation patterns differently east and west of the Continental Divide. These differences are also notable in the state's river basins.

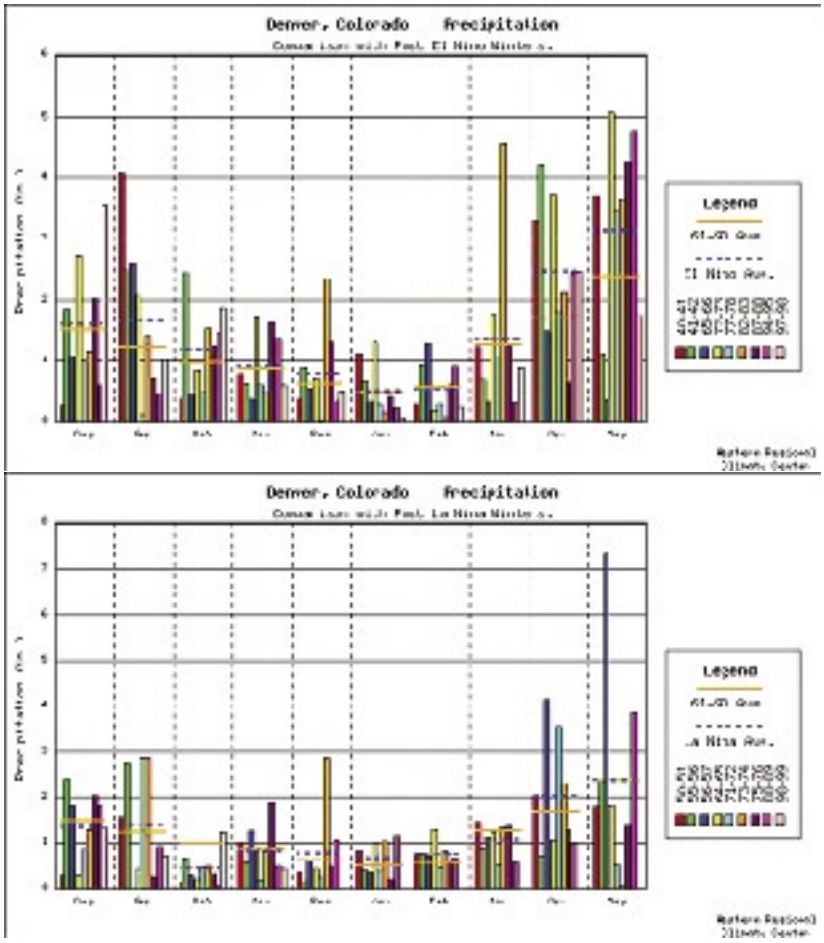


Figure 15. El Niño and La Niña impacts on monthly Denver precipitation.

Precipitation variability across Colorado's major river basins

Due to the variability in climate and topography that defines Colorado's landscapes, it is important to have an understanding of drought at a watershed level. "For many water management and planning applications," reports McKee et al. (2000), "Colorado is divided into seven water divisions". Each of these basins originates in high mountain environments and descends through mountain valleys and eventually drops to much lower elevations. Thus, we can roughly divide each basin into an upper and lower basin based on approximate elevation and mountain proximity." A general picture of typical wet and dry periods in Colorado, as well as the principle demands in each water division, are provided for each of the seven major Colorado river basins (Figure 17). Note the great variability in precipitation across different seasons and different regions. An understanding of the various regional demands is important in order to determine the impacts of drought on a particular area of the state.

Figure 18 was prepared by the Colorado Water Conservation Board and presents the periods of moderate, severe, and extreme drought by basin since the late 1800s. The figure shows that major droughts rarely impact all of Colorado's major river basins simultaneously. When they do, as noted in the 1890s, the 1930s, the 1950s and the 1970s, the impacts are significant. On the other hand, many regional droughts occur almost every decade that impact only one or two basins for periods of one to two years.

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 long-term weather station records, it was observed that at least 5% of the state is experiencing drought on 3- to 24-month timescales almost all of the time (McKee et al. 2000).

Drought cycles: what goes around comes around.

Many drought observers insist that drought cycles exist. Some suggest that the sunspot cycle of 11 years or a "double sun spot cycle" of 22 years controls Colorado's drought patterns. Others claim that a 3- or 7-year cycle exists in local or regional drought occurrence. An extensive review by the Colorado Climate Center on drought's cyclicity was inconclusive. So can you believe what you want?

An example of how new information can be developed through "database mining" can be seen in Table 4. Table 4 shows a comparison from 1900 to 1999 of decadal occurrences of basin-specific annual precipitation that is 2 inches or more above or below average. The base annual precipitation information was derived from Western Regional Climate Center database. Let's look at two fresh approaches to viewing the information.

Table 4 shows some interesting basin-specific information, but let's concentrate for the moment on the big picture. The droughts of the 1930s, 1950s and the 1970s show significant decades of below average precipitation in Colorado's major river basins. Wet periods also show

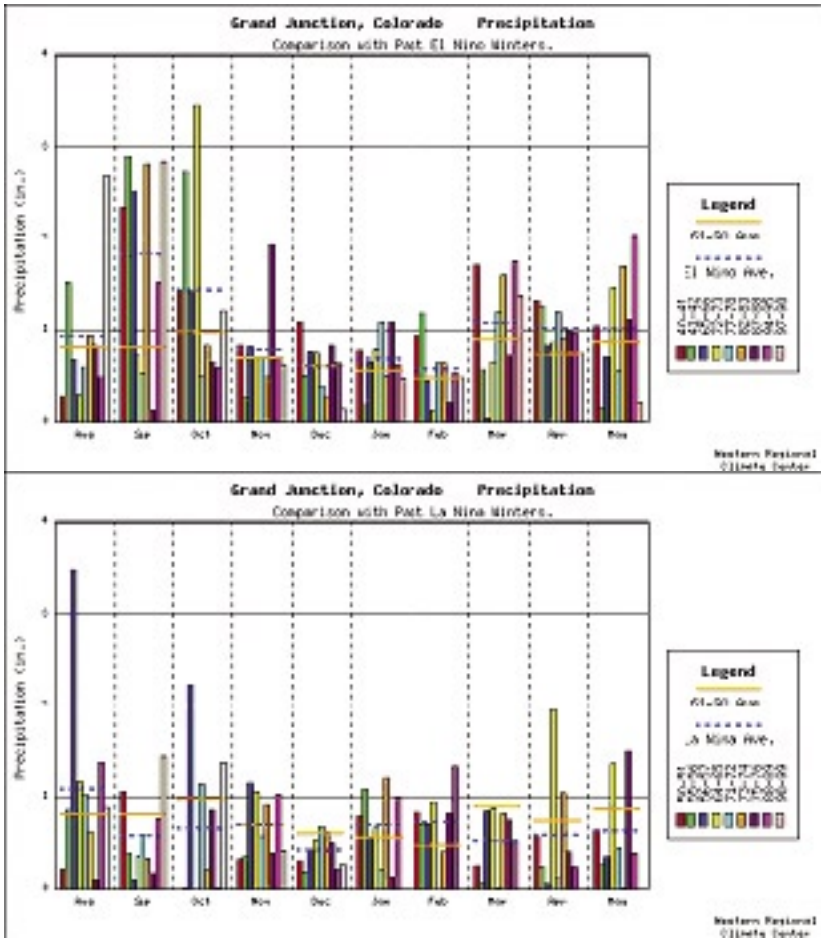


Figure 16. El Niño and La Niña impacts on monthly Grand Junction precipitation.

up clearly. Note the drought of the 1950s was not "as sync" from basin-to-basin as during the other droughts. Of equal importance is the plotting of the decadal changes from basin-to-basin as shown in Figure 21.

Figure 19 was prepared by plotting the sum of the basin decadal differences in the number of 2-inch above and below annual precipitation events by decade for the Platte, Colorado, Arkansas, and Rio Grande basins. This analysis portrays the number of "extreme" events and their decadal changes.

The precipitation rich decades of the 1910s and 1920s and the recent wet 1980s and 1990s are easy to pick out. Conversely, the drought or dry periods of the "turn of the century," 1930s, and 1950s to 1970s can be looked at from a relative stance. Note that the two wet periods of the past millennium appear to provide less durational impact than the entire extended dry period of the 1930s through the 1970s.

The extended period of the dry '50s, '60s and '70s offers an amazing difference in duration and intensity compared to the "spike" of the Dust Bowl 1930s. Why? Are there differences from basin-to-basin or do the basins operate more in tandem then separation? Why? Perhaps, the answer is in the meteorological causes of the dry and wet periods.

El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. Wolter and Timn (1998) monitor ENSO by basing the Multivariate ENSO Index (MEI) on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure (P), zonal (U) and meridianal (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C).

Figure 20 shows the variation of this MEI index from 1950 to 2003. Note that the red values above 0.5 indicate El Niño periods while the blue values of -0.5 or less indicate La Niña periods. Note the regular cycles of the El Niño and La Niña.

A clear way to merge the two data bases in Figures 19 and 20 can be seen in Table 5. Note that the El Niño, or red periods, coincides with periods of above normal precipitation in the Colorado river basins. On the other hand, the La Niña, or blue spikes, coincides with the dry periods or decades in the Colorado River basins. This apparent relationship is reflective of an apparent cause-effect relationship. Additional work will be required to answer the questions posed by this relationship, but it may hold a promising means of anticipating above or below water yields in river basins before the start of the Water Year.

What might the future hold?

Drought will be a continuing "unwelcome guest" to Colorado's climate. Despite all the good science applied to understanding drought, considerable uncertainty

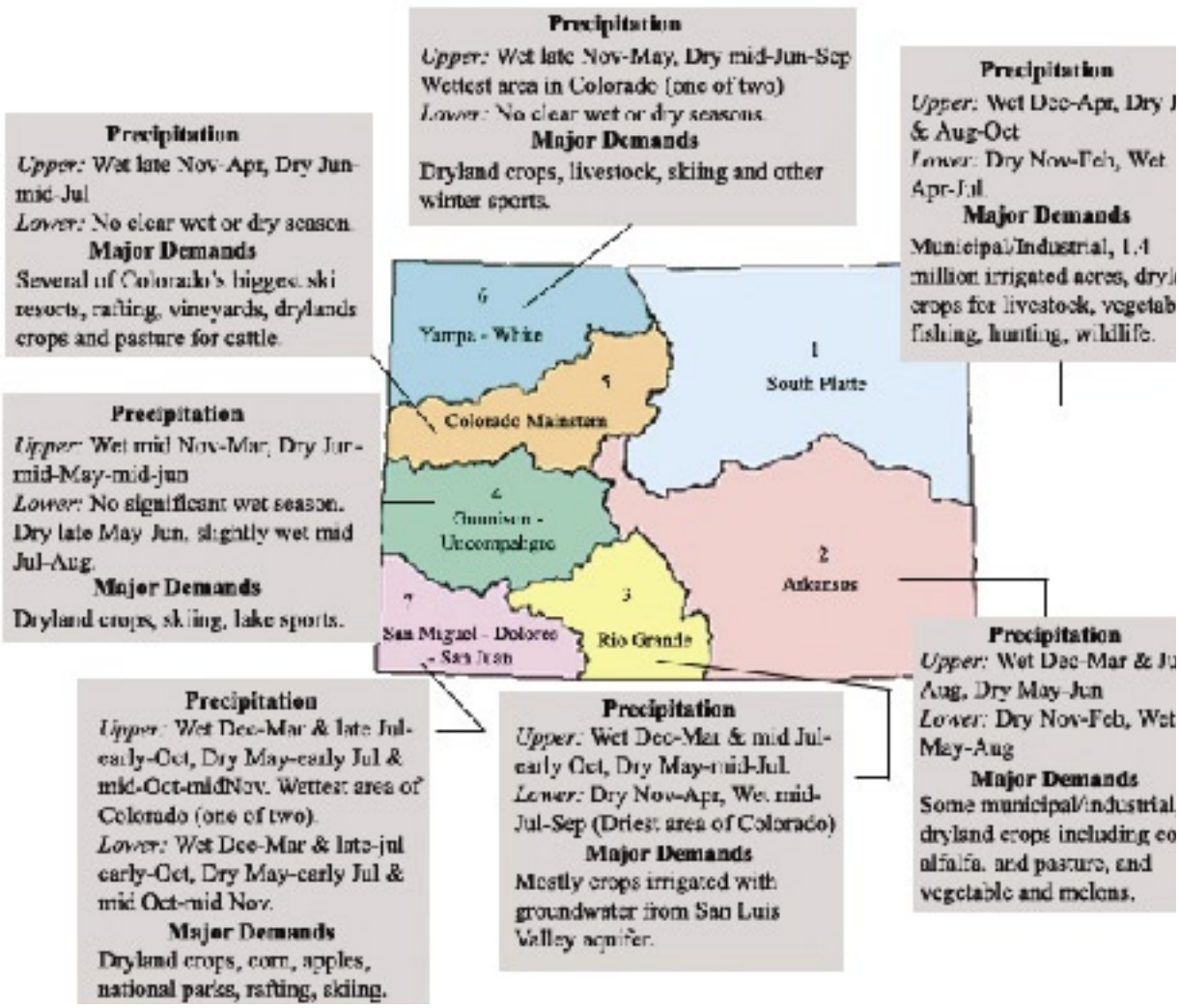


Figure 17. Major water demands in the seven Colorado water divisions (McKee et al. 2000).

exists in trying to anticipate its arrival, duration, severity and departure. The only thing certain is that drought will come again.

Henz and Badini, 2002 attempted to take a bold look into the future of Colorado's climate from 2000 to 2075. Their look ahead, shown in Table 6, favors several periods of state-wide drought. Of particular concern, an extended period of drought appears likely within the next 50 years. This result should not be considered unrealistic given the paleoclimate research results reported earlier.

An extended drought may have chased the ancient Anazazi Indians from their dwellings in the Mesa Verde area. If a similar strong and protracted drought occurred over the next 100 years, it would cause major impacts on modern Colorado residents and their way of life. The Drought of 1999-2003 has shown that major impacts on our quality of life and water supplies can be inflicted by short-term drought. We need to plan for "the inevitable major droughts of the future". As Colorado's population and economic bases grow in the next century, careful stewardship of our water supplies will be mandatory.

"Those who do not remember the past are doomed to repeat it."
George Santayana (1863 - 1952)
American Philosopher
The Life of Reason, Volume 1, 1905

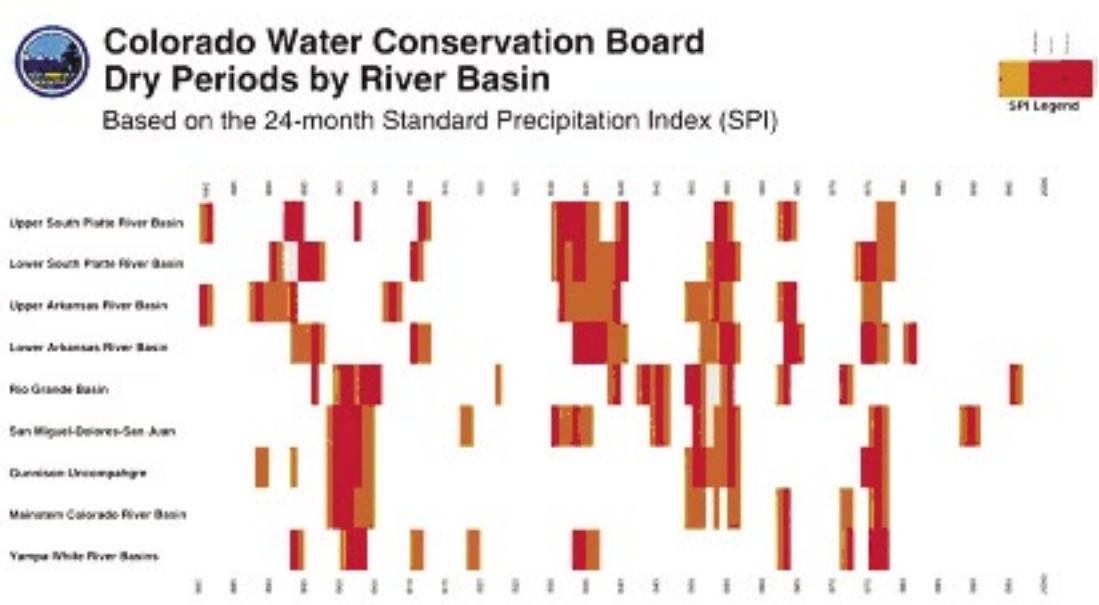


Figure 18. Plot of drought severity by year for major Colorado River Basins based on 24-month Standard Precipitation Index (created by CWCB, Stanton and Busto, 1997).

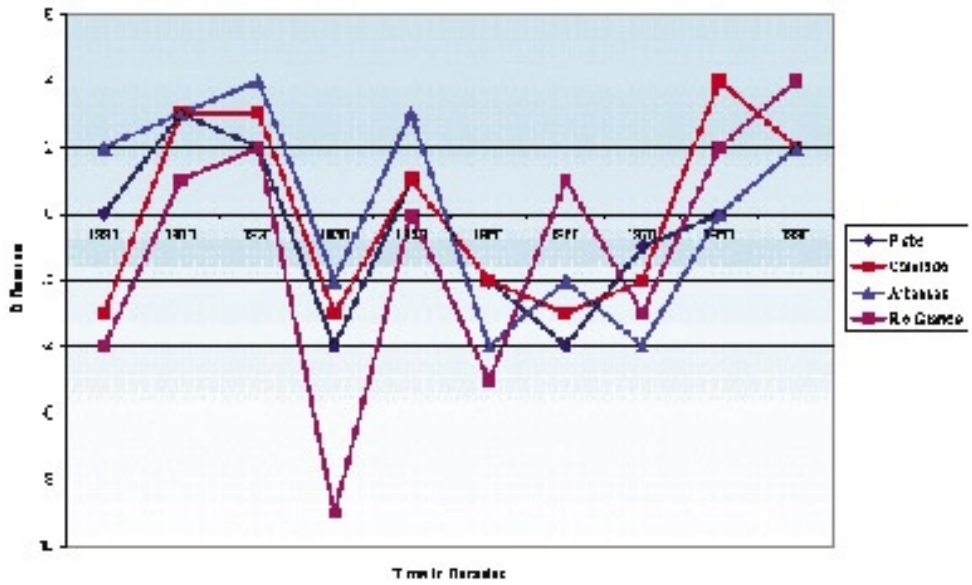


Figure 19. Comparison of the difference between the numbers of annual basin precipitation years. 2" above and 2" below average summed by decade and by basin.

TABLE 4. Comparison of the Number of Annual Basin Precipitations +/- 2" of Average/Decade.

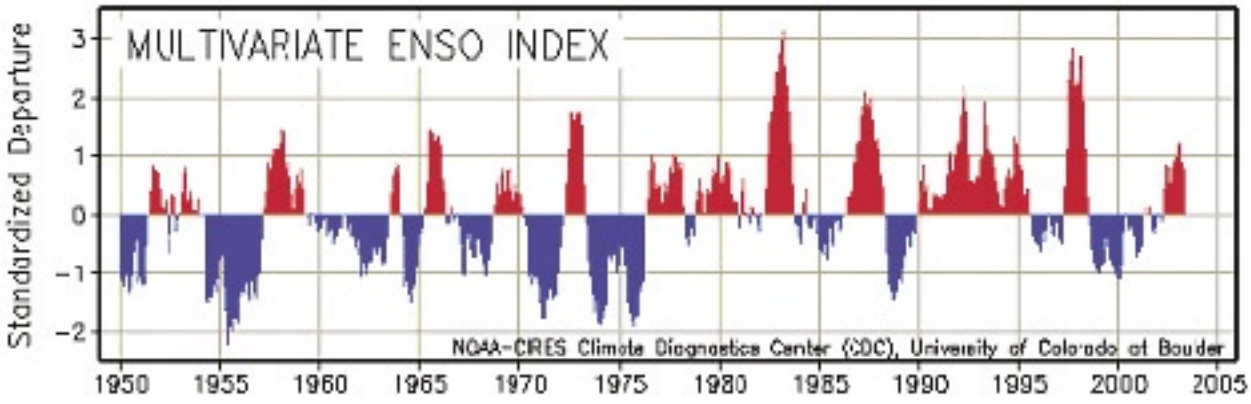
Basin	00s		10s		20s		30s		40s		50s		60s		70s		80s		90s		Basin		100 year
Above/Below	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
Platte	0	0	3	0	2	0	1	5	1	0	0	2	1	5	0	1	0	0	3	1	11	14	-3
Colorado	1	4	3	0	4	1	0	3	1	0	2	4	0	3	0	2	5	1	3	1	19	19	0
Arkansas	2	0	3	0	4	0	1	3	3	0	1	5	2	4	0	4	0	0	2	0	18	16	2
Rio Grande	0	4	1	0	2	0	0	9	1	1	0	5	1	0	1	4	2	0	6	2	14	25	-11
Total	3	8	10	0	12	1	2	20	6	1	3	16	4	12	1	11	7	1	14	4	62	74	12
Difference	-5		10		11		-18		5		-13		-8		-10		6		10		-12		-12

A = Years with annual basin precipitation of equal to or greater than 2" above average.
B = Years with annual basin precipitation of equal or greater value than 2" below average.

TABLE 5. Comparison of the Number of Annual Basin Precipitation +/- 2" of Average/Decade Compared to decadal El Niño and La Niña Avg. MEI.

Basin	1950s		1960s		1970s		1980s		1990s		2000s*	
Above / Below	A	B	A	B	A	B	A	B	A	B	A	B
Platte	0	2	1	5	0	1	0	0	3	1	1	2
Colorado	2	4	0	3	0	2	5	1	3	1	2	2
Arkansas	1	5	2	4	0	4	0	0	2	0	0	2
Rio Grande	0	5	1	0	1	4	2	0	6	2	1	2
Total	3	16	4	12	1	11	7	1	14	4	4	8
Difference	-13		-8		-10		6		10		-4	
MEI Decadal Avg.	-1.3		-0.8		-1.1		+1.4		+ 1.3		?	

* Note that the WY 2002-2003 values are estimated.



Red values indicate El Niño periods. Blue periods indicate La Niña periods.

Figure 20. Annual variation of the MEI from 1950-2003 (Wolter and Timn, 1998)

TABLE 6. Trend analysis of a blended climate data set for average precipitation in the major Colorado River basins from 2000 to 2075

Time	Precipitation/weather factors outlook
2000-2009	An "average" decade marked by an early drought and wet El Niño
2010-2019	Significant multi-year drought likely due to extended La Niña
2020-2029	Drought gives way to a "mildly wet" strongly El Niño decade
2030-2065	Extended period of drought possible as La Niña is enhanced
2065-2069	El Niño returns to bring a wet end to the decade
2070-2079	An extended period of above average precipitation returns Note: This outlook is experimental

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CLIMATE PROJECTIONS: ASSESSING WATER YEAR (WY) 2002 FORECASTS AND DEVELOPING WY 2003 FORECASTS

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This paper documents my approach to seasonal climate predictions as of late 2002, synthesizing several years of experience in the field. In this context, it includes (1) a brief overview of the status and premier role of ENSO (El Niño/Southern Oscillation), (2) the rationale for new climate divisions, (3) a 'short theory' of climate forecasts, (4) last year's first suite of public climate forecasts, and why they failed during the spring and early summer, and (5) my outlook from Fall 2002 through Winter and Spring of 2003. Think of it as a glimpse into the creation of climate forecasts, reflecting the current state of the art (and science).

1. EL NIÑO IS AFOOT – WHY SHOULD WE CARE?

Seasonal climate forecasts have been attempted for at least a century (reviewed in Chapter 9 of Hastenrath, 1991). Originally trying to predict the Indian monsoon, Sir Gilbert Walker defined the 'Southern Oscillation' (e.g., Walker and Bliss, 1932) as a global pressure seesaw between the eastern Pacific and the Australasian region. This pressure oscillation was subsequently linked to the occasional warming of the tropical eastern Pacific that is often referred to as 'El Niño' (e.g., Philander, 1990). The coupled ocean-atmosphere phenomenon of El Niño/Southern Oscillation (ENSO) is now considered the most important (and predictable) component of year-to-year climate variability in the tropics, if not the globe. Once a warm ENSO event (El Niño) or cold ENSO event (La Niña) is in place, it typically lasts six to nine months, and has ramifications for earth's climate from pole to pole (ref. Ropelewski and Halpert, 1987), including the continental U.S. (e.g., Wolter et al., 1999), and Colorado in particular (detailed in section 5). The seasonally varying consequences for U.S. temperatures and precipitation are documented on the web under: http://www.cdc.noaa.gov/Climaterisks/ (which is based on Wolter et al., 1999).

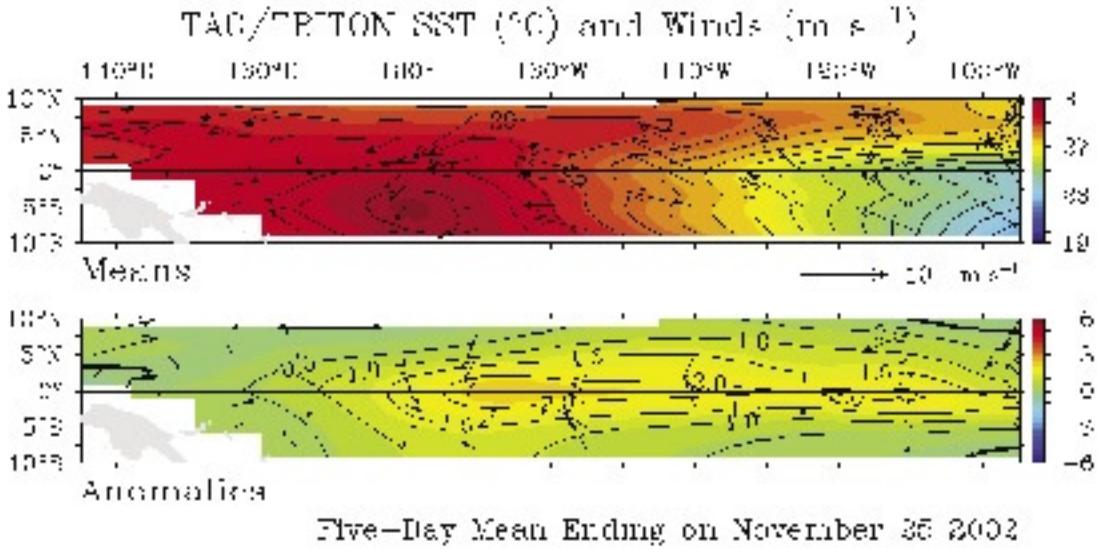

Figure 1. Tropical Pacific sea surface temperature (SST) and surface wind conditions in late November 2002, close to the peak of the 2002-03 El Niño event. Positive anomalies of 1°C or more cover the equatorial Pacific from 170°W to at least 100°W, and denote at least moderately strong El Niño conditions. Northerly wind anomalies to the north of the Equator and westerly wind anomalies west of the dateline are typical for El Niño as well.

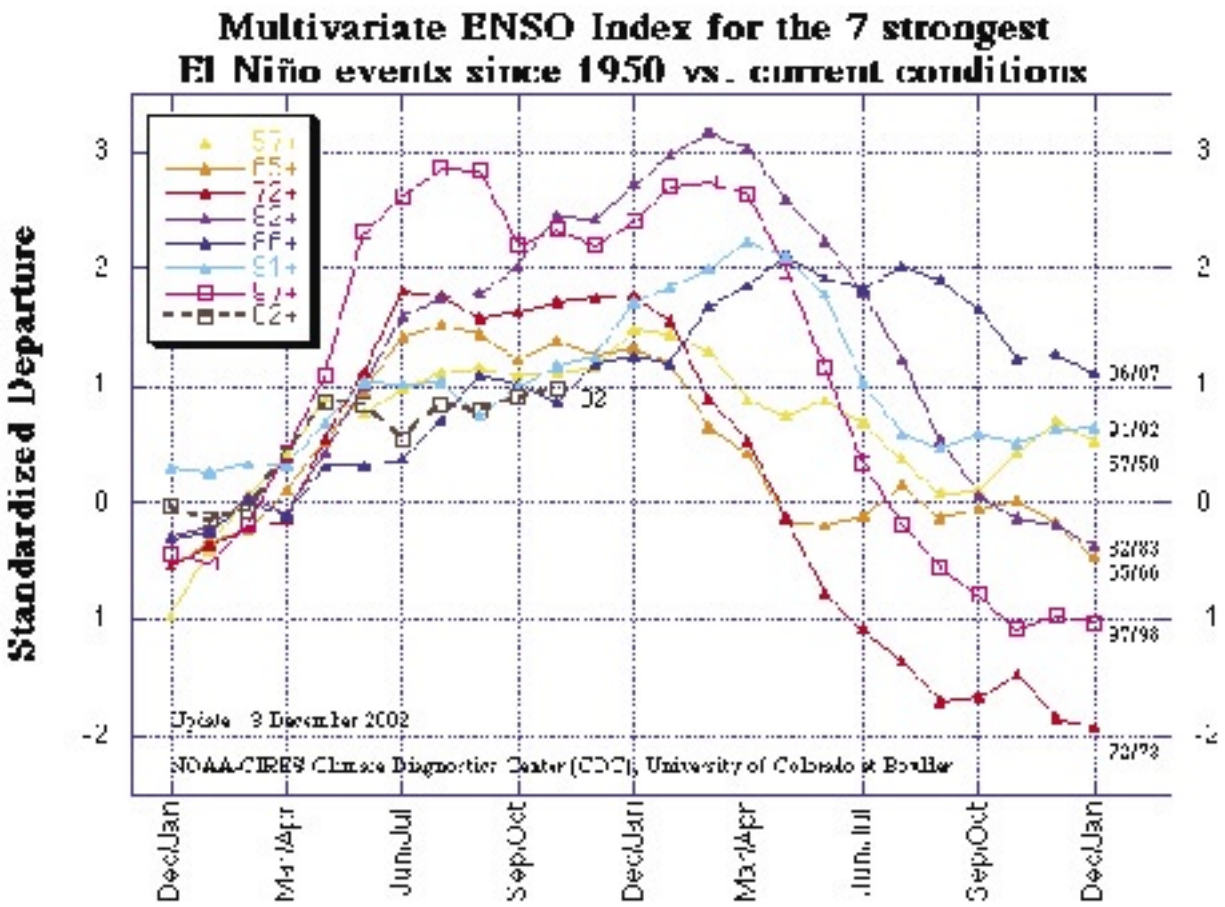

Figure 2. Comparison figure of historic El Niño events since 1950. The most recent El Niño (02) is plotted through November 2002, and can be compared against the most well established seven El Niños since 1950. At the tick mark shown next to "02", the value ranks 10th overall, and remained at or above that level through March 2003.

After a shaky start during the first half of 2002, the end of this year featured a moderately strong El Niño event, as can be tracked on a daily basis on the internet (http://www.pmel.noaa.gov/tao/jsdisplay/). Figure 1 depicts the conditions for late November 2002, as they are monitored by the international Tropical Atmosphere Ocean (TAO) project through about seventy moored buoys in the tropical Pacific. The maps shown here feature the measured sea surface temperatures (SST) and surface winds in the upper panel, and their respective anomalies from the long-term climatologies in the bottom panel. Whenever SST anomalies exceed 0.5C in the so-called Niño 3.4 region (120-170W, 5N-5S) for at least three months, an El Niño event is defined. Clearly, late November 2002 boasted SST anomalies much larger than that. In fact, this snapshot was taken close to the peak of the event, as we now know.

To put the situation of late November 2002 in a temporal perspective, Figure 2 documents the evolution of a more comprehensive measure of ENSO during 2002, compared to other El Niño years. This measure of ENSO is known as the 'Multivariate ENSO Index' (MEI; defined and discussed in Wolter and Timlin, 1993, 1998; updated monthly under: http://www.cdc.noaa.gov/~kew/MEI/). The tick mark for October/November 2002 elevates the 2002 event to the top 10 El Niño category since 1950 (where it remained until February/March 2003). This categorization was important for some of the expected climate anomalies during the winter and spring of 2002-03.

Once an ENSO event is established, simple persistence is a forecast tool that is hard to beat, especially during our fall and winter seasons. Considerable efforts have been made to provide forecasts that foresee the evolution of ENSO beyond the persistence time horizon. One such forecasting tool is the coupled ocean-atmosphere model that the National Center for Environmental Prediction (NCEP) runs. Figure 3 shows the predicted SST anomalies for Niño 3.4, as compared to what observations were through November 2002. During much of 2002, this

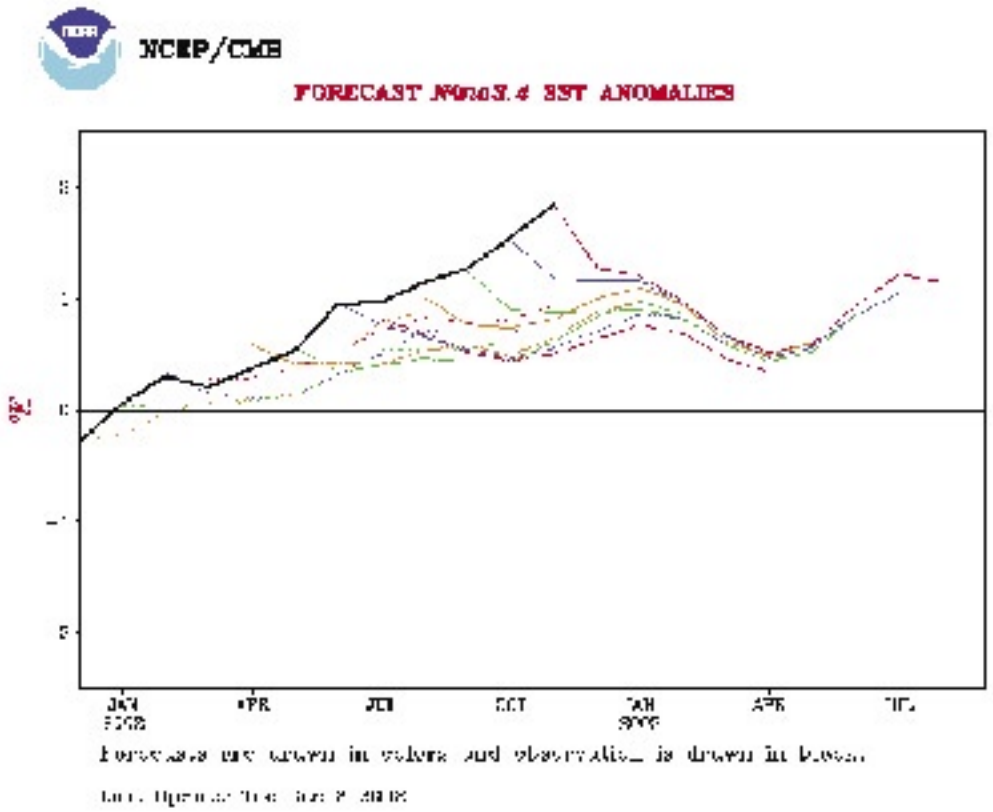

Figure 3. Predicted SST anomalies for Niño 3.4, as compared to observations through November 2002 by the coupled ocean-atmosphere model which is run by the Coupled Modeling Branch (CMB) at the National Center for Environmental Prediction (NCEP). The forecasts shown here are monthly averages of multiple such calculations performed each week.

model had a tendency to underpredict the size of the 2002 El Niño event, as indicated by the colored lines that represent the average forecasts for different monthly starting points from

January 2002 onwards. In fact, this model flaw was shared by most competing forecast tools, not only in 2002, but also during earlier El Niño events (Landsea and Knaff, 2000). For the purpose of making a climate forecast for Colorado, it is sufficient to know that at least moderately strong El Niño conditions were expected to persist into the spring of 2003.

2. EXTRACTING THE SIGNAL FROM THE NOISE – THE CASE FOR BETTER CLIMATE DIVISIONS

"Climate Divisions" are being used for many purposes, most importantly for keeping track of recent climate anomalies (the most prominent example of such usage is the U.S. drought monitor: http://www.drought.unl.edu/dm/monitor.html), and for making climate forecasts at NCEP's Climate Prediction Center (CPC; http://www.cpc.ncep.noaa.gov/products/predictions/). They were originally defined separately for each state, and are prone to distort local conditions in states with large orographic relief, such as Colorado.

The top panel of Figure 4 shows the official climate divisions (CDs) for Colorado, with a whopping total of five. Note how CD 2 stretches from the Four Corners region all the way to the Wyoming border. Everybody who lives here knows that Steamboat Springs does not have the same climate as Durango. Similarly, CD 4 encompasses the South Platte basin as well as North Park, as if Walden's climate had much in common with Fort Morgan's. Only CD 5, covering the San Luis valley, makes intuitive sense. Instead of just criticizing this state of affairs, I have developed new experimental CDs that have their basis in the statistical similarity of the reporting climate stations. In brief, my approach groups those stations into one CD that share the most climate variability with each other. The bottom panel of Figure 4 documents the results for Colorado. In addition to regular climate stations with human observers (labeled as COOP in Figure 4, and shown as circles), this regionalization also

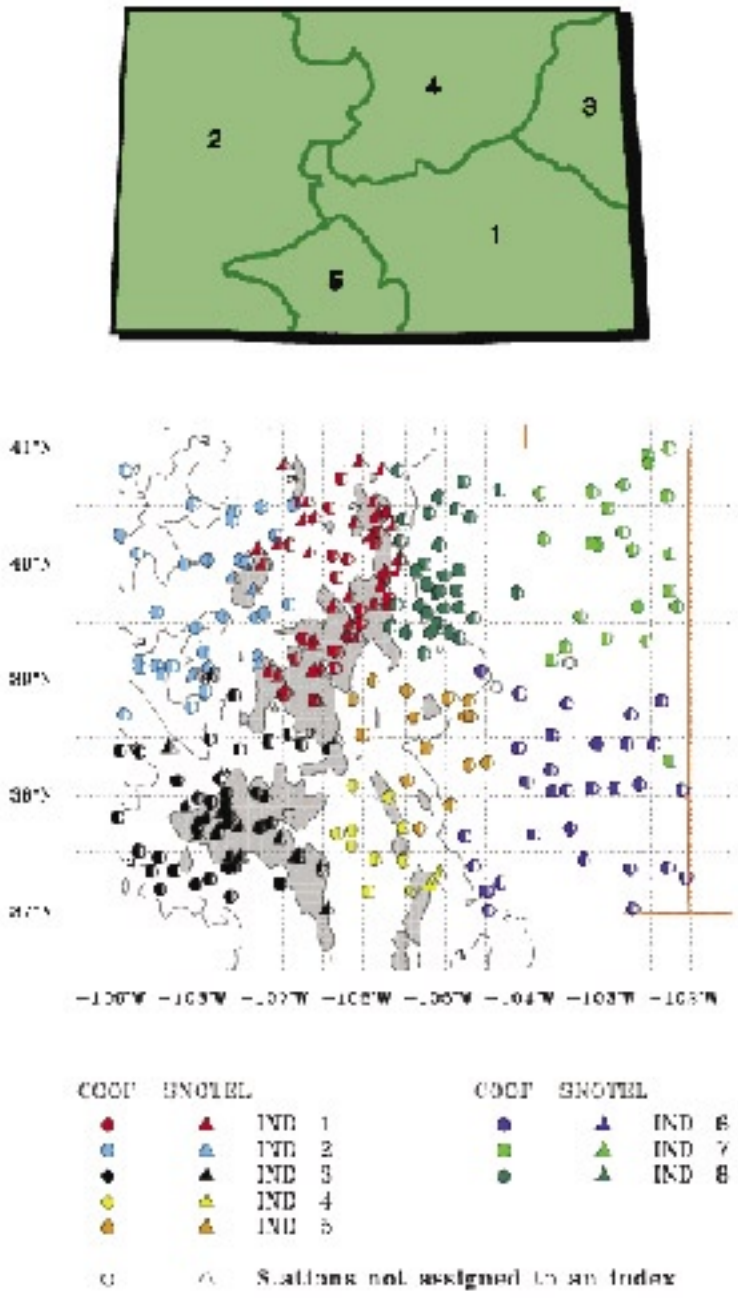

Figure 4. Colorado Climate Divisions: conventional version from the National Climate Data Center (top), and new experimental version (bottom). Climate stations with human observers (COOP) are shown as circles, and automated, high-elevation sites (SNOTEL) are shown as triangles. Eight different colors represent the new climate divisions, or index regions (IND).

utilizes high-elevation SNOTEL data from automated sites that were originally used for snow course observations (shown as triangles). Eight instead of five climate divisions provide for better representation of West slope climates in particular. The amount of color in each station symbol stands for the amount of statistical variance that is explained locally by the average time series (IND) for the whole climate division.

Why are these new CDs important? By maximizing the shared information represented by each CD time series, one achieves higher fidelity in the representation of regional climate anomalies (e.g., drought), and a better signal-to-noise ratio for use in climate prediction efforts. In recognition of the relevance of this idea, NOAA Climate Services is now funding my project to reorganize climate data for all the U.S. into new climate divisions.

3. HOW TO MAKE A CLIMATE FORECAST

Upfront, let me state that all climate forecasts are by their very nature 'probabilistic', i.e., there is a range of possible outcomes, due to the chaotic nature of the system, and that one should beware of climate forecasts that claim an exact and single possible outcome. Reflecting the current state of the art, my forecasts attempt to assign probabilities to the occurrence of above-, below-, and near-normal conditions (so-called terciles).

(i) 'Status quo'

Originally motivated by the 'dust bowl' years of the 1930s, CPC is the government agency tasked with creating and disseminating seasonal climate forecasts for the U.S. Although many different tools have been developed and considered for this purpose, the most reliable ones have proven to be (a) ENSO (climate impacts of El Niño and La Niña), and (b) 'Optimum Climate Normals' (OCN), otherwise known as long-term trends. These two 'workhorses' have been used in tandem with significant success during the 1990s. In my opinion, continued success has been elusive due to two factors: targeting forecasts on traditional CDs, and only weak La Niña conditions since 2001.

(ii) Suggested improvements

Aside from advocating the usage of better CDs, I have been researching the utility of other predictors (aside

from ENSO and OCN) for climate forecasts in Colorado in particular. It appears that useful information can be derived from regional SST anomalies beyond ENSO, such as the subtropical eastern Pacific and Caribbean, from antecedent land surface conditions in the Western U.S., such as the late season snowpack, and from remote 'teleconnections', such as the status of Indian Ocean SST. For instance, the Colorado drought conditions since late 1999 are really part of a much larger drought complex girdling the globe from the Mediterranean across Southwest Asia and much of the southern U.S. Although persistent La Niña conditions can be blamed for at least part of this pattern, recent modeling studies point to the persistent warmth of the Indian Ocean and Western Pacific as a further significant cause (ref. Hoerling and Kumar, 2003). Last but not least, I believe that ENSO impacts in Colorado (and elsewhere) can be better described ('downscaled') with the help of improved CDs, as introduced in the previous section (2). As we will see further below, there is considerable variation across Colorado and from season to season in terms of the expected climate anomalies during an ENSO event.

(iii) Experimental climate forecast approach

'Stepwise Linear Regression' (SLR) is a fairly old-fashioned statistical approach originally applied to monsoon predictions in the tropics by Walker and co-workers. In fact, Indian monsoon predictions have a century-long history of utilizing such methodology (ref. Hastenrath, 1991). As with any statistical approach to the climate forecast problem, one has to (i) avoid overfitting, (ii) (cross-)validate the technique, and (iii) calibrate the forecasts against observations. As far as overfitting is concerned, one should not add predictors just because they explain, say, one more percent of the target time series – I advocate the threshold of having to explain at least 10% additional variance with each new predictor. As far as cross-validation is concerned, one approach is the creation of ensemble forecasts based on at least five different training periods (say, trained on four decades of data, with one sliding decade of data held out). As far as calibration is concerned, one should check how well drought (or wet) conditions are predicted in the held-out portions of the record, and adjust the new predictions accordingly.

4. 'TRIAL BY FIRE' – LAUNCHING NEW SEASONAL FORECAST PRODUCTS DURING THE 'DROUGHT OF THE CENTURY' (AT LEAST IN PARTS OF COLORADO)

Although there are national products of this type (CPC), the lack of skillful climate forecasts for Colorado was one of the motivating factors for this exercise. After establishing an initial suite of candidate predictors for my new climate divisions, I developed the SLR-based approach described in the previous section, and presented my forecasts to the Colorado Drought Task Force from November 2001 onwards. Since these forecasts were updated every month, for up to ten target regions, this entails more than 100 forecasts. In this 'postmortem' on the 2001-02 Water Year, I will stick to a few general comments.

My initial fall and winter forecasts had mixed success. The best forecast detail was for a DRY winter in the north-central mountains of Colorado, which unfortunately verified, along with severe drought conditions in much of the interior Southwest. My subsequent forecasts for spring and summer 2002 did not verify, to put it politely. A modest tilt of the odds towards a wet spring 2002 in northeast Colorado verified only in the sense that the severity of drought conditions did not accelerate as fast over Boulder and Larimer County as was observed further south and west. Expectations of a wet monsoon in eastern Colorado were only fulfilled towards the end of August and during September, too late to tip the balance for the full season (July-September 2002). Clearly, something was missing from my kit of forecast tools, and here is my best guess at the syndrome of causes that 'spoiled' the outcome:

(a) Forest fires erupted early AND on a very large scale in Colorado during April 2002, injecting large amounts of small particulates into the atmosphere that hovered over the region for several months, possibly peaking in June, when the Hayman and several other large fires covered much of Colorado with thick haze (Figure 5). Although the combustion of trees provides for a local source of water vapor that often condenses into 'pyro-cumulonimbus' clouds, these generate only modest amounts of rain. On a larger scale, forest fires produce long-lived haze layers in the atmosphere that absorb sunshine and heat up elevated atmospheric layers rather than letting the sun heat up the ground and surface air. My conjecture is that the atmosphere gets stabilized in this manner, and that thunderstorms are inhibited in a large region surrounding the original fires. In July

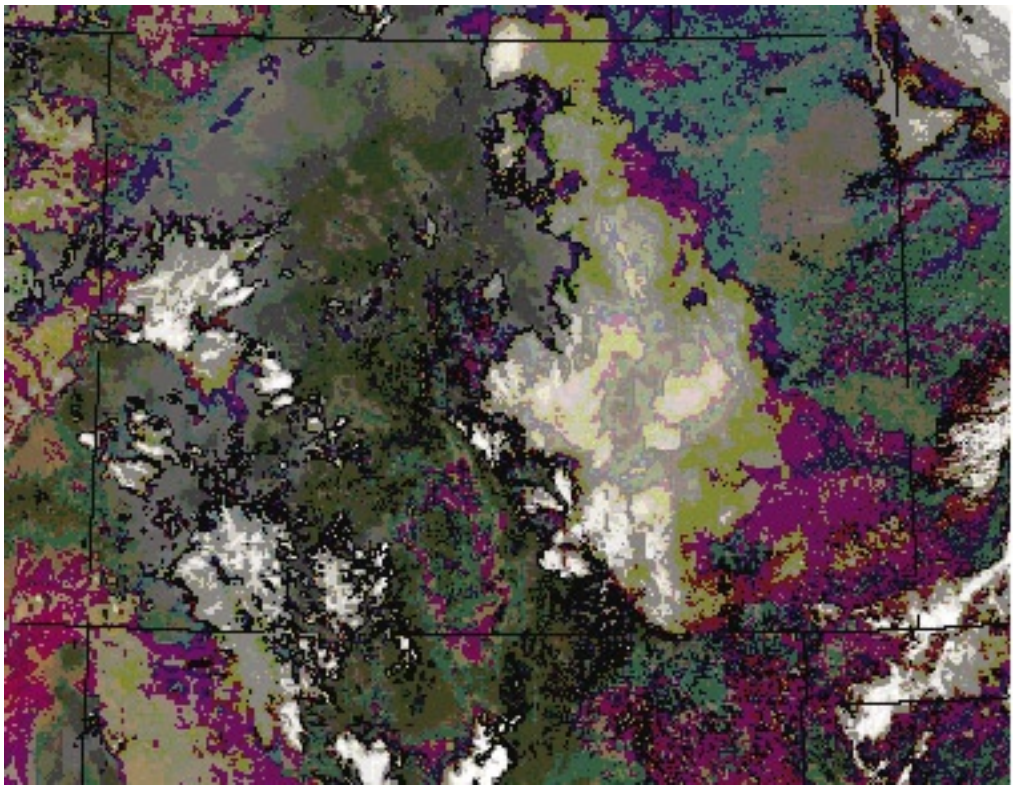

Figure 5. Satellite photograph of Colorado, taken on June 20th, 2002. Widespread haze from several large forecast fires is clearly visible, covering much of the state in smoke.

and August 2000, when Colorado had relatively few fires compared to Montana, pronounced haze layers may have played a similar role in the delayed onset of the monsoon season. Fortunately, fire seasons like 2000 and 2002 are still the exception rather than the rule in the Western U.S.

(b) Large-scale soil moisture deficits developed west of the Mississippi from 2000 through 2002, and may have played a negative role during the spring and early summer of 2002. This was particularly noticeable during 'upslope' weather conditions that would normally result in precipitation over the Front Range within hours of the onset of easterly flow. Instead, it often took half a day or longer to moisten up, losing valuable time at the beginning of such episodes, which typically only last for one or two days. Just as wet conditions can reinforce themselves due to the 'recycling' of moisture via evapotranspiration, drought conditions tend to perpetuate themselves due to the added heat stress once all moisture has left the soil (e.g., Lyon and Dole, 1995).

(c) Last but not least, El Niño went through a noticeably weakened stage early in the summer (ref. Fig. 2) that may have diluted the more typical wet response to full-blown El Niño conditions over northern Colorado in particular. The advent of the first significant wet spell in about 12 months in late August/early September followed the return of moderately strong El Niño conditions just before then (Fig. 2).

5. WHAT IS AROUND THE CORNER? – PROJECTIONS SINCE SEPTEMBER 2002

This section documents the downscaled El Niño impact for key climate divisions in Colorado, the "official" CPC forecast for January-March 2003, and my own experimental forecast for the same season. All of these forecasts refer to precipitation amounts only. While my experimental forecasts were developed with near-neutral ENSO conditions in mind, it is a useful test to see how well they perform during a full-blown El Niño situation. All of the figures shown below were originally displayed on my monthly updated forecast website (http://www.cdc.noaa.gov/~kew/SWcasts/). Based on preliminary data, I also offer a postmortem for September 2002 through May 2003 in Colorado.

Figure 6 shows ranked seasonal precipitation amounts (in percentiles from 1950-99) for ten historic El Niño events in four Colorado climate divisions (ref. Bottom of Fig. 4): northern Front Range cities from the Palmer Divide to the Wyoming border (GREEN), the north-central mountains of Colorado from Crested Butte to the Wyoming border, and from the Park Range and eastern Flat Tops to the Front Range (RED), the San Jeans and adjacent valleys in southwest Colorado (BLACK), and the Arkansas Valley east of Pueblo (PURPLE). There are three seasons considered here: September-November, December-February, and March-May. The ten El Niño event years are: 1957-58, 65-66, 72-73, 77-78, 82-83,

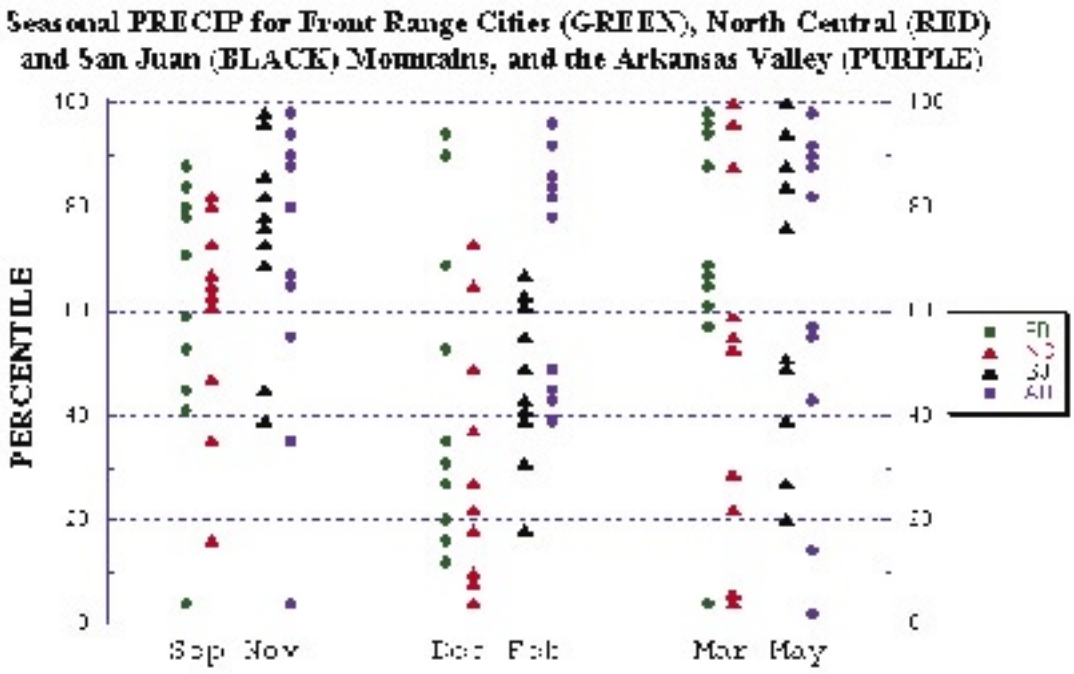

Figure 6. Ranked seasonal precipitation amounts for ten historic El Niño events in four Colorado climate divisions and for fall, winter, and spring. The ranking applies to the period 1950-99, with a 100% ranking referring to the wettest season on record.

86-87, 87-88, 91-92, 94-95, and 97-98. If eight or more cases out of 10 reside above or below the median (50%), the distribution is significantly shifted. Similarly, if four or more cases reside in the upper (80%) or lower (20%) quintile, there is only a 10% chance that this result is by accident (ref. Wolter et al., 1999). As anticipated, the new 2002-03 El Niño event ended up strong enough to be ranked 10th overall, pushing 1977-78 into 11th place. This justifies the application of this particular analysis to the recent situation.

During El Niño fall seasons, all four CDs tend to be wetter than the long-term median, with either seven or eight out of 10 cases being in that half of the distribution. For the two southern regions (San Juan and Arkansas Valley), at least four cases reside in the upper quintile, indicating at least doubled odds compared to "normal" of being in that wettest category. Preliminary data confirm wetter-than-average conditions for all four CDs during September-November 2002. On the heels of one of the worst drought years in recorded history, this was welcome news, and matches the El Niño "fingerprint" well.

During El Niño winters, only the Arkansas Valley maintains a tilt of the odds towards wetness, while the rest of Colorado shows a majority of historical cases in the dry half of the distribution. This is particularly true for the north-central mountains where eight out of 10 El Niño winters ended up on the dry side, and four in the lowest quintile. The outlook for the San Juan was not quite as bleak, with only one case in that lowest quintile. Based on preliminary data for December 2002 - February 2003, a dry winter was indeed observed in all but the Arkansas valley, so that El Niño continued to "deliver" the expected results.

During El Niño springs, all four regions tend to be wet, especially the northern Front Range cities (nine out of 10 above the median translate into a 1% probability that this occurred by chance only) and the Arkansas Valley. The latter shows half of its springs in the wettest quintile, cementing this region's claim to having the most reliable year-round wetness associated with El Niño. The largest range in possible outcomes is documented for the north-central mountains, where some of the wettest AND driest springs on record occurred during El Niño, although six out of ten cases reside above the median. Now that preliminary data has been received through May 2003, it can be confirmed that the two northern CDs were indeed "wet" this spring, while both the San Juan and the Arkansas valley ended up drier than expected (the only "failed" forecasts). All in all, ten out of 12 seasonal forecasts (SEP-NOV, DEC-FEB, MAR-MAY for four key regions in Colorado) appear to have verified with the correct sign. This postmortem is paraphrased from (http://www.cdc.noaa.gov/~kew/SWcasts/).

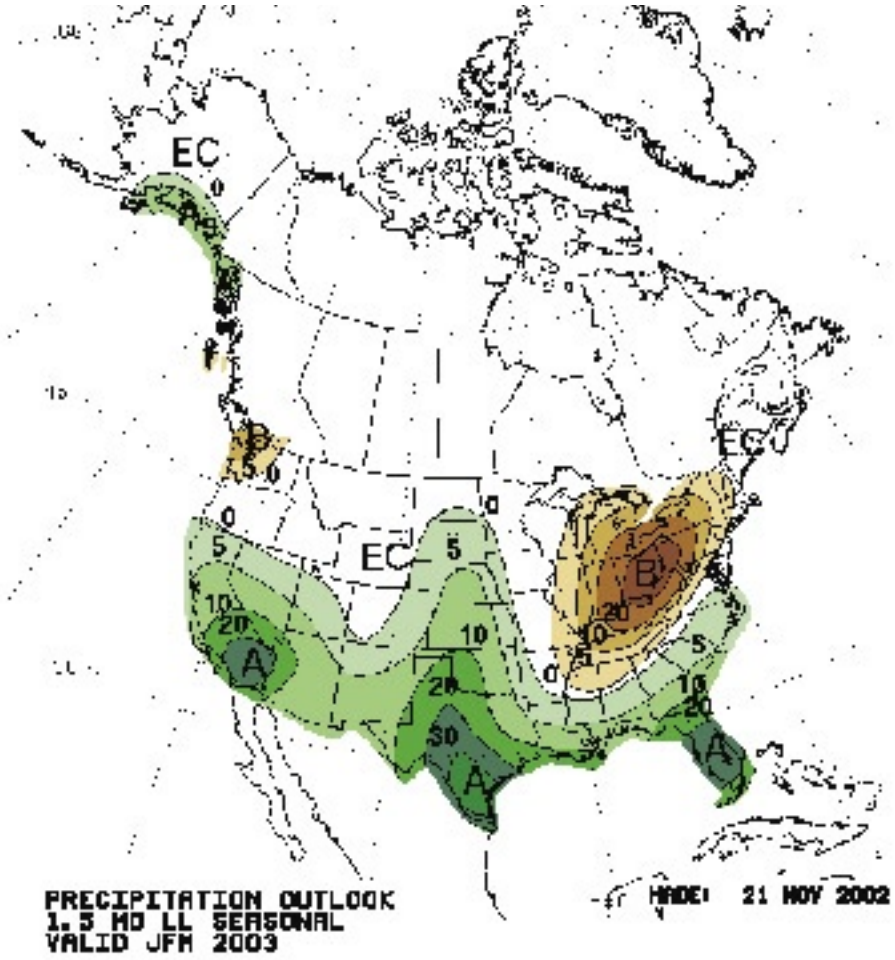

Figure 7. CPC precipitation forecast for January through March 2003, issued in late November 2002. This map shows increased odds towards wet conditions in green, and towards dry conditions in brown. For example, the extreme 30% shift in the odds towards wet conditions in southern Texas translates into a 63% expected chance of observing late winter precipitation in the wettest tercile, 33% of recording near-normal precipitation, and only 4% of registering a late winter in the driest tercile. "EC" refers to "equal chances" of either anomaly sign.

Figure 7 shows the official CPC forecast for January through March 2003, issued in late November 2002. Due to the pronounced El Niño conditions, it was based on typical moisture patterns during El Niño for that season. Simply put, it looks like a "W", with expected wet conditions extending north to cover all of California, much of the Great Plains, and the eastern seaboard up to the mid-Atlantic states. The northwestern third of Colorado is left blank ("EC" standing for equal chances of any tercile category). The Ohio valley was expected to receive less moisture than the long-term average.

Figure 8 documents my experimental forecast for the same late winter season, also issued in late November 2002. The most controversial aspect of this forecast map is that it predicted wet conditions for January-March 2003 over the north-central mountains of Colorado, even though the typical December -February "response" to El Niño is dry. Mother Nature resolved this conundrum by providing us with a dry December and January in this region, juxtaposed with a wet February and March, and, voila, both forecasts ended up correct! Figure 9 displays the preliminary national rankings for January through March 2003, based on traditional CDs. This confirms the overall wetness for Colorado and adjacent states to the south and west.

Summary (as of December 4th, 2002)

The original motivation for this work was to get at a better representation of ENSO impacts in Colorado, and, to find out whether other climate forecasting tools can be brought to bear here. During the last year and a half,

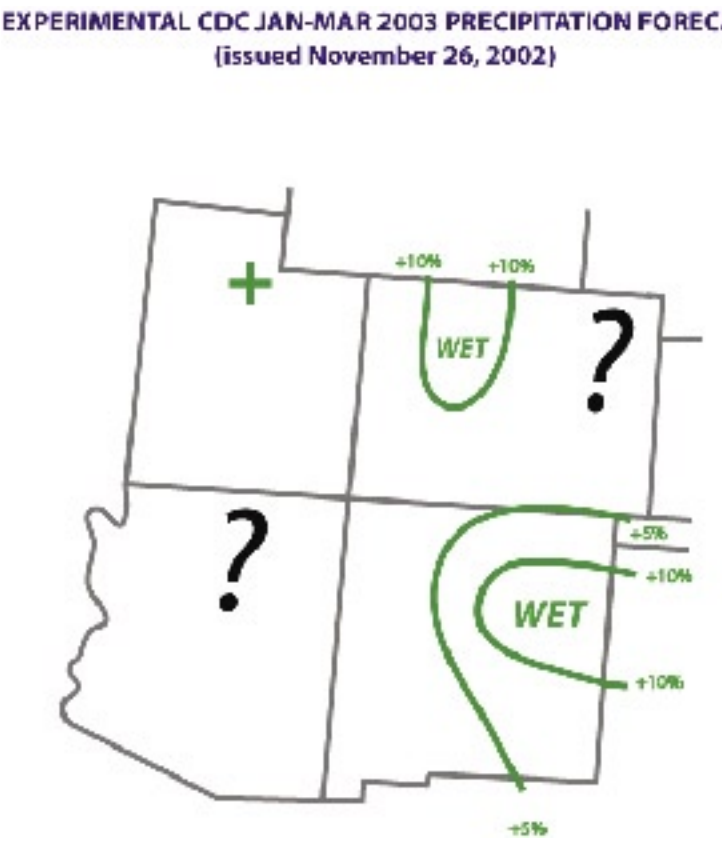

Figure 8. Experimental CDC forecast for January-March 2003, issued in late November 2002, with "?" replacing "EC".

I have had mixed success, but I have certainly gained a better appreciation for toughness of this problem.

The late 2002 El Niño allowed for a comparison of pure El Niño-based vs. more comprehensive SLR-based forecasts. Both approaches appear to have worked quite well during the 2002-03 winter and spring. As I put it in my presentation, "expect a dry winter in most of the mountains, and occasional drought relief in plains, especially in southeastern Colorado. Our best shot at substantial moisture can be expected during spring, in particular for the Northern Front Range. The experimental (SLR) approach argues for a wet late winter in the north-central mountains". The dry forecast for December-February, and the wet outlooks for January-March, as well the subsequent spring season materialized much as expected, except for a dry March-May in southern Colorado. Monthly updated climate forecasts will continue to be posted under: http://www.cdc.noaa.gov/~kew/SWcasts/

ACKNOWLEDGMENTS

This work has been funded through three separate grants from NOAA, under PACS, RISA, and Climate Services. I thank Barbara DeLuisi for her help in creating the experimental forecast maps. I am grateful for numerous seasonal forecast discussions with Randy Dole, Marty Hoerling, and Klaus Weickmann here at CDC.

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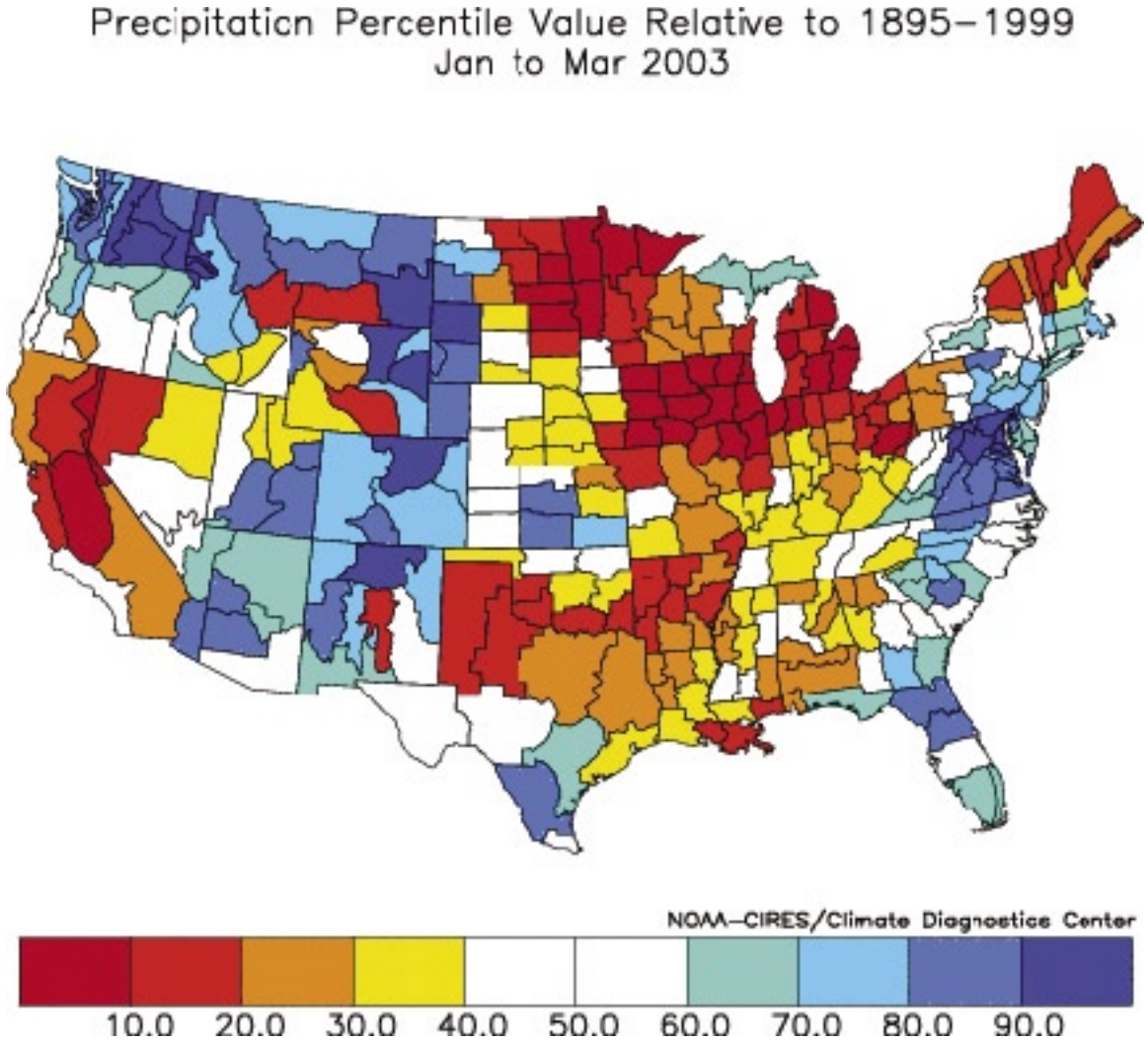

Figure 9. Preliminary national rankings for January-March 2003, based on traditional CDs. Note the wetness in CO!

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LESSONS LEARNED WHILE MANAGING WATER IN COLORADO DURING THE 2002 DROUGHT

Moderator:

Neil S. Grigg
Professor of Civil Engineering
Colorado State University

ADMINISTERING WATER RIGHTS DURING THE 2002 WATER YEAR: LESSONS LEARNED

Hal Simpson
State Engineer
Colorado Division of Water Resources

Good morning and thank you for attending. It's a great turnout. I'm going to use a PowerPoint presentation and try to move through it as efficiently as possible, talking about stream flow, reservoir storage, some of the impacts of drought, and some of the lessons we've learned. Jack Byers, my assistant state engineer for engineering and technology, is the PowerPoint expert who helped put this presentation together and is assisting me up here.

Figure 1 shows the map of Colorado with outflow at the state shown in blue arrows. The magnitude of the outflow is indicated by the width of the arrow. In the Colorado River basin, you can see 4,632,000 acre-feet of outflow. Total outflow on the western slope is 9,246,000 acre-feet; on the East slope much less, with 1,476,000. Total outflow leaving the state is about 10,726,000 acre-feet. This is the long-term average of all gage records up through about 1999. This year, based on what we now know, that run-off will be in the range of 25-30 percent of that long-term average. So, rather than having the amount you see here, it will be much less. If we add to the outflow our estimates of consumptive use, the undepleted, or virgin water supply in Colorado is about 16 million acre-feet; so, 25 percent of that is roughly 4 million acre-feet. That's what we had to deliver and allocate by my staff of water commissioners. So, you can

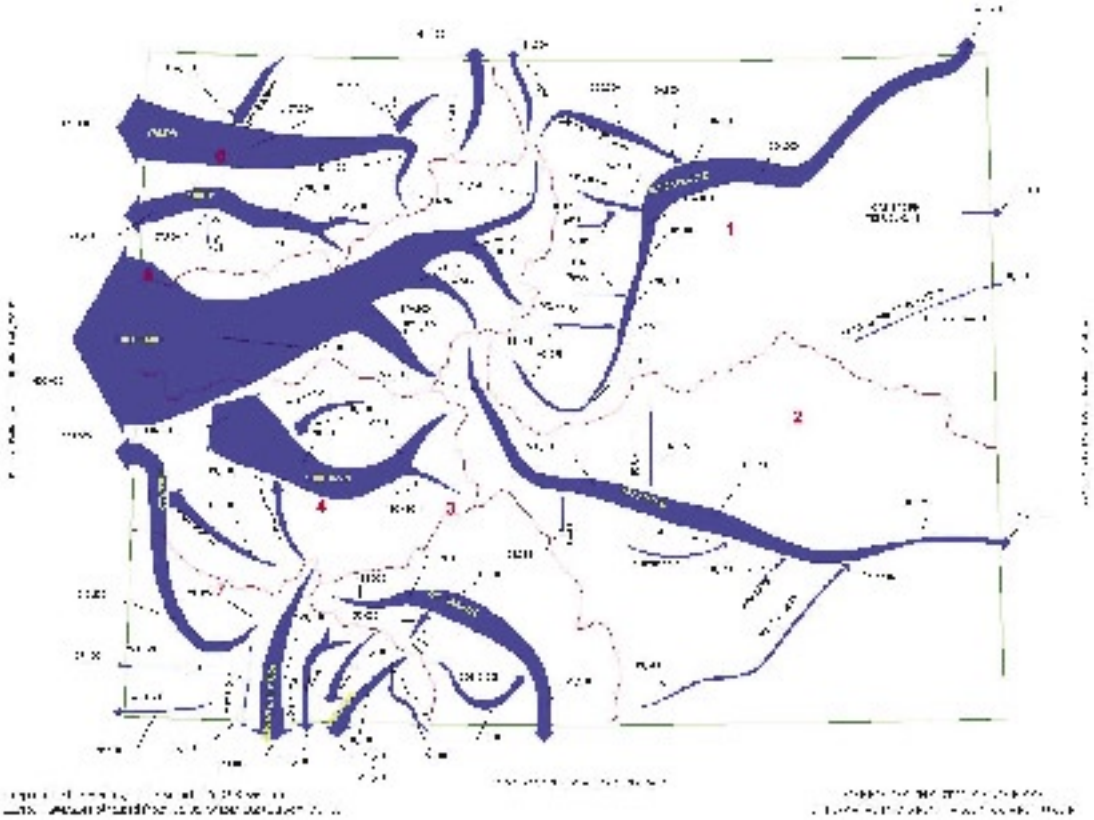

Figure 1. Colorado Historic Average Annual Stream Flows.

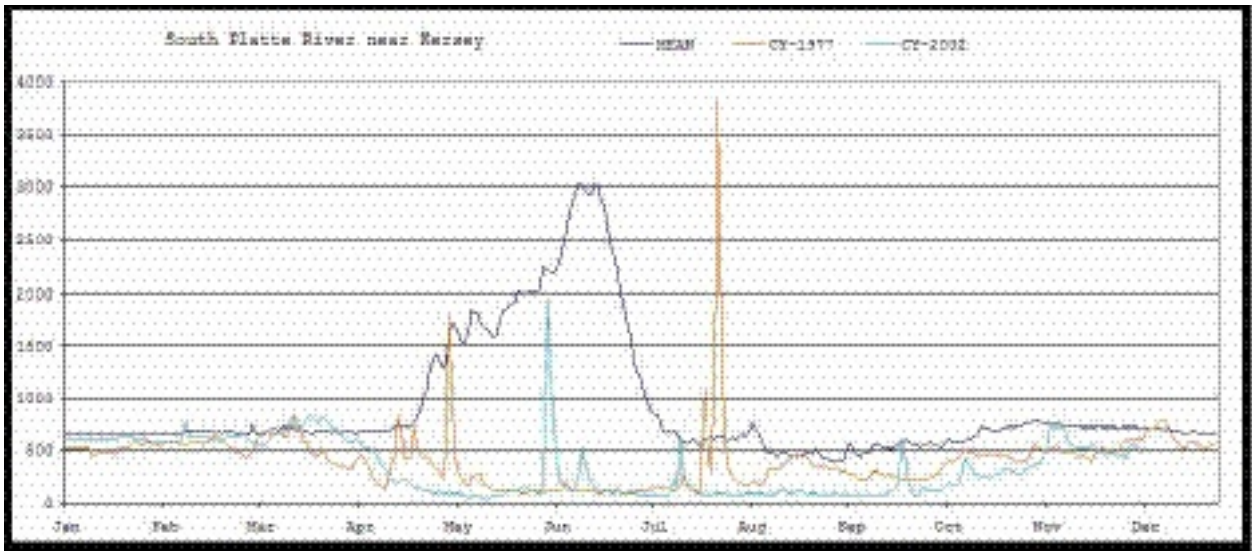

Figure 2. South Platte River near Kersey.

see that outflow or streamflow is much less, and what I hope to do is move through three representative river basins to give you an idea of what the run-off this year is like compared to a very dry year, 1977, and the long-term average.

The first river basin we will look at is the South Platte River near Kersey, just below Greeley (Figure 2). It is a good indicator of the water supply available to the irrigators on the Platte. The dark blue trace is the long-term average, the red trace is 1977, and the light blue trace is the year 2002. Now, 1977 was a very dry year, but we had a situation occur that really saved the irrigation economy of the South Platte. In 1977, you can see the impact of the monsoon events. Just about the time State Engineer Kuiper was looking at having to deal with potentially well curtailment, it started raining, and it really made a difference. Unfortunately, this year we didn't get the monsoon rains, as you can see. And we're seeing probably record low flows in several locations in the

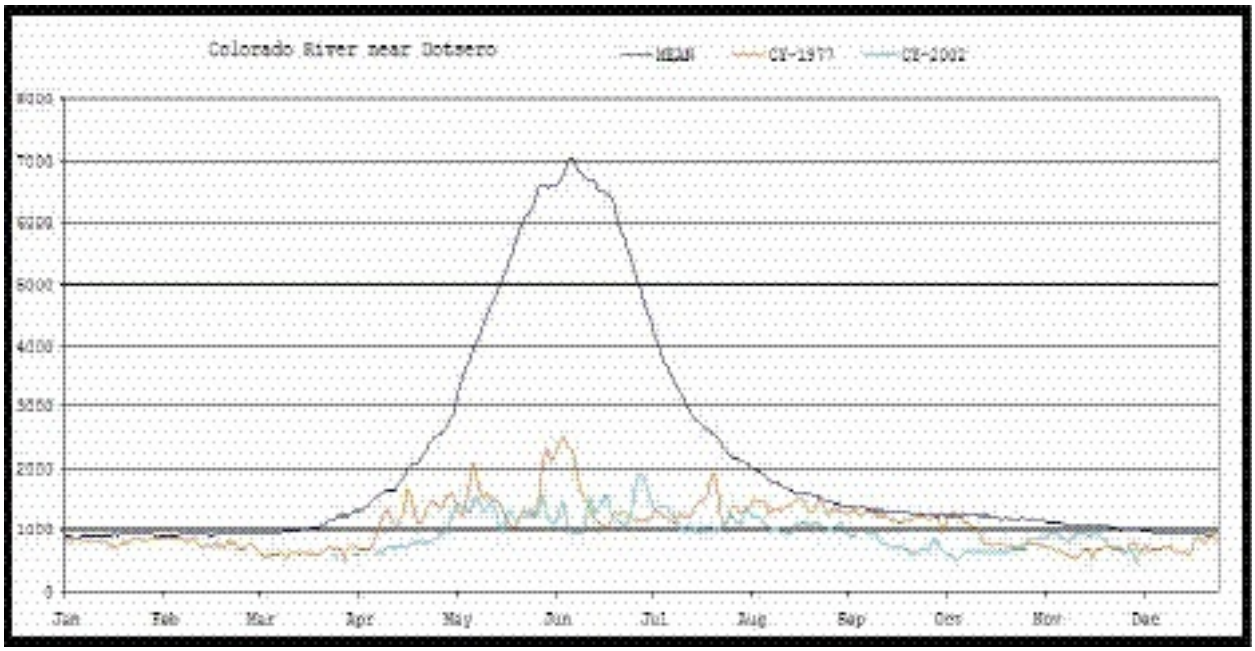

Figure 3. Colorado River near Dotsero.

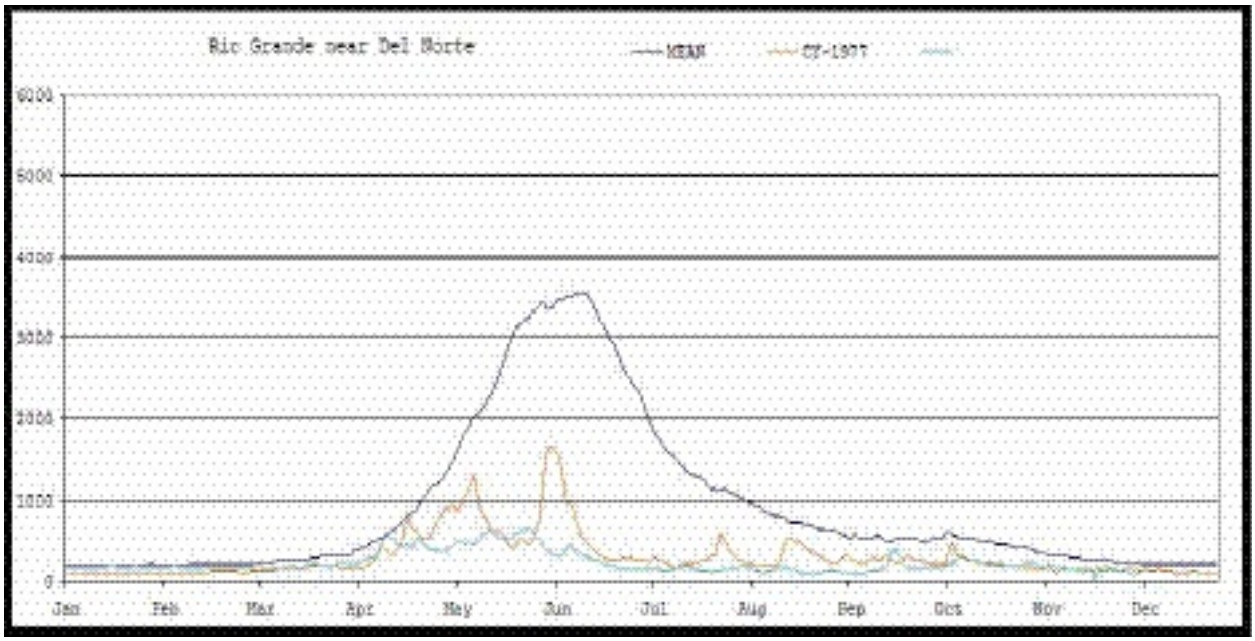

Figure 4. Rio Grande near Del Norte.

South Platte River Basin. May and July were the driest years of record at this particular gage and as other data become available, I think we'll see more and more gages setting new records.

The next basin I'd like to look at is the Colorado River Basin (Figure 3). This is at Dotsero, another key indicator gage that's just above Glenwood Canyon, but one we look at as an indication of run-off of the Colorado River main stem. You can see again the average is quite high, peaking at 7,000 cfs. In 1977 with this trace, you can see that there was some snow-melt runoff even in a dry year like '77. This year; there was hardly any snowmelt runoff, the reason being the watersheds are so dry. Three years in a row of below average snowpack; the soil moisture was so low, the moisture content of the trees was so low, that the combination of that prevented much runoff at all throughout the state, so we didn't see the peak we normally see. Normally, we get two-thirds of our runoff in a fourth of the year. This year, we didn't see that. Statewide, the snowpack was 22 percent of average on May 1st, clearly indicating how serious this situation was. And, using some of the information from one of the previous presenters today, from a precipitation perspective 2002 in this basin was the driest since 1579.

Now, we move to a basin in the southern part of the state, the Rio Grande near Del Norte (Figure 4), which is an index gage for the Rio Grande compact. We again look at the average; 1977, which was thought to be nearly the driest year in record, and here is the 2002 tracking, much below that.

Total flows in June, which is our big month on the Rio Grande, this year were 13,212; seven percent of average, much less than 1977. Of course, the average is 190,000. We're running into some unusual sets of circumstances on the Rio Grande, because it's so dry and runoff is low, we project the total runoff for the year to be about 160,000 for this gage; normally it's about 700,000.

There is a table of values in the Rio Grande compact to establish how much we have to deliver each year. It's adjusted for drought. The driest, or the lowest value in the table, starts at 200,000 and we have to deliver 60,000 acre-feet. We are below the lowest point in that table, so at the compact meeting in March with the states of Texas and New Mexico, we will be debating what will be Colorado's true delivery obligation, since we're outside the range of the values in the compact. This creates an interesting set of circumstances with respect to the compact.

Table 1 shows the current active storage of the larger reservoirs in Colorado, those that we inspect. The total capacity is about 6,400,000 acre-feet. We do have some dams restricted and we have this indicated – about 142,000 acre-feet restricted for 198 dams due to unsafe conditions. This number is much smaller than it was just a few years ago, when it was closer to 200,000 acre-feet.

And, since in the last 10 or 11 years we were able to construct 49 new dams with a combined capacity of 120,000 acre-feet, the point I would like to make here is that this year the lost streamflow is about 12 million acre-feet compared to average. Storage was just about half of that, so to offset a drought of this magnitude with storage is virtually impossible, just because we built upon the best reservoir sites in Colorado and captured most of the usable water, so we're dealing with a set of circumstances, again, that we've never had to deal with in the recorded history of Colorado.

I would like to share with you some projections on reservoir storage, and these are west slope reservoirs, based upon what we now know (Table 2). Blue Mesa reservoir, when it's full, is 940,000 acre-feet. It will be down to 260,000 acre-feet and it is dropping. Releases are, I believe, 250 cfs for endangered species issues and fish. Taylor Park was drawn down significantly. Ridgeway carried over pretty well, but if we get into March of next year, some of the big reservoir that are really important to this part of the state – Northern Colorado Water Conservancy District – Granby reservoir will be down to 74,000 acre feet; that's the dead pool and they can't remove anymore water and pump it to the Front Range. That's the level of the intakes to the pumps. Dillon Reservoir will be down to 95,000. Green Mountain will be down to its new dead pool. That pool is normally 7,000, but because of the potential slide, where the community of Heeney is located, the Bureau of Reclamation doesn't want to pull it down because of concern about slippage and damage to buildings, so they restricted releases to that level and it's at the level now, or will be. And Wolford Mountain, one of the newer reservoirs that has been built in the last ten years, certainly will be and has been pulled down also.

Table 1. Reservoir Storage.

Current Storage		Restricted Storage* Total a-f	(#dams)
Division 1	1,787,810 a-f	33,900	(99)
Division 2	893,544 a-f	89,200	(31)
Division 3	297,261 a-f	9,700	(3)
Division 4	1,447,948 a-f	4,200	(28)
Division 5	1,166,040 a-f	2,990	(19)
Division 6	165,387 a-f	1,400	(11)
Division 7	665,356 a-f	1,460	(7)
Total	6,423,345 a-f	142,850	(198)

- August 20, 2002
- 1990-2001 : 49 New dams with a combined storage of 120,000 a-f
- Div 2 Two Buttes 31,500 a-f and Cucharas 33,000 a-f - very expensive reconstruction necessary.

Table 2. Reservoir Storage.

October 1, 2002 statewide Reservoir storage is 48% of average, 56% of 2001. The Colorado River Basin at 42% of average.

➢ November 1, 2002 content;	
Blue Mesa Reservoir (940,000 a-f)	260,000 a-f.
Taylor Park (106,000 a-f)	41,000 a-f.
Ridgway (84,000 a-f)	53,000 a-f.
➢ March 1, 2003 projected content is very bleak.	
Granby Reservoir (544,000 a-f)	74,000 a-f. dead pool
Dillon Reservoir (252,000 a-f)	95,000 a-f.
Green Mountain Reservoir (154,00 a-f)	27,000 a-f. dead pool
Wolford Mountain Reservoir (66,000 a-f)	13,000 a-f.

I would like to share with you, briefly, the importance of groundwater especially in a dry year. Figure 5 shows the designated ground water basins that are under the jurisdiction of the Colorado Groundwater Commission. They are shown in color on the map. The biggest basin is the Northern High Plains Basin, and the Southern High Plains has some irrigation. We irrigated probably 600,00-650,000 acres in those two eastern designated ground water basins and provide a significant attribute to the economy, because that pumping can continue. It is not restricted by protecting senior water rights. I also wanted to show the location of the Denver Basin, which is primarily, along the Front Range, and is being used for municipal use. I think it'll be used much more. We're seeing a lot of active drilling this winter by Aurora and the East Cherry Creak Water Sanitation District trying to get additional wells into these non-tributary aquifers so they'll have additional water by next summer.

Also on this map we have the South Platte alluvium, where we have significant irrigation, the Arkansas alluvium, and an area down here in the San Luis Valley called the Closed Basin Aquifer, and we'll share with you some information on that.

Our projections of ground water use in Colorado are somewhere around 2 million acre-feet per year. You can see it's rather extensive out in the High Plains, a million acre-feet. In years like this it becomes an important supplemental supply, or in some cases the only supply. Normally, we would use or deliver statewide about 20 million acre-feet of surface water and ground water on an average year. In a year like this, where we're looking at 25 percent of that, the 2 million acre-feet that would be 10 percent in an average year is more like 20-30 percent of the available supply in a dry year like this.

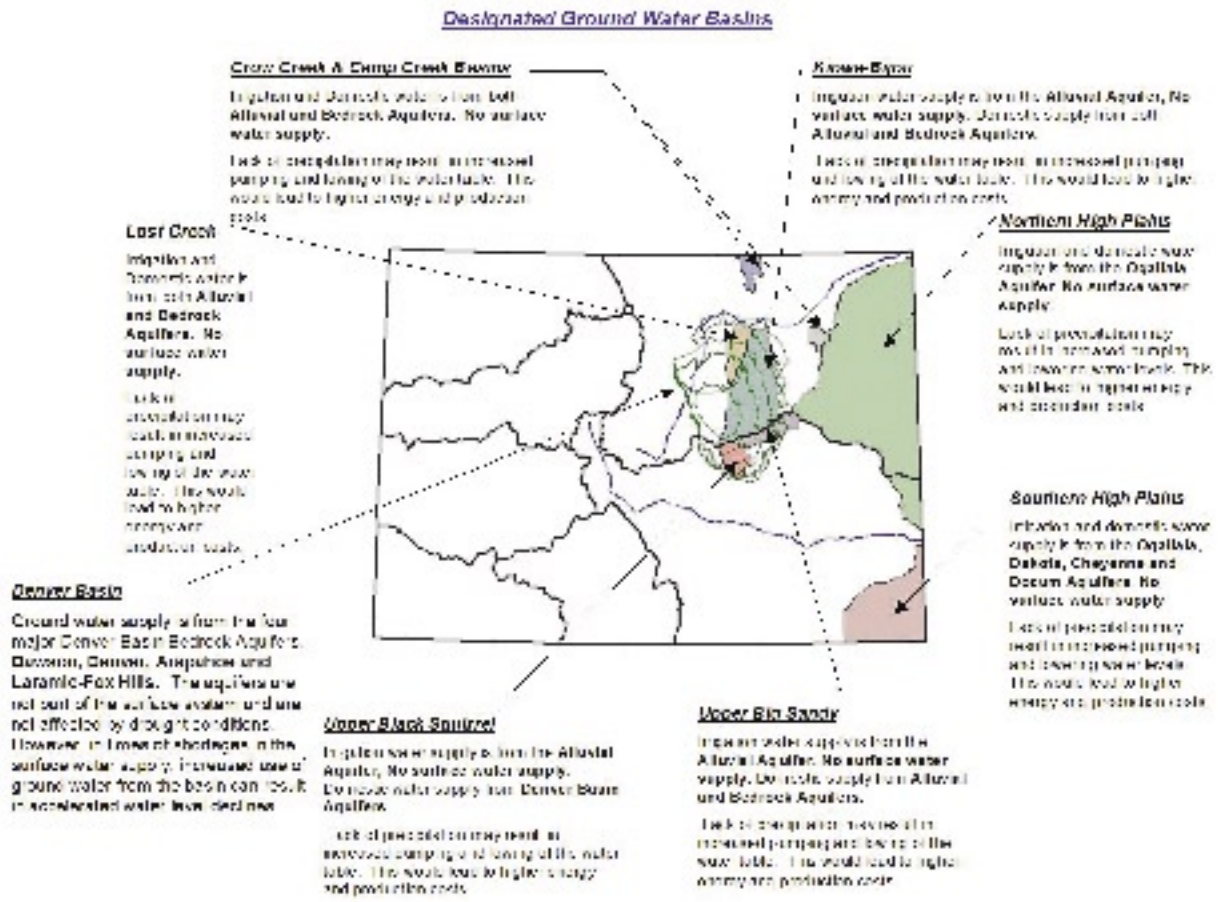

Figure 5. Designated Ground Water Basins.

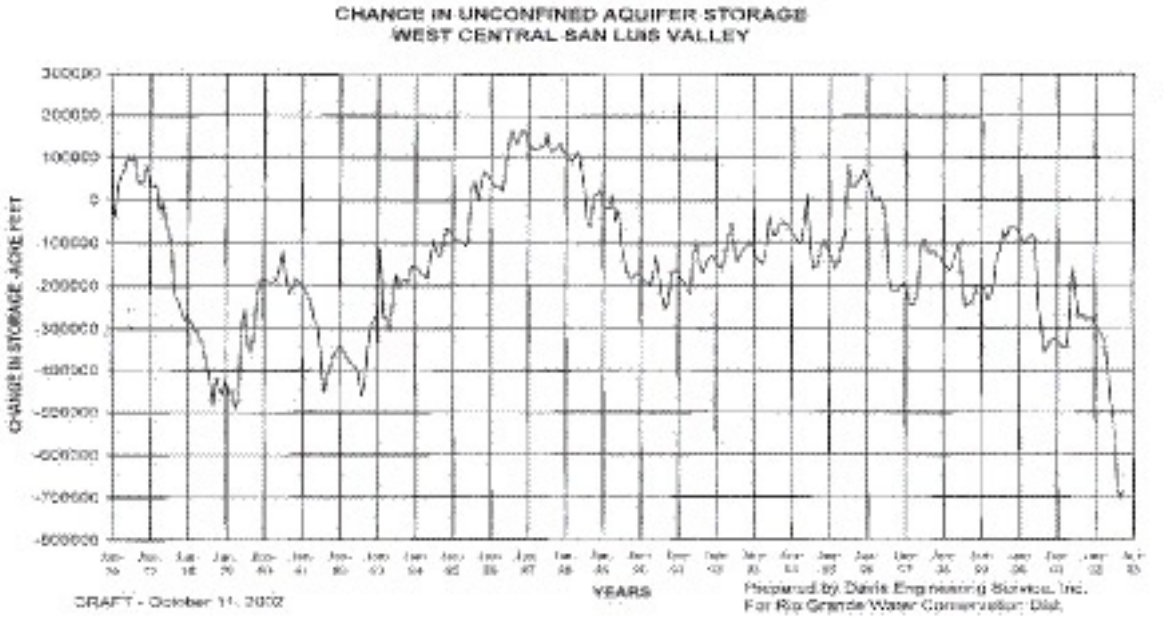

Figure 6. Change in unconfined aquifer storage, West Central San Luis Valley.

Figure 6 shows the change in water storage of the unconfined aquifer that we call of the Closed Basin in the San Luis Valley or the Rio Grande Basin. They started keeping information in 1976. This is through June of this year. You can see that in dry years, such as '77 and '78, the water in storage dropped; picked up in a wet year, dropped again, really picked up with that strong El Niño in the '80s, and then the bottom dropped out this year – removed 700,000 acre-feet from storage. And it is the major reservoir of the San Luis Valley.

They recharge this aquifer through diversions of large canals into recharge pits, and then they pump it out with 1500 center-pivot sprinklers, irrigating some of the best potato land in the United States. So they very carefully manage their resource, but they're quite concerned that over the long-term; we may have over-developed this aquifer. We stopped issuing well permits down there in 1981, so there has been a moratorium on, but even with that there is a concern about the long-term viability of the aquifer.

We are finishing up development of a decision-support system that should be finished this late fall or early next year, in conjunction with the Colorado Water Conservation Board. It's a set of models that model both the confined aquifer and the unconfined aquifer and the river system. With those tools, we'll have a better idea on what we need to do to bring the system into balance, if needed.

I have the responsibility to promulgate rules by July 1st of next year. We're asking for a one-year extension to find how to better manage that particular aquifer and the confined aquifer that is situated below it.

Next, I will go through the seven water divisions, as we call them, and talk about some of the things we've run into and some of the lessons we've learned, and then try to wrap up with a few points.

Division one is the South Platte River Basin. Calls came on very early – April 1, and they are on as I speak. We had direct-flow calls all summer into the end of October. Normally the call changes from direct flow to storage, sometime around October 1st, the direct flow rights called clear up to November 1, so we did not go into storage until the first of November. We had very senior calls: the Farmers Independent 1865 call was one of the more senior ones we've had to deal with in a number of years. We basically emptied all the reservoirs on the plains that served the South Platte. We may be at 5 percent capacity because we have started to fill some, but basically, if you've driven east along I-76 every reservoir out there is dry. We used it and we even dredged some to get additional water out of a few dead pools.

Because of the long call, the amount of augmentation water for the wells, that's the three augmentation associations, or the big ones, are GASP, Groundwater Appropriators of the South Platte, the Lower South Platte Water Conservancy, and Central Water Conservancy District had to acquire additional replacement water or face a potential of curtailment. So there were a lot of creative actions taken by the water users and my staff, Dick Stenzel in particular, in finding ways to keep the wells pumping so they could get a complete crop production this year.

We had a lot of cooperation. The water providers in the metro area assisted us, made available usable return flows that were leased to GASP to keep them pumping and offset depletions in the upper part of their service area. Denver, Aurora and Thornton worked a three-way deal that resulted in effluent being made available to GASP and Central.

The legislature helped in the special session this summer. They appropriated $1 million to make grants available to augmentation associations to acquire that additional water. Representative Hoppe was very instrumental in getting that legislation through, and I know the water users are deeply appreciative of her efforts.

Division 2 is the Arkansas River Basin. We ran into a number of very senior calls. We have a call on the Arkansas year-round, because of the compact, but it varies in how senior it is. This year, for the first time in history, the 1869 water right of the Rocky Ford canal called. And it took out the City of Pueblo's 1874 water right for 45 cfs, and that was the foundation of their drought plan. They always assumed that they would have that 45 cfs available, so when the call came on and we told Pueblo you have to shut off, they of course had to scramble. And Alan Hamel was to speak today, but I guess he couldn't make it, would have shared with you what they went through in the way of switching from direct flow to storage, having to undo some contracts they had entered into with some augmentation associations to lease what they thought was surplus water to the augmentation groups down there. But because of less augmentation or replacement water available, we had to cut back the pumping of some of the augmentation associations. The Arkansas Groundwater Users Association had to cut back their allocations by 25 percent and that was a real scramble to even let them pump 75 percent of what they wanted.

Division 3 is the Rio Grande Basin. I have shared with you some of the issues we've dealt with there. We're dealing with compacts, low flows that we've never had to deal with. The Rio Grande at Del Norte will set a record low. We ran as much reservoir water as we could, but the transportation losses on these three; Rio Grande, Continental, and Santa Maria – because they're so high up on the Rio Grande, the owners stopped making releases – were only getting about a 50 percent delivery of the water released. They thought that this was too much of a waste of a valuable resource, so they stopped running reservoir water and decided to carry it over. And as I indicated to you, we're experiencing significant problems in the Closed Basin. That dropped water level caused a number of wells to pump air. The water levels in the aquifer were below the intake to a number of pumps, and if we don't get good runoff next year, so the big canals can recharge that aquifer, we will see a very serious impact of drought carried into next year.

Division 4 is the Gunnison Basin. Again, we had a situation develop with respect to the Gunnison Tunnel call. Since Blue Mesa was constructed, that call has never moved up above Blue Mesa. There has been sufficient water plus the releases from Blue Mesa to keep that call off. This year that wasn't the case; they placed the call in April and it stayed on most of the summer. That caused us to have to regulate water rights junior to 1901, which hadn't happened for about 50 years. We had a whole new generation of ranchers and people living in the area that simply didn't understand the priority system, and how we could shut down their water rights, so it was quite an effort by my water commissioners to have to regulate water rights that hadn't been regulated for over 50 years.

Division 5 is the Colorado River Main Stem. I've shared with you some of the things that have happened. We expect record low flows. We've had to manage reservoir waters very closely. Because that 20,000 acre-feet was not available in Green Mountain Reservoir, there was a lot of cooperation between the Colorado River Water Conservation District and the Northern Colorado Water Conservancy District in finding that 20,000 that was needed. Fortunately, there was surplus water that could be purchased in Ruedi Reservoir, and so Ruedi was lowered quite a bit to offset the 20,000 acre-feet of replacement water not available out of Green Mountain.

We've had a lot of cooperation in that basin. The Conservation District entered into agreements with some of the hydropower plants to not call, to compensate them with money rather than let them produce energy to sell. The Redlands Mesa power call was taken off the Gunnison. Right now, as we speak, there are negotiations to take the Shoshone call off right now on the main stem – that's owned by Excel Energy. Hopefully, a decision will be made Friday on whether that can happen. If that call goes off, then we can go into storage in the high reservoirs above that point.

Division 6 is northwest Colorado – the Yampa and White River systems. We expect record low flows. We have used most all of the reservoir water that was available. Some of those reservoirs over there, Stagecoach, Steamboat and Elk Head, release water for power plants in dry years, so to get those power plants through the summer, when they had very little, if any, direct flow rights, they were running reservoir water to those particular power plants. It was a new situation for my staff. They never had to protect reservoir releases that far down into the system, so we were scrambling to try to protect the reservoir releases to make sure they got to the power plants.

Division 7 is Southwest Colorado – the San Juan, the Animas, and Delores River Basins. Again, the stream flows are extremely low. This may be the driest basin of any, based upon what we're seeing. It or the Rio Grande, are really close as far as how serious the situation is. Many of the perennial streams went dry. We had a lot of streams that people always expected to see flowing that dried up, and it wasn't due to diversions – there just wasn't any runoff. Most of the reservoirs were emptied. We're down to dead storage or to some Division of Wildlife conservation pools to protect the fish population.

We've run into an interesting set of circumstances with the La Plata River Compact. It's a compact with New Mexico on a small stream and produces about 30,000 acre-feet of water. The compact requires that we deliver from the upper station at Hesperus to the state line, which is about 30 miles downstream, one-half of a flow the next day during the irrigation season. Well, in dry years we lose the river; it dries up because of phreatophytes and the geology. This year, 26 miles of the stream dried up. We were trying to push one half the flow through, and we finally realized that we were just wasting water and stopped making those deliveries and curtailed all diversions in Colorado below the dry reach, where there were return flows coming back to give New Mexico what we could, but it was about half of what they were entitled to. So, obviously, they weren't happy, and this has happened the last three years, because we've had three dry years, but this year, it became a major issue with Tom Turney, the state engineer, and he has threatened to sue

us over not being able to make those deliveries. So, we'll see how that turns out. He won't be the state engineer next year; we have learned that new Governor is to replace him, so we'll be dealing with a new state engineer and he may have a different perspective.

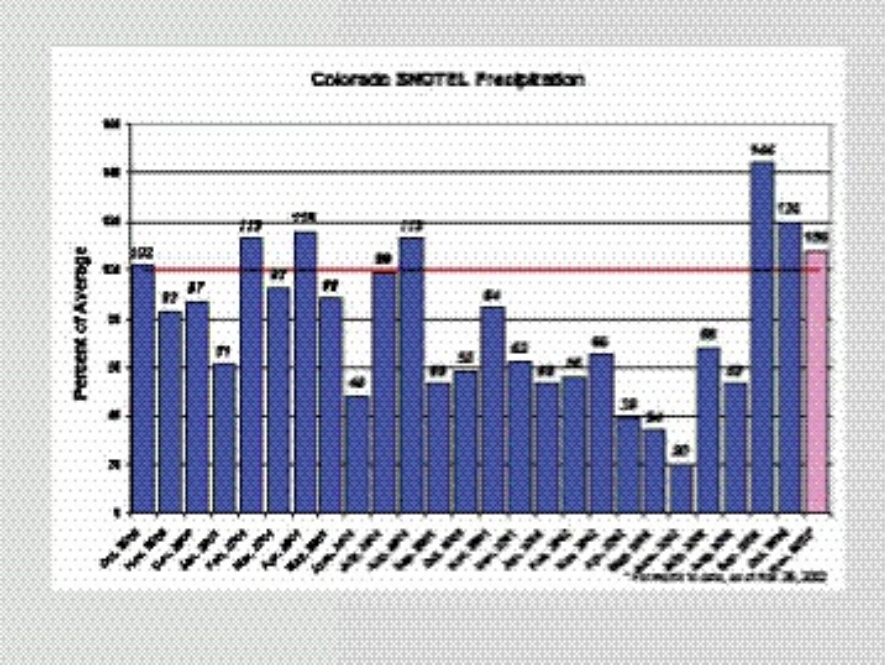

Figure 7. Colorado Snowtel Precipitation.

With respect to substitute water supply plans, we were given authority under House Bill 1414 in the last session to give emergency approval for up to 90 days, without any public notice, without any other review than this office determining that a plan could be put in place to help a city to get through at least a 90-day dry period. We still had to look at the injury question, but we were able to approve about 14 plans quickly under that legislation; and again, Rep. Hoppe, who is here, was very instrumental in getting that legislation through. It's something we anticipate we may have to do again next year, because if it continues to be dry, some of these communities will need assistance next year.

Let me wrap up – conditions are serious, although we have some hope that maybe things are turning around. The state has done some things to deal with drought. There was a conference held in 1999. The governor called on drought and flood efforts. It was prior to the start of a three-year dry period, so it was a good time to conduct a drought conference. They updated the drought plan in 2001. The water availability task force has been meeting regularly since we went into this dry period, trying to deal with impacts as much as they could. The Colorado Water Conservation Board is doing a study that started about a year ago looking at drought needs of communities throughout the state in a drought.

Certainly, the year 2002 will set a new target for needs that might have to be met, should such an event occur again in the future. And following that study and working closely with the results of it, is a study that's just getting underway called the statewide water supply initiative. It is a study with up to $2 million dollars available to identify actions that could be taken in each river basin to deal with some of the shortfalls that would be identified in a drought study. So that study and action plan is just getting underway. Consultant selection is in the next month or so, so we will start to see some ramping up of that study and hopefully, about two years from now, we will have some concrete actions that the state can employ to assist water users in developing additional supplies.

We've heard that El Niño is building, and that's very encouraging, but we also know that we need good runoff next year – and runoff is really going to be hard to generate, because of the dry conditions in the watersheds as it was this year. Some of the communities along the Front Range are saying they may not be able to allow any outside use at all. That's a very difficult decision that entities like Denver Water will have to make.

Figure 7 indicates just what has happened from October 2000 to the present. The September, October, November snowpack is encouraging, but we're seeing it starting to dry out. As some experts indicated, we could have a dry winter. Just hope and pray that next spring it turns around and we have good snowpack and good runoff.

EXPERIENCES OF DENVER WATER

Rocky Wiley
Denver Water

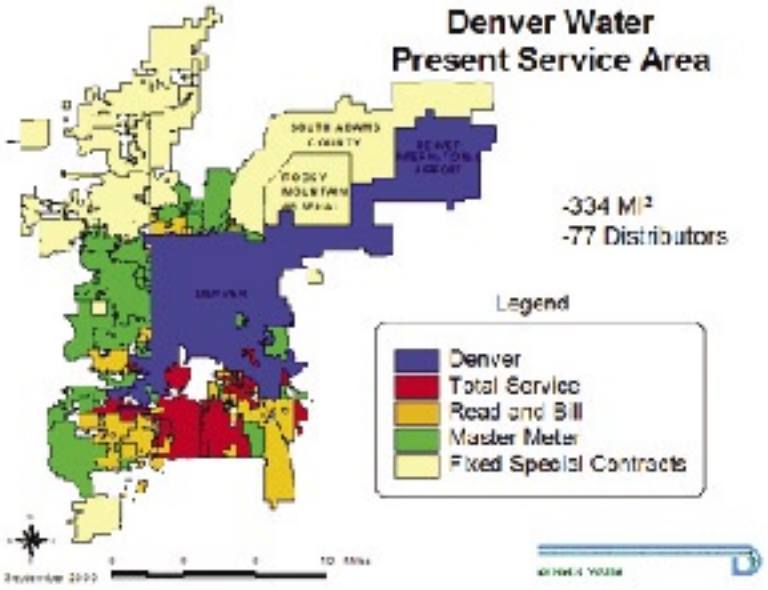

Figure 1. Denver Water Present Service Area.

I am supposed to talk about "lessons learned while managing water in Colorado's drought of 2002," but I was thinking about changing to "lessons learned while reacting to or trying to catch up with the drought of 2002." You can read my bio in the information you have, but I might just tell you a little about the person talking to you here today. My wife has started another business at home, and so we have a room full of her stuff. As I was getting on her the other day about it, she said, "Now wait a minute. Let me check this out. You have been the healthy forest coordinator for Denver for about five years now, right? And you are the drought coordinator, and let me see if I have this right – we can't water our lawns and the forest burned up." So, that is the perspective you are getting and where I am coming from here.

The first thing we ask ourselves at Denver Water is, "How did this happen to us?" – a water provider responsible for about 25 percent of the state's population, about half of the Front Range's population, serving one-half million people in the City and County of Denver and another half-million people in 77 distributors that we serve outside the city (Figure 1) – a water provider that has four different water collection systems, which we are very proud of, eight major reservoirs, 673,000 acre-feet of storage, and watersheds on both the East and (as many of you know) West Slopes (Figure 2). We always say we ought to be covered no matter what drought conditions happen.

If you look at our supply/demand curve, we have a supply of about 375,000 acre-feet of safe, annual supply. We talk about that safe annual yield all the time that will get us through the worst drought we know about – the '50s

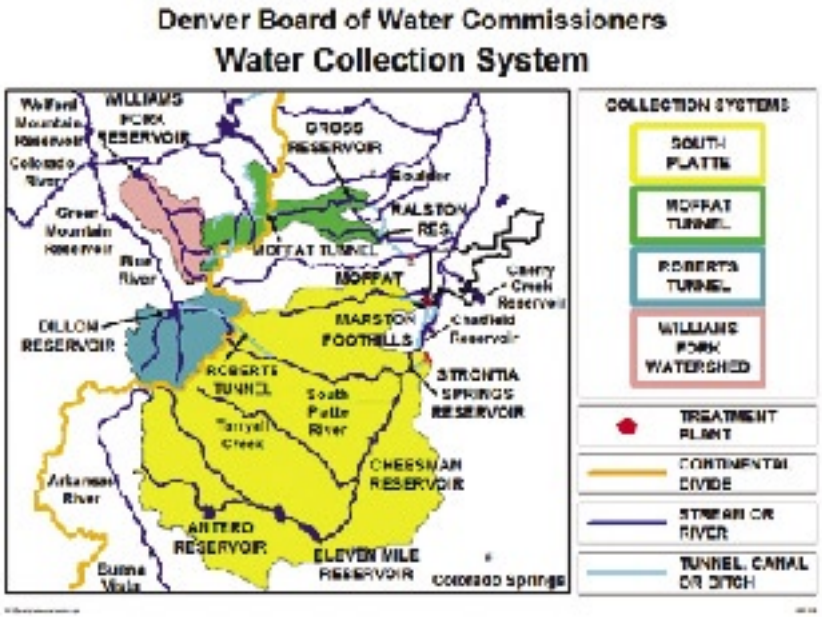

Figure 2. Water Collection System.

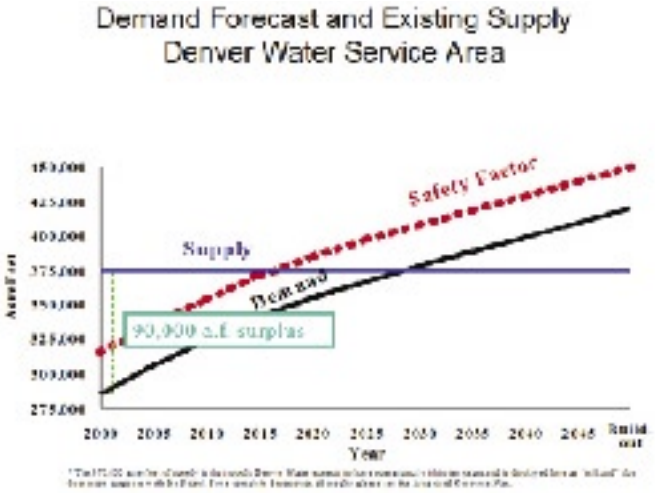

Figure 3. Demand forecast and existing supply.

drought – we still ought to be able to serve our customers without them really knowing a drought is going on. We have about 90,000 acre-feet of surplus today – 90,000 acre-feet more than is necessary to serve our customers. Even with a 30,000 acre-foot safety factor that we put on top of that, we ought to be able to make it until 2015 without any problem. So how could the country's greatest water provider (wait . . .) how could one of the top 47 water providers in the West get into this much trouble in just one year?

How did we go from this

to this?

Figure 4. Frisco Marina.

I have to admit, when Frisco built its marina it didn't choose the greatest place, but if you go to Dillon now, you won't be taking any kind of boat in and out of there for quite a while.

If you look at our drought chronology, April, with the projections we are making on snowpack and storage (Figure 5), says everything's fine and no restrictions; come May 1, the snowpack – lack of precip – a big thing we have heard about here today. And here is how the water department reacted. May 1 – snowpack, lack of precip, lack of runoff – May 15 we were going to voluntary demand restrictions – June 1 – mandatory restrictions were recommended by Denver Water Board – July 1 – we go on second-stage mandatory restrictions.

Mark Waage is in the audience somewhere, and all of these projections are Mark's fault. Mark is our manager of water resources, and that sounds like it's right up there near the top, doesn't it? But in our hierarchy, Mark has to go up a couple of steps before he gets to the Board, and it took the water department a while to say, "Okay, maybe Mark is serious about what is going on." Our board meets twice a month, and you know, it seemed to them that every time they showed up there was a different deal – "Hey, don't worry about anything." "Ah, maybe we ought to put on voluntary . . ." and then, "Hey – we have to get after this."

We are projecting here July 1 storage, and this is what triggers everything we do. This is what we use to set our raw water operations – and then in turn, the demand we will allow on the system is projections of our July 1 storage (Figure 6). In April we are saying 87 percent, "Hey, we will be fine;" May we are going 75 percent; June we are going 60 percent; and that is what we were looking at as we saw the reality of what the snowpack was really

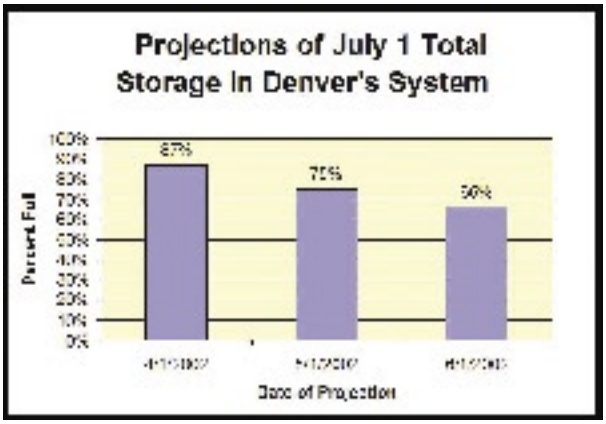

Figure 5. Storage Projections.

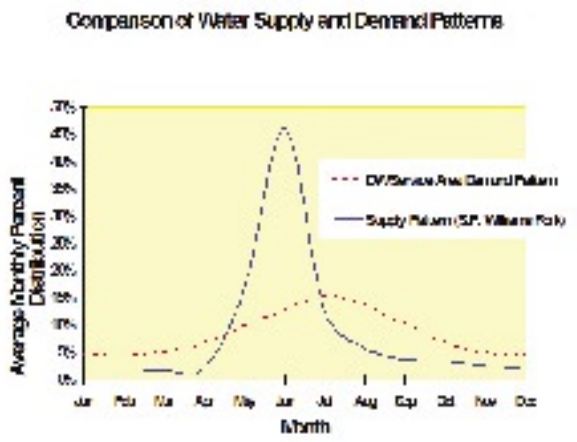

Figure 6. Supply and Demand Patterns.

going to do. Today, we are at about 48 percent and we are hoping to be not any lower than 40 percent by April 1, and that is about half of what we are usually at or where we would like to be.

If you look at April NRCS snowpack (Figure 7), that is the one you want to use, we say, "Hey, it's about average; things ought to be good; projecting about 87 percent storage in July; 90 percent is our average of that snowpack; and then it was the first lesson we learned – the snowpack isn't the whole answer here. The 2002 snowpack was better than '81, better than '77, and better than the '54 drought period that we had and that we looked at to design our system. But as this slide shows, spring precip, soil moisture, and high evapotranspiration were the problems – big problems that perhaps we were not taking completely into consideration.

The second lesson we learned, then, was that the watershed gets or takes its share of the water before we ever get our turn. Figure 8 shows some real numbers looking at different precip stations on our system along the bottom – Antero, Eleven Mile, Cheesman – you get out there to the end and it's 54 percent-of-average, then you say, "That isn't too bad." But then I went to Steve Schmitzer, chief of our water resource analysis, and another one responsible for the problems we are having at the water department. I went to his guys and I said, "Hey, with this precip, snowpack, runoff, give me a couple of slides that will show the difference between a good and a bad natural flow that we get in our reservoirs" (Figure 9). Believe it or not, this is good and bad – decent snowpack, little precip, high ET, low soil moisture – we got very little inflow; the top one was Dillon and the bottom one

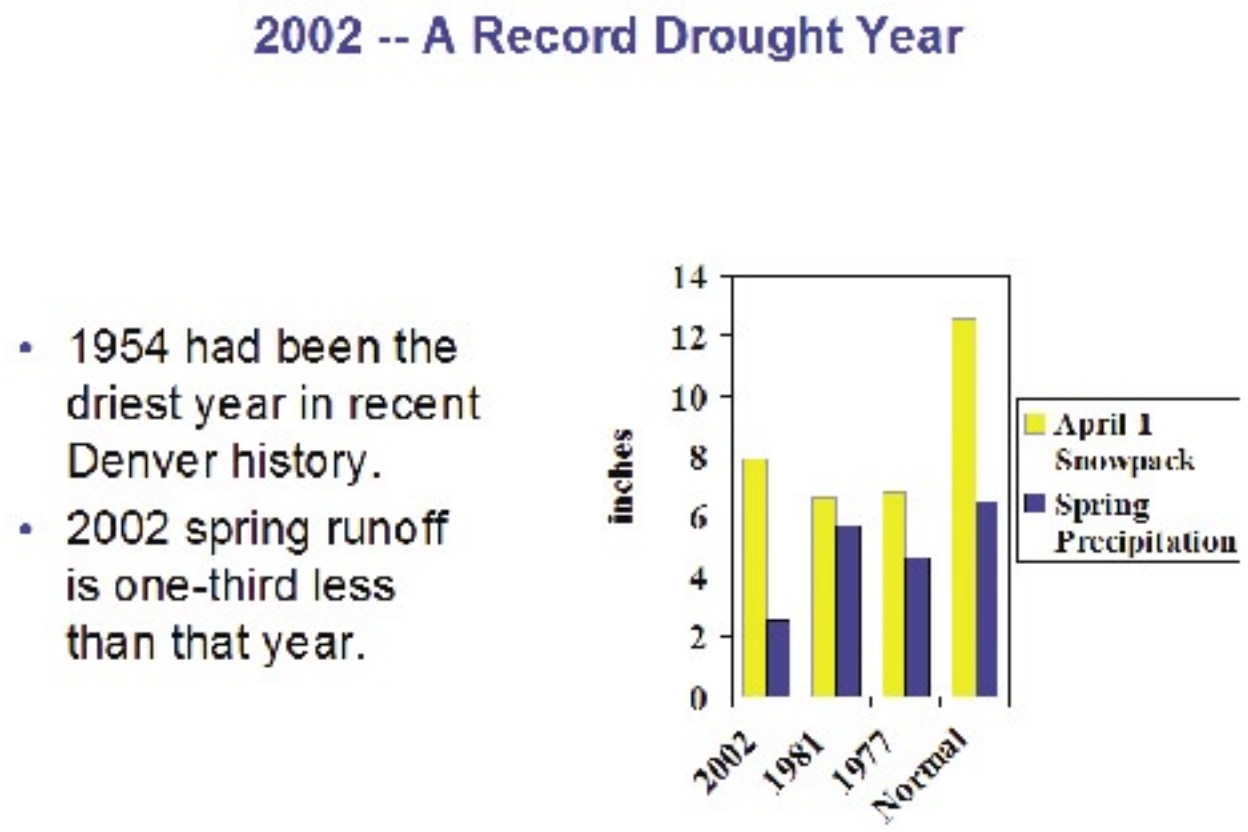

Figure 7. 2002 – a record drought year.

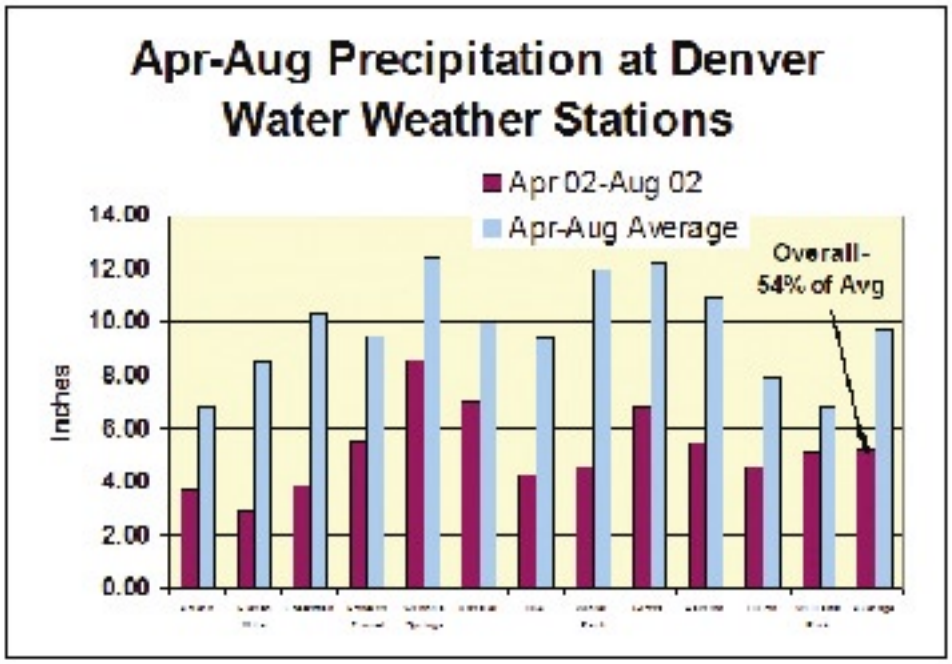

Figure 8. Apr-Aug Precipitation at Denver Water Weather Stations.

was Cheesman. Red is the actual, and honest to goodness, some actually came into Cheesman. But as you can see, again, snowpack is not the whole answer – there are other things. This is the kind of natural inflow we got in these two reservoirs.

How we responded – just quickly again, April everything is okay; May we go to voluntary demand reduction and ask the people of our service area to voluntarily go on some programs; mid-June-July 1 we go on mandatory restrictions; we are looking for 30 percent savings – we have things like every three hours, permits, water cops, penalties, outdoor-use restrictions – and one I didn't put up here, one of the biggest problems we faced in this whole deal – fountains. Fountains were unbelievable. We spent an hour a day talking about fountains – are there fish in there, are fish a pet, and did somebody just put some goldfish in there – fountains took up a lot of our planning over the past year, and I am not too sure even now we have the answers.

Then in August we went to full restrictions, limited the hours to two, no Sundays, eliminated permits; October, we went to no lawn-watering irrigation. This is how our customers responded – blue is actual, dotted red is expected – and expected takes into consideration the weather, the precip, the temp and tries to take all of that out, the question being with the weather conditions the way they were, what would we have expected our customers to use?

Under the voluntary restrictions we don't make any projections then because people usually don't water in April. The last frost is sometime in May, you wait until Mothers' Day to buy the annuals you put in, and then there is always "Maybe the last frost isn't over – cover up your tomatoes, etc." – but there was a tremendous watering in April and May that we didn't expect (Figure 10). Now, total, that was only

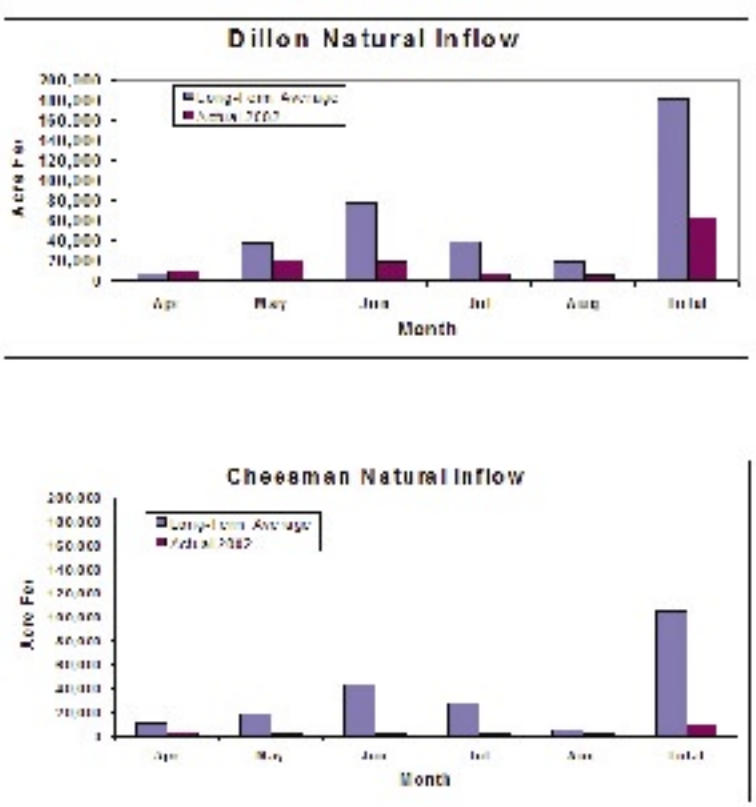

Figure 9. Reservoir natural inflow.

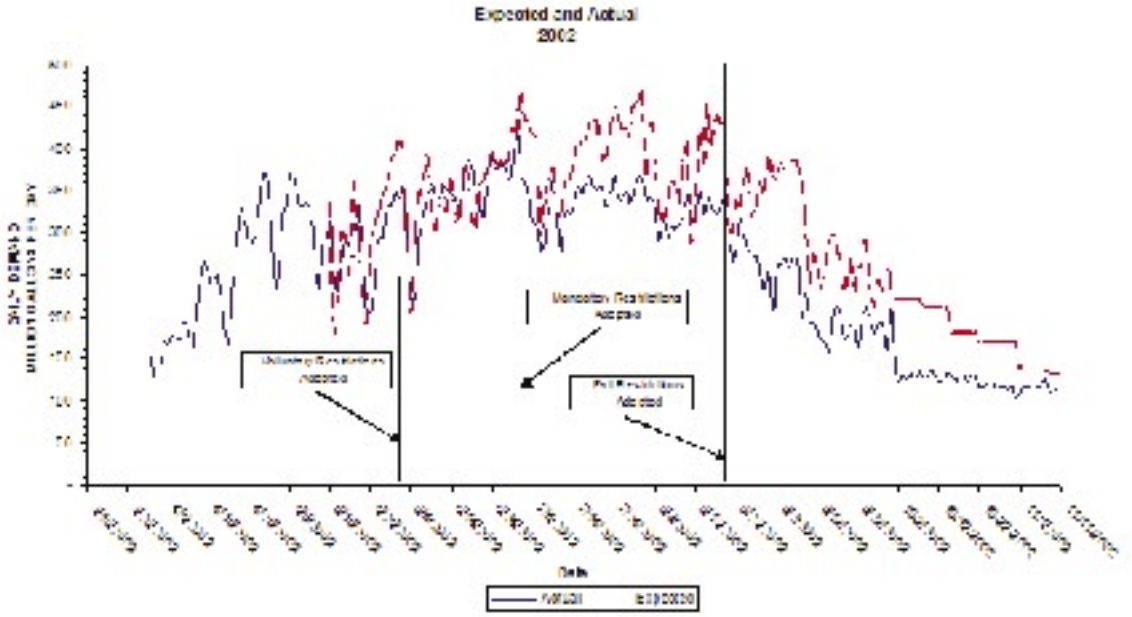

Figure 10. 2002 expected and actual water use.

about 10,000 acre-feet more than would have been done on average, but maybe we should have known something was going on there.

When we got to involuntary restrictions, people used about what we thought they would use. But when we got to mandatory restrictions as you can see, it flattened out. Then, when we got into the fall-winter, as you can see, the public is really taking this on and they are saving a lot of water. We really didn't have a raw water problem; we had a treatment problem, max-day problem – that is when we went to the every third day.

It does take a little while like it took Denver Water to catch on to this. It takes a little while for our customers to say, "Is there a drought? Are they serious? What's happening here?" And they were getting so much different information. Aurora went on earlier than us, we went on earlier than someone else, some people had every third day, some had two days a week – it took a while, in our opinion, to catch up. Once they finally got with it, they started saving water. But they do look to the water community, the water providers, to tell them what to do. It took the water community in the metropolitan area and Denver Water to get our act together at first. You have all read the newspaper – there is a different story after every one of our board meetings.

Looking at fall-winter restrictions – we eliminated a day, went to two hours, no new lawn permits, prohibited outdoor water use – and there is something else – do you want to talk about golf courses? And we put on a drought surcharge. You saw how the people started using less water there – really dramatically less water. What we are doing with this program is saying, "If next year is as bad as this year, we need to do something to be prepared if we are going to go to no outdoor watering except for trees and shrubs." If we have to do that, we want to be in a position to have some water to do something up-front in the spring when the bluegrass is really growing. So, that is what this program was started for. We projected 16,000 acre-feet, and it looks like we got at least that. If we really come to a place where we are not going to allow outdoor watering, we are trying to work out something with the Green Industry as to what do we really do for bluegrass lawns so they don't die during that year when we don't allow any watering.

What is a drought? You all have talked and heard about this. Ours is the '53-'54-'55 design period, and after listening to Connie Woodhouse maybe we ought to expand a little on how many years we look back at. But, we look at the '50s drought, of course, and there is the intensity and the duration. How deep? How long? This is one of the deepest drought years that we have had. Now the question is, how long? What is the duration? How long will it last?

If you look back at our reservoir content (Figures 11, 12, and 13), and again we relate to the '50s drought (and this

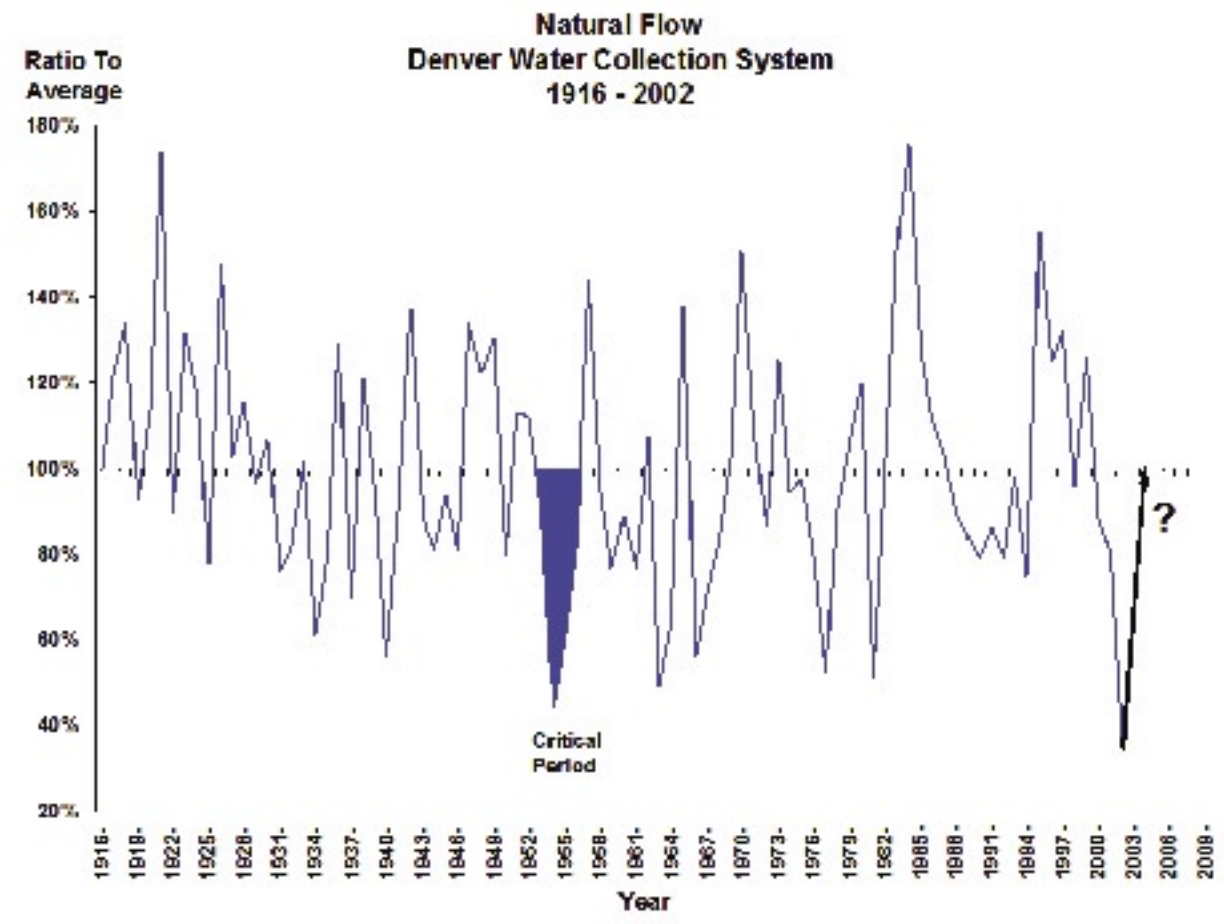

Figure 11. Natural flow, Denver water collection system.

is how our reservoir content went through that period of time), and you look at where we are now, we are at about 40 percent or below that blue line. We ask, if the drought continues, looking at average weather, wet weather, here is what we have come up with. And if you look at what we might anticipate, again if the drought continues, we will be looking at stage 3 – no outdoor watering, maybe this plan I just mentioned.

If we have normal weather, and we are projecting this by 2003, we will probably still be in stage 2 (Figure 14). Even with the best of things maybe we could get back into voluntary, but I will tell you, we are running scared now, and some of our board members are even more scared. For us to get into voluntary again, almost no matter what happens, I wouldn't count on it. I wouldn't be out buying a lot of sod if you live in Denver these days.

Lesson 3 – You don't want to have a fire while you are in the midst of all this. The Hayman fire – 138,000 acres – we were lucky enough(?) to be 88,500 acres of that fire. And I might mention that for the last 10 years we have been conducting a tree-ring study on fire regime with Dr. Merrill Kaufman, Colorado State Forest Service, CSU. His lifelong study and those trees burned up. We are now doing a study on whether the trees with core holes in them fell over faster than the ones that had just been burned without core holes in them. We do have a lot of information on Cheesman.

When you are in a drought, you have everyone doing the Indian rain dance and all. Then you look at Cheesman and it's down, and you think about the fire, and say, "Man, I hope it doesn't rain above Cheesman." Figures 15 and 16 are of a storm with 1/4 inch of rain. Not that much of a deal, but 1/4 inch of rain above Cheesman – and here you can see the sediment ash coming into the reservoir, running along the bottom of the reservoir, and then, of course, the debris that came in after that one small rainstorm. Two-thirds of the high-intensity burn area is above Cheesman, and one third is below Cheesman. Working with the Colorado State Forest Service's Chuck Dennis, we have a plan and are doing a lot of things on our 8500 acres at Cheesman. In fact, we had

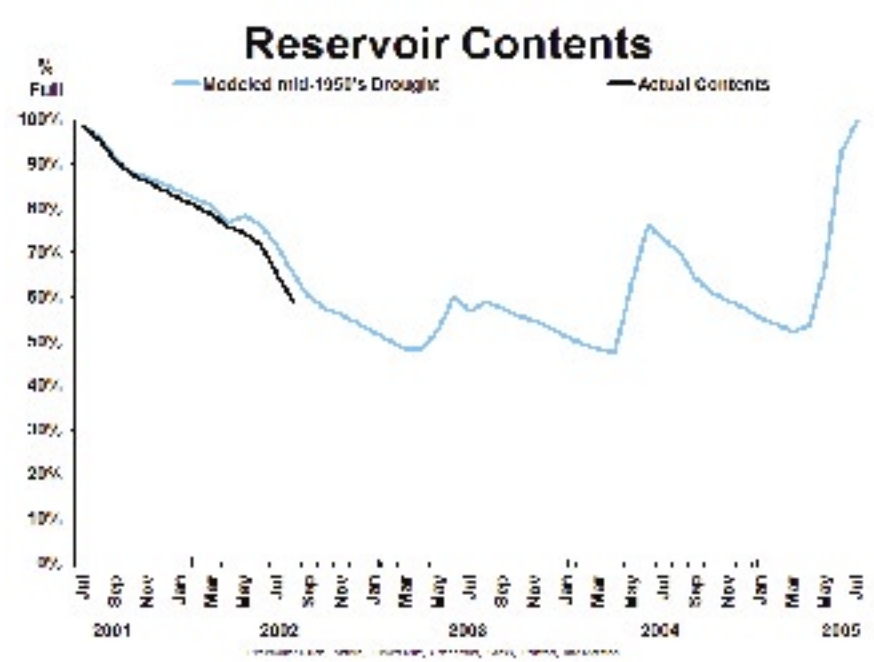

Figure 12. Reservoir contents (a).

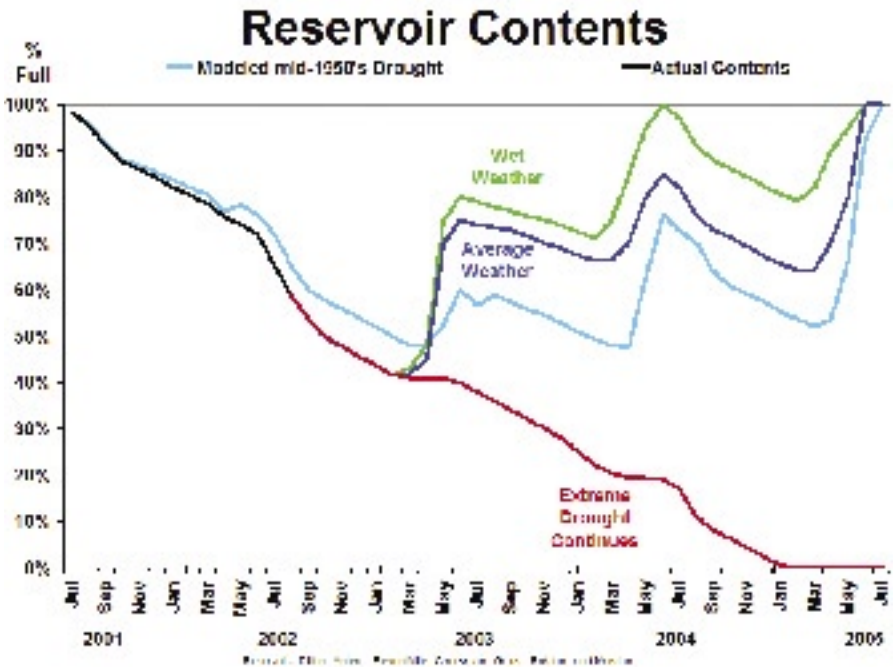

Figure 13. Reservoir contents (b).

a staff meeting of the Interior Department here about a month ago to see what was going on there. If you look at what the Forest Service did, it is not as much as we did, with the tongue-in-cheek idea that Cheesman will stop this stuff, and below Strontia will stop it. That really isn't what we are there for.

I want to talk about Antero Reservoir. We have been working with the West Slope, Division 5, and helped out on a lot of things they are doing, and they in turn help us. In the Metro area, we are working with the Forest Service, the Corps, Chatfield, State Parks and even Westminster. That is how bad we are hurting. The ash and sediment that was coming into Cheesman was really downgrading the water. In fact, it got to the point that . . . Cheesman is our "Let's hold the water there; let it settle out before it goes down to Strontia Springs, before it goes into our treatment system." The water was getting so bad in Cheesman that it was killing the fish, and we didn't want to dump it down the river because of our concern about whether we could treat it or not. So, we chose to dump Antero and get that water over into Cheesman for a dilution factor. It was so low that the water coming in was short-circuiting to the outlet. We got Antero water in there and slowed it down, so some of that material would settle out.

So, because of the drought, and in turn because of the fire, those are some of the things we have been doing.

Another lesson we learned . . . and this is Strontia Springs . . . is clean up immediately after something happens. We have over 600,000 cubic yards of sediment in the bottom of Strontia Springs from the Buffalo Creek fire. This is the intake to our Foothills Treatment Plant. The water short-circuits. You can see here, again, it is a small reservoir but it did settle out some things. You can see how the water runs right down the middle to the intake and hits the dam.

July 1 Storage

Denver Water Customers Must Reduce Use if Drought Continues

Year	Actual Storage	Drought Continues	Normal Weather	Wet Weather
2000	99%			
2001	98%			
2002	66%			
2003		35 - 36%	75%	80%
2004		20%	85%	100%

The July 1, 2003 projections assume we remain in Stage 2 until that date.

The July 1, 2004 projections assume the following:

Drought Continues Scenario – Stage 3 starting July 1, 2003

Normal Weather Scenario – Normal weather starting July 1, 2003 and subsequent restrictions progressively relaxed after July 1, 2003.

Wet Weather Scenario – Wet (above normal rainfall in 2003 and 2004) and no water restrictions after July 1, 2003.

Figure 14. "If Drought Continues" scenario.

Another story about how things went on this last summer. This last summer everyone must have been gone but me, because in comes Bob Steger, one of our water resource people, Ken Pollack, head of treatment, and Steve Lohman, our water quality guy, and the water quality people are saying, "We have to dump Strontia. We have some bad water coming down the stream. It is 400 NTUs (a measurement of turbidity), it is 100 going into Strontia right now; it's hitting the dam at about 30 NTUs;" when it hits the dam, we found out, it circles back up and goes over to the intakes. We also found this last year. The second intake is Aurora's; they don't have a problem because our intake takes all that first stuff, but we have changed the hydrology and Aurora will get a lot of the stuff next year. Anyway, Bob says, "I'm not dumping the water. You guys are crazy. We're in a drought." The treatment guy says, "If it gets 30 NTUs (it was four at that time) at the intake, you're going to make us shut down the plant. It will screw up the beds and we won't be able to treat the water." At this time another one of our treatment plants, Marston, we had completely down because of disinfection byproducts coming out of the '86 Safe Drinking Water Act reauthorization. At the Moffat end we don't have enough supply. Here are the guys who are proud of all the different places we can get water – proud of our three treatment plants. We are one of the greatest, and we're going to have to shut down Foothills and not be able to serve the people. I sat there trying to look like I knew something, and then Lohman had people running up and down the river testing the water, and they said there are eight miles of bad river. Finally, and I don't know what happened, things started getting better. The NTUs were going down, and they all left my office. That is the kind of thing that we are now doing that not only makes the drought, the fire, and the combination of things an unbelievable year for us.

John Henz and I were on a program a few months ago, and John asked a question, and I thought he was suggesting that we didn't take advantage of all the information that is out there and we could have done a much better job with better foresight. Then, I listened to Roger Pielke about the skills of a climatologist when it comes to making projections, not just for five years but for next year. John, I appreciate what you and Bill put up here – your last three or four slides – Mark has copies of those and we are going to run the department that way and use your telephone number in one of our brochures.

Figure 15. Cheesman Reservoir.

After looking at Figure 17, I turned quickly, Hal, to a book we had when we were here in 1967,

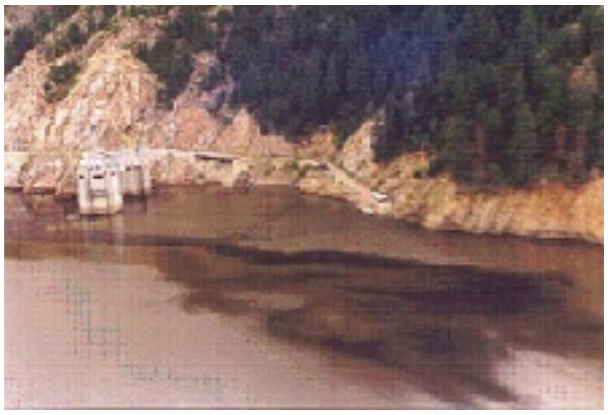

Figure 16. Foothills Plant Intake, Strontia Springs Reservoir

Hydrology 101, and I am now with a guy – a CSU hydrologist I heard on the radio a few months ago when the Farmers' Almanac came out, and they were projecting better weather – a lot of rain, a lot of cold, and everything will be fine. This gentleman said, "You know, it is fun to read that almanac." But in fact, there is just so much water in the world – it has always been there – and some people will get it and some people won't. We are just hoping that it comes our way this year. In fact, we end up as Representative Hoppe said. There is a talk this afternoon at 3:30 on cloud seeding, weather modification. Our manager, Chips Barry, will be there. You can be sure the four of us will be in the front row in case you would like to come by.

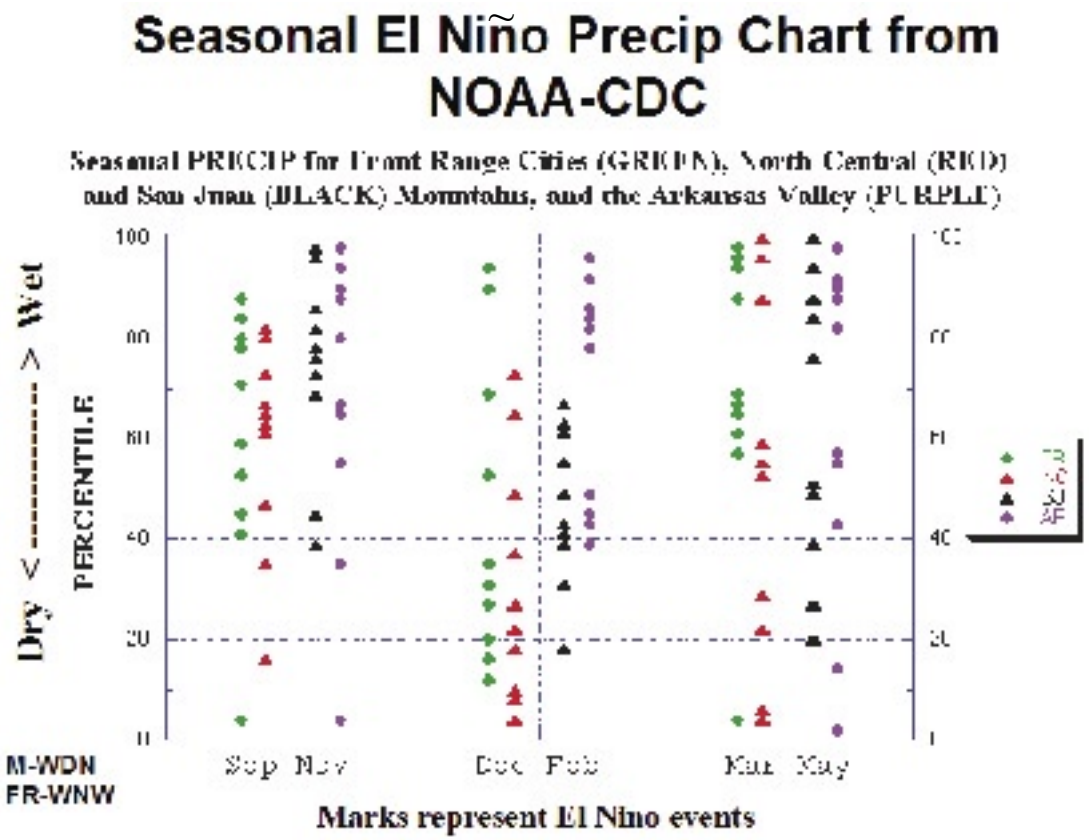

Figure 17. Seasonal El Niño precipitation chart.

EXPERIENCES OF THE DOLORES WATER CONSERVANCY DISTRICT

John Porter, Retired Manager
Dolores Water Conservancy District

Normally, when I get up to talk, I would tell Dr. Ward it is a pleasure to be here. Look at this crowd and the expertise – I am not sure it is! Dr. Ward is a friend of mine, so I really couldn't turn him down. This is dealing with drought – I don't think you manage drought. You only have so much water (or, you don't have the water). If you don't have the water, it is tough to manage, so you just have to deal with it the best you can.

I think Dr. Ward wanted us to talk about things we have learned during this drought period. We ought to conservatively estimate the supply and do it fairly early, if we can. There is a fine line between early and a figure that farmers and irrigators can use. In our case, it is not so much senior water users as it is contracts out of McPhee Reservoir. Include those users in the process as you develop a plan. Probably the biggest lesson is that reservoir management is a multi-year proposition. And there are some positive things we can look at.

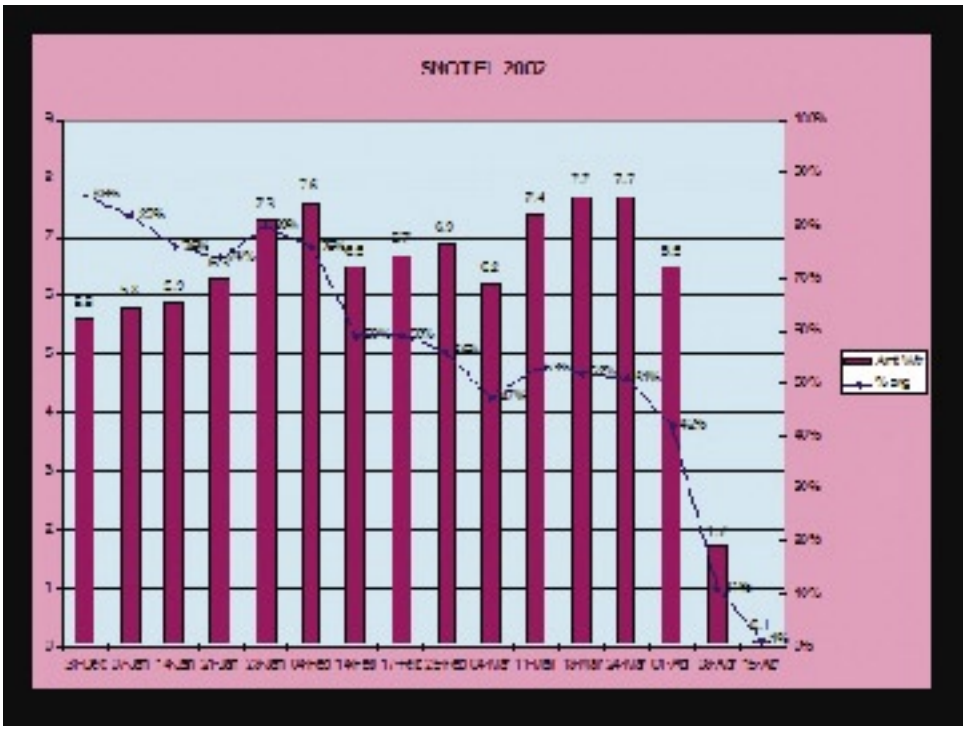

Figure 1. Snotel 2002, amount of water.

Figures 1 and 2 show the last years of SNOTEL on April 1st from 1993 to 2001: the percent-of-average and the amount of water. This is the progression as we go through the year starting December 31. One SNOTEL malfunctioned, so that shouldn't be there, but as you see the percent-of-average dropped. And as other speakers mentioned, even on April 1 we had a 42-percent supply of water. This was a wake-up call. In one week, we lost 5 inches of water and nothing showed up in the river. That made you sit up and take notice.

The Lizard Head snowpack (Figure 3) has records clear back to 1920. From 1986 on, the 16-year average for 1934, 1977 and 2002 was the same.

Besides the SNOTELS, we have manually read snow courses (Figure 4). Five of those we read three times: February 1, March 1, and April 1. April 1 there was no snow on two of them; the blue was the average. There was snow on three of them, so the average was 23 percent.

MANUALLY READ SNOW COURSES

After the SNOWTELS show zero, there is still runoff to come. For the last 17 years I have taken pictures of what I call the shark's tooth. It is on the La Plata Mountains, and you can see it from Cortez.

I had one rafter actually write a letter to the Bureau of Reclamation early on, and tell the Bureau's Commissioner there was an old clod who looked at rocks to

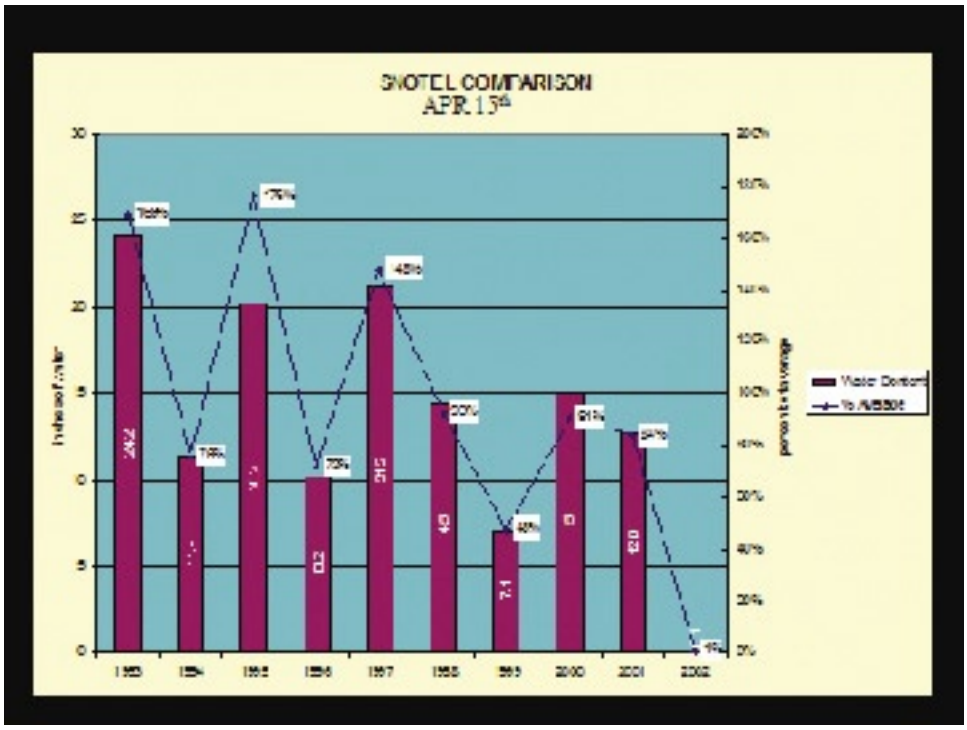

Figure 2. Snotel comparison, water content.

go like that, but in 1999 the actual runoff was 30 percent greater than the forecast, and the next year it was a flop. That is kind of tough to manage, when it comes to spilling a reservoir. Because of that, we had a private enterprise out in Logan, Utah develop our own model, and we used that as a tool to work back and forth against the official. If they are tracking each other, we don't worry about it too much, but if they aren't tracking, then we massage it ourselves. In our case, it actually came down to allocation of that resource – what was in McPhee and what we

predict snow. And that is true. After that SNOTEL shows zero there is still snow to come. Look here – May 21, 2001 (Figure 5), 24 percent of that was open. On April 4 this year, 45 days earlier, only 69 percent open (Figure 6).

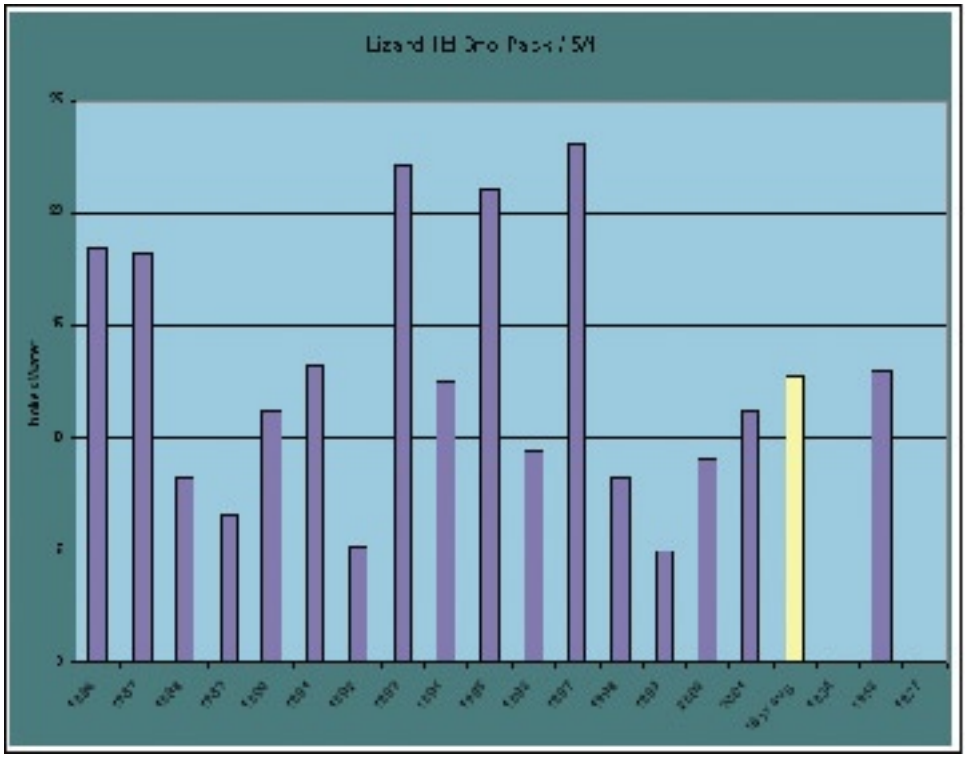

Figure 3. Lizard Head Snowpack.

We all are used to the basin forecasts. I call them the official forecasts, because I have been able to hang my hat on them most of the time. What I look at is that most probable number, 50 percent, which said on April 1 this year we would get 110,000 acre-feet of runoff.

This is a chart of the actual runoff vs. the April-May, and as you would expect, they pretty much expected to get. We formed a drought committee of the major users. We didn't include the M&I, the municipal

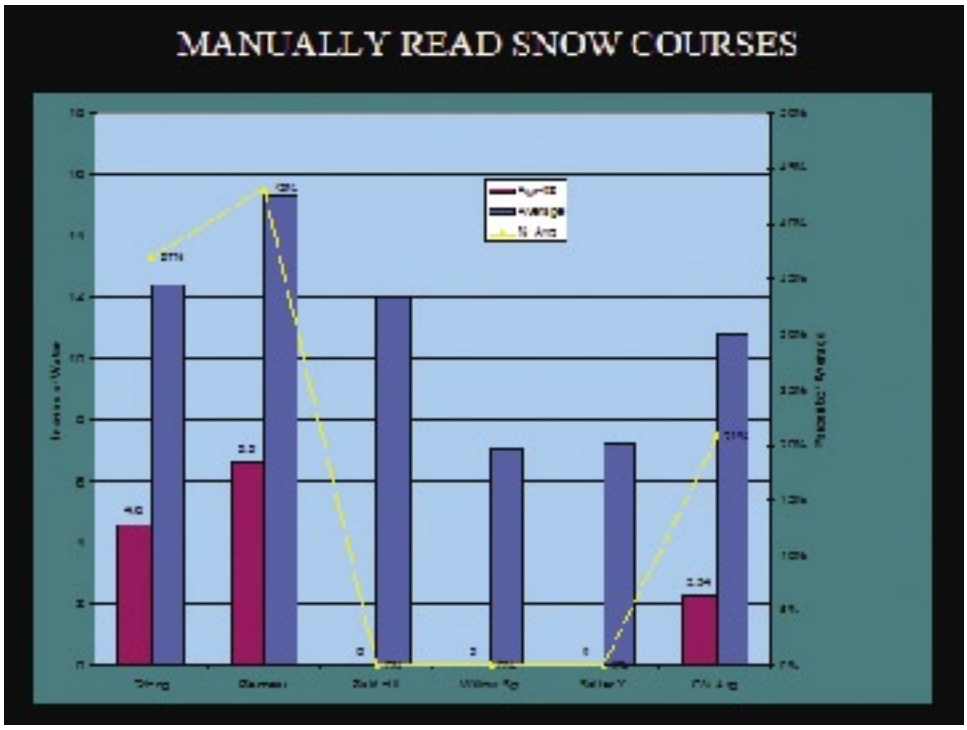

Figure 4. Manually Read Snow Courses.

these other calculations. Sixty-percent is built on contracts, and that is what I was talking about – follow those contracts to the letter of the law, and involve those users as you go through that. Once they all understood the contracts, we really didn't have any trouble except with the fishery. Fish don't share shortages. They do by contract, and that is the way we did. We will come to that supply in a little bit.

Figure 7, a runoff hydrograph of the Dolores River, shows the river flows – outflows, inflows, and reservoir elevation.

users, because they get 100 percent supply, and we had plenty of water for them.

Montezuma Valley Irrigation Company, the old-line, private, nonprofit company that irrigated that 37,000 acres around Cortez, has a lot of senior water rights – 795 cfs. They have storage of their own, so they are not part of McPhee. The last four users – full service, Indians, fishery, and fish and wildlife – have a set allocation, so if you know how much water is in McPhee, you can divide by those easily. But MVI is a variable. It all depends on

And in 2002, not much happened. The reservoir elevation stayed about 50 feet lower than it normally does.

Reservoirs are a multi-year operation. This starts in March 1999: the reservoir filled; 1999 it started raining in the summer and we refilled again. It really was a tough decision on when to spill. The day we started spilling it stopped raining, and I don't think it has rained since. I made a mistake the next year, and actually let the rafting season go five days longer than it should have. It cost 8,000 acre-feet of water. What was the worth of that

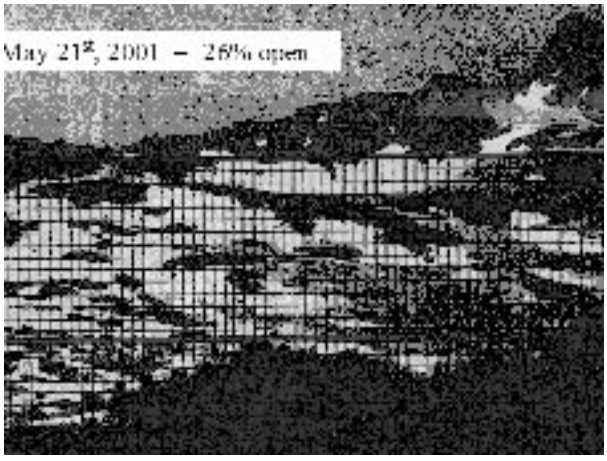

Figure 5. May 21, 2001, La Plata Mountains near Cortez.

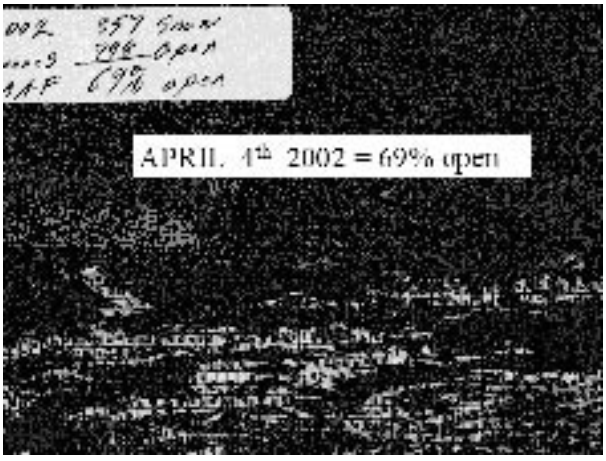

Figure 6. April 4, 2002, La Plata Mountains near Cortez.

APR 1ST Stream Flow Forecast

SAN MIGUEL, DOLORES, ANIMAS, AND SAN JUAN RIVER BASINS

Streamflow Forecasts - April 1, 2002

	<---- Drier ---- Future Conditions ---- Wetter ---->						
Forecast Pt	========== Chance of Exceeding * ==========						
Forecast Period	90% (1000AF)	70% (1000AF)	50% (1000AF)	(Most Prob) (% AVG.)	30% (1000AF)	10% (1000AF)	30 Yr Avg (1000AF)
McPhee Reservoir inflow							
APR-JUL	51	89	110	34	154	202	320

8,000 acre-feet of water to irrigators? Sure, it has worth to recreation and it has worth to the rafting community. But in terms of the irrigators, it amounted to about $1,200,000. Some would say I should have retired three years ago, not just this last year.

How those users fared. – Municipal users had 100 percent supply, so they had no shortages, although it was the municipal manager who was the first to call me in March and said, "I recognize we don't have to share the shortage, but what can we do?" I thought that was a pretty good demonstration of cooperation. He knew he wasn't short, but he wanted the politics to say to the community, "We are doing our share."

The other side of drought. – As I walk down the street, as you read the newspapers, everybody is aware of it. They appreciate the value of that resource. Whether it is the level of the reservoir, the fishery, agriculture, diversions, municipal use – they all have a better understanding of the intricacies that make it work. It vividly demonstrates that there is a value to that storage. It motivates cooperation.

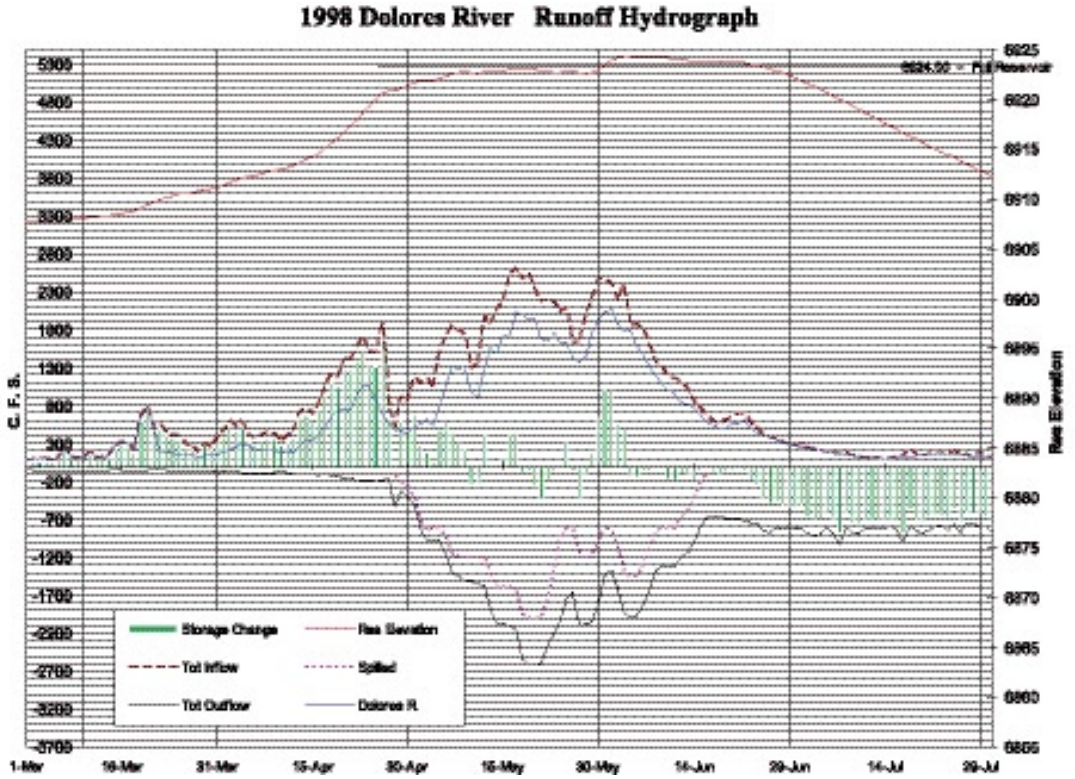

Figure 7. Runoff Hydrograph of the Dolores River.

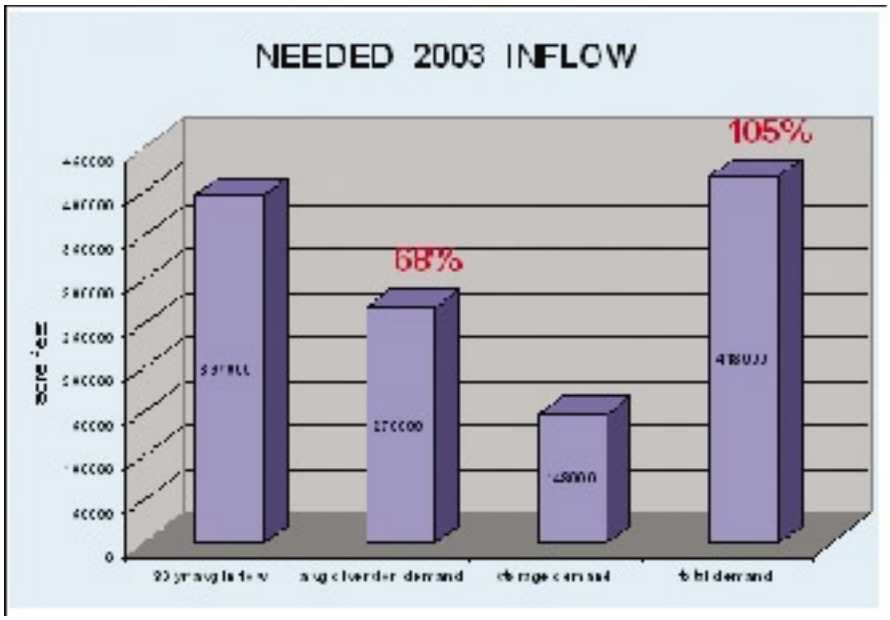

Figure 8. Needed 2003 Inflow.

And, you know it is a finite resource. We say we look for win-win situations, and in many cases we can. But with a finite resource, water is a private property right; there is only so much of it and competing demands, and we cannot find a win-win situation for everything. We must try, we must cooperate, we must talk, but the realization is: there is only so much water, and when it is short that makes it that much tougher.

The future: We do know we want to conserve, but you want to look at the big picture of conservation. Who gets hurt with somebody else's conservation or how does it work? We have to take advantage of this situation. It is a wake-up call. We must recognize that the state's infrastructure needs attention both in rehab and construction of new systems.

In the San Juan Basin, 1955 was a dry year, '64 was a dry year, '83 was wet, '89 was dry again, '97 was wet. So as I talked to groups this summer, I said, "I believe in this now, and I am betting my job on it." A lot of them didn't know I was retiring, and it took them a while to figure that out.

But you do hear a lot that it is going to take five years to recover from the drought. In terms of the McPhee water supply, it won't. In terms of the banker and the farmer and their relationship, rebuilding cattle herds and dead trees, on the Dolores it only takes 105 percent of runoff (the average is 397,000 acre-feet – that's a year's supply) to refill the reservoirs to where they normally are this time of year - 105 percent, or 418,000 acre-feet will do it (Figure 8). This just means water supply; it doesn't talk about the total effects of drought.

Lest we forget. – Between Mesa Verde and the town of Dolores, there is a lot of Bureau of Land Management land, and 85-95 percent of the trees on that land are dead. Fire will get them – that's one of my biggest fears with the drought. I guess it is a combination of bugs and stress due to no water.

EXPERIENCES OF THE CENTRAL COLORADO WATER CONSERVANCY DISTRICT

Tom Cech, Executive Director
Central Colorado Water Conservancy District
Greeley, Colorado

We have a bit of a drought of time on our hands right now, but I would like to talk about a few things – more about the human side of the drought this past year. I will discuss our water district briefly, about how the past summer went, the ruling in Empire Lodge, and the potential for wells to be shut off next year – all in about seven minutes.

The office of the Central Colorado Water Conservancy District is located in Greeley, Colorado. The boundaries go from Commerce City to Greeley to Fort Morgan along the South Platte River. Our Board of Directors were formerly all farmers; now we have a Denver firefighter, realtor, and other none full-time producers on our board. We provide augmentation for about 1,000 irrigation wells. Augmentation is the process of allowing junior priority wells to pump out-of-priority, as long a depletions are replaced, during times when there is a call on the river by a senior.

We started this spring with hope. I was hopeful that El Niño would kick in during the month of June and bring substantial rainfall. That was my outlook for the spring, and that is how we were going to get through this really tough-looking year of 2002. It didn't happen. We went from hope to fear. The first part of June I got a call from the Division Engineer's office, Jim Hall, and he said, "You know what? I think your member wells are going to be shut off, or some other wells in the neighborhood, in a week or two. We have to do something." There wasn't enough replacement water to put back in the South Platte to keep the wells pumping.

We then had a meeting with the Farmers Independent Ditch Company – at Frank Eckhart's place near LaSalle. Jim Hall showed up – one of Hal Simpson's assistant division engineers – and met with about ten farmers saying, "If you don't do something drastic here, your wells get shut off." Basically, it's the same as if you have a salaried position at a business in town, we're only going to pay you maybe six months of the year but you still need to work full-time for us. We are going to eliminate six months of your salary – that is what shutting a well off means to these guys.

One guy was sitting there looking right at me, a local producer, and I will never forget the look on his face when he heard those words that his well might be shut off. His jaw dropped, no lie, about six inches toward the floor. From the look on his face, he had just lost his farm. That is the human side of this drought. Part of this is legal fallout from Empire Lodge, but there are guys out there who will lose their farms because of the drought.

So it is June, 2002, and everyone is fearful. Then Central started having more meetings with local ditch companies. The Greeley No. 3 Ditch Company – we met with them about five times because it appeared that certain shareholders kept taking our water. We were meeting with them because we needed that water to augment our wells. We met in a room kind of like this one in Greeley; there were about 100 people; the president stands up and says, "You know what? We are going to start locking headgates to prevent shareholders from taking too much water." And no one said a word! What does that tell you? Extra water was being diverted. So, they started locking headgates.

Two weeks later we had another meeting with the same shareholders, and you know what? There was not enough water available in the Cache la Poudre River to get to the end of the ditch. The president of the Greeley #3 Ditch said, "We will have to section the ditch – the top half gets water for three days, then the bottom half for three days. That is how we will share our limited water."

We had another meeting two weeks later. It was so dry on the Poudre River that the ditch company had to section it into thirds. This is a ditch that was built in 1870 by the Union Colony, had never been in sections during that entire period, and here they went from locking the headgates to going to halves, to going to thirds, and by August we quit fighting. There was simply no water to fight about. We were like good ol' boys, then, comment-

ing on how the ditch was just plain dry. So it went from hope to fear to resolution – "It's damned dry out here."

I kept reminding our board and our irrigators to pay attention to what's happening all around us this summer. We are living through Colorado water history. They will talk about this year, '02, 100 years from now. Just like these charts that were shown earlier today – they will be talking about this into the next century. This is big stuff, "but, oh, by the way, you are going broke – you're going to lose your farm during this drought. This is history we are going through – and we need to pay attention to that.

Let's talk about fights. I give presentations to school kids and used to say, "You know, there hasn't been a fight over water in Colorado since 1980 where someone physically got hurt. I think it was a San Luis Valley fist fight. Well, they had a fight east of Greeley by Kersey this past August, in 2002. A fellow broke his leg, fisticuffs in the ditch.

How are farmers reacting to this drought? It's very interesting. Farmers are so resilient. First of all, all farmers are long-term weather forecasters. They are very concerned about El Niño and La Niña because they must figure out what they are going to plant next year. I've been getting a call about once a month from an attorney in Denver who represents a turf farm, and he asks about the legal outlook for augmentation. Well (and Hal, I will put you on the spot), Hal Simpson at the Colorado Water Congress meeting this past summer said, "Wells may be shut off by the end of the year." He didn't say will; he said may. I told the Denver attorney "That's a good sign, because a month before he used the word probably, and now it's may. Those slight word changes are hopeful, but I told the attorney, "I would still, for your clients' sakes, tell them to buy a lot of water to augment their wells. If they have turf farms, they better make alternative plans for next year."

I had a call from a guy who owns a farm near LaSalle. He asked (this was in July), "Should I sell my farm because of the drought and augmentation issues?" So we talked about El Niño, La Niña, about long-range weather forecasts, the probability of snow next winter, Empire Lodge, the value of ag property – he had to make the decision, but here were some factors to think about. The turf farm attorney from Denver called me back two weeks later. "What did Hal Simpson say about the wells at the last meeting you were at?" "Well, now we are hearing, instead of 'wells may be shut off,' last week he said 'We think we can get through August.'" The words changed from may to maybe not, and we are excited about those word changes – we are hanging onto anything.

Then the media started calling us in Greeley – the Rocky Mountain News, the Greeley Tribune – I used to get excited when the Fence Post called me from Windsor for a comment. Now I have reporters calling – "What do you think about the drought, about augmentation?" I don't know: if it rains we're fine; if it doesn't it will be tough. Then we heard that NBC News out of New York City is going to do a story on the wells; CNN is coming out; this is getting wild. The year 2003 will be really outrageous, because the national media will be out here eating up the story if it stays dry. Of course, the local farmers will be going broke, topsoil blowing away, lawns in town will be dead, but it will be history.

Drought isn't unique to Colorado. I was in New York City this summer, and buses in Manhattan had ads that said, "Conserve Water – We're in a Drought." The New York Times had a big story on the Colorado drought back in June. My sister lives in Wilber, Nebraska and they were worried about their town well going dry in July. The Platte River at Grand Island in June was bone dry – not even a dribble. I have never seen that before in my life.

So what did we learn about the drought in 2002? At Central, we learned we need to acquire more water, so we put a bond election for $20 million on the ballot in November to build reservoirs – these are lined gravel pits – and to buy senior water rights. It passed. We did no campaigning; we did no lobbying; we didn't form a Political Action Committee; it passed 54 to 46 percent. President Bush called me the next morning and said, "How the hell did you do that? I've been on a 20-day tour around the country promoting these politicians for reelection. You did no campaigning and you obtained voter approval by a greater margin than Senator Allard's margin." So we have $20 million for water acquisition.

We are now dealing with bond brokers and farmers. The realization is, producers are growing $1.80/bushel corn with water that, in some cases, is worth a lot of money – like the English Ditch that has C-BT water worth $10,000 a unit. Shareholders sold about 5,000 units last week and made about $50 million to divvy up among about 50-75 farmers. The realization to some is, "Why am I killing myself trying to farm?"

We are going to lose a lot of farmers due to the drought, and that is just reality. If the drought is prolonged, the loss of agriculture will be quicker. If it is not because of

the drought, it will occur because of urbanization. I have had farmers say, "You know what? This is kind of like Kiota in northern Weld County. Maybe we have irrigated too much ground out here in Colorado. We live in a dry place. We do have drought. Maybe we overextended ourselves with all the irrigation we have done. Maybe we should have some farms dry up." These are farmers talking. At a meeting last week in Fort Lupton, a young farmer said, "This clear-cutting idea of harvesting the forest to create more water is the stupidest idea I have ever heard of. This is a grower in Fort Lupton. He said, "We have to protect our forests." I said, "Yes, but the science says if you patch cut; if you take necessary precautions; it's okay for the environment. He said, "I don't think that is right." That blew me away, for a grower to say that.

Next year, the wells may not get to pump. That would mean tens of thousands of acres of Colorado farm ground will dry up and blow away, or there will be a lot of dryland wheat and small grains. We have farmers calling every day asking, "What should I plant? Will I have water next year?" We don't know. "What will the Legislature do?" We don't know. "Will the Governor say, "Oh, let the wells pump. Don't worry about the senior ditches." I doubt it, but we don't know. What's the solution? There is none – or no easy solution, that is for sure. These are really tough times, historic times. A conference like this here today is excellent. The numbers – streamflows, reservoir levels, etc. – are really important, but the human side, which this afternoon we will get more into, is the fascinating and historic side.

LUNCHEON ADDRESS

Kent Holsinger, Assistant Director for Water
Colorado Department of Natural Resources

It is a pleasure to be here today. I want to start by thanking CSU and the Water Resources Research Institute for having this terrific conference with so many great speakers to talk about one of the most important events that has come upon Colorado in many, many years. Governor Owens sends his regrets. He was unable to make the lunch today; he is meeting with his cabinet as we speak. It is good to be here today on behalf of the Governor and to talk a little bit about what the Department of Natural Resources is doing.

I am the Assistant Director for Water Issues at the Department of Natural Resources. As you all well know, last summer was a very tough summer. We had the worst drought in Colorado's recorded history. I am sure there was a great presentation on tree-ring studies, but I understand that it could be our worst drought in maybe 300 years. We also had our worst fire season in recorded history in Colorado – over 500,000 acres around the state burned up. It was a terribly destructive summer.

I also happen to be the chair of a federal and state task force that is charged with looking at how Colorado can clean up after the devastating wildfires that struck us last summer. Between drought and wildfires, I was afraid if things got any worse I would be labeled the Assistant Director for Fire, Water, Plague and Pestilence. Thankfully, we have not become quite that bad, but nevertheless, times are tough.

It strikes a personal note with me as well. My family ranches up in North Park. We had about a 17 percent hay crop this past summer. We watched our most productive hay meadows bake under the sun without a drop of water all summer. But we consider ourselves lucky compared to what many people have experienced.

I mentioned fires. It is interesting to note that the same forest conditions – these overcrowded, unnaturally dense stands that now describe our natural forests and many other forests across the West – are not only fueling catastrophic wildfires but robbing our river systems of water yields that used to be there in the past. There has been a lot of press lately, and I am probably lucky I haven't been labeled the Assistant Director for Clear-Cutting as well, if you read some of the articles. But I did want to talk a little about how the state views the relationship between our forests and our water, particularly after this last summer.

One thing I think is important to keep in mind is that the state is not a proponent of massive clear-cutting as you might see in newspaper articles and some of the letters to the editor. Rather, what we are interested in seeing is that our forests are healthy; that they are vibrant, diverse, that they are not diseased, decayed, and subject to these catastrophic wildfires as we have seen in recent times.

These wildfires are unnatural. They are not the historic events that we have seen in Colorado, in that they are exceptionally hot, exceptionally destructive fires. What the state is interested in seeing is that we try to maintain or restore more natural forest conditions with the benefits that will mitigate against future wildfires like we saw last summer, that will improve wildlife habitat, and that will restore water yields that once used to be in our river systems. The Water Resources Research Institute's last paper had some wonderful excerpts from articles about terribly destructive water quality impacts that we see after these fires. We know that elk were incinerated; we know that watersheds are at risk; we know that streams are choked with ash and sediment; we know that reservoirs that are terribly low right now are filling up with ash and sediment from these horrible fires that struck us last summer. That is why the state is interested in sounder management; so that our wonderful natural resources do not go up in smoke as we have been seeing.

Back on the drought, over a dozen communities last summer had to rely on emergency water supplies issued through Hal Simpson, the State Engineer, through his statutory authority. We are likely to see a tremendous amount of legislative activity this next session. I know Representative Hoppe, the Chair of the Ag Committee, is here, and opened with some remarks about what we might be likely to see. One bill I think the state will be interested in is insuring that the State Engineer has the authority to do those things – ensuring that Hal Simpson and future state engineers can help communities when

they need truly emergency water supplies to meet their needs.

Another thing that they will probably be looking at this legislative session is authority for the Water Conservation Board, again with review as the State Engineer may do under his statutory authority , to approve instream flows on a temporary basis. We had circumstances last summer – circumstances where folks worked together, incredible success stories through very difficult times – but we had a few circumstances where truly water could have been left in the stream for instream flows to help fish populations that certainly suffered through the drought as we did, but there wasn't really the authority to do that. So, that is another thing we will be looking out for this next legislative session.

I know you have heard a lot about the drought and a lot about what folks have experienced around the state, but I want to step through reservoir storage levels on some major reservoirs across the state to give you an idea of what circumstances we are in today. It is not very cheery, I am afraid to say. Cheesman Reservoir has about an 80,000 af capacity. At the time this was put together, we were projecting storage levels for November 1. Things have probably changed a bit, but Cheesman was projected to be 40,000 af. Pueblo Reservoir – 358,000 af capacity, November 1 storage roughly 72,000 af. John Martin – 233,000 af capacity, 18,000 af in storage today. Blue Mesa – nearly 1 million af storage capacity, 200,000 af in storage today. You can go across the State of Colorado – Granby Reservoir – 540,000 af capacity, 155,000 af in storage – the list goes on and on. Green Mountain – 155,000 af capacity, 32,000 in storage.

Obviously, Colorado faces a drought next summer as well. I have heard from Mr. Simpson and others that it could take 3-5 consecutive wet years just to fill our reservoirs back up. Peter Binney, when we spoke to the Denver Chamber of Commerce recently, said very eloquently, "We have 120 days to prepare for the next drought in Colorado." This legislative session will be incredibly, incredibly important.

Our capacity to store water is critical. Eighty percent of our water in Colorado comes from snowmelt. Were it not for the reservoir storage we have today, that water would come in raging spring torrents that leave the state, never to be seen again, to water golf courses and lawns in California and one of the 18 other downstream, thirsty states that always looks up to Colorado. Colorado is one of two headwater states in the entire Nation. Hawaii is the only other state that doesn't have a river flowing into it. I might say, our interstate compacts are absolutely essential to protect this water. All of these 18 thirsty, downstream states have congressional delegations that are looking upstream toward Colorado.

Thankfully, California has agreed to cut down on its water use to their allocated share under the Colorado River Compact. We are working very had to see that they continue to do that, and that they implement the water-saving measures they have agreed to. But it never hurts to keep in mind that California has some 52 members in its congressional delegation. A lot of other powerful states downstream from us take a real interest in Colorado water. It is very much in our interest, as Coloradans, to make sure that we utilize Colorado water – to make sure that we protect it for not only the present but for future generations. That is something that over the last three decades Colorado has fallen behind on. It is much akin to California and the power crisis. While we have grown by a million people a decade in Colorado (that is projected to continue although the numbers seem to be down a little now), much like California, not building infrastructure to supply power to its citizens, Colorado has not built infrastructure to capture and conserve our precious water resources.

One thing we have learned in the last couple of decades is that the buy-up and dry-up of irrigated agricultural lands is not the answer to Colorado's problems. Those lands also happen to be about 95 percent of the habitat for endangered species in Colorado and across the West. Those lands happen to provide open space; those lands also happen to provide tremendous economic, aesthetic and community benefits to the state as a whole. Our agriculture is not the place to look to solve our water problems. Rather, Colorado needs to take a state-wide approach. One of the bills that we will see this legislative session is the state-wide water supply initiative. That is something that the Water Conservation Board is undertaking, in which the Board will literally travel to every community in the state, to every county, to every water district, and ask at a grassroots level what they need to meet their demands for the next 30 years. We are not prejudging what projects – whether they be structural projects, new reservoirs, pipelines; or whether they be nonstructural, such as conservation, reuse, conjunctive use. The state is not presuming to know what is best for local communities. That is why we want to solicit from them what they need, compile those projects, again structural and nonstructural, and eventually build those projects so that future generations of Coloradans don't suffer as we have through this drought.

As Robert Ward mentioned in his remarks, we had a Flood and Drought Conference in 1999. There, we learned from the Army Corps of Engineers that for every $1 spent on a reservoir you save $6 in flood and drought mitigation. We also learned that the best answer to mitigating long-term drought is a sound long-term water supply. In addition to the state-wide water supply initiative, repair, enlargement and rehabilitation of existing projects is a high priority for the state. Over the last four years under Governor Owens' leadership the Water Conservation Board has rehabilitated, repaired and enlarged over 100,000 af of storage in Colorado, to the tune of about $11 million. We have also loaned about $42 million for new reservoir projects, for new storage as well.

In addition to storage, we also will be looking at a Colorado River return project. This idea is to study the technical feasibility of returning unused compact waters from the Colorado-Utah state line for use again on the West Slope and potentially the Front Range. This study will be a nuts-and-bolts look at whether something like that could be feasible and might play into Colorado's water issues down the road.

One thing is certain. When we see the myriad of water bills this legislative session, there is certain to be a lot of controversy. There is certain to be folks who believe that the Prior Appropriation system has failed us – that state water law is inflexible. I think those things are absolutely untrue. If you look at Colorado water law, it is an extremely flexible and adaptable system. Within the last few years, we have seen new authority for instream flows in Colorado, new recognized beneficial use in recreational in-channel diversions, and Colorado water law continues to adapt to the times. While the drought was difficult, while it hurt many people, our water law is not to blame. Along with protecting our interstate compacts, the state will vehemently protect our system of water laws – our time-honored system that has served us so well through thick and through thin.

Education and conservation are also tremendous issues. The Water Conservation Board helped fund, for the first time, a nonprofit group, the Colorado Foundation for Water Education. I believe the executive director is here. Representative Hoppe is on the board, as am I and several others. This represents a real opportunity to get the word out, while public awareness is so high about drought, water, and the importance of water to Coloradans. It is important for all of us to do everything we can to educate folks about where our water comes from, how we use our water, and why it is so important. The Foundation for Water Education will be a tremendous new beginning in that direction.

In addition, at the State Fair last summer the Department of Natural Resources had a truly incredible water exhibit in the Natural Resources Building. The exhibit is literally a scale model of where water comes from in Colorado – snowmelt, draining into a mountain lake, and then into a reservoir where hydroelectric power supplies power for a town and irrigation water for farms down the way. It even shows how ground water works in Colorado. Some 50,000-60,000 people traveled through that exhibit and saw a hands-on look at how Colorado water is used and where Colorado water comes from. Education obviously is critically important.

Conservation is another item that we are certain to see in this legislative session. It is something the state has a great interest in, so long as it doesn't injure other water right owners. There could be good things that come from this raised public awareness on drought and the importance of water. Certainly, conservation measures are part of that. Innovative means to use water such as conjunctive use also need to be looked at.

Other challenges to Colorado water that I might mention – federal challenges – remain very trying to us. Between reserved water rights filings, the extortion of bypass flows from folks who have permits that come due, we have a tremendous time dealing with the Federal Government and need to constantly remind them that the Congress and the U.S. Supreme Court have spoken. State water laws should govern state adjudications and state administration of water.

QUESTIONS

Q: During the special session, Representative Hoppe carried a bill regarding funding for water projects. Greg Walcher testified in support of that bill. In he last couple of weeks Greg Walcher said he would not support that. Is that indeed the Governor's stance, and if so, if the Governor is opposing that type of funding for those bills, then what is the Governor's plan in funding water storage?

A: A good question – not that it put me on the spot or anything. Financing is an important issue for water projects. It is something that we are continuing to discuss. There are discussions with the Governor's office on that very issue. I think it is something that we will have to take a look at in the legislative session. We are in discussions with the Governor's office so I can't say precisely what position we will take on financing bills. There are

existing financing authorities out there; for example, the Water Resources Power and Development Authority. The question in many peoples' minds is, "Is that group fulfilling its mission"? It has bonding authority currently, as do many water districts and local governments. What we really need to explore is how best the state can help with financing these projects It would be wonderful if we weren't in these budget times and we could say monetarily we can help. Obviously, there is the Water Conservation Board's construction fund; we have loans/grants for feasibility studies, but that doesn't get you toward the incredible cost of building and permitting new storage facilities in Colorado today. I wish I could be more specific on what we will see and what the state will support in terms of financing, but at this point we still are looking through that and taking a good, hard look at exactly the best ways we can help folks. One thing that has been talked about a little bit is the difficulty for ag producers to pay for water projects. The astronomical costs of permitting – Two Forks permitting alone was $40 million, and we didn't see a drop of water out of that – given the astronomical cost of water, are there other ways? Maybe innovative partnerships with municipalities, water banking, other issues, that we might be able to bring to the forefront to help projects be built and financed in such a way that many folks benefit.

DROUGHT MITIGATION SUCCESSES AND FAILURES IN 2002: PLANS FOR 2003

Session Moderator:

William Horak, District Chief
U.S. Geological Survey Region 8
Denver, Colorado

MANAGING WATER SUPPLY AND DEMAND IN THE TIME OF DROUGHT

Ray C. Christensen
Executive Vice President
Colorado Farm Bureau

Colorado Farm Bureau thanks Colorado State University for sponsoring the Colorado Drought Conference. Farm Bureau is a general farm and ranch organization representing the agricultural industry and producers throughout the state.

INTRODUCTION

The only true way to mitigate a drought in a successful way is for Mother Nature to provide sufficient precipitation at the right locations and at the right time. I submit that if annual precipitation were merely average throughout Colorado all the time, agriculture could still survive at its current levels of production. But there really is no such thing as an average year of precipitation as far as agriculture is concerned, especially in semi-arid Colorado where extremes seem to be the average.

Colorado agriculture is experiencing the fourth year of drought, with 2002 being the worst. Drought impacts agriculture as much, and possibly more, than any other single industry. Dryland agriculture is impacted more than irrigated agriculture. Irrigated agriculture provides water supplies to raise crops and livestock even in dry conditions. Irrigated agriculture is already a mitigation success during droughts. But even irrigated agriculture can be damaged when the drought conditions last long enough such as we have today.

Tree rings is one way to measure drought. For agriculture, it's soil moisture content. Today, you can't find soil moisture until you go down at least one foot below the surface and in some cases, it's 18 inches or more.

COLORADO AG INDUSTRY IMPACTS FROM DROUGHT SUMMARY – OCTOBER, 2002

<u>Drought Impact on Ag</u>

Colorado Farm Bureau, along with other ag interests, prepared an analysis of the drought impacts on various commodities produced in this state. Colorado agriculture is the third largest contributor to the state's economy. Total farm marketing receipts is over $4.3 billion. The total contribution of Colorado's food production system to the economy is much higher. This does not include the fringe benefits which agriculture provides basically free to the rest of society such as open space and wildlife habitat.

The total monetary impact of the drought on agriculture is not completely available at this time. However, economic impact from the drought is projected to reduce farm income by at least one-half. Low commodity prices are just more salt to the wounds. A catastrophic impact on agriculture and rural businesses may not occur immediately, cut could be felt for years to come.

- Colorado is in its fourth drought year.
- '01 had most counties in drought disaster, while '02 has every county in drought disaster
- Wheat – economic loss of '02 winter wheat estimated at $120 million. Crop projected at only 38 million bushels (83.4 million bushels is 10-year average – smallest harvest since 1968). 30% (700,000 acres) abandoned and not harvested.
- Dryland corn – "toast"
- Irrigated corn – waiting for harvest, but early projections show reduced yields by at least 10-15% or more. At best, corn yields may be only average
- Sugar Beets – "Bittersweet" Sugar content is higher than norm, but shortage of irrigation water pushed yields down. Normal production is 50,000 acres.
- Sunflowers – down 71% in production
- Sorghum for grain – plantings down 3%

- Hay – production down, acreage decrease about 100,000 acres, but prices up
- Dry beans – smallest acreage planted since 1921
- Crop abandonment across all growers
- Cattle – 50% of cows have been sold statewide, 80% of the cows in the southern 1/3 of Colorado have been sold equating to about 450,000 head of cows, over 1 million total sold statewide. Not a significant decrease in fed cattle to date. Financial impact: $154 million loss, multiplier effect could be as high as $462 million. Some ranchers are paying high prices to move their cattle out of state to feed them this fall and winter.
- Dairy – dairies around 500 head are losing $15,000-20,000/month, low milk prices, no cash flow, rising feed prices, no expansion during past two years, many dairies face financial trouble, lenders don't know how to renew their dairy notes
- Sheep – range in poor conditions (fall and winter), lack of crop aftermath for winter grazing (lack of wheat stubble, corn stocks, alfalfa field, etc)
- Irrigation companies have turned off water to irrigators
- Reservoirs are less than one-half full
- Livestock watering concerns
- Farmland property values reduced
- Very little or no soil moisture
- Water quality impacts
- Very poor range conditions
- Financial losses for agri-business and other businesses
- Rural banks, more foreclosures likely
- Rural communities will also suffer
- Few or no off-farm jobs available
- Next year? No reason to plant fall crops at this point given the dryness
- How many farmers, ranchers will we lose? 20-50%
- How many rural businesses will we lose?

FARM BUREAU CONCERNS

Farm Bureau is very worried about the short- and long-term impacts of the drought on agriculture. Addressing the drought became our number one priority this year. Compounding the drought problem are difficult issues dealing with endangered species, federal interstate water compact agreements, water quality, competition for water, Colorado's budget cuts, basin diversions, federal grazing permittees' concerns, loss of agricultural water, agri-business and rural community impacts, tax revenue losses to rural communities and many others.

Colorado's water needs are both short-term and long-term.

Farm Bureau has been and will continue to play a lead role in addressing water and drought issues. Farm Bureau has worked on state and federal legislation, conducted water development studies, conducted water task forces and been involved with many other groups in the water arena.

During the first year of Governor Bill Owens' administration, Farm Bureau was among the first groups to urge the Owens' administration to convene a water conference primarily to address two key areas: drought preparedness and flood protection. While Colorado has been preparing for these two areas since statehood, more can and should be done to help Colorado meet long-term water supply needs.

The 2002 Colorado Water Convention was held with many statewide and local groups represented. Several good ideas and recommendations came out of that convention to help address water needs statewide.

Earlier this year, Farm Bureau conducted a quick survey of our members on how the drought is impacting their farm operations.

During the special session, CFB supported HB 1022 & SB 14 – Bonding for Water Infrastructure Projects. During the regular session, we supported HB 1414, which authorized the state engineer to approve temporary substitute supply plans for wells. We believe that this authority needs to be extended for another 18 months.

CFB, along with other ag leaders, met with Governor Bill Owens last September to discuss the drought and review potential solutions, including a need to support additional water project financing.

Now is the time for leadership and for organizations to work even closer together to seek solutions beneficial to agricultural and other water users. Drought is the Number 1 issue.

DROUGHT MITIGATION SUCCESSES

- Governor Owens requests federal disaster assistance
- USDA Secretary Veneman announces all counties eligible for drought disaster
- Emergency grazing on CRP acres approved by USDA for numerous counties, extended through Dec. 31, or until disaster no longer exists. Emergency haying not authorized.
- Veneman announces $150 million for beef cow-calf assistance in four states including Colorado. Makes available nonfat dry milk for livestock feed for eligible producers at reduced or no costs
- Veneman announces $752 million in Livestock Compensation assistance for livestock producers. LCP includes cattle (beef & dairy), sheep, goats and buffalo producers. Hogs not included. Program sign-up for period ends Dec. 13.
- Veneman announces the availability of $10 million in Environmental Quality Incentives Program through NRCS for drought-stricken states, including Colorado which received $1,168,000 for conservation measures.
- Veneman announces $94 million will be released for the Emergency Watershed Protection Program (EWP) in 36 states, including Colorado which received over $13 million. This program will provide assistance to help restore natural resources from the devastating effects of wildfires and other natural disasters.
- American Farm Bureau Federation and 30 other ag groups urges U.S. Senate to support S. 2800, Emergency Agriculture Disaster Assistance Act of 2002 (Baucus/Burns) – direct payments to crop and livestock producers ($6 billion). Bush Administration opposes additional funding disaster assistance, but supports taking funds out of new farm law to fund disaster assistance
- CFB President Alan Foutz sends follow-up letter to Senator Allard urging support for disaster assistance
- Ag groups meet with Allard, Campbell, Tancredo, Schaffer, DeGette, Udall and Hefley
- U.S. Senate approves disaster assistance amendment (Allard & Campbell support)
- AFBF and 30 ag groups send letter to all House members urging support of the Senate's disaster assistance amendment. AFBF supports Rep. Cubin's H.R. 5383, a companion bill to the Senate language. All but one in our House delegation support H.R. 5383
- Disaster assistance stalled in Congress
- Election
- Congress' lame-duck session produces no disaster assistance legislation
- Any disaster assistance is up to new Congress in January, 2003
- State Legislative Special Session
- Governor signed two bills:
  - Provide state tax credit for weather related livestock sales
  - Provide $1 million to purchase augmentation water
- CFB and other ag group leaders meet with Governor Owens to discuss state measures that can provide assistance. The group requested Owens support of S. 2800, federal capitol gains relief on livestock producers, water project financing, Amendment 14 hog regulations relief and transportation regulations relief.

DROUGHT MITIGATION FAILURES

- Water financing legislation failed, but helped drive a new focus on how Colorado can provide financial assistance for water projects

- SB 156 instream flow law is not our idea for mitigating the drought. It failed to provide any safeguards during droughts like this one.

- SB 148 tax loss from water sales. FB did not support this bill because it went beyond the tax replacement issue, but legislation is needed to address local tax revenue losses when irrigated lands are converted to drylands.

- Federal weather disaster assistance legislation for 2001 and 2002. However, we expect Congress to act early in 2003, but the total funding will likely be half of the original $6 billion requested. More states are being declared disasters late this year.

Overall, it's difficult for states like Colorado to provide large sums of money to mitigate drought impacts, especially during a down cycle in the economy and lower state revenues. In fact, the state is cutting funding and more cuts may yet come again next year.

2003 OUTLOOK

Farm Bureau initiated a water development study in 1996. The purpose of the study was to gather baseline data on current water supplies, determine population growth and future water needs throughout the state; and to identify threats to Colorado's water and development potential. We also made recommendations for potential solutions to address long-term water supply needs. An update to the study was completed in 1999. The studies were provided to the General Assembly, water community and others. We believe the water studies are still relevant today and the information and recommendations should be implemented.

Threats to Water Supply Development

- 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 use due to interstate compact requirements

- Unsustainable growth

- Reduction of return flows due to conversion of irrigation use to domestic use

CFB Recommendations for Water Development Policies

- Colorado should take aggressive action in developing its water sources

- Protect prior appropriation system

- Protect Colorado's interstate water compact entitlements

- Protection of existing water rights

- Allow the free market system to work in the pricing of water

Potential Statewide Water Development Opportunities

- Develop cooperative water resource planning processes for local, regional and state agencies

- Develop alternatives for further funding, both private and public, for water development projects

- Lease, rather than purchase, senior water rights from the ag sector for M&I use

- Encourage conservation and carry out programs to educate the public on water use entities and importance of water efficiency and to the state's economy

- Develop additional water supplies by supporting large and small water projects, wastewater reuse, and groundwater recharge programs

- Enhance and expand statewide computer databases and decision support systems to improve development and management of existing supplies

- 2003 – Support and participate in the new CWCB water survey being conducted.

Governor Bill Owens has made water a top priority – that's great. DNR and the CWCB are promoting a new statewide water survey – that's helpful. The CWCB is the

primary water entity in the state and needs to continue to address this issue head on. The State Engineer plays a key role as our state's water policeman and support for that office needs to continue. The state legislature will be confronted with numerous bills all attempting to address water and the drought. We are likely to see legislation that will attempt to change Colorado's long-standing water law and measures for more conservation. It would be a tragic mistake if the legislature moves very far on Colorado's basic water law. The prior appropriation doctrine works in semi-arid states like Colorado and we should adamantly oppose any efforts to undermine it with something else.

Conservation is fine, but is no panacea. In fact, so-called water salvage measures can actually damage our water rights system. Farmers should not be required to plant only certain crops and we should not even attempt to dictate agricultural production. Leave that to the markets. Farmers can decide for themselves what they should produce.

CONCLUSION

Every Coloradoan should read former U.S. Senator Hank Brown's "Green is Beautiful" speech. Brown clearly makes the case that Colorado needs to further develop its water resources. He says that many new people moving to Colorado mistakenly take the position that growth needs to be limited and the best way to limit such growth is to place a moratorium on adding new water storage. He believes the state must take a leadership role to bring about a dramatic increase in surface water storage facilities to preserve the environment. He says they clearly do not understand our water system and I agree. They make the mistake of thinking that if we don't build storage projects, the people won't move here and growth can be controlled. What a tragic myth and how untrue with our population increasing easily by another million over the last few years?

A Circular poll last summer shows that 70% of Colorado voters support new storage, so the drought has gotten the public's attention and that dealing with the drought is a very important issue for 80%. 63% oppose taking water from agriculture, even though 90% of water is used for ag. 86% says farmers and cities should share water as a way to help keep farms in business.

Last summer CFB and many others interested in developing more water strongly believed the real question is how to finance the projects. We know now that Colorado has the ability to finance projects through entities like the Colorado Water and Power Authority. The CWCB will continue to provide funds for the water construction loaning program. If financing is not the real problem, then it's more a case of political will and leadership. One big obstacle continues to be environmental regulations and permitting, mostly at the federal level. Congress needs to seriously begin an overhaul of federal environmental laws, but that won't be easy. Farm Bureau has established a new water task force to help address legislative remedies.

The ag economy is not in good shape, with generally low commodity prices, with some exceptions. Wheat prices are up, but little wheat to sell in Colorado. Many farmers and ranchers are sole searching on whether to stay in agriculture or not. Older farmers and ranchers have or are ready to retire. Are their sons and daughters going to take over the farm or ranch? Many don't' know, yet. The younger farmers and ranchers are struggling getting started, but have not necessarily made big investments and may choose to get out.

Perhaps the most vulnerable group might be the middle-aged group of farmers and ranchers. They are in it too far to just quit, but still have a long ways to go before retirement. Bankers are probably getting more nervous every day as the drought drags on, no federal disaster assistance, and the potential for foreclosure and farm sales increases. If too many foreclosures occur, land prices may drop. The value of the water rights becomes their greatest asset. Water and land sales get escalate even more. Ag and rural Colorado will suffer even more – not an exciting thing to think about. Unless you are in the farming and ranching business, we can't possibly comprehend or understand what they are going through.

But, many in agriculture have gone through drought cycles before, and while many did not make it, there will be those who survive this drought, too.

Scientists can try to predict or forecast the weather and now one knows how long this drought will continue. One prediction – farmers and ranchers will have to plan and prepare their operations as if the drought will continue with no certainty of production and income next year.

MUNICIPAL DROUGHT MITIGATION SUCCESSES AND FAILURES IN 2002 – PLANS FOR 2003

Peter Binney
Director of Utilities
City of Aurora

Good afternoon. I am here to represent the strongest water utility in the whole nation. Well, actually, it is one of the 47 best in the West. We are the petrie dish for Denver Water. I always get a kick out of the way the guys at Denver Water introduce themselves. I covet their water.

I am going to talk about what the drought of 2002 has done to our water supply system. You heard a lot about some of the antecedent conditions and how quickly it came on this year. What does it take for a city of 300,000 to go from a mildly comfortable, scientific interest in climate to Oh, heck – What are we going to do now? I will talk about the City of Aurora as a case study – what we plan to do for next year, and I will spend most of my time on successes and failures. You have heard some very strident remarks today. You probably will hear more this afternoon about how each of the water users covet what they have. I will spend some time at the end thinking about the journey we are going to take over the next few years.

What has the drought done to municipalities? Until April of this year, we knew we were in dry conditions. We designed our municipal water supply systems to take us through three-four years of drought. When we started our water supply forecasting for this year, we felt a mild level of discomfort, because of what we had gone through in '99, 2000, and 2001. As you heard this morning, the climate conditions in early April, though, really changed the picture for all of us. Where are we at the moment? We have a reduced ability to meet demands on our system. We cannot meet the water demands of the third largest city in the State of Colorado at the moment.

We put very high levels of water restrictions in place early this year. We went to the books on water conservation, and I am here to tell you that the history of water conservation as it was chronicled in California in the 1970s is not applicable to these semi-arid conditions. As we went along, we found that there is a physical limitation on the level of demand we can meet with the current water infrastructure. My feeling is, as you sit here today, that this is similar to the level of discomfort that our forefathers felt back in 1954-1955 as they were going through that drought. We do not have the infrastructure in place to be able to meet sustained droughts along the Front Range at the moment, and we certainly don't have the infrastructure, the water rights development, or the

Figure 1. Homestake Reservoir

water allocation procedures to meet the needs of that other 800,000 to one million people who are on their way here. I would submit to you that we are sitting in a room somewhat like the people did back in 1954-1955, and that somewhere there is the equivalent of a C-BT or a Blue River or a Fry-Ark project in our future.

What is the drought doing? It is a wake-up call to all of us. This should be the catalyst to say either we are going to stop growth – we are going to modify the demand patterns, we are going to adapt the water allocation procedures in the future – or, we have some very fundamental decisions we will have to make. If we don't pay attention to what this drought is telling us, we will have some real problems in the future.

You have seen a number of different pictures of what reservoirs look like. This is Homestake Reservoir (Figure 1) on the upper east fork of the Eagle. It is a facility we co-own with Colorado Springs Utilities. At the moment, the water level there is about 70 feet below normal, and we have zero water there.

That is a conservation pool. All the water that the City of Aurora has is now sitting in Spinney Mountain Reservoir. If I look like I am a walking ulcer, there is a reason why.

One of the speakers this morning talked about the multiple-year history of how these reservoirs work. We get our water supplies in about a six-week period, and we have to meter that out through the rest of the year. Figure 2 shows the combined storage in Aurora's water supply system. At the moment, we actually have around 150,000+ available to us. In 1997 we were in a relatively drying period; 1990 through '98 we were in very wet periods so we were filling these reservoirs over time. The current drought, year 2000, we had very little yield coming into our system so we were drawing the reservoirs down. You see that inflow minus outflow change in storage, and sure enough the reservoirs did exactly what they should do.

That's not too bad from a water management standpoint, but this is what has happened and what will happen through May of next year. There was essentially no runoff into our water supply system, so everything that we were meeting was coming out of storage. For a city of this size, we should have a conservation pool, so we are getting into the public health, safety, and welfare capabilities of the water supply system at this stage. Again, in one year if we could bounce these reservoirs back, you would be okay. But at the moment we are going through some analyses of what next year might look like, and it is ugly. It doesn't matter how much snow we

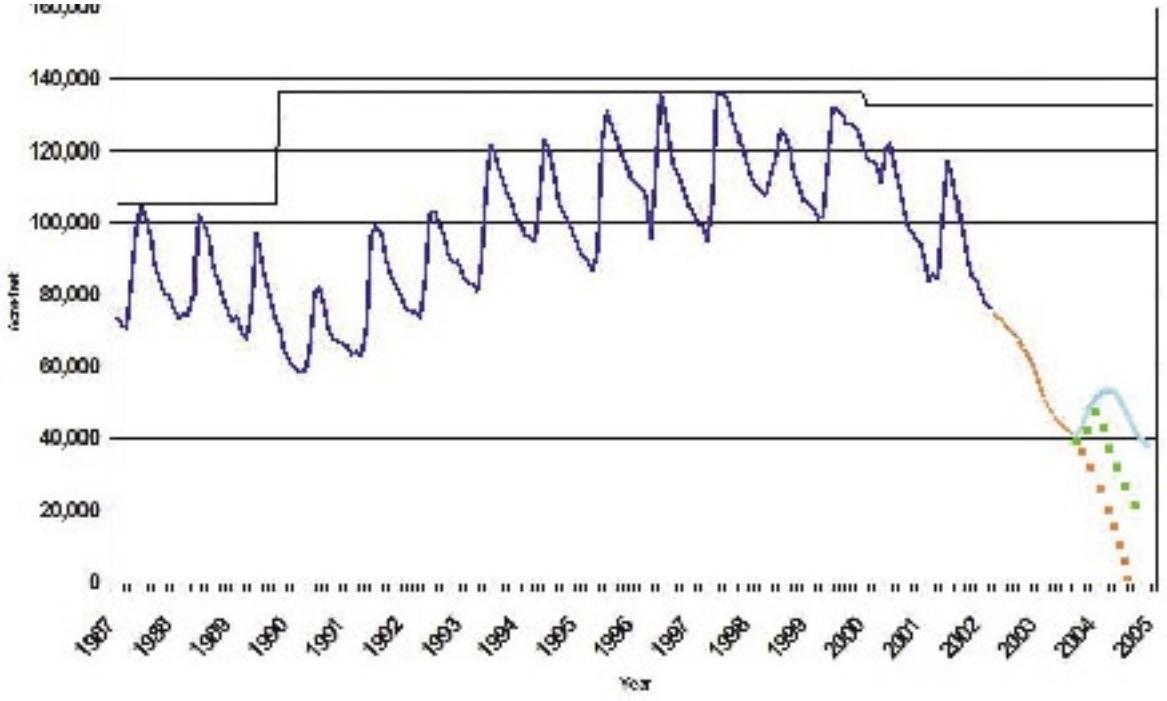

Figure 2. Reservoir Water Levels Depend on Runoff and Demand

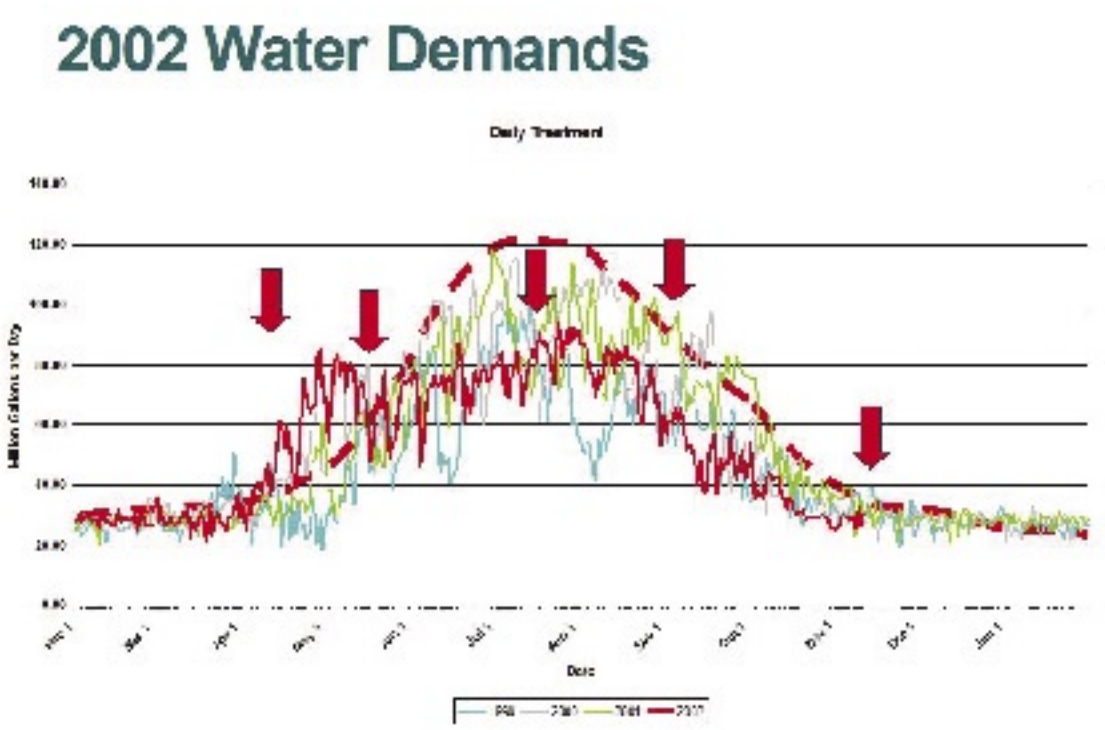

Figure 3. 2002 Water Demands.

get, we will have a drought next year, the year after that, the year after that, and most likely the year after that. If we have a repeat of this year, we will drain our reservoirs. We will have nothing left in May, 2004, and that is only giving us the ability to meet indoor demands. If we have an average year, we will get a little bit of water into storage and in May 2004 we are right back where we started. So, when people talk about drought it is not only climate, it's also the water supply that is developed for your demands.

Summer 2002 Drought Strategy – What did we do during 2002? When we got the information on the yields and conditions of our reservoirs, we put in a very aggressive water conservation program. The only thing we had left to us at that time was demand modification. In late April-early May we started a very aggressive public education and awareness program. We had a water-wasting ordinance on the books from back in 1981. We updated that to $100, $250, $500 fines and suspension of service. Concerning city compliance of water use guidelines, we started drawing down our reservoirs. We executed water trades. We were doing everything within our power to develop water supplies under our system, but I will tell you today that there is no technical solution to this drought. Everything that we are going to be able to do to come out of this drought faster is legislative. It is institutional. It is working with other water rights owners over the short term.

Someone talked this morning about cooperation. What you get when you have these conditions is statesmen and charlatans, and I think it is about a 50-50 split. I have had people come to my office – totally mercenary – they were going to solve my problems as I was going to line their pockets. But I have also found that there are certain people in this state who understand what is going on, and they are the true leaders. I will talk a little more about some of those folks a little later on.

Figure 3 shows the actual water demands on our water supply system. You see a very traditional bell-shaped curve.

What we are seeing for this year, and this is similar to what Rocky Wiley was showing for Denver Water, are very dry, spring-like conditions. You can see the demand coming on to our system about April 1. This is where we realized the severity of the drought of 2002. In Aurora, this was our target of water demand that we could normally take on our water supply system. We have a trajectory of demand that we try to manage within, and that is how we operate our reservoirs – those were the good old days.

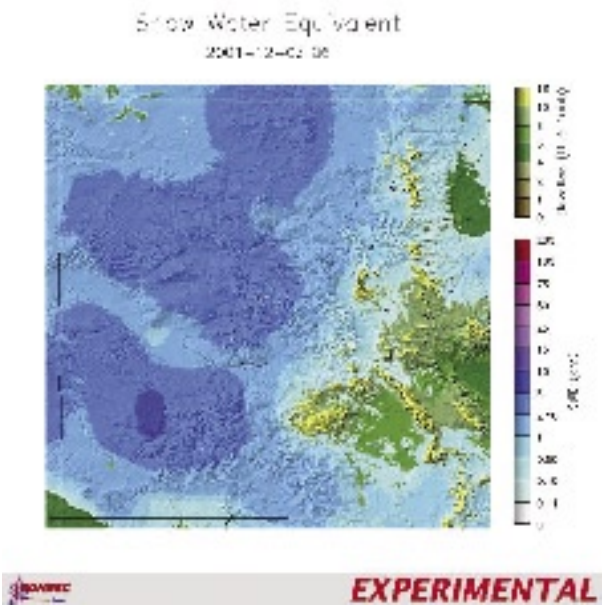

Figure 4. Snow Water Equivalents.

This is where we declared a drought emergency in the city. We have statutory reporting periods, so we had 30 days in which to notify the public of ordinance changes, so you can see the demand was still coming onto the system. Our citizens didn't get it at that stage. This is where we went into the three-day mandatory outdoor watering restrictions. So, you see some awareness of what was going on here, and then we dropped the demand down. These are the individual storms. John Henz, if you are still in the room, you can go back and calibrate each day that a thunder cell went through the City of Aurora. This is when people stopped watering outdoors. You can see that through the early spring months the demand was coming back onto the system. What we found is that people use as a barometer the greenness of their grass. That was the primary determinant on how much water demand we had coming onto our system.

July 6 was the earliest possible date that we could put in our increasing tiered rate structure. So, on this date, 20 percent of our water was sold at double the rate, and 20 percent at triple the rate. We had people in the City of Aurora paying over $2000 per acre-foot per year for the right to water their lawns. I would suggest that is one of the economic realities that, as the urbanites and the farmers start thinking about this, may be the funding source that you are looking for. It is quite a bit more than the $1.80 per bushel.

In Aurora, we go through 19 different billing cycles in a month. When the first wave of bills started hitting customers, that is when we saw the actual break in the demand pattern. You can see that the effect of rate structures, on top of outdoor water conservation, results in the demand dropping off significantly. This is when we started phasing out outdoor water use. Now we are back into winter demands.

SWE MEASUREMENTS (2001 - 2002)

One of the things we look at is snow/water equivalents (Figure 4). For all those folks who were telling me there is a lot of snow out there, I am not seeing it. We see a lot of moisture up in Summit County along the north part of the Front Range. This is not a good picture of what our water supply conditions are going to look like next year.

What are we going to do next year? We are going to meet the indoor demands of the city. This represents around half of the water that we typically use. We are setting up a volume allocation system where we will make water available for indoor use. If that is all the water we have, you will get water at the tap, you will get water for trees and shrubs, and you will have nothing else. What we are going to do, then, is make blocks of water available depending upon how much inflow or other water sources we may expect. It will have a severe impact on the community.

What were successes? We certainly have a better informed public. We did have a very effective outdoor water use program and during the peak of summer 24 percent or so reduction in demand. In one afternoon, we raised $760 million to address our problem, and I think

that was the easiest part of the problem that I have ahead of me. We raised our tap fees 56 percent on September 28. We increase water use fees 15 percent next January, the January after, and the January after that. So, we have the money to go out and deal with the issues that are ahead of us. Financing is not the issue. I think we have a better assessment of the portfolio of water projects we will take in the future, and I would say that overall, intergovernmental cooperation between agencies is extremely high. I think that what will come out of this is a better relationship between the cities and the farming community. I think there is a lot of opportunity there.

What needs to be addressed? We must work with the legislators to find mechanisms to move water now – not to analyze it, not to study it, not to wring your hands over – we must find a way to move water to selected water uses in the next 120 days. We can't sit here and talk about how we are going to solve the problem six months from now, because that will be too late. Legislative action will be very important in terms of allocating the water that is available to us next year. Mid-term, I think there are a lot of opportunities for cooperation between senior water rights holders and the cities on an interruptible supply basis; dry-year leasing - I do expect that there will be some agricultural or industrial transfers to municipal purposes. I think if they are done right, they can be very positive for both sides.

Times like this bring out the best and they bring out the worst. I have seen the plus or minus three standard deviations of human behavior over the last six months. Everybody has platitudes about how they are going to solve the problem. Trust me - this is for trained professionals and it shouldn't be tried in your home without the proper training. With substantive and constructive approaches and by setting up the right forums with the right people, we can find ways to work with water both in severe droughts and with the changes that will happen in the state over the next 15-20 years.

HOW DID THE DROUGHT OF 2002 AFFECT INSTREAM FLOW WATER RIGHTS?

Dan Merriman, Chief
Stream and Lake Protection Section
Colorado Water Conservation Board

Figure 1. Cochetopa Creek – July 2002

I appreciate the opportunity to be here this afternoon. We have heard about agricultural uses and we have heard some eye-opening comments relative to municipal supply.

I am going to talk about the ways the state addresses drought through its Stream and Lake Protection Program. Figure 1 is a picture of Cochetopa Creek taken in July 2002. This is an area that is designated by the Division of Wildlife as a Wild Trout water. As you can see, it is not in the best of shape. But water is flowing, there is a riffle, and there is holding habitat in that particular stream reach.

THE COLORADO WATER CONSERVATION BOARD

The Colorado Water Conservation Board was created in 1937 to aid in the protection and development of the waters of the state for the benefit of present and future generations. The Board is made up of 15 members (Figure 2). Nine members are citizen appointees from eight of the major drainage basins in the State of Colorado, and one member is from the City and County of Denver. We have also six ex-officio members. They include the State Attorney General, the State Engineer Hal Simpson, the Agricultural Commissioner, the Director of the Division of Wildlife, the Director of the Water Conservation Board and the Executive Director of the Department of Natural Resources – the tenth and final voting member on the Board. It takes six members, rather than a simple majority, to conduct business or take any affirmative action. This requirement ensures a geographical "buy-in" on any Board action.

Figure 2. Board Representation

To address the various program responsibilities of the Board, the agency is divided into five sections (Figure 3).

1. Drought and Conservation Planning – This section assists water users with water conservation and drought planning. Brad Lundahl is the head of this program area.

2. Water Supply Protection – This program area addresses protection of our river compacts. Randy Seaholm oversees this section.

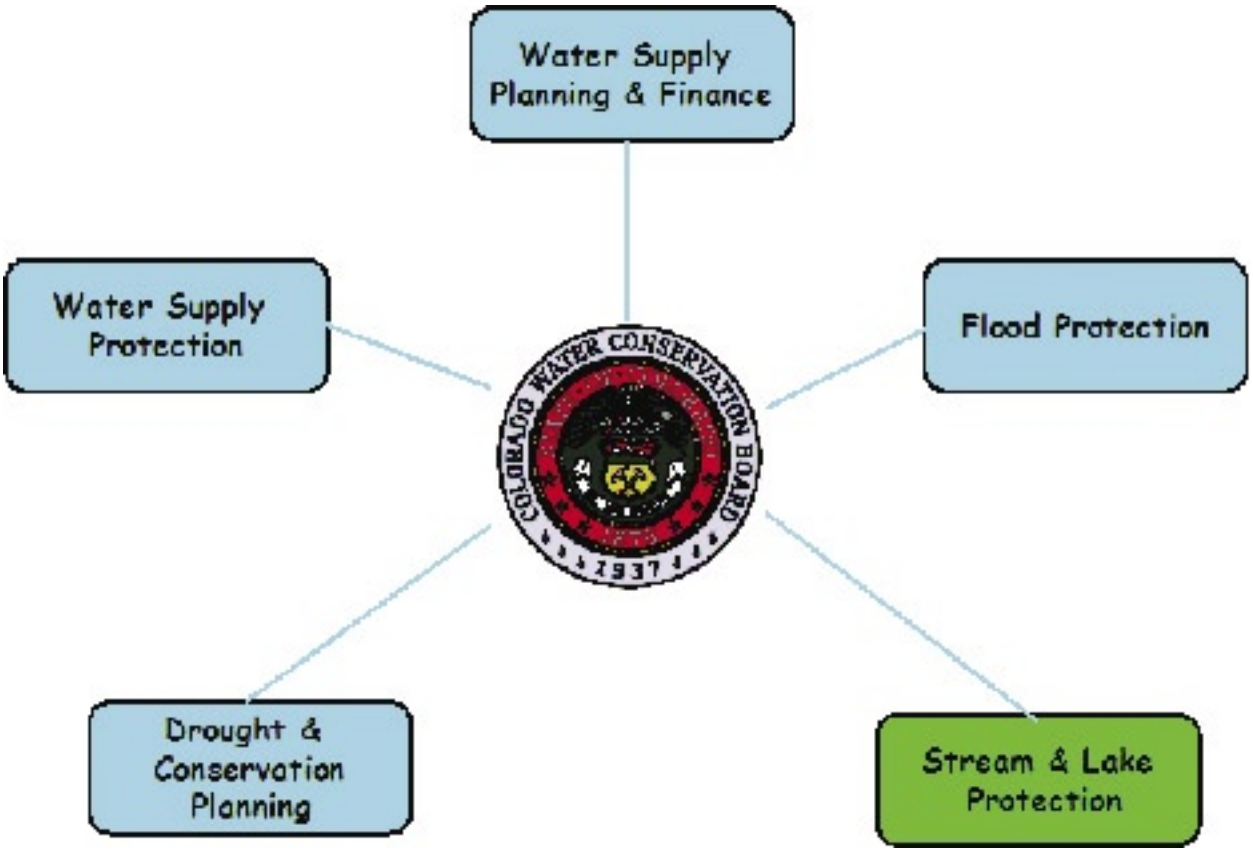

Figure 3. Board Program Areas

3. Water Supply Planning & Finance – Assists water users with planning and financing water infrastructure. Mike Serlet is chief of this section.

4. Flood Protection – Larry Lang, section chief, has stated that "First comes drought; then comes fire, then comes flood." This section oversees flood protection efforts in the state, delineation of 100-year floodplains, and coordination with federal agencies.

5. Stream & Lakes Protection – This section, which I am responsible for, provides reasonable protection for the state's water-dependent natural environment.

STREAM AND LAKE PROTECTION SECTION

The Stream and Lake Protection Section is comprised of six sub-areas (Figure 4).

- New Appropriations – These are new junior water rights; the Board still is active in appropriating both instream flow and natural lake level water rights in the state.
- Water Acquisitions – The Board is also authorized to acquire senior, decreed water rights, on a voluntary basis, to preserve or improve the natural environment.
- Legal Protection – The Board protects its water rights by monitoring water court cases and securing terms and conditions, when appropriate, to prevent injury.
- Engineering and Water Quality; Biology and Methodology – These are support services – they provide technical support for the section.
- Physical Protection & Monitoring – This area monitors stream flows to ensure that instream flow rights are met. The drought really made this a significant part of our activities. We work cooperatively with the U.S. Geological Survey and the Division of Water Resources in their data collection efforts.

All of these aspects of our program were affected by the 2002 drought.

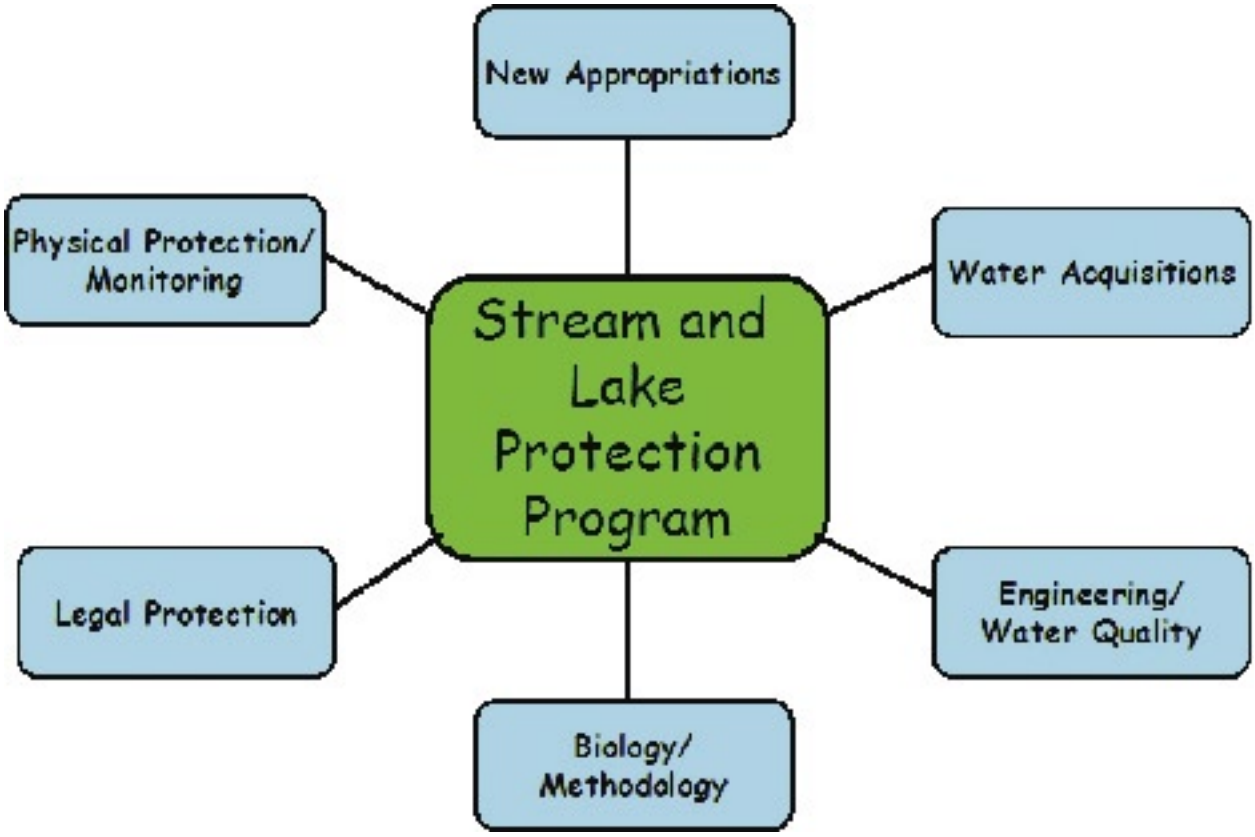

Figure 4. Program Areas

WHAT IS AN INSTREAM FLOW OR NATURAL LAKE LEVEL WATER RIGHT?

An instream flow or natural lake level water right is the tool Colorado uses to provide a reasonable degree of protection for the natural environment. It is an in-channel or in-lake appropriation of water; it is non-consumptive. An instream flow or natural lake level water right is:

- made exclusively by the Water Conservation Board;
- for minimum flows between specific points or levels in natural lakes;
- to preserve the natural environment to a reasonable degree; and,
- is administered within the state's water right priority system.

HOW DID THE DROUGHT OF 2002 AFFECT INSTREAM FLOW WATER RIGHTS?

Increased Available Flows

One surprising effect of the drought was an increase in available streamflows. That may seem like a contradictory statement, however, as the State Engineer has indicated, the drought caused downstream, senior water rights to place "calls" for water earlier in the season than most years. These senior "calls" curtailed upstream, junior consumptive water uses. In addition, water users requested that contract water be released from federal reservoirs earlier in the season. Both of these actions resulted in more water being called through instream flow segments, and more water physically available for the non-consumptive instream flow water rights than we would perhaps see in an average or below average year.

Improved Communication and Cooperation

In April 2002, Governor Owens declared a drought emergency and created the Wildlife Drought Task Force to address drought-related impacts to wildlife. The Wildlife Drought Task Force included representatives from state and federal agencies, as well as public interest groups, and worked to identify and protect critical aquatic resources, and address low flow concerns. Following are several examples of the Task Force's efforts:

Medano Creek – Medano Creek (Figure 5) is a small stream that flows through the Great Sand Dunes National Park. It is home to one of the few populations of naturally reproducing Rio Grande Cutthroat Trout in the state. There is a transbasin diversion in the upper portion of the drainage that diverts water across the divide into the Arkansas drainage. The concern was if the flows dropped too low, the native cutthroat trout population would be impacted. Through a joint effort with the Division of Wildlife, CWCB, Division of Water Resources, and the Nature Conservancy District, flows were monitored very closely. There was an effort to initiate some discussions with the water user to cut back on that diversion if it looked like the stream was going to go dry. However, the prior appropriation system came to the rescue of the fish. This particular water right was called out of priority in mid-to-early July. Stream flows increased, and that was a success story for the fish.

Dolores River – There was a lot of concern this year about the Dolores River (Figure 6), which is located in southwestern Colorado, downstream from McPhee Reservoir. There is a pool of water reserved in McPhee Reservoir for fishery releases, and over time, a very productive brown trout fishery has developed. But in the summer of 2002, the pool was short due to limitations in physical supply, and it became quite obvious that the water was not going to go very far. There were no opportunities to purchase or lease additional water and the effects on the fishery were expected to be devastating. Again, through a joint effort of the CWCB, Division of Wildlife, Division of Water Resources, the U.S. Bureau of Reclamation and local water users, flows were monitored to provide as much protection as possible for the fishery. Although flows dropped to critical levels, many fish were able to survive in pools of water.

Figure 6. Dolores River.

Figure 5. Medano Creek.

Communication Protocols – The CWCB staff worked with Division Engineers and Water Commissioners to establish communication protocols for monitoring and enforcing instream flow water rights. CWCB staff established a "watch list" of satellite stream gages on critical instream flow reaches of stream, and developed a notification system with Water Resources staff. In late summer, staff met with ski areas to discuss low flow triggers, notification procedures and augmentation requirements. These early meetings also allowed the ski areas time to secure alternative water supplies to mitigate the impact of their snowmaking diversions on natural streamflow.

Figure 7. Low river flows have potential impacts on native fishery.

Water User Cooperation – The CWCB holds a junior (1977) instream flow water right on the White River near Meeker. The Board's water right was not fully met due to physical and legal water availability. In August 2002, the Division of Wildlife became increasingly concerned about low flows in the river and potential impacts to the native fishery (Figure 7). The Division of Wildlife owned water stored in Lake Avery. Although the Division could release water from this upstream reservoir, the water was not decreed for instream flow uses and could not be protected from diversions. Under the law, it would become available to the next downstream appropriator in priority. CWCB member, Dave Smith, who has been on the Board for a number of years, represents the Yampa-White Drainage. Mr. Smith is also a rancher and diverts water from the White River downstream from Lake Avery. Mr. Smith worked with the Division of Wildlife, Division of Water Resources, and his neighbors (who were also agricultural diverters who did not have a sufficient supply for their full agricultural use), and was able to develop a voluntarily agreement to allow the water released from Lake Avery to bypass their headgates and supplement instream flows in the critical reach of river. This was a real success story that showed how cooperation can help achieve streamflow protection goals.

NEW DATA COLLECTION OPPORTUNITIES

Due to the higher flows in larger rivers around the state, the Division of Wildlife generally has difficulty collecting the base information and data necessary for making instream flow recommendations. This year, the Gunnison River was flowing at about half of its normal level, and the Division of Wildlife was able to complete data collection efforts. Data was also collected on the Animas River.

A couple of positive notes on these two rivers: In the Gunnison River downstream from Blue Mesa Reservoir, an instream flow level of 250 cfs was maintained through the Black Canyon National Park. The Division of Wildlife's end-of-season assessment was that, despite the lower flows, the brown trout fishery actually did quite well in the canyon. Brown trout are a species that tends to like warmer water temperatures and the more moderate releases coming through the Black Canyon have allowed for a fairly significant recruitment in the brown trout fishery.

Similarly, in the Animas River, except for the area impacted by post-fire mudflows, the fishery appears to be doing fairly well.

ADMINISTRATION OF INSTREAM FLOW WATER RIGHTS

Calls – The low streamflows associated with the drought triggered administration of instream flow rights. The CWCB placed a formal call against an upstream junior piscatorial water right on Surface Creek in Water Division III. The water right was being diverted into a pond and utilized for a private fishery. Our instream flow was not being met below this diversion. CWCB staff notified Water Resources personnel and worked with the Water Commissioner in the particular area. He contacted the water right holder, and gave him an opportunity to either move the fish to another location or provide another source of water. Rather than have strict administration where they would wake up one morning and find the headgate shut off and their pond empty, CWCB staff worked with the water user to provide a reasonable amount of time to accomplish this effort.

Other streams where the CWCB placed formal calls included Abrams Creek in Water Division V, and Four Mile Creek just west of Boulder.

Enforcement – One of the ways the staff protects instream flow rights is by monitoring changes of water rights/augmentation plans filed with the water courts. If staff identifies a proposal that could potentially impact instream flow rights, staff files a statement of opposition. We work with the applicants to identify impacts and negotiate language to protect the Board's water rights and

still allow the project to go forward. Over the years, the CWCB has negotiated numerous stipulations requiring protection for instream flows.

This year, on many streams where flows were low, there was a lot of clamor urging the Board to place calls. But if you are a junior water right, there may be no one to call out. If you are a junior water right and there is a senior call downstream, you may already be benefiting from administration, and the low flow condition may simply be the result of a lack of physical supply. One of the areas where staff believed it could look to improve streamflow conditions was to ensure that the numerous negotiated stipulations were in compliance. This year, Greg Walcher, Executive Director of the Department of Natural Resources, and Rod Kuharich, Director of the Board issued a press release advising that the CWCB was seeking enforcement of stipulated decrees. Staff is working with the Division of Water Resources to identify augmentation plans or water right decrees that are not in compliance with stipulations, and has requested the Division of Water Resources to take the necessary actions to bring them into compliance.

Drought Reversion Clause – One of the Stream and Lake Protection Section's program areas is Water Acquisitions, and one of the most successful acquisitions is a water right donation by the City of Boulder. In 1990, Boulder conveyed to the Board some 15 cfs of very senior water rights dating back to the middle 1800s. Prior to this donation, the area below the Broadway-12th Street crossing (where several major headgates are located) had flow in the summertime that was limited to whatever water leaked past the headgates. The stream was just kind of a stinking sewer - old tires, bicycles, etc. in the stream bed. Boulder approached the Board with an offer to donate water rights to maintain instream flows in the creek. The City and the Board went through a water court change case, and entered in to a comprehensive "donation agreement" that detailed the terms of the water right conveyance. One of the conditions in the agreement allowed Boulder to recall, or utilize, these conveyed water rights during extreme drought or emergency conditions. In the event the City experienced a failure of their pipeline system or were experiencing an extreme drought, they could utilize the conveyed water rights for municipal purposes rather than allowing them to remain in the stream.

The CWCB staff met with representatives of the City of Boulder in May and reviewed their runoff forecasts for summer 2002. Much of the City's analysis was based upon the tree-ring analysis conducted by Connie Woodhouse, where tree rings were correlated with streamflow information. That data indicated conditions approximating a one in 300-year drought. Boulder had met the necessary drought triggers in the donation agreement, and was able to invoke the reversion clause to use the conveyed rights for municipal needs. It was a benefit to the City to have those rights available in this time of severe shortage, and the reversion clause demonstrates the flexibility of the Board's water acquisition program.

ADDITIONAL PROGRAM NEEDS

Staff also identified additional program needs as a result of this drought. Senate Bill HB1414, the Substitute Supply Plan bill which became effective in July 2002, provides authority for the State Engineer to approve emergency substitute supply plans when public health and safety are at risk. It also provides the authority to approve temporary substitute supply plans for other consumptive uses and requires a 30-day notice provision for the State Engineer to consider that plan. This provision allows substitute supplies to be approved without having to go through a water court process. However, there is no specific authority in the statute, as we understand it, to allow decreed water rights to be used for instream flows on a temporary basis, or to allow water users to make their water rights available for protection of the natural environment. In a drought situation, timing is very critical. Oftentimes we just cannot move fast enough, and going through a water court process may take a number of years. This is something Kent Holsinger alluded to at the luncheon today, and it appears there will be discussion in the Legislature to address this issue.

<u>What are Our Plans for 2003?</u>

CWCB staff will continue our low-flow data collection efforts, continue enforcement efforts with the Division of Water Resources, maintain communication and cooperation with public and private entities, identify mechanisms for temporary or emergency instream flows, and identify water-leasing opportunities. There are a number of entities that are interested in these issues, and are willing to provide support to the Board in accomplishing these tasks.

We do have successes, and one of the primary successes, I believe, is a result of the flexibility in very dynamic systems – both the natural system and the state's water right system. The flexibility and elasticity of the natural environment allowed it to survive the critically low flow conditions; and likewise, the state's water rights system adapted to meet the needs of the water users and help us through these difficult times.

THE ECONOMIC IMPACT OF DROUGHT ON RECREATION AND TOURISM

Chad A. Schneckenburger
Robert Aukerman

INTRODUCTION

The summer of 2002 has been one of the driest in the State of Colorado in close to 25 years. The current drought that Colorado is experiencing is in its fourth year and has begun to wreak havoc on a wide range of areas – environmental, social, and economical. When people think of the economic damages occurring as a result of a drought, they most often think of the harm done to the agricultural industry. While the effects on this industry can be disastrous, other industries, such as recreation and tourism, are suffering on a much larger scale than agriculture. As history has shown in Colorado, the recreation and tourism industry often takes a back seat to the interests of agriculture in terms of policy and public support, yet it generates roughly twice as much revenue. Much of this can be attributed to the fragmentation of the industry and lack of a central representative authority. It is an industry that has seen its largest growth occur primarily in the last 20 years.

As more and more people move into the state, they no longer do so to "grab a piece of the frontier" and sow the land, but rather to improve their quality of life by surrounding themselves with the state's abundant natural resources. Additionally, every year more and more people travel to Colorado from out-of-state for these same reasons. Last year the recreation and tourism industry injected over $8.5 billion into the state's economy (Hart 2002) while the agriculture industry in the State of Colorado generated close to $4.3 billion (Christenson 2002). Recreation and tourism clearly represent a significant sector of Colorado's economy that cannot be ignored when considering drought mitigation options.

It must be recognized that the damage drought has brought to the recreation and tourism industry is monumental. The damage involves sectors such as the transportation, hotel and ski industries, as well as many small businesses such as independent river rafting and fishing guides and sporting goods and bait stores, to mention a few. Each and every sector of the tourism and recreation industry within the State of Colorado has been negatively affected by the drought. Likewise, the damage to the recreation and tourism industry extends to include a regional economic impact on indirect services that include gasoline, groceries, restaurants, retail, and more. When recreation and tourism in Colorado suffer, so do the services that depend on this industry. Additionally, the State of Colorado itself has suffered as much as, or more than, any one single industry. For a state park system that depends almost entirely on revenue generated at water-based recreation areas, the damage has been substantial.

Each sector of the industry, including the state park system, will be forced to make some difficult decisions over the next several months in order to cope with the heavy financial losses sustained this year. Consequently, barring a particularly heavy snowpack this winter and a wet spring of 2003, many small businesses may be forced to close their doors, and Coloradoans may see drastic cutbacks in staffing, maintenance and other services within the state park system.

Tourism and Recreation in Colorado

It is estimated that tourism and recreation inject more than 8.5 billion dollars into the state's economy and comprise roughly 8 percent of the state's workforce, or approximately 220,000 jobs. Additionally, the tourism and recreation industry provides approximately $550 million in revenue for both state and local governments each year (Colorado Travel Inputs Study, 1996-2000, June 2002).

In examining recreation and tourism within Colorado, it is important to keep in mind that certain areas of the state are more directly dependent on recreation and tourism than others, and any economic effect on the industry will have a substantially larger effect on their regions. Much of eastern Colorado is involved in agriculture, while the Front Range has a widely diversified economy with a great deal of industry to support local economies. Yet, in many of the mountainous areas of the state, communities are solely dependent on recreation and tourism for

both employment and income. The part of the state most dependent on recreation and tourism includes Eagle, Grand, Jackson, Pitkin, and Summit counties. In this region, tourism comprises roughly 51 percent of the resort counties' employment and 76 percent of its income. The second-highest dependent area, encompassing Archuleta, Dolores, La Plata, Montezuma, and San Miguel counties, rely on recreation and tourism for 27 percent of its income and 21 percent of its employment (Colorado Travel Inputs Study, 1996-2000, June 2002). Other high-recreation and tourism regions of the state are equally as dependent on related income and employment.

Another important point about regional economic impact is that it quite often involves small businesses in particular regions rather than single large businesses within an industry. For example, visitors to Colorado who stayed in commercial accommodations, such as hotels, motels, inns and B&Bs, accounted for roughly 60 percent of travel spending within the state. Additionally, retail purchases by travelers accounted for $1.2 billion, and the restaurant and transportation industry (including gas purchases and local fares) garnered roughly $1.6 billion and $1.3 billion in expenditures respectively (Colorado Visitors Study, 2001). Although some large businesses such as hotel chains are sure to be affected, it is the small-business person in the communities surrounding parks and resorts that depend most heavily on recreation and tourism spending.

Effects of Drought on Various Recreation Sectors

What is the impact on each sector of the recreation and tourism industry? Due to a limit in time and resources, a complete research study and analysis was impossible. However, a snapshot of the effects on various sectors of the industry was possible through a series of one-on-one interviews with representatives from these sectors. It was decided to focus primarily on local, recreation-oriented private businesses such as fishing and rafting, as well as locally affected, government-run parks.

Colorado state parks probably have been the most severely affected of all sectors of the recreation and tourism industry due to the drought. The Colorado state park system is largely a water-based recreation system with lakes and reservoirs being the focal point of the bulk of the parks within the state. An interview with the director of the northern region of Colorado state parks revealed a number of interesting and alarming facts. First, the state park system is roughly 75 percent self-sufficient, with the bulk of their revenues coming from user fees. Most of these user fees are from day-use boat launches at state parks and related camping and day-use hiking fees. The northern region also receives a small amount of revenue from concessionaire fees of the marina operators at the parks. Last year, the parks system decided to increase fees across the board approximately 20 percent. In a normal year, a 15 to 20-percent increase in revenue would have been expected as a result. Yet, due to the drought this year, they were forced to close several lakes and reservoirs early due to low water levels and the inability to launch boats.

A typical year would allow lakes and reservoirs to open until around the end of October. Many lakes, such as Boyd Lake and Jackson reservoir, however, were forced to close their water access around the middle of July this year. Additionally, there was the widespread perception from people around the state that all the lakes were dry and many people simply quit coming, even to the parks that had enough water and were open. The statewide ban on fires also impacted use of state parks, national forests, national parks and other public areas. Recreationists do not want to camp in areas where they cannot have campfires. Many went out of state to recreate where there was water and campfires were allowed. This leads to a drain of revenue due to residents taking and spending money out of state.

The northern region of Colorado state parks saw a reduction in revenue of between 35 to 40-percent across the board, with some individual areas generating almost 57 percent less than 2001. Another indicator of the situation was the decline in camping reservations at various parks around the state. In general, reservations were down approximately 20 percent across the board. According to the park representative, as Colorado State Parks is largely self-sufficient, drastic measures may have to be taken to meet revenue shortfalls. These measures will include cost-reduction strategies including a hold on all non-essential maintenance, no new equipment purchases, and most importantly, a large reduction in staff, both part-time and possibly full-time.

In addition to Colorado state parks, county parks have also been affected. An interview with the director of Larimer County parks and recreation showed similar problems at Horsetooth Reservoir. The boating season at Horsetooth ended on July 15, with water levels being too low for boats to launch. Horsetooth, even with dam construction, normally has a 100-day boating window. This was reduced by roughly 30-45 days this year. For the two-month period of July 15 through September 15, Horsetooth was down approximately $200,000, or roughly 25 percent from normal revenues. Again, as a re-

sult of decreased boating, and the ban on fires in Larimer County, camping was down 15-20 percent as well. The representative from Larimer County parks indicated that a large number of people were traveling out-of-state to lakes where water levels might have been higher. Additionally, he stated that the county will have to undertake several cost-cutting measures for next year, including a 20 percent reduction in seasonal employment.

As well as parks within the state, the three major water based recreation industries in Colorado – the marine/boating industry, the rafting industry, and the fishing industry – have been enormously affected.

The marine/boating industry was one of the hardest hit of the private industries. An interview with two local marine dealers revealed that early closures of parks have seriously strapped their cash intensive industry. They revealed that they saw a reduction in revenues of close to 50 percent by July. The two largest revenue-generating months, July and August, saw their revenue slide even further. New boat sales had virtually stopped while the maintenance side of the business actually saw an increase. They attribute this to the fact that people were not buying new boats, but rather spending money on fixing up what they currently owned. It should be noted that they had a harder time attributing this reduction in new boat sales entirely on the drought, as some of it may have to do with the current state of the economy. However, one representative indicated that in tough economic times people were more likely to spend less money on travel and more on recreational toys such as boats and jet skis. Still, both dealers claim that they would not have been able to hang on financially had it not been for the flexibility of manufacturers working with them on volume-buying programs and inventory control.

The rafting industry has probably received the most press about its situation due to the effects of drought this year. According to an article in the November 6, 2002 edition of the Coloradoan, rafting industry revenues are down as much as 50 percent this year. This information conflicts somewhat with interviews conducted with representatives from two different rafting companies as well as representatives of the Colorado River Outfitters Association (CROA). They claim the numbers to be closer to 35 to 40 percent, which is still a substantial reduction in revenue. The rafting season generally lasts through mid-September, but many rivers were too low to launch by mid-August. Although both companies saw a drastic reduction in adventure rafters, there was still strong interest in the sport by families, church groups, etc. According to both representatives, their biggest problem this summer was fighting the perception of out-of-state visitors about the widespread fires in the state.

Similar to the rafting industry, the fishing industry fought a battle of perception all summer. According to representatives from three separate fishing shops, their biggest obstacle this summer was convincing people that the fishing was actually very good. Low water level and high water temperatures led to some very good fishing in certain areas. Yet, many of their repeat customers opted to travel to other western states where water levels were higher and temperatures were more normal. According to the representatives, gear sales were down close to 30 percent and guided trips were down close to 20 percent. One local bait shop, Dave's Bait and Tackle, saw a 70 percent reduction in revenue and was forced to permanently close its doors. They attributed this directly to the drought.

Lastly, the ski industry had reduced revenues of over 5 percent last season due in part to the drought. Repeated contacts with representatives from individual resorts proved futile, and we found a reluctance from Ski Country Colorado to speak on the issue. However, past numbers indicate that the drought of 1977 caused a 40 percent reduction in lift ticket sales and a 15 percent drop in employment (Hart 2002). It must be remembered, however, that this was before many advances in modern snowmaking ability.

There are two recurring themes found in this research. First, there may be a substantial amount of leakage occurring from the State of Colorado. Defined simply, leakage is the payment for wholesale and retail products and services brought in from outside the region, plus the interests, profits, rents, and taxes paid outside the region (Loomis and Walsh 1997). Conversely, in this case, large numbers of people are leaving the state and out-of-state visitors are bypassing Colorado for other states where they can find substitute recreation areas or activities. Although no solid number has been determined on the amount of leakage occurring, there is consensus among representatives from all the recreation and tourism sectors studied that it most definitely exists. The declines in recreation and tourism revenues that we found in this study do exist and are significant. Even though our study was not scientific and was but a snapshot of the industry, we believe that a safe guess of the revenue decline this year is around 20 percent. This is a decline of $1.7 billion in Colorado's tourism and recreation revenues due directly or indirectly to the drought. Research is needed to verify this estimate; however, many of the actual figures will be coming in the early spring of 2003.

Mitigation Efforts

To date, there has been no single united effort by the recreation and tourism industry to combat the crisis it faces. This may have to do with the fragmented nature of the industry. There is no single, representative authority to speak for the industry as a whole. There is a Colorado Tourism Board run by the state that recognizes the importance of the industry to the state's economy; however, it does not seem to be fully representative of the entire industry, especially some of the smaller, recreation-oriented businesses. Many of the individual sectors of the industry do have associations, such as the Colorado River Outfitters Association (CROA) and the Colorado Marine Dealers Association (CMDA), yet they all seem to be lacking in resources and strength to be able to wage the full-scale assault necessary to fight politically for an agenda that would benefit their businesses. An organized and politically motivated association representing all affected and interested recreation and tourism institutions within the State of Colorado would greatly benefit their cause.

Individually, however, each sector and business is doing what it can to stay afloat. The parks, both state and county, will be taking drastic cost-cutting measures, including a halt on maintenance and staff reductions, both seasonal and possibly even full-time. The marine/boating dealers have had to drastically reduce inventory and work with individual manufacturers on inventory control issues to keep their overhead costs down. The fishing and rafting companies have waged an aggressive PR campaign against the perception that the state was on fire and there was no water anywhere.

Consensus among all the sectors of the industry is that the only sure way to get out of trouble is to have an abundance of snow this winter and heavy rainfall in the spring. Yet all agree that if water levels remain where they were this past summer, or worse, many will not be able to survive another year.

It must be remembered that much of the recreation and tourism industry is on a small scale. A sustained drought of the likes of this past summer will have devastating effects on the small business person. They simply do not have the financial resources that some of the larger sectors have to weather the drought. Additionally, much of the indirect, tertiary business connected to recreation and tourism is on a very small scale. It is these "mom and pop" businesses that have been the first to feel the pressure and financial effects of a sustained drought.

One final consequence that has not been given much attention is the quality of life of Colorado residents. A large percentage of the people who live in Colorado, and those who continue to move here, do so for the opportunity to lead a very active lifestyle in connection with the natural environment. A sustained drought is bound to have an effect on the quality of life enjoyed by residents of this fine state. Although this is much harder to quantify, it is something that should not be ignored.

Conclusion

It is clear that the drought, technically in its fourth year in Colorado, is having an economic impact on the recreation and tourism industry. In the face of tremendous growth, recreation and tourism hold one of the major keys to the prolonged financial stability of Colorado's economy and to its residents' quality of life. Thus, in the face of drought, we must begin to look at ways to help ensure the survival of individual sectors of the recreation and tourist industries. There is no easy answer as to how this should be done. Clearly, agricultural, industrial and municipal uses of water are very important and control the states water. If the recreation and tourism industry could unite and work with these other industries, some cooperative efforts and efficiencies in the use and management of water might be found that would benefit all.

More than anything, the current situation shows the need for future research in this area. This study has been a simple snapshot of a tremendously large problem. A well-organized and funded examination into the direct and indirect economic effects of a prolonged drought on the recreation and tourism industry is needed. This is an issue both private industry and state and local government should be concerned about. The economy and quality of life in Colorado are dependent on this.

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DROUGHT IMPACTS ON WATER QUALITY

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BACKGROUND

The Water Quality Control Division (Division) is an active member of the State's Water Availability Task Force, i.e., Drought Task Force. Under the auspices of the Drought Task Force, the Division chairs the Health Impact Task Force. As the State agency which oversees water quality in streams and lakes and regulates Colorado's drinking water (DW) and waste water (WW) treatment systems, the WQCD has closely followed the drought impacts, as well as the related fire impacts, to the state's water bodies and water quality infrastructure. (The WQCD has similar involvements related to fire.)

PROFILE OF COLORADO'S WATER BODIES AND WATER QUALITY INFRASTRUCTURE

Water Bodies:

- Streams: 107,403 river miles
- Lakes: 164,029 surface acres

Drinking Water Treatment Systems:

- 300 surface water systems
- 1700 ground water systems

Waste Water Treatment Systems:

- 1,000+ domestic systems
- 500+ industrial systems

DROUGHT AND FIRE-IMPACTED INFRASTRUCTURE IN 2002

Water bodies: Most water bodies in the state experienced the effects of the drought, with two exceptions: waters in those areas of the state experiencing only modest drought, and streams where very senior water rights were "called out" which actually augmented stream flows.

Drinking Water (DW) Treatment Systems: Approximately 100 of the surface water systems in the state experienced impacts. Many systems faced challenging treatment conditions, taste and odor events, lack of supply, and higher operating costs. Runoff from wildfire burn areas compounded these issues in many communities. The drought short-list identified 20 systems with severe problems, primarily in southeast Colorado. (The related fire short-list identified 52 systems with severe problems, primarily Hayman and Missionary Ridge-related)

Wastewater (WW) Treatment Systems: The concern with WW treatment systems is that their discharge permits are designed so that the final dilution of effluent occurs in a "mixing zone" in the stream; this requires adequate stream flow. Drought-shrunken streams can carry inadequately diluted effluent downstream and cause fish kills and operational problems for downstream DW treatment systems. To date, only one example of this has occurred.

EXAMPLES OF SEVERE PROBLEMS

Drought-Impacts:

- Water Shortage: Several local systems simply ran out of water, e.g., Buelah, causing them to make arrangements with a nearby, larger system and to haul water. In other situations, systems deepened existing wells or drilled new ones.
- Upstream WW treatment plant and downstream DW treatment plant with an intervening drought-shrunken stream segment, e.g., Evergreen and Morrison on Bear Creek. This situation caused a fish kill due to elevated ammonia levels and for Morrison to issue a bottled water advisory. The WQCD worked closely with these communities to educate residents and to protect public health.

Fire-Impacts:

- Burned Watersheds: 21 of the DW systems reported fire impacts.
- Burned Infrastructure: nine of the DW systems reported partial to total loss of critical infrastructure.

WATER QUALITY CONTROL DIVISION ROLE

The WQCD has field engineers experienced in dealing with operational "upsets" with both DW and WW treatment plants who worked closely with impacted systems. Similarly, the WQCD has a significant grant and loan program which was revamped to address drought (and fire) impacts. In addition, the WQCD worked closely with the Department of Local Affairs/Division of Local Government to coordinate grant and loan programs.

Infrastructure Financial Assistance:

- EPA Impact Grant Funds
- CDPHE Supplemental Environmental Project Grants
- Drinking Water Revolving Fund (Grants and Loans)

Watershed Financial Assistance:

- Nonpoint Source Program Grants

DOLA Financial Assistance:

- Energy and Mineral Impact Assistance Fund (Grants and Loans)
- Community Development Block Grant

In total, the two agencies provided over $4 million in grants and loans to drought (and fire) impacted communities.

A FINAL PERSPECTIVE ON 2002
AND LOOKING AHEAD TO 2003

In general, the drought of 2002 stressed the streams, lakes and water infrastructure throughout the state. In several locales the impacts were severe, e.g., Buelah and Bear Creek. One could anticipate that if a serious drought (and fire) season develops in 2003, that these types of impacts could be widespread. The WQCD technical assistance capability is currently extremely attuned to identifying and responding to DW and WW treatment systems experiencing operational difficulties. Similarly, CDPHE and WQCD have revamped their grant and loan programs to be able to respond quickly to priority needs.

HYDROLOGY, LAND USE AND WATER QUALITY

Michael Lewis
U.S. Geological Survey

Figure 1. Record Low Streamflows

I am going to provide an overview of a work in progress. It is a statewide drought water quality synoptic that the USGS Colorado District is conducting. More than likely, I will raise more questions than I answer, and please catch me at the break or call me at the office to follow up.

Record low streamflows (Figure 1) have led to an unprecedented combination of hydrology and land use. As we have heard from several sources today, we are not in unprecedented times with respect to hydrology. We have been here before. We have been in worse conditions before. But what is unprecedented is the combination of the hydrology and the land use in which we currently live. As a result of this combination, we began talking very quickly last May, when the drought accelerated, about what our concerns are with respect to water quality in speaking with the Colorado Department of Public Health and the Environment.

Some of our concerns are highlighted here: Less dilution, Less reservoir "flushing", Increased primary productivity, Associated anoxia problems, and Pathogen concerns (Figure 2).

One is simply less dilution. If the solution to pollution is dilution, we have problems. That is bearing out here. The other is reservoir flushing. Most of our reservoirs are very productive. What keeps them from

Figure 2. Concerns are less dilution, less reservoir "flushing", and increased primary productivity, anoxia and pathogens.

becoming overly productive is this annual flushing with very dilute snowmelt runoff every summer. We are not getting that, so it is a concern. Increased primary productivity both in lakes and in streams is a concern. Associated anoxia problems both in lakes and streams is a real concern, and finally pathogen concerns came up, primarily from the aspect of decreased dilution in primary contact waters.

So, we began to design a study very quickly in May and June to go out and begin to characterize water quality. That's exactly what the objective of the study was: Let's characterize water quality during the current drought conditions. As mentioned earlier, we are looking at a very unusual combination of hydrology and land use. We are at a place we have never been before. It was recognized that we needed to collect this information in order to work with future planners for the condition we are going to get into again, probably, this summer.

The network was indeed statewide. There were 162 sites across the state in all the major basins. We sampled each site one-two times during the period of late July through early September. The USGS should receive credit for bringing the monsoon rains in, because as soon as we started the work it started to rain in certain places, which makes a drought study very interesting.

The constituents varied by site, depending on any known or suspected problems at the sites and input we received from the cooperators on this study. Proximity to any known significant point or non-point sources of pollution also came into account when we designed the list of constituents at each site.

What is important with respect to consistency is that all the samples collected were collected by consistent means and were analyzed by the same laboratory using the same methods.

Figure 3. Sampling network statewide.

Following is a list of 21 cooperating agencies who participated on a cost-sharing basis with the USGS in conducting this work.

Statewide Synoptic Network

All major basins 162 sites 1-2 samples/site	Constituents varied: physical, nutrients, majors, trace elements, pesticides, E-coli, wastewater compounds

COOPERATING AGENCIES

- BOR
- Big Thompson Watershed Forum
- City of Fort Collins
- City of La Junta
- CDNR, Parks & Recreation
- Colorado River WCD
- Eagle River Watershed Council
- Grand Co.
- Jefferson Co.
- Las Animas Co.
- Northern Colorado WCD
- Pueblo Board of Water Works
- Pueblo Dept. of Public Works
- Pueblo West Metro District
- Southeastern CO WCD
- Southwestern Water Cons. Dist.
- St Charles Mesa Water District
- Upper Arkansas WCD
- Upper Gunnison River WCD

I imagine we overlooked some people because of the rapid pace at which we put this project together. We contacted many more agencies than are listed here, and they couldn't participate. If we overlooked you, we apologize. We tried to get as much input as we could in this study.

Figure 4 is an overlook of the network in each major basin. If you have localized interest, yes, we did collect samples there. In the South Platte, we had 21 sites. These are all surface water sites, mainstem and some major tributaries, and a few smaller tributaries as well.

The Arkansas had 28 sites: 24 of these were surface water, and we had four reservoir sites. On the Rio Grande, we only had four sites: four on the mainstem and then one on the Conejos. In the San Juan Basin, it was 14 sites through the mainstem and major tributaries throughout the basin. In the Dolores we had five sites on the mainstem and on the San Miguel as well. In the Gunnison, there are 22 sites, a pretty good representation of major tributaries in the basin. In the Upper Colorado, there are 48 sites: 40 surface water and importantly here, we had eight reservoir sites – Lake Granby, Wolford and Grand Lake were sampled. In the Yampa, there were 20 sites: the mainstem, the major tributaries and a few smaller tributaries. All the data has been analyzed by the laboratory and is now in the USGS database awaiting final review and interpretation. There will be a great deal of consistency and repetitiveness in how this data is interpreted. For every site we will be looking at historical data making a comparison for that site. That was also key in selecting these sites. We wanted to select sites that had some historical data with which we could compare.

Secondly, we want to look at water quality standards. Were there any unusual exceedances of water quality standards during the drought? What kind of patterns might fall out there? Lastly, we want to look at spatial trends. Are there any interesting, useful, insightful spatial trends that fall out with respect to basin characteristics in their correlation to unusual water quality conditions during the drought.

Quickly now, I am going to give you a brief example of a few data points at one site just to let you know how we might be looking at the data and some of the things we will be looking at.

This data was collected at South Platte at Denver, which is right downstream from the REI store near 20th. There are three parameters here: dissolved oxygen, ortho-P, and nitrate. There is a 10-year record of data here for most of these constituents, about 135 samples. So we have a nice basis of comparison. The last two were high-flow samples collected in September by a different study.

You can see from the drought study that we had new maximums – pretty significant maximum values – for dissolved oxygen and Ortho-phosphorus. When you look at dissolved oxygen, you go, what's the big deal? Isn't high DO good? High DO is good, but this high a DO, up around 17 milligrams per liter, in concert with very high Ortho-P, is indicative of what we talked about earlier, what we were wary of – enhanced primary productivity in some of these streams.

What's interesting here is, you will see elevated values of DO, Ortho-P and nitrate. Historically, those have always occurred during the colder months. There aren't the issues associated in the colder months that there are in the warmer months. What likely happened the night after

South Platte River Basin

San Juan River Basin

Arkansas River Basin

Dolores River Basin

Rio Grande River Basin

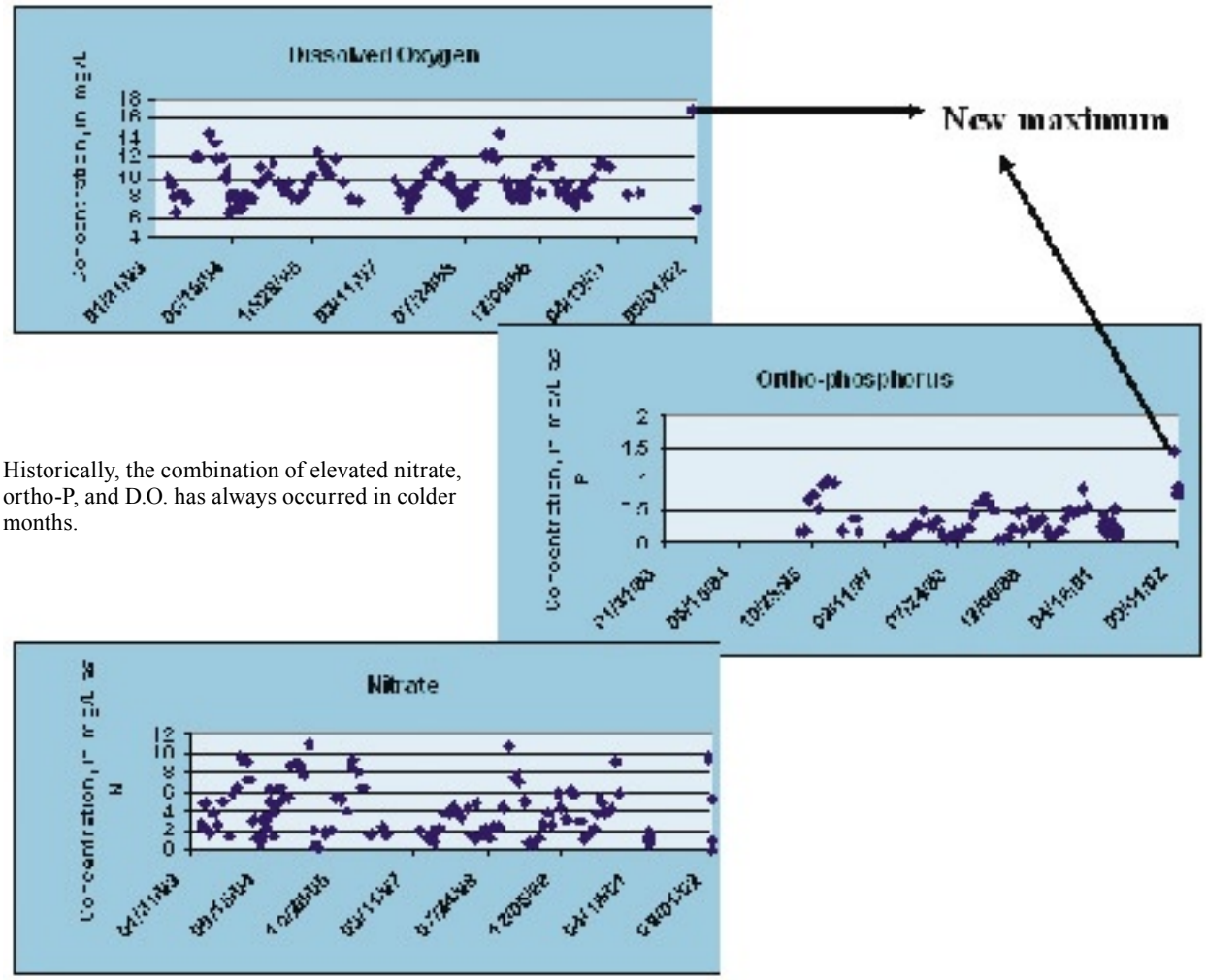
Gunnison River Basin

Figure 4. Major basin networks.

Figure 4. Continued.

Upper Colorado River Basin

Yampa River Basin



Historically, the combination of elevated nitrate, ortho-P, and D.O. has always occurred in colder months.

this sample was collected is during the process of respiration, when the plants can no longer create photosynthesis, DO likely crashed. That is what we are interested in looking at and trying to pick out of this database. This was one of the issues that got us into this study. We want to see, is this more widespread?

Products and Timelines

We are going to deliver data via publication in our annual data report which is usually available in April-May. We will also be supplying this data publicly via the Web. This is publicly available data. If you should have the need for it before you can get it from these sources, please contact me.

Also, we will be presenting a number of oral presentations later this winter, probably late January-February time frame. Some of these are scheduled already with some groups who have shown interest. If you are interested in hearing the results, please give me a call and we can either put you in touch with a presentation that is already scheduled or maybe we can get something together especially for you and your group.

We will have a final interpretive report due out late in the spring. This will present the data and the interpretations that I previously described.

For additional information contact Michael Lewis, USGS, 303-236-4882 x290, mlewis@usgs.gov

OPTIONS FOR SHORT AND LONG-TERM DROUGHT PREPAREDNESS

Session Moderator:

Jack Byers, Assistant State Engineer
Colorado Division of Water Resources

LEGISLATIVE OPTIONS FOR MITIGATING DROUGHT

Dick MacRavey, Executive Director
Colorado Water Congress

As you no doubt are aware, the state budget is experiencing around a four hundred million dollar shortfall. This certainly sets the tone of what we are up against in dealing with the drought financially.

I would like to pose for your benefit a number of issues that we must deal with in 2003 and beyond.

First, we have one hundred and ninety-eight dams that have State Engineer safety restrictions. In other words, we have one hundred and forty-two thousand acre-feet of water that is not available.

Second, the State Engineer's budget is in bad shape. The state, however, wants his budget cut by an additional six percent. This means that we have an impact on water commissioners and other State Engineer employees who are the water cops. In other words, the staff enforcement at the head gate is in desperate straits.

Third, the settlement with the State of Kansas for the Kansas v. Colorado law suit before the U.S. Supreme Court may require anywhere from twenty-seven million dollars to fifty million dollars. In other words, how will Colorado finance that requirement?

Fourth, last year the legislature took five and one half million dollars from the endangered species trust fund. In other words, what happens if some activist files a law suite in federal court alleging that Colorado is not in compliance with the Endangered Species Act?

Fifth, the Federal Safe Drinking Water Act has some very specific requirements in regard to drinking water that must be met. If Colorado is not ensuring the safety of our drinking water; and furthermore, we have a problem with Girardi, this could have an impact on the tourism industry of Colorado. In other words, how do we ensure that we are financially responsible in making sure that we have safe drinking water?

Sixth, with the threat of terrorism requiring that we have adequate water security, do we have sufficient funds to protect us? As you may recall, there have been some recent threats to the Winter Park water supply. In other words, it appears that we need to finance the state's security programs.

Seventh, as you all are aware during the past summer, we had some disastrous fire problems that require attention to our forests. Also, there is a feeling among some that a thinning of our forests could be a benefit to water supply. In other words, we need money to finance these requirements.

Eighth, we have other disasters that affect our tourism and recreation needs such as the problem that we are experiencing with the wasting disease. In other words, we have a need to address these issues.

Ninth, we also have requirements in regard to the Federal Clean Water Act. Notwithstanding the fact that we increase the discharge program fees, there is the feeling that the aforementioned developments were temporary at best. In other words, we need money to finance this important program.

Tenth, I recently saw a Colorado tourism poster suggesting a river with abundant water and rafters enjoying that recreational opportunity. If the drought continues, I do not think we are going to have a lot of well-filled rivers providing rafting or other water sports. In other words, if tourism is important, then where is the money going to come from?

These are not necessarily the Ten Commandments, but they are ten important subject areas that need to be addressed in 2003 and beyond. We in fact, have a water drought and a money drought. So, ladies and gentlemen, what do we do?

Notwithstanding the fact that nobody wants a tax increase, I think that we have to face reality and be prepared to suggest to Coloradoans that we must ask them for a tax increase. Specifically, I respectfully suggest that we must go to the people at a general election in November 2003 and ask them to increase the state sales tax by a quarter of a cent. I realize that these sales taxes are not

producing lots of money now, but they do produce some money. A quarter of a cent sales tax would produce between one hundred sixty and one hundred ninety dollars, which would be a big help in addressing the ten items that I have mentioned in my remarks. Thank you.

[Economic and Revenue Forecast for Colorado, 2002-2008, which backgrounds the above remarks, is presented in the Appendix.]

QUESTIONS

Q: I would like to ask Dick if he has any ideas about legislation requiring mitigation to rural communities if the buy-up/dry-up occurs?

There are some good examples of what can be done which have been done recently. One is the Northern Colorado Water Conservancy District, where they did compensatory storage to the Colorado River Water Conservation District which totaled out to $10.2 million. They also invested that well. It probably went up to $17 million in terms of the investment value. They then got money from the Water Board construction fund, about $17.5 million, and through the responsible relationship between the NCWCD and Denver Water, they worked out a 25-year lease. My point is, you can do a quid-pro quo where everybody gets something, which they did in this case. This is an example of what we can do. Everybody got something, and it resulted in the reservoir up by Kremmling that the River District now owns.

Q: Are you interested in supporting such legislation?

A: I am interested in anything where all my friends come together in a common effort to achieve something that is mutually beneficial to all sides.

FOREST MANAGEMENT AND WATER YIELD

C.A. Troendle
MATCOM Corporation

INTRODUCTION

More than 80 years of watershed research throughout the United States, much of which is specifically oriented toward the West, has demonstrated timber harvest, or vegetation removal, reduces net evapotranspiration (ET) and results in increased stream flow (Troendle and Leaf 1980; Bosch and Hewlett 1982; Callaham 1990; Stednick 1996). In the snow zone of the Rocky Mountains such increases have been documented following forest removal on experimental watersheds at Wagon Wheel Gap (Bates and Henry 1928; Van Haveren 1988) and at Fool Creek (Hoover and Leaf 1967; Troendle 1983; Troendle and King 1985) and Deadhorse Creek (Troendle and King 1987; Troendle and Olsen 1994) on the Fraser Experimental Forest in central Colorado. Other studies have shown similar responses in stream flow occur following deforestation due to insect epidemics (Love 1955) and fire (Troendle and Bevenger 1996). The magnitude of the observed changes in flow in the snow zone is similar in nature to those observed elsewhere in forested environments for similar levels of impact; although the distribution, or timing, of the flow change is more reflective of the dependence on snow melt (Troendle and Leaf 1980; Troendle and Kaufmann 1987; Troendle, et al. 1998). The sub alpine environment is also unique both in terms of the time of year when the flow change occurs, and in the persistence, or longevity, of the treatment effect (Troendle and Leaf 1980; Troendle and King 1985; Troendle and Kaufmann 1987).

In the snow zone of the Central Rockies, forest removal has been shown to reduce canopy interception losses in the winter months, resulting in greater snow pack accumulation (Wilm and Dunford 1948; Dietrich and Meiman 1974; Gary and Troendle 1982; Troendle and Meiman 1984; Potts, 1984; Gary and Watkins 1985; Troendle and King 1987; Meiman 1987; Schmidt and Troendle 1989; and Troendle and Reuss 1997). A similar reduction in interception loss (E), as well as reduced transpiration (T), occurs during the growing season following harvest (Wilm and Dunford 1948; Troendle 1987a; Troendle and Reuss 1997). The reduction in summer ET results in less soil-water depletion onsite, but it is only at the hillslope level that these wetter soils have, heretofore, been demonstrated to result in an increase in either late season base flow, or summer storm response (Troendle and Reuss 1997). In all snow zone studies, monthly flow change has been observed to consistently occur only in May and sometimes in June during snowmelt runoff (Troendle et al. 1998) with no detectable change during the balance of the runoff season. In addition, the largest increases in seasonal flow, following timber harvest, occur during the wettest years while the smallest increases in seasonal flow are usually associated with the drier years (Troendle and Leaf 1980; Troendle and King 1985, 1987; Troendle et al. 1998). These two factors mandate that adequate storage be available to make the increases in yield available when needed such as during periods of low flow. The slow growth rate of sub alpine vegetation makes hydrologic recovery following timber harvest, or the return to pre-harvest flow levels, quite slow (Troendle and King 1985; Shepperd et al. 1991) and makes the efficiency and cost effectiveness of water yield augmentation seem quite attractive, however.

DEVELOPING THE TECHNOLOGY

The classic watershed experiment, in terms of both the length of record and the duration of treatment response, has been the Fool Creek Watershed on the Fraser Experimental Forest, CO (Hoover and Leaf 1967; Troendle and King 1985). Following a 12-year calibration with the control watershed, East St. Louis Creek, approximately 40 percent of the 714 acre Fool Creek drainage was harvested in alternating clear cut and leave strips during 1954-1956. The average hydrograph before and after treatment is depicted in Figure 1. On average, total seasonal flow increased by 40 percent, average peak flow increased by 20 percent, and most of the detectable change in flow occurred in the month of May (Troendle and King 1985; Troendle et al. 1998). The largest peaks were not significantly increased and the largest increases in flow occur in the wettest or largest flow years (Troendle et al. 1998; Troendle and King 1985). In the case of Fool Creek, “bankfull discharge” increased from an average duration of 3.5 days prior to harvest to more than 7.0 days following harvest (Troendle and Olsen 1994). The most frequently occurring, or lowest, flows were not

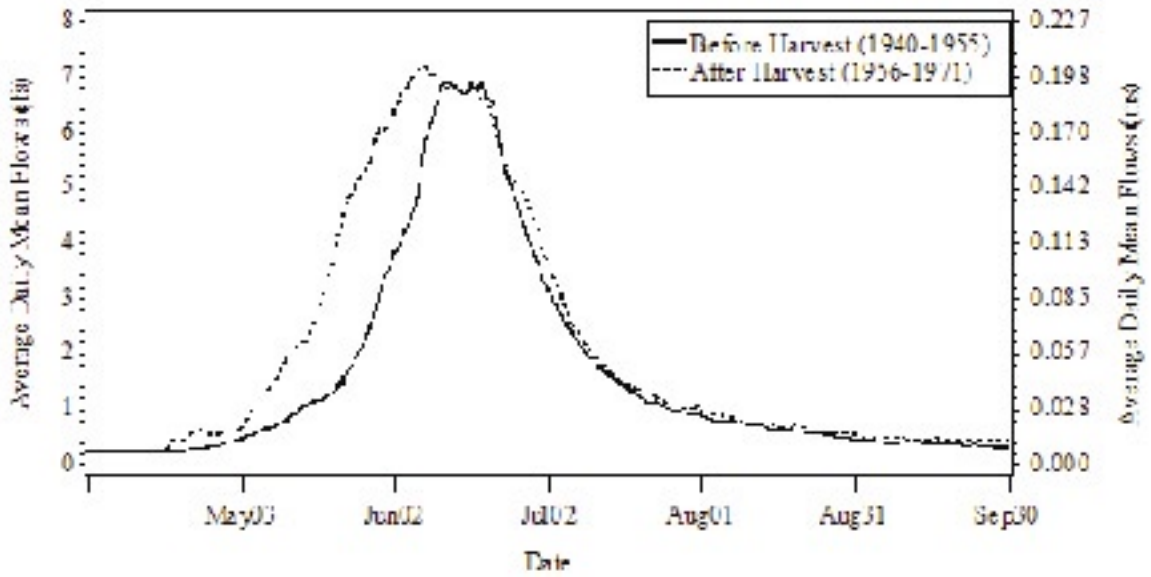


Figure 1. Seasonal mean daily flow for Fool Creek before (1940-1955) and after harvest (1956-1971).

affected by timber harvest (Troendle and Olsen 1994). The response at Fool Creek was similar to that of Wagon Wheel Gap and depicts the nature of the change that occurs when the forest in the sub alpine environment is disturbed by harvest, fire, or insect mortality. Fool Creek was harvested over 40 years ago and although the initial response to treatment has diminished as the Forest has recovered, full recovery is not expected to occur for yet another 25 to 30 years.

One of the more significant issues regarding water yield augmentation is the limited experience we have in applying research based technology at the landscape level in forest and wild land management. The last formal assessment of the potential for water yield augmentation through forest and range management was by the American Water Resources Association in the early 1980s (Ponce 1983). Douglass (1983), Harr (1983), Kattelman et al. (1983), and Troendle (1983) presented regional summaries of the opportunity to increase water yield through forest management based on what was ca 1980s technology. In a summary manuscript, Ponce and Meiman (1983) concluded that the opportunity to augment water yield through timber harvest, as a large-scale land management program, may not be as great as would be implied based on small research watershed results because of the diversity of land ownership patterns and the conflicting physical, biological, and administrative constraints associated with implementation of the technology. However, because of the limited supply and high value of water in the Rocky Mountain West, interest arose in the early 1980s in demonstrating that the water yield augmentation technology, demonstrated to work on small-scale experimental watersheds, such as Fool Creek and Deadhorse Creek on the Fraser Experimental Forest, could be applied at an operational or landscape scale by forest managers and yield similar results (Figure 1).

IMPLEMENTING THE TECHNOLOGY

A water yield augmentation initiative was implemented in the Rocky Mountain Region to demonstrate that research results from small watershed experiments could be extrapolated to the operational level. Coon Creek, on the Medicine Bow National Forest (MBNF) was selected. Located on the East Fork of Encampment River, Coon Creek was a large, uncut, and non-roaded watershed of the size necessary for evaluating the hydrologic impacts of a commercially viable timber sale while East Fork was a contiguous watershed of comparable size, aspect, and timber type, allowing a paired watershed study. The treatment watershed, Coon Creek, was logged by conventional harvesting methods using standard silvicultural practices (small clear cuts) of the times.

Initially the intent was to harvest approximately one-third of the Coon Creek watershed, as was done in research at Fraser Experimental Forest. However, this was an operational effort and technical considerations, as well as compliance with resource constraints imposed by the MBNF Forest Plan (primarily for minimizing impairment of visual quality as well as riparian and old-growth protection), reduced the opportunity for harvest. Although minimal in nature, these considerations and

constraints resulted in only 24 percent of the watershed area actually being impacted by either road construction or timber harvest.

Although the length of the post-treatment record for Coon Creek is short (5 years), the impact the treatment had on seasonal water yield is quite clear (Figure 2). Removal of vegetation from 23.7 percent of the area significantly increased flow by an average of 3.0 inches (Troendle et al. 1998). The increase is proportionally consistent with what has been observed to occur on small experimental watersheds elsewhere, and extrapolation of empirical estimates of change, based on process research at the Fraser Experimental Forest (Troendle and Reuss 1997), compare well with the observed changes at Coon Creek.

REGIONAL ASSESSMENT

The Platte River EIS is examining alternative approaches to improving river flows in the Central Platte River for four threatened and endangered species (target species). Many different approaches to increasing basin storage of waters, management of waters, and retiming of river flows are being examined. Among the alternatives suggested during the scoping process is the concept of increasing the timber harvest on National Forests in the headwaters of the Platte River as a means of augmenting the water supply. Troendle and Nankervis (2000) provided a reconnaissance-level analysis of the water yield that might be expected from such an action as well as an assessment of the current impact of past management activity on water yield in the North Platte.

Based on information provided by the U.S. Forest Service for the Medicine Bow, Routt, and Roosevelt National Forests; trends in forest stand condition, from 1860 to present, were described and hydrologic simulation used to model the affects of those stand projections, or trends, on water yield from Forest Service lands in the North Platte River Basin (Troendle and Nankervis 2000). In addition, using existing data and documents provided by the Forest Service, in concert with consultation with other Forest Service staff, Troendle and Nankervis (2002) determined the range of potential changes in water yield that could be obtained through prudent management of National Forest Lands on the North Platte River Basin. Proposed silvicultural prescriptions reflected the laws, regulations, and policies that empower, direct, and

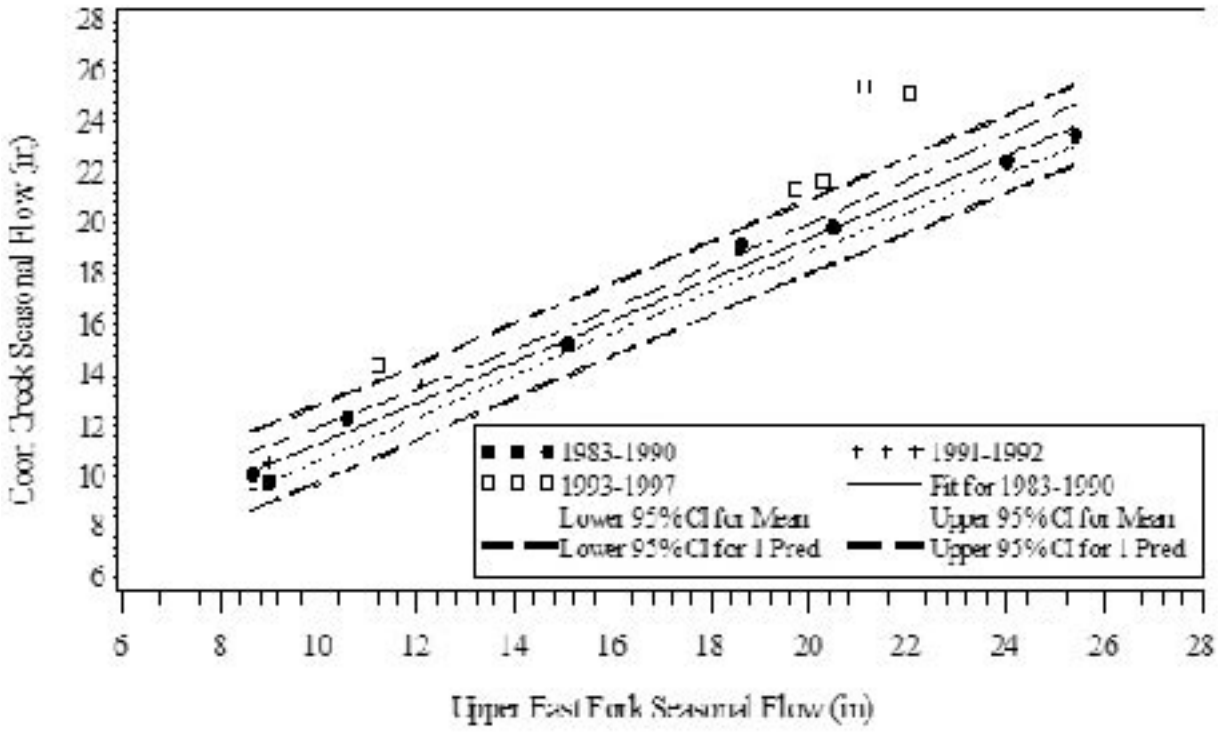


Figure 2. Seasonal water yield for Coon Creek watershed (harvested) plotted over that for the Upper East Fork (control). Pre-harvest, harvest, and post-harvest data are presented.

constrain vegetation management by the U.S. Forest Service. The objective of the exercise was to optimize timber production, maintain sustainability of forest ecosystem, and augment water yield as a secondary benefit.

Of the total 1,343,000 acres of National Forest Land (NFS) in the North Platte drainage, approximately 223,000 acres, or 16.5 percent of the total, is designated Wilderness. Approximately 391,000 acres, or 29 percent of the total, has been determined to be Unsuitable for Timber Harvest. Of the remaining 731,000 acres, 502,000 acres, or 37 percent of the total, is designated Suitable for Timber Harvest while the remaining 229,000 acres are considered Tentatively Suitable for Timber Harvest.

Less than one percent of the total 1,343,000 acres of Forest Service ownership is covered by water (8303 acres). Barren Area designation occupies 2.75 percent of the total area or 36,971 acres, while grasses occupy 5.8 percent or 77,729 acres. Brush dominates on 112,000 acres or 8.4 percent of the total NFS lands. Because of the minimal acreage occupied by cottonwood, the 122 acres were added to the acreage designated as water or "wet." In total, 227,511 acres or 17 percent of the total Forest Service ownership is classified as non-forest. The balance of NFS lands, 1,107,593 acres or 83 percent of the total ownership, is cover typed as forestland.

Specie composition on the forested land consists of 61,869 acres of aspen (5.6 percent of forested area), 12,257 acres of Douglas fir (1.1 percent of forested area), 11,546 acres of Limber pine (1.0 percent of forested area), 87,849 acres of ponderosa pine (7.9 percent of forested area), 306,000 acres of spruce-fir (27.6 percent of forested area). Lodgepole pine occupies 627,963 acres or 57 percent of the total forest area. Rocky Mountain Juniper occupies about 70 acres and was not considered further in the analysis.

Average size class of the individual stands further characterizes forest cover type. Size classes for each stand (polygon) consisted of N (non-stocked), E (seedlings 0.0-0.9" DBH), S (seedlings 1.0-4.9" DBH), M (saplings 5.0 -8.9" DBH), L (poles 9.0-15.9" DBH), and V (saw timber 16" + DBH). For purposes of further analysis, some of the classes were combined and four general size class categories were retained 1) non-stocked (N), 2) seedlings (E + S), 3) poles (M), and 4) saw logs (L + V). The lumping was necessary to coincide with the stand age data also provided by the Forest Service. Approximately one percent of all Forest Service land currently typed as forested is non-stocked (N), 10-11 percent is in the seedling stage (E+S), 30 percent is in the pole class, and the balance of over 55 percent is in the saw timber class (L+V). However, only two percent of the total forested area is occupied by saw timber stands that average 16" DBH and larger. The percentages are similar across all management classes (e.g. Wilderness, Suitable for Harvest, etc.).

Characterization of historical stand condition on National Forest land started with the current condition and worked backwards, in 20-year increments, to 1860. Numerous assumptions were made in the process. First, it was assumed that the average age of the forest, by stand size class, was a reasonable estimate of mean age for that size class. Individual plot data provided by the U.S. Forest Service, indicated that individual trees within the stands could be much older, for example than the 150-year mean age for Lodgepole pine saw timber. Personal communication with Dr. Wayne Shepperd (Research Silviculturalist, Rocky Mountain Research Station, Fort Collins, CO) supported the assumption. Second, it was assumed that as 20-years was subtracted from the current age of each stand, it remained in the same size class (and hydrologic condition) unless the new stand age fell below the midpoint in the range in years between the current size class and the next younger size class. Once past the mid-point between two age classes, the stand was moved to the next lower age class. If a size class was non-stocked, it was assumed that 20-years earlier it was a saw timber stand and the pattern repeated. In this way, the current size classes were projected back in time, at 20-year intervals, to the year 1860. Stand evolution or changes in specie composition that might also have occurred over time was not accounted for. The hydrologic model, WRENSS, was used to characterize the annual water yield for the forest conditions characterized at 20-year increments from 1860 to 2000 and the average annual water yield is presented in Table 1.

TABLE 1. Historical trend in water yield, all species.

Year	Water yield (area inches)
1860	14.8
1880	13.5
1900	14.4
1920	13.4
1940	12.1
1960	11.9
1980	12.1
2000	11.8

Evaluation of the trends in water yield as a result of the historical changes in stand structure and vegetation density was based on all NFS lands in the North Platte drainage that are currently occupied by forest. Nothing was assumed to have changed with respect to water, barren, grass or brush lands.

An evaluation of the current opportunities to increase water yield, through forest management, could only be done on that portion of NFS forestlands considered Suitable for Timber Harvest. In total, there are currently 502,000 acres of NFS land considered suitable for timber harvest. Of the 502,000 acres, 71 percent or 355,354 acres are lodgepole pine dominated. Spruce-Fir represents 25 percent, or 124,281 acres of the balance. The remaining 4 percent of the suitable acreage consists of ponderosa pine (14,179 acres), aspen (7,278 acres), douglas fir (764 acres), and limber pine (118 acres). Although insignificant in the water yield alternatives, the area in limber pine and Douglas fir was lumped with ponderosa pine and managed similarly.

Managing the 502,000 acres of NFS land on a 120-year rotation, using a silvicultural alternative most appropriate to each forest type; an additional 37,000 acre-feet of water could be realized by the year 2015. Maintaining the proposed rotations could result in a sustainable increase in water yield of 50 to 55,000 acre-feet of water per year by mid-rotation. Increases or decreases in the area considered Suitable for Harvest would result in a proportional increase or decrease in the potential flow change. The long-term potential increase equates to 0.11 acre-feet of water, or 1.3 inches, per acre of Suitable land. If, for example, the 227,000 acres of NFS land currently considered Tentatively Suitable for Harvest were included in the management rotation, another 16,000 acre-feet of water could be realized by year 2015 (Troendle and Nankervis 2000).

The Troendle and Nankervis (2000) estimate of 50 - 55,000 acre-feet of water represents the increase in flow that might be attained through reasonable and prudent management. However, at least 12 percent of all NFS forested lands are still below complete hydrologic utilization and these will continue to deplete the water resource as they mature. In the near term (next 30-50 years) the simulated increases will be offset, somewhat, by recovery in the younger, existing stands.

SUMMARY

Sound forest management can contribute to increasing stream flow. However, as noted, the increases in flow occur early in the runoff season and are greatest in wet years; both factors require adequate storage in order to make the water available when needed. As such, forest management is not a short-term fix for water yield deficiencies.

However, any change in forest density can result in a change in water yield. If density decreases as a result of timber harvest, mortality due to insect or disease, blow down, or fire stream flow will increase. Increases in forest density will result in decreasing stream flow. As a result, virtually every management decision will affect water yield, one way or another.

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QUESTIONS

Q: In your assessment, did you look at the fact that you probably increased density of vegetation in the last 20 years before the drought started, and how that would affect your calculations? I suppose you are assuming a static climate in terms of rainfall, because the runoff will obviously depend on how much precipitation you have.

A: All of our simulations were done based on average precipitation using the Oregon State climate map. There would be a lot of changes based on the amount of precipitation that you have in any given year. I guess in this particular case if I had to guess, which is what it would really be, I would argue that the increased density probably worsened the conditions to some degree.

Q: (Couldn't hear question)

A: We have two sets of data. On the one that I showed you, it only shows maybe a five percent decrease in the discharge. We are doing some more work now, because we are taking a second look at it. In that one, it is probably more, say from '60 to 2000. There, about 18-20 percent of the change that I indicated probably occurred during that period. From '60 to present it is becoming more apparent.

Q: But that doesn't account for the fact that you had ...

A: Yes, these are simulated based on average. If we had wet years, the difference would be even greater.

Q: Do you calculate a cost associated with that?

A: The answer is no, but I will talk anyway. No in the sense that I don't think anyone has taken a look at it in recent years, because the value of water has gone higher. There were studies that looked at this in the '80s. Tom Brown with the Rocky Mountain Research Station did some work, and John Crutilla, who was an economist with Resources for the Future, looked into it about 1980. He used Fool Creek as the example. His argument was that Fool Creek produces about 200 acre-feet of water per year increase. It goes downstream a couple of hundred meters and drops into a box going into the Denver Water Board collection system. His thinking was that that was worth $100/acre-foot when it went into that box, but we have never been able to get them to pay us. When Tom Brown did it, his conclusions were different. He didn't put a value so much on the water except the biggest value he had was for dilution purposes and also for hydroelectric power generation.

Q: Whose job would it be to get permission to do this? To take this further?

A: You mean get approval for timber harvest? It has to go through National Forest Systems. They are the administrators of the land. I guess what you have to do is make contact at the forest level or even at the regional level to try and get that into the scoping process. The question would be whether or not that would ever flow out at the end as a viable prescription for forest land.

Q: The water yield that you increase there, is that simply used . . .

A: It gets complex depending on the aspect and whole bunch of other factors of species composition. Basically, what we found, on average, is about one-half of the increase comes from a reduction in the transpirational use of water by trees in the summertime. Kill the tree and it stops using water, so what happens in the summertime is a savings onsite of about 5 to 7 centimeters of water that stays in the soil. The other part comes from a reduction in the winter interception losses, the interception of snow in the canopy, and the summer ET component is not aspect-dependent. We find that happens on north/south/east – it doesn't matter. The interception component is very aspect dependent and species dependent, because it is a function of surface area and direct solar loading. North slopes actually have the greatest effect. Most slopes you can increase the snowpack on the ground by as much as 50 percent on the north slope by reducing stand density. You can only increase it about 20 percent on a south slope, and that savings generally runs over. East and west slopes are about 35 percent.

WEATHER MODIFICATION/CLOUD SEEDING

Chips Barry, Manager
Denver Water

It is a little hard to be the last person in the day, although following Dick MacRavey it is always good, collected, and reasonable by comparison. I also learned something from Dick. Until today, I always thought Greg Hobbs was the Poet Lariat, and I find out that Poet Laureate is the right word. So, I have learned something here today, and I am going to be pleased to call Greg Hobbs the Poet Laureate next time I see him, just because that will be fun.

The topic that I am supposed to talk about is weather modification as that relates to drought. I know you all heard a lot about drought already today, so I will just hit a couple of highlights. I think you have heard this before, but it is insights from Denver Water about the drought so far. It is worse than 1954, '55 and '56, which is our design drought. We designed the system to get us through a drought like that; this one's worse. How much worse? We don't know. How do you measure a drought? It is a combination of severity, or intensity, and duration. We know this one is severe, or it is intense, meaning the level of precipitation is considerably less than we have ever seen in recently recorded history. What we don't know is how long it will last.

Our response to that, of course, has been a number of things. One, we had a great ad campaign and I hope you all saw it this year – little coasters and little signs that said things like, No water – no beer, It's a drought – do something. We had a couple of others that I loved: One was, Instead of a dishwasher, get a dog. We had another that said, Brush every other tooth, and actually, believe it or not, we got a letter from the American Dental Association complaining about that campaign, which tells me that some people do not have a sense of humor. The purpose of that campaign was to raise awareness about the fact that we have a drought and not be to doom-and-gloom about it. I think that as the drought persists, while we still are going to try not to be too doom-and-gloom, you won't see quite as much humor next year as you saw in the past. But I did really enjoy these little sayings. Another one was, Instead of washing clothes, don't wear any. I am told that one person on 16th Street Mall, when she saw our person with a sandwich board on, proceeded to take off all her clothes. I am sorry I wasn't there to see that, but it did prove to me that our advertising campaign is having an effect, although we can't measure it in acre-feet.

In any case, as you well know, the first thing you have to do when you get a drought is to conserve – you have to limit demand and you have to work hard on that. It is very important to that. But one of the things which we all know intuitively, even the environmental community, is that you cannot conserve your way to abundance. All you can do is reduce the rate at which you are using up your existing supplies. You cannot conserve your way to abundance. There is only one solution to a drought, and that is precipitation. Now, you just heard Chuck Troendle talk about one potential way to do something about precipitation and runoff, and there are a couple of other ways. One of the early ways suggested to us was that we simply ask Berthoud Pass, Arapahoe, Keystone, and Winter Park to run their snowmaking machinery longer. We submitted that to the CSU Experiment Research Station and asked them to tell us if that would work, and after a year-and-one-half of work they came back and said no, they didn't think that would work. So, we abandoned that idea. (I don't hear any laughter. You guys haven't figured out from the beginning that they use our water to make their snow and then we get it back? It works out real well for them and for us, but running those machines longer wouldn't do anything.)

So, you abandon the idea of running the snowmaking machinery longer. Then you go to the rain dance theory. But of course, in the Denver system we don't need rain – we need snow. I don't know anything about snow dances. I don't know if such things exist. Besides, even if they did exist, maybe that isn't politically correct anymore. I have diminishing faith in rain dances and snow dances, so that led me quickly to the third option, which is officially known as winter orographic snowpack augmentation, otherwise known as cloud seeding. It was done in Colorado on a very small scale experimentally by the Bureau of Reclamation in the '70s. It has been done by Vail for the last 15-18 years, and if they are putting money in it you know that they believe that it works. It was actually done, I am told, by Denver Water in 1977-78 for a short period of time.

What is cloud seeding? How does it work? It is a fairly simple process. I know that it works in a laboratory setting. You put something in a cloud that has the right composition in terms of temperature, moisture, etc., that causes more water droplets or snowflakes to form. You can do it with dry ice or with a number of different things. In fact, my own personal observation this year (and some of you may have noticed the same thing and not made the connection) is, after the Hayman fire, when there was a lot of smoke in Denver, we had rainfall which, in my view, was caused by the smoke. The fine particulates in the smoke caused more rain to fall than otherwise would be the case. I haven't actually asked anyone if that were true, but I am fairly convinced that it is.

As I say, you can do this with dry ice, with silver iodide. Silver iodide appears to be the most effective. You take silver iodide, dissolve it in acetone, burn it in a ground-based generator, and it goes up as a vapor into the sky. If you are doing this right, you obviously are seeding a cloud, not blue sky. You cannot see blue sky and have anything good happen. If you pick the right clouds, you can increase snowfall – that is the theory. I don't have any trouble believing it. Proving it to everybody's satisfaction is a little more difficult. I think the fact that it has been done in 28 countries across the world – some countries do this for summer weather, either to suppress hail or to increase rainfall. They usually do that with airplanes. I think that is a bit more difficult to control. You are talking about summer thunderheads which are a lot more volatile than the winter storms we see throughout Colorado.

Our proposal is that we will see clouds moving west to east; we will seed them anywhere from about 30 miles west of the Continental Divide to 15-20 miles east of the Continental Divide. You want to hit them and have them produce additional snow in the areas from which Denver Water collects its water. We have contracted with Larry Hjermstad, who runs Western Weather Consultants. He is the only cloud-seeding specialist in Colorado who has a history of doing work and doing it reasonably successfully. He has installed 41 new, ground-based generators for us. Those generators will run a maximum combined total of 26,000 hours of seeding time. Obviously, you must have clouds to seed. I don't expect we will get 26,000 hours. I think it would be great if we did, at least as long as we are seeding clouds and not blue sky; that would be terrific. The total cost of that program will not exceed $699,000.

In a frenzy of participatory democracy, I invited 22 other jurisdictions who share the same watersheds to participate financially in the program. I am happy to say that almost all of them have agreed to do so. I have gotten two nos, about 15 yesses, and about $200,000 so far. There is an interesting moral dilemma in the middle of this: in my letter to them, I said, "We would like you to participate. We all know we have a terrible drought. We think this will help. But if you don't pay, you get the water anyway." Now, where else in our collective or individual lives is that true? Nowhere, right? Isn't it, If you pay you get, and if you don't, you don't. This is a completely different deal, although Chuck, you raise the prospect that Denver Water has been getting the product of somebody's work for years. Maybe so, but in any case, the snow that is produced by winter orographic snowpack augmentation cannot be segregated or identified differently, and even if it could, I don't think the water rights system that Jack and crew administer could administer it differently. The fact is, everybody who may benefit – and there are a lot of people who may benefit from Denver Water's cloud seeding efforts – I have asked those with a conscience to pay and those without will get the water anyway.

I am looking forward to this. People say, "Does it work?" My usual answer these days is to point up to Mount Evans and say, "You see that white up there? It snowed, didn't it?" We got a permit – we had to go with an expanded permit from the Colorado Water Conservation Board – Larry Hjermstad had an existing permit. We expanded it to cover both more area and more time. We received that on November 1 and we began seeding on November 1. As you know, we have had a very good beginning to the snowpack this year. In all candor, I won't tell you that we can take credit for all that, and I don't know that we can take credit for any of it, but I think there is a good chance that we got more snow than we otherwise would have.

What the experts tell me about this augmentation process is that you don't make it snow more at A and less at B, although I have said many times I look forward to the cloud-rustling lawsuit from Kansas when it comes, but I don't expect to see it, because you make it snow more than it otherwise would have. It snows more at A and snows the same at B further downstream. I actually don't know how good the proof is about that, but I don't have any great difficulty believing it. They tell me that clouds are ten percent efficient, meaning when it snows, what you will normally get is ten percent of the potential moisture in that cloud that will fall as snow. If you seed it, you can push that up to 12 percent at the highest. So, there is still a lot of moisture left in the clouds as they go by. I guess that is right, when you think about it. You get

clouds that begin in the Pacific Ocean; they drop snow in the Sierras, and when they get here they have a lot left, fortunately for us.

So, that is sort of a general outline of our program. In terms of cost per acre-foot, our contractor tells us that he thinks the cost per acre-foot produced is in the $5 to $9 range. I think that may be true according to his calculations, but that assumes that all the additional snow that falls could be collected by Denver Water. I think that is probably not true. If we get a 10-percent increase in snowpack, that probably is in the range of $20/acre-foot. That is still very cheap water. Chuck was quoting $100/acre-foot for raw water. When we have extra raw water to sell, we will sell it at $160.

So, almost any way you cut this, if you get a 10-15 percent increase in snowpack, that is cheap water. Denver is proposing to do it this year, perhaps next year, and maybe even a third year. I don't think we ought to do it every year. I don't want to build into the system a reliance on this – I wouldn't say it is questionable technology – but it seems to me you would build in a reliance that ought not to be there. It is the other side of the coin from whether I think people should be allowed pump nontributary ground water as a permanent source of water for development. That doesn't make a great deal of sense.

QUESTIONS

Q: Are you doing anything to monitor weather modification practices to see whether they are effective?

A: Yes, we have signed a separate contract with a different weather modification expert, actually in Utah. In some ways I think it is similar to the kind of statistical analysis you have done on the forest management practices. There are a couple of ways you can try to see whether this works. One is basically a statistical analysis. Unfortunately, they don't make clouds in standard sizes – where you can seed A and not seed B and compare the results – it doesn't work like that. So, one way is a statistical analysis of a watershed that was seeded with an adjacent, companion watershed that was not targeted to see how much difference there is and compare past and present results along those lines. You can also do tests of the snow to see if there is silver iodide there, but you are talking about parts-per-billion, and that doesn't tell you much other than perhaps whether the area you targeted is the area you ended up seeding. We do have a contract to try to tell us how well we did.

Q: In the 1970s we had a contract here at Colorado State with Hubert Morel-Seytoux to see whether that Bureau program worked or not. Have you run across his work?

A: I remember the name and I remember seeing the report in the '70s, but when I went back to my collection of comic books and other paraphernalia under my bed, I couldn't find that study. So, we didn't look at it.

Q: In the 1970s the Northern Colorado Water Conservancy District had a program for a number of years and we used North American. There was very extensive monitoring of that pilot program. I think that could probably be made available to you.

A: I think your impression was that it did work. Somebody told me that there were some folks who did seeding but then, because the generators were on federal ground and you had to do an EIS, it got to be too complicated and people dropped it.

Q: I wrote that paper with Morel-Seytoux. I can get you a copy of it. We found out in targeting 20 years of data we couldn't find any difference. I know that for years France was looking at this to develop more hydropower and more productivity, and they gave it up. I think it is one of the biggest white elephants; the data is not there. I would challenge anybody to show statistically based data to show that cloud seeding will increase significantly the amount of runoff. We do know from studies in South Africa that cloud seeding decreases the size of hail and decreases crop damage, but as far as increasing the amount of runoff above the white noise that you get on a regular basis on just variations, it hasn't been found. Otherwise, France and other places trying to produce hydropower would be doing it. I am afraid a lot of countries are doing it with the hope that it helps. That is no basis for it – we need scientific proof, and in our work we couldn't find it.

A: As you have now heard, there is a range of scientific opinion on the question. In my view, the jury is out, but in this kind of a year with this kind of a drought, I felt, and so did the 15-18 other jurisdictions, that it was well worth an effort. There is no downside to doing it, and there may well be a decent upside.

CONCLUDING REMARKS – PREPARING FOR FUTURE DROUGHTS

Dr. Evan Vlachos
Department of Sociology
Colorado State University

First, I would like to honor Professor Salas. He started with a quote from Aristophanes, so I don't want to hear him telling me that "It is Greek to me."

In 'concluding' this conference, I would like to remind you that something is changing. Behind all our discussion about drought is the question we have to ask ourselves. I am familiar with paleodendrology and the archaeological findings of how things were. Even in ancient Athens there were tigers around, and it is a desert now because they cut the trees. What is different today in Colorado? It is the context. Context is a word that the futurists have found, and it is called "raplexity." It is rapid change and high complexity. What we have now are competing and conflicting groups, competing and conflicting ideas, and problems that occur very quickly and need a quick answer.

That brings us to the only analogy I will use from Greek mythology: namely, the Gordian Knot. As life becomes more complex, it reminds us of the Gordian Knot. That knot, as you may remember, was a knot that was very difficult to take apart. What did they do? Myth has it that he or she who could untie the knot would become Master of the Universe. Be it social welfare, taxation, Iraq, Saddam Hussein – whatever our problems are, they are interlocking. As the world becomes more globalized, the situation is analogous to what happened to Alexander the Great as he was passing through Asia Minor and saw the Gordian Knot. Everyone had tried, but no one could solve it. Alexander the Great, who at the age of 24 was a four-star general, thanks to his father the king, seeks to solve the Gordian Knot. The priests who keep the Gordian Knot (how will we survive with enough water, a comfortable life, and enough people in Colorado) ask, "Can you take it apart?" and he did it. He took his sword out of the scabbard and cut it apart.

What is the moral of this story, today, in Colorado, during a time of drought? As the problems become more and more complex, we seek simplistic solutions. Send in the marines! Increase taxes! Build a dam! What we are looking for is immediate relief from the uncertainty of a very difficult problem. This problem took some years to develop, and it is coming due now during a time of water shortages. The problem's solution involves how we organize our resources, our communities, and our economy. I heard fantastic data – how the skiers are suffering – and I am asking a simple question (if I offend you, please line up for the lynching): Why should we build, at the expense of many common projects, a skiing resort at the end of every canyon in the state? We have the question of threshold and carrying capacity facing us, especially with respect to our water resources.

Complexity and raplexity are happening. About 25 years ago Neil Grigg and I did a study that is giving us a feeling of deja vu – Drought Water Management. It included a comparison between western and eastern approaches to drought management – supply augmentation, demand reduction, or impact minimization. You try to do something to accommodate water shortages, but what impressed me is a word that has appeared over and over again: vulnerability. The environment and its resilience are being tested. This vulnerability has to do with a number of people – not only with a drought, but the perception of drought, and at the same time the capacity of the system to absorb the shocks that are not only about water, but that involve other events. This vulnerability is the result of a volatile, highly complex, highly competitive environment. As a result, we need to practice a vigilant strategy that I would call "risk management" and not "crisis management."

You have seen the cartoon on drought – it is not a hydrologic problem, it is a hydroecological problem. Simply, people forget quickly once it is gone. Like anything else, it doesn't bother us any more until it repeats. It is a periodic disaster, and part of this is that we are living not in water-short environments that are temporary: it is an arid, highly ecosystemically sensitive environment. I would propose, then, that we need to understand what has changed in our state, in the West, and all over the planet in terms of these highly complex, interdependent questions that we are discussing here. What is the resil-

ience of the ecosystem, and should we provide water ad infinitum for human use?

From what I have heard today, there are two fundamental conflicts in this room. One is cognitive conflicts: we disagree about the facts. Whose facts will we use? I am terribly confused – today I have seen more water and weather models and the 20 scenarios that they follow. What we have is the computerization of prowess. Thus, the first problem is what facts?

Second, we have stakeholder conflict. The agricultural interests are paramount. The ecosystem is paramount. Municipal needs are paramount. Parties of interest and those, of course, whose ox is gored, may take a particular interest in presenting data – the old, the young, citizens of the cities, etc. – but what is most important, underlying everything that we have here, is the ideological conflict – it is a world view between the Prometheans and the Cassandras.

Prometheus was the first engineer who stole fire from God and believed that technology, like the cavalry, will come to the rescue – full speed ahead, dam the torpedos – and that the world is not going to change by Buddhist chanting – it will be by the bright engineer who stands on Lookout Mountain and throws all of this dark cloud to Nebraska. It is terribly important to believe that trend is not destiny.

Then there are the Cassandras. Cassandra was the beautiful, wailing lady of Greek mythology. Zeus gave her the greatest gift: the ability to see the future. But, because Apollo asked her for a date and she declined, he cursed her. He couldn't take the gift of seeing the future away. He said, "Yes, you can foresee the future of Colorado, but no one is to believe you." And so they are out there, wailing in the wilderness, that what we have is the gloom doom, the coming not of evolution but devolution. And between these two, between stakeholders and the facts, we have now the futurists.

To sum up, the problem we have in Colorado is not experts giving us solutions. It is actively engaging in a common vision – empowered, participatory democracy and enactment. Everything that was said here is wonderful, but the problem is that we are treating it simply – as an expression of what we want to do with the future of this state, some of us by choice, others by chance, biological and otherwise, we are here. We need to keep one thing in mind: unless we practice a democracy of restraints, we will end up with a tyranny of constraints.

Drought forces us to reflect on the balance between restraint and constraint. I hope the meeting today provides much fuel for your reflection on how Colorado can prepare itself for future droughts.

Thank you.

COLORADO DROUGHT CONFERENCE:
Managing Water Supply and Demand in the Time of Drought

December 4, 2002
Colorado State University

POSTER ABSTRACTS

"An Integrated Assessment of the South Platte Basin," Jill Baron, Natural Resources Ecology Laboratory, Colorado State University. Abstract not available.

"Drought of 2002," Nolan Doesken, Department of Atmospheric Science, Colorado State University. Abstract not available.

"Secondary Water Systems for Landscape Irrigation: A Drought Mitigation Strategy?, by John Wilkins-Wells, Department of Sociology, Colorado State University; Stephen W. Smith, Aqua Engineering, Fort Collins, Colorado; and Terence Podmore, Department of Civil Engineering, Colorado State University.

"Landscape Irrigation: Sprinkler Application Efficiency," Stephen W. Smith and Scott Addington, Aqua Engineering Inc., Fort Collins, Colorado.

"Grey Water Recycling: Conserving Water, Saving Money," by Christine Marjoram, Dr. Larry Roesner, and Dr. Kenneth Carlson.

"Update on the Drought and Water Supply Assessment Project," Tracy Bouvette, Bouvette Consulting; and Brad Lundahl, Colorado Water Conservation Board.

"Drought in Colorado – A CSU First-Year Seminar Project," R.P. Fedel, C.M. Haines, N.S. Ksiazkiewicz, K.X. MacKnight, J.X. Schrader, R.J. Weidenkeller, with Dr. Sara Rathburn, Colorado State University

"Characterizing the Severity and Risk of Droughts of the Poudre River, Colorado," by J. D. Salas and C. Fu, Department of Civil Engineering, Colorado State University; D Dustin and D. Bode, Water Resources Department, City of Fort Collins; and Andy Pineda and Esther Vincent, Northern Colorado Water Conservancy District, Loveland.

"Deficit Irrigation Practices Yield 75 Percent Water Savings for Apple Orchards," by Todd Einhorn and Horst Caspari, Department of Horticulture and Landscape Architecture, Colorado State University.

"Water Conservation and Xeriscaping," by Mike Cook, Little Thompson Water District; and Roberta Depp, Berthoud Public Library. Abstract not available.

SECONDARY WATER SYSTEMS FOR LANDSCAPE IRRIGATION: A DROUGHT MITIGATION STRATEGY?

by
John Wilkins-Wells[1]
Stephen W. Smith[2]
and
Terence Podmore[3]

In the Rocky Mountain region, particularly in northern Colorado, the cost of water rights preferred by municipal and rural domestic water districts for potable water has risen dramatically. This has stimulated interest in developing parallel water systems for non-potable uses, such as for irrigating residential and commercial lawns and gardens, parks and recreational facilities. These are called secondary water systems. Both surface and ground water rights are used to develop these parallel secondary systems.

In many cases, the savings realized by the potable water provider in water treatment costs, and for the land developer in reduced water turnover requirements for potable water needs, can justify development of a secondary water system infrastructure. Meanwhile, long-term management and operation of these secondary systems may be provided by several different entities with differing results.

This poster describes both physical and organizational design considerations for secondary water systems in urbanizing areas. Issues to be discussed include the effect of secondary system development on water rights, what kind of entity appears most suitable for providing secondary water service, water rate structures for secondary systems, regional cooperation necessary for these systems to develop if desired by the community, and liability and other legal requirements. Physical issues include anticipated annual water requirements under secondary systems, water well and surface water delivery constraints on secondary systems, storage requirements for these systems, determination of peak demand flows for secondary water systems, pump station and control requirements, distribution system layout, service connections for residential/commercial customers, and secondary system operation and maintenance.

A perspective on the potential role of regional secondary water system development as a viable approach toward drought mitigation is presented, focusing on how canal companies serving agricultural water users can be strengthened and modernized through providing secondary water service to residential subdivisions coming into irrigated areas. This drought mitigation perspective includes revenues from secondary systems being used to pressurize and conserve more water during agricultural deliveries, while providing means for irrigated agriculture to adjust to urban encroachment onto prime irrigated lands. Case studies and exemplary design approaches will be referenced based upon several Rocky Mountain projects.

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LANDSCAPE IRRIGATION: SPRINKLER APPLICATION EFFICIENCY

by
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When drought occurs, and water restrictions are set in place, the rather poor application efficiency of many landscape sprinkler systems becomes quite evident. Sprinklers apply water in an inherently inefficient manner. Sprinkler spacing and suitable overlap result in patterns that can be described by several uniformity metrics. These metrics, such as distribution uniformity and scheduling coefficient, can be used during design to assist with optimal spacing and nozzle selection. Irrigation designers can use several metrics to improve their design, ultimately conserve water, and result in efficient application of water.

This poster describes sprinkler performance, both graphically and visually, and educates regarding the need for proper landscape irrigation design to achieve suitable application efficiencies with limited water supplies. Case studies and exemplary design approaches will be referenced based upon accepted industry standards.

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GREY WATER RECYCLING: CONSERVING WATER, SAVING MONEY

Harold H. Short Urban Water Infrastructure Laboratory
by
Christine Marjoram[1]
Dr. Larry A. Roesner, P.E.[2]
Dr. Kenneth H. Carlson, P.E.[3]

The seriousness of current drought conditions across the United States is prompting water suppliers and local governments to consider alternative methods for reducing both water demand and usage. Residential and commercial greywater recycling is a viable and sustainable solution to water demand issues that provides significant financial savings to both water utility managers and community members. However, few sates are actively practicing grey water recycling.

A prototype grey water reuse system that can be mass-produced and installed by municipalities at the residential and commercial level to reduce potable water demand and wastewater flows is proposed. For this project, grey water is defined as sink, shower and clothes washer discharges. Grey water recycling is predicted to cut residential demand by up to 30 percent and wastewater by 50 percent. Several significant benefits are anticipated. First, energy would be saved by reducing the demand for both treated municipal water supplies and the amount of wastewater that must be treated. Second, scarce source water supplies would be preserved by reducing municipal water demand. Finally, adverse impacts associated with municipal wastewater discharges would be the environment would benefit because.

The project has three distinct phases. Phase I involves re-plumbing two to five facilities (private homes and institutional/commercial establishments) to separate the grey water and redirect it to an appropriately sized storage tank. Over a three-month period, tank outlet flow and water quality will be monitored. Phase II develops and tests the prototype equipment package. In addition to the storage tank, this package consists of an irrigation pump, stirring or aeration device (if needed), and a UV disinfection unit if required. Pumped effluent from the tank will be monitored for solids, color, odor and pathogens before being discharged to the sanitary sewer. Phase III implements a pilot system to provide landscape irrigation. Also, as part of Phase III, tank size and components of the equipment package will be evaluated to determine the efficacy of designing a system that can be mass-produced for widespread distribution.

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UPDATE ON THE DROUGHT & WATER SUPPLY ASSESSMENT PROJECT

by
Tracy Bouvette and Brad Lundahl

This is the first statewide project to determine whether Colorado has enough water to meet its existing and future needs. The CWCB will utilize this assessment to reinforce its statewide advocacy focus on water issues.

The project consists of developing a target survey participant list of water users throughout the state and a survey instrument; conducting the survey; and ultimately developing an understanding of drought preparedness, carryover storage, and structural and non-structural project needs of the Colorado water community. The target survey participant list will represent each of the seven major water basins, or divisions, and each of the key segments of water users including agricultural, municipal, industrial, power, federal, and state. The survey will include questions addressing water use, water storage, concerns and limitations in water supply and water supply planning, and identification of water user needs for structural and non-structural solutions in periods of low water availability. The survey will be piloted to a small set of water users and then rolled-out to the larger community in January 2003. The survey will be completed by April 2003 such that the results will be available for the development of water policy and, water studies for FY2004. The survey will also be used to help the CWCB and DNR identify technical assistance needs to communities and agricultural interests.

Brad Lundahl – Brad is the Conservation and Drought Planning section chief for the Colorado Water Conservation Board (CWCB) and the current chairman of Colorado's Water Availability Task Force. Additionally, Brad is the project co-manager of the Colorado Drought and Water Supply Assessment - the first major statewide project to determine if Colorado has sufficient water to meet existing and future needs. Prior to his current position, Brad was the Assistant Director of Legislative Affairs for the Colorado Department of Natural Resources. He has also worked for the Arizona State Land Department and the Arizona House of Representatives. Brad earned a B.S. in Political Sciences from Utah State University.

Tracy Bouvette – Tracy is a principal at Bouvette Consulting. He specializes in water resources planning, policy and management. Tracy is currently co-manager of the Colorado Drought and Water Supply Assessment. He has also has been responsible for development of the CWCB's strategic and long-range plan. Tracy has over 23 years of environmental and water resources experience in the West and throughout the US. He has a B.S. in Civil and M.S. in Environmental Engineering both from Rice University. He also has a MBA from the University of Denver.

DROUGHT IN COLORADO – A CSU FIRST YEAR SEMINAR PROJECT

by
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ERCC192 - Fall 2002

With
Dr. S. Rathburn
Department of Earth Resources
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The population explosion which Colorado has experienced in the past 20 years has made available water even more valuable. Extensive construction of water transport systems in the past 150 years has brought water to areas along the Front Range, which otherwise would not be able to meet the needs of the population. Though the majority of students in our First Year Seminar in Earth Resources class are Colorado natives, a large minority come from out-of-state where water is not nearly as large of an issue. As part of our class project, we decided to learn more about the current water issues in Colorado, and to help educate other students on campus.

The poster will provide a variety of different charts, maps, and data regarding drought and the effects of drought around the state. This will be backed up with text explaining the information in greater detail. In addition a history of water use in Colorado and examples of past droughts and solutions will be presented. Finally, we provide our thoughts on ways to remedy future water shortages along the Front Range.

CHARACTERIZING THE SEVERITY AND RISK OF DROUGHTS OF THE POUDRE RIVER, COLORADO

by
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The planning, design, and operation of water resources systems generally take into account the vagaries of atmospheric and hydrologic processes particularly the occurrence of periods of surplus, floods, deficit, and droughts. For example, the design water supply capacity to satisfy the municipal consumption of a given city may be based on meeting water demands during a critical drought that may occur in a specified planning horizon (Frick et al., 1990). Many water related agencies in the western states (e.g. Cities' Water Departments, Water Conservancy Districts, etc.) are faced with the question of how critical or how severe the ongoing drought is. For example, the streamflows of the Poudre River, Colorado in the water year 2001-02 has been the lowest in the historical record and the ensuing water deficit in the three-year drought (1999-02) is the second largest deficit of any three-year drought on record. The implementation of water use restrictions in a given water district is very much related to the degree of severity that an evolving drought reaches at a given point in time. While this question has been typically answered using the Palmer Drought Severity Index (Palmer, 1985), the Standardized Precipitation Index (McKee et al., 1992), or the Drought Monitor (Svoboda et al., 2002), unfortunately they do not provide any information on the frequency or recurrence time of the drought nor the risk that specific drought events may occur in a given time horizon.

In this paper we use the concept of return period (mean recurrence time) to characterize the severity of extreme droughts. In particular, we focus on the ongoing drought that has been occurring in the Western United States and take as an example the annual flows of the Poudre River in Northeastern Colorado. We define the severity of droughts following similar concept as is commonly done regarding the severity of extreme floods e.g. a 500-year flood is a severe flood event and indeed is a very rare event. For analyzing the severity of droughts, we need to specify the drought event under consideration taking into account not only the duration of the drought but drought deficit or drought intensity, etc. More specifically, defining by L, D, and I to be the drought duration, deficit, and intensity, respectively, and by l_0, D_0, and I_0 specific values or thresholds, the following drought cases are considered: (1) $L = l_0 (l_0 = 1,2 \ldots)$ and $D > D_0$, (2) $L \geq l_0$ and $D > D_0$, (3) $L = l_0$ and $I > I_0$, and (4) $L \geq l_0$ and $I \geq I_0$.

One hundred and nineteen years of records (1984-2002) of annual naturalized flows for the Poudre River at the Mouth of the Canyon gaging station are available for the analysis. The first order autoregressive model was fitted to the historical data so that long term synthetic flow records can be generated. The fitted model was tested using well-known statistical tests and comparing key statistics obtained from the historical records and from the generated samples. In addition, drought severity, deficit frequency, and drought risk statistics obtained from the historical sample and from the generated samples were compared. The referred AR(1) model was used for two purposes: firstly for simulating a 50,000-year sample from which the return period of alternative drought events were determined and secondly for forecasting

the flows that may be expected for year 2003 and further evaluating the evolution of the ongoing drought.

The water demand threshold used for the drought analysis of the Poudre River has been the long-term sample mean, i.e. x_0 = 299,011 acre-ft. The Poudre flows in the four-year period 1999-2002 have been 384,158, 198,076, 199,946, and 95,000 acre-ft, respectively. Thus the current drought started in the year 2000, the accumulated deficit in the three-year period reached D_0 = 404,011 acre-ft, (i.e. $\beta = D_0/x_0 = 1.35$), and the drought intensity became I_0 = 134,670 acre-ft/year (or $\Psi = I_0/x_0$ = 0.45). The drought analysis results for the drought definitions and events specified as in (1) and (3) above showed that the current drought for the Poudre River has a severity of the order of 1,000 years return period and about 800 years for the drought defined as in (4). In addition, the risk that certain type of droughts may occur in a given time horizon n has been also determined for the four cases of drought definitions as described above and various values of n. For illustration, the risk that the ongoing three-year drought (i.e. 3-year drought with D > 404,011 acre-ft) will occur in a 25-year period is about 2%, and 11%, 38%, and 94% are the risks that three-year droughts with deficit coefficients β of 1.25, 0.75, and 0.0 will occur in the Poudre in a 25-year period. Note that the risk of 94% for $\beta = 0$ is simply the case of the occurrence of three-years droughts (regardless of the deficit).

DEFICIT IRRIGATION PRACTICES YIELD 75% WATER SAVINGS FOR APPLE ORCHARDS

by
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Two deficit irrigation techniques [Partial rootzone drying (PRD) and Regulated Deficit Irrigation (RDI)] were compared to determine the effects of water savings, via irrigation volume and placement, on fruit growth, shoot growth, stomatal conductance and plant water status for the apple cultivar 'Gala'. The irrigation treatments were a well watered control, 25% PRD, 50% PRD, 75% PRD and 50% RDI (all percentages are from Control volumes). Data from two years of field research in both Washington and Colorado as well as 5 years in New Zealand suggest that a savings of 50%-75% of control irrigation volumes can be achieved under PRD without negatively impacting fruit size. Stomatal conductance was significantly reduced to maintain favorable plant hydration status across all treatments. In Colorado all treatments achieved similar mean fruit weights at harvest. The use of soil moisture monitoring techniques to aid in irrigation timing also aided in the large water savings.

APPENDICES

Attachments for Dick MacRavey's Paper

Drought Conference Registrants

September 20, 2002

TO: Members of the General Assembly

FROM: The Economics Staff, (303) 866-3521

SUBJECT: Focus Colorado: Economic and Revenue Forecast, 2002-2008

In this report, we present the September 2002 General Fund revenue forecast and overview, the cash funds forecast, the projections of surplus TABOR revenues, and the national and state economic forecasts. We include two General Fund overviews: one with current law appropriations and transfers and one with a reduced appropriations level to prevent budget deficits. The forecast document is abbreviated from the usual publication length for budgetary reasons.

SUMMARY

- The forecast of General Fund revenues for FY 2002[03 was reduced by $252.2 million from the June 2002 estimate. There is not much evidence of an economic turnaround in Colorado thus far and the stock market declines are continuing. Additionally, the drought and wildfires are impacting travel and tourism to Colorado.

- Based on current law for appropriations, reserves, and transfers, as well as the Governor's budget restrictions ordered before FY 2002-03 began, an additional $388.3 million will be needed to prevent a deficit and maintain a two percent General Fund reserve in FY 2002-03. This compares with an estimated $133. 4 million needed reduction in the June 2002 forecast. The additional money could come from appropriations reductions or cash fund transfers and capital construction reductions similar to last year. If the FY 2002-03 reduction is entirely from General Fund appropriations, and additional $194.5 million will be needed in FY 2003-04 while maintaining a four percent reserve. If a combination of transfers and appropriations reductions are used in FY 2002-03, the needs for FY 2003-04 will be larger than $194.5 million.

- Total cash fund revenue subject to the TABOR revenue limit will increase 5.2% in FY 2002-03. The estimate for the current year was reduced by $60.9 million. The majority of the reduction occurred for tuition fees and taxes on workers compensation insurance premiums compensation insurance premiums and oil and gas production.

- Total revenues will be less than the TABOR revenue limit by $337.4 million in FY 2002-03. The growth dividend will eliminate an expected TABOR surplus in FY 2003-04 and reduce the expected surpluses for at least the following four years. TABOR surpluses will average $261.6 million from FY 2004-05 through FY 2007-08. When TABOR surpluses are expected, they will not be large enough for all refund mechanisms to by utilized.

GENERAL FUND REVENUE

This section presents a review of revenues in FY 2001-02 and the Legislative Council Staff outlook for General Fund revenues for FY 2002-03 through FY 2007-08.

Review of FY 2001-02. Revenue in the General Fund decreased a record 14.5%, or $952.3 million, in FY 2001-02. A deteriorating economy and a fall in stock values were largely responsible for the decline.

Colorado began to lose jobs in January 2001. While the average amount of the job decline was just over 1,000 during the first six months of 2001, the pace accelerated to a monthly average loss of 3,700 jobs during FY 2001-02. The hardest-hit sectors – manufacturing, data processing, and telecommunications – have earnings that are well above the statewide average. Thus, the types of job losses have had an even larger impact on state revenues.

The dismal performance of the stock markets has impacted tax receipts on capital gains. Capital gains increased at a 25.3% annual pace between 1991 and 2000. Although the state does not have data on capital gains income filed on the 2001 income tax return, the TABOR refund for Colorado capital gains declined 31% through August, compared with the same period last year. If this

decline is representative of all capital gains, the income tax reduction in FY 2001-02 that could be attributed to the stock market was nearly $200 million.

The economic recession, the terrorist attacks of September 2001, and a drought combined to severely impact tourism in Colorado. Because Colorado is a tourism leader, the state's revenue was heavily influenced by the tourism downturn.

Colorado is also a leader in the telecommunications and high-tech industries. The national slump in these industries again disproportionately affected Colorado. The loss of thousands of high-paying jobs and substantially lower bonuses greatly affected state income taxes. A significant portion of our use tax revenue comes from the telecom industry and the telecom downturn partially contributed to a 10.9% decline in use tax revenues in FY 2001-02.

Corporate profits nationally declined by nearly 14% during FY 2001-02. Again the state's mix of industries led to a larger impact on state corporate income tax receipts. Corporate income taxes declined 46% during FY 2001-02.

Two non-economic factors also contributed to the decrease in revenue last fiscal year. FY 2001-02 marked the first full year of the diversion of a portion of the state's income taxes to the State Education Fund (SEF) and a lower sales and use tax rate.

The General Fund Forecast. The Colorado economy has likely bottomed and will show gradual signs of improvement in FY 2002-03. However, this will not be reflected in significantly higher General Fund revenues in FY 2002-03. The outlook is for a 1.5% increase in General Fund revenues. After FY 2002-03, we estimate that General Fund revenue will increase at an annualized pace of 7.1% during the remaining five-year period after the previous Colorado recession that ended in 1987.

We reduced the previous General Fund forecast by $252.2 million for FY 2002-03. At the time of the last forecast, the wildfires in Colorado were just beginning. Additionally, the drought situation became worse. These two factors contributed to a lackluster summer tourism season and led to reduced sales tax receipts. The stock market indices have declined more than expected and will likely lead to weaker-than-expected capital gains realizations this year. After showing signs of a turnaround in April and May, the first employment gains since December 2000, the labor market once again shed jobs in June and July. While employment rose again in August, the state economy is slow in entering a solid recovery phase. As evidenced by wage withholding taxes, wage gains have also been less than expected. In fact, overall wage gains may be nonexistent at this point.

Individual income taxes will increase by 2.4% in FY 2002-03, following a 16.7% decline in FY 2001-02. The previously mentioned factors of a lagging recovery for jobs, weak wage gains, and the poor outlook for capital gains realizations are contributing to another poor outcome for this tax source. Other factors that will contribute to the small increase include interest and rectal earnings. The outlook for individual income taxes is more positive after FY 2002-03 when receipts are estimates to increase at an average annual pace of 8.0%.

Corporate income taxes will increase 23.4% in FY 2002-03. The strength will be largely due to positive accruals. In FY 2001-02, the accrual process reduced cash-basis receipts by $27 million. In FY 2004-05, corporations will begin to pay additional taxes because the time period for the accelerated depreciation provisions of this spring's new federal tax laws will have ended.

Sales taxes have decreased in six of the last seven months, compared with the previous year, dropping 3.7% during that time. The last extended period of sales tax declines was in Colorado's last recession in 1986 and 1987. We estimate that sales Tax revenues will increase 0.9% in FY 2002-03. A stronger national economy and a dwindling impact of the terrorist attacks on willingness to travel will boost tourism later this fiscal year. However, if the drought continues into the winter months and the mountain snowpack is below average, sales tax receipts will suffer. After the state's economic recovery is more solidly in place in mid-2003, sales taxes will increase at an average annual pace of 5.9% through FY 2007-08.

In the June forecast, it was not anticipated that there would be an over-refund of the FY 2000-01 TABOR surplus during FY 2002-03. This was based on the trend of the TABOR refund to that point and what was expected to be refunded during the remainder of 2002. We now estimate that the total refund would be approximately $37 million below the required $927.2 million. However, an administrative decision was made to count $69.6 million of the over-refund of the FY 1999-00 surplus that occurred during FY 2001-02 as satisfying the $927.2 million requirement. Thus, we now estimate that an over-refund of $32.3 million will occur during FY 2002-03.

Another year of a decrease for use taxes will occur in FY 2002-03. The tax is highly correlated to activity in the telecom and construction industries. Construction and telecom investment will be down again in the state this fiscal year. More typical growth rates will occur after FY 2002-03.

Estate taxes will be affected by a change in federal tax laws beginning in FY 2002-03. The federal government is phasing out the credit for state estate taxes that can be used on a federal estate tax filing. This will flow through to Colorado's estate tax. The Colorado estate tax will no longer be effective for persons who die after 2004. After FY 2005-06, the estate tax should be completely eliminated, though the state will likely collect minimal amounts for several years from delinquent filings and reassessments of property asset values.

Insurance premium taxes have surged over the past three years. A relatively large increase will occur again in FY 2002-03. We expect that gross taxes will increase by 8.0%. This gain will be partially offset, however, by a tax credit that may be claimed by insurance companies that make an investment of certified capital in a certified capital company. The capital companies will provide investment funds to companies that create jobs in Colorado, with an incentive for investment in rural and distressed urban areas.

Gaming taxes that are credited to the General Fund will increase 16.2% in FY 2002-03. A portion of gaming taxes and fees spill over into the General Fund after allocations to the Division of Gaming for their administrative costs, the Tourism Promotion Fund, the State Historical Fund, the gaming counties and cities, and to the State Highway Fund (SHF) for road improvements in gaming areas. The 16.2% increase in FY 2002-03 is attributable to a decrease in the appropriation from gaming revenues to the SHF for use in road projects near the gaming communities. While $4.8 million was appropriated in FY 2001-02, only $1.0 million was appropriated for FY 2002-03. The estimate for FY 2003-04 includes an appropriation amount of $4.2 million to the SHF. If the requested amount of $10.8 million by the Colorado Department of Transportation is granted, the amount of gaming revenue that accrues to the General Fund will be $6.6 million lower than indicated in this forecast.

CASH FUNDS REVENUE FORECAST

Total cash fund revenue subject to the TABOR revenue limit will increase 5.2% in FY 2002-03, and increase at an average annual rate of 4.5% over the forecast period. We decreased the forecast of cash fund revenues by $60.9 million in FY 2002-03 and by a total of $200 million between FY 2002-03 and FY 2006-07. The largest decreases occurred in higher education tuition, taxes on workers compensation insurance premiums, and oil and gas severance taxes. The forecast for unemployment insurance taxes contributed to a lower overall forecast in FY 2002-03 through FY 2004-05, but a higher overall cash fund forecast in FY 2005-06 and FY 2006-07. Table 2 presents a summary of all cash fund revenue subject to the TABOR revenue limit.

Total cash fund revenue subject to the TABOR revenue limit decreased 6.1% in FY 2001-02. The decline in revenues is a direct result of an accounting change required by the Governmental Accounting Standards Board (GASB) that reclassifies higher education scholarship allowances from tuition revenue to TABOR-exempt non-tuition revenue starting in FY 2001-02. Without the accounting change, overall cash fund revenue would have remained essentially flat, falling 0.6%.

Transportation-related cash funds, which include the Highway Users Tax Fund, the State Highway Fund, and several smaller funds, will increase 2.4% in FY 2002-03, and at an average annual rate of 2.7% between FY 2001-02 and FY 2007-08. The HUTF will increase 2.5% in FY 2002-03 and at an average annual rate of 3.3% over the forecast period. Motor fuel tax revenue will slow somewhat to a 2.0% increase in FY 2002-03, and grow at an average annual rate of 3.1% through FY 2007-08. Vehicle registration fee revenues will grow at a slow 0.8% in FY 2002-03, and at a healthier average annual rate of 3.5% over the forecast period. Revenue to the State Highway Fund, comprised primarily of interest earnings and matching funds from local governments for projects partially-funded with state dollars, will decrease 1.7% in FY 2002-03 and at an average annual rate of 7.4% over the forecast period. Although we expect State Highway Fund revenues to decrease, they are decreasing from a historically high level due to high levels of matching funds from local governments for projects accelerated with the use of Transportation Revenue Anticipation Notes. Meanwhile, the Senate Bill 97-1 diversion will not be funded. While House Bill 02-1310 and Senate Bill 02-179 allowed for additional funds for the State Highway Fund, there will be no money available in the excess General Fund reserve for transfer to the State Highway Fund for the entirety of the forecast period.

Higher education cash fund revenue decreased 9.7% in FY 2001-02. This was due to an accounting adjustment pursuant to the GASB statements 34 and 35, that

required public higher education institutions to report scholarship allowances as transfers rather than revenue. Without this accounting adjustment, revenue to the higher education cash fund would have increased 8.6%. The adjusted growth in the higher education cash fund was due to strong enrollment increases from workers affected by the economic slowdown. Enrollment increased 4.0% in FY 2001-02, the strongest gain in 12 years. The state community college system led all governing boards in enrollment gains in FY 2001-02 with a 5.2% growth rate. Following a national trend of strong enrollment gains in community colleges, this was the strongest growth in Colorado's two-year college system in 10 years.

FY 2002-03 revenue will post a strong gain with an 8.1% growth rate in combined tuition and nontuition revenue (net of scholarship allowances) and a 1.2% growth rate in enrollment. While enrollment gains will be much lower in FY 2002-03, the growth rate for revenue will be comparable to FY 2001-02 because of larger tuition increases. Once the economy recovers in 2003 and job growth improves, enrollment and revenue growth will taper. Over the six-year forecast period through FY 2007-08, higher education revenues will grow at a 5.4% average annual growth rate. Meanwhile, public higher education enrollment, based on the number of resident full-time-equivalent students, will increase at an average annual pace of 1.3% over the forecast period.

While total unemployment insurance (UI) revenue will increase at an average annual rate of 6.5% over the forecast period, the pattern of growth will vary. Total UI revenues will increase significantly in the first four years and then decrease substantially during the last two years of the forecast period. The pattern is due to the appreciable increase in UI tax rates and consequent UI tax revenue during the coming years. These result from explosive growth in benefit payments in FY 2001-02. UI tax revenues will increase 21% in FY 2002-03 following 165.7% growth in benefit payments to UI claimants in FY 2001-02. Despite the strong growth in UI taxes, this represents a decrease in the forecast relative to the June forecast because the solvency tax will not be effective until 2004, one year later than expected in June. The solvency tax will not go into effect as expected in 2003 because of a one-time transfer of $142.7 million from the Federal UI Trust Fund into Colorado's UI Trust Fund. The solvency tax will be effective from 2004 through 2006, generating a total of $555.3 million between FY 2003-04 and FY 2006-07. Meanwhile, the UI fund balance will not be large enough to allow the 20 percent tax credit in 2003 through the remainder of the forecast period.

Limited Gaming Cash Fund revenue, which includes gaming taxes and license fees, will increase 6.8% in FY 2002-03 after increasing 7.7% in FY 2001-02. The recession and a saturation point in the industry will slow growth in gaming taxes from the double-digit pace experienced during the last half of the 1990s. Total gaming revenues will increase at an average annual rate of 7.8% between FY 2001-02 and FY 2007-08.

Total severance tax revenue, including interest earnings, will decrease 10.6% in FY 2002-03 following a 23.1% decrease in FY 2001-02. However, the level of severance taxes will remain healthy by historical standards. Oil and gas severance taxes will decline 13.9% in FY 2002-03, after a 31.0% decrease in FY 2001-02 and a 112.1% increase in FY 2000-01. Between FY 2001-02 and FY 2007-08, total severance tax revenues will increase at an average annual rate of 1.5%.

Interest earnings to the Controlled Maintenance Trust Fund (CMTF) fell from $18.4 million in FY 2000-01 to $0.5 million in FY 2001-02. Earnings to the fund will be at more normal levels beginning in FY 2004-05 when General Fund repayments to the CMTF are complete. Interest earnings to the Capital Construction Fund will also be historically low in FY 2002-03, falling from $17.5 million in FY 2001-02 to $6.9 million in FY 2002-03. Revenue to the insurance-related cash funds will fall 2.6% in FY 2002-03 as a result of an expected 10.2% decrease in premiums on workers compensation insurance policies and lost interest earnings due to the transfer of $75 million from the Major Medical Fund to the General Fund. Finally, after falling 9.8% in FY 2001-02, all other cash fund revenue will decrease 1.8% in FY 2002-03 and increase at an average annual rate of 4.6% over the forecast period.

THE CONSTITUTIONAL REVENUE LIMIT – TABOR

The provisions of Article X, Section 20 of the Colorado Constitution (TABOR) require that revenue collected above the TABOR limit be refunded to taxpayers within one year after the fiscal year in which they are collected. TABOR limits annual growth in most state revenue to inflation plus the annual percentage change in population.

An important change was made by the General Assembly as to how future TABOR surpluses will be determined. During the 1990s, the federal government underestimated Colorado's population. Therefore, the state refunded $483 million to taxpayers under TABOR

that would not have been refunded if the proper population estimates had been made. TABOR allows for the limit to be adjusted each decade in accordance with the Census count.

The General Assembly determined that the appropriate way to make that adjustment was to use the official percentage change in the state's population (6% between July 1, 1999, and April 1, 2000) in the TABOR limit for FY 2001-02 and then measure the amount that revenue comes in below that limit. This effectively incorporates the underestimate from the 1990s. The percentage points of population growth in the limit that are not used in FY 2001-02 can be carried forward into future years and used to increase the limit in those years until such time as all of the population percentage change that was carried forward is used or a new Census is conducted. The carry-forward of the population figure to future TABOR calculations has been commonly referred to as the growth dividend.

The change was made because the state did not have a TABOR surplus in FY 2001-02. Revenues were $337.1 million below the adjusted revenue limit. Revenues will be below the TABOR limit and again lead to a lack of a TABOR surplus in FY 2002-03. Revenues will be above the TABOR revenue limit in FY 2003-04. However, use of 4.5 percentage points of the growth dividend will eliminate the expected surplus for that year. The growth dividend will allow the state to retain an additional $353.1 million in FY 2003-04 and $497.3 million in FY 2004-05. The additional revenue will increase each year as long as a TABOR surplus exists. TABOR surpluses will resume in FY 2004-05 and average $261.6 million through FY 2007-08. Table 3 shows a detailed calculation of the TABOR limits and surpluses.

Based on the relatively small amounts of projected TABOR surpluses from FY 2004-05 through FY 2007-08, only a few of the 19 methods to refund TABOR surpluses will be used. When adopting refund methods, the General Assembly considered that surpluses would be relatively low in some years and implemented threshold levels for 18 of the 19 refund methods. For the FY 2004-05 surplus, only the earned income tax credit and sales tax refund will be used. In addition to these refund methods, the foster care refund, the business personal property tax refund, and the individual development account refund will be used in the next three years.

GENERAL FUND OVERVIEW

This section presents a review of the recently concluded fiscal year and the outlook for the General Fund balance.

Review of FY 2001-02. With the $952.3 million decline in General Fund revenue in FY 2001-02, many budget actions needed to be taken. In the legislative special session in October 2001, capital construction transfers were reduced by $219.3 million and the Senate Bill 97-1 diversions were eliminated for the remainder of the fiscal year for a decrease of $160.2 million. General Fund appropriations were reduced by an estimated $139 million from the original appropriation amount. The General Assembly passed several bills that transferred $482.7 million from 24 cash funds to shore up the General Fund. Table 4 shows the amounts of the transfers.

Other budget actions by the General Assembly included:

- allowing participating public hospitals to pay $11.2 million to the state in a Medicaid refinancing;
- allowing the interest earnings from the Capital Construction Fund to be credited to the General Fund for FY 2001-02;
- delaying the payback of the Controlled Maintenance Trust Fund to future years;
- transferring $53.5 million from the Capital Construction Fund to reflect a reduction in construction projects that were less than 25% complete; and,
- eliminating the General Fund reserve requirement.

A recent decision was made regarding the $69.6 million over-refund of the FY 1999-00 TABOR surplus in FY 2001-02. Because the required FY 2000-01 surplus of $927.2 million would not be fully refunded based on current estimates, the $69.6 million will be counted against the refund shortfall. This bolstered the General Fund reserve by $69.6 million in FY 2001-02. The decision is currently under review by the Office of the State Auditor.

The budget reductions, transfers, and other decisions resulted in a General Fund reserve of $165.3 million for FY 2001-02. This compares with reserves of $786.8 million and $469.3 million in the previous two fiscal years.

The Outlook for the General Fund Overview. Table 5 presents the General Fund overview after incorporating the revenue forecasts, any expected TABOR surpluses, and other expenditures from the General Fund. The overview incorporates the Governor's vetoes of line items in the annual budget bill that reduced General Fund appropriations by approximately $45 million and a reduction of available revenues of $130.6 million that resulted from the paybacks to cash funds. However, the overview in Table 5 does not account for a budget restriction of $139.9 million ordered by the Governor in June 2002 and other savings that will total $30.1 million.

The weak economy and resulting General Fund revenues will place ongoing pressure on the balance of the General Fund. Table 5 indicates deficits for the General Fund reserve balance. The deficits will grow to over $3 billion. However, the Colorado Constitution prohibits a deficit. Thus, further actions will need to be taken for the FY 2002-03 and FY 2003-04 budgets.

While an option to transfer balances from other funds will help the General Fund, the transfers provide only a one-time savings for the General Fund. For example, if only additional cash funds are transferred to the General Fund in combination with the Governor's actions thus far, the budget deficit would still approach $3 billion in FY 2007-08. In order to provide continuing savings, another option is to reduce General Fund appropriations.

Table 6 shows a General Fund overview that incorporates the Governor's restrictions that will save $170 million and indicates the necessary additional reductions in General Fund appropriations to prevent budget deficits. The additional reductions would need to be $388.3 million for FY 2002-03 and $194.5 million for FY 2003-04. These figures assume that a two percent and four percent reserve would be maintained for the two years, respectively, and that all reductions are made from General Fund appropriations.

If the additional reductions are made, they will create the ability to pay back selected cash funds and resume the diversion of sales and use tax revenue to the Highway Users Tax Fund (HUTF) beginning in FY 2004-05. The payback of the cash funds is contingent on available monies and totals $69.6 million in FY 2004-05 and FY 2005-06. Through FY 2005-08, the diversion to the HUTF would total $966.4 million. Additionally, funds would be available for additional transfers to other funds beginning in FY 2005-06. House Bill 02-1015 provided for the transfer of up to $25 million annually to a reserve fund to eventually establish the resumption of accrual accounting procedures for the TABOR refund. The transfer will occur only when there is money available in the General Fund excess reserve. House Bill 02-1310 and Senate Bill 02-179 provided that when money is still available in the excess reserve, two-thirds will be transferred to the Highway Users Tax fund. The transfers to the TABOR refund reserve, HUTF, and CCF would total $75.0 million, $202.2 million, and $101.1 million, respectively, from FY 2005-06 through 2007-08.

NATIONAL ECONOMY

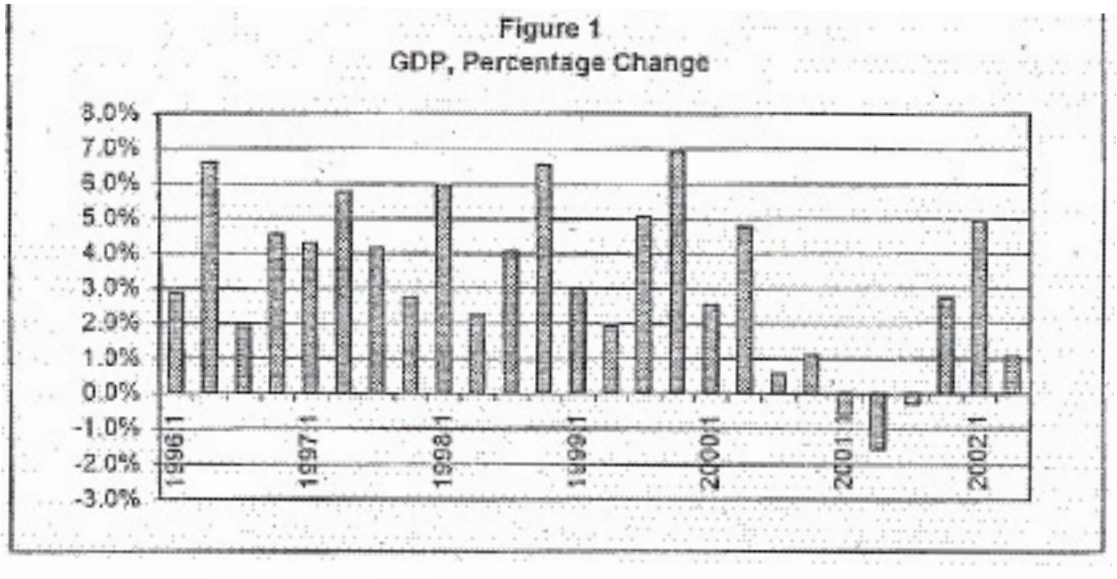
This section provides a review of the recent performances of the national economy and the national economic forecast.

Recent Data. The declaration of a recession by the National Bureau of Economic Research was confirmed by the release of revised economic data. Inflation-adjusted gross domestic product (GDP) declined for thee consecutive quarters beginning in the first quarter of 2001, thus confirming the standard definition of a recession – two of more consecutive quarters of a decline in GDP. Prior to the revision, the data indicated only on quarter of decline.

The economy rebounded in a solid fashion after the output declines and the shock of the September 11 terrorist attacks. The rebound was attributable to high growth in federal defense spending and consumer spending spurred by zero- or low-interest rate financing. However, worries about the strength of the recovery returned when GDP increased at a 1.1% annual rate in the second quarter 2002.

Consumer spending slowed to a 1.9% annual pace during the second quarter, following gains of 6.0% and 3.1% in the prior two quarters. The slowing was to be expected as much of the earlier strength was "borrowed" from the future because of the low interest rate environment that was specifically targeted to boost consumer demand after September 11. Consumer spending surged in July and August as auto sales were boosted by the resumption of low interest rate financing. Recent spending trends are somewhat at odds with steep declines in consumer confidence in July and August.

Investment spending has declined for seven consecutive quarters. However, the decline in the past two quarters has not been as severe as the early part of the investment contraction. Business investment in equipment and software advanced 3.1% in the second quarter, showing the first gain in seven quarters. Additional gains in this



category will be necessary for a continuation of the economic expansion. High vacancy rates have pulled down nonresidential building investments, leading to annualized double-digit declines for the past three quarters. Credit conditions have deteriorated in recent months as bank loans to commercial and industrial firms have declined and new corporate bond issues became tougher in light of weak or nonexistent corporate profits and accounting scandals.

Government spending grew at a 1.4% annual rate during the second quarter. The increase was much lower than in the previous two quarters when federal defense spending jumped in response to the terrorist attacks of last September. Defense spending is slowing down, while state and local government spending is increasingly strained by the economic slowdown.

The manufacturing sector had the initial signs of economic weakness in late 2000 and started to recover in early 2002. The sector, as measured by the Institute for Supply Management index, has turned in a tepid performance for the past two months. The index was at 50.5 in July and August, barely above the 50 level that marks an expanding manufacturing sector. The indices for backlog orders and new orders were below 50 in August, indicating that difficult times are ahead for manufacturing.

The economic recovery has not affected the jobs market in a significant positive way as of yet. The number of initial claims for unemployment benefits has been trending up recently, not improving significantly from the early months of last year's recession. The most recent report available at the time of this forecast indicated that jobless claims reached a 41/2 month high in early September. Job creation is lagging as only 162,000 jobs have been added in the past four months. This compares with close to 200,000 additional jobs monthly during the height of the last expansion. The lagging recovery of the labor market indicates the uncertainty of businesses and their efforts to contain costs. One positive aspect of August's jobs data was the increase in temporary help jobs, a leading indicator for economic expansion.

The housing market is one of the bright stars in recent economic performance, buoyed by low interest rates. Sales of both new and existing single-family homes have been at or near record highs in recent quarters. Housing starts were at a 15-year high earlier in 2002. The low interest rates have enabled many homeowners to refinance their mortgages, often taking cash out from equity gains. Refinancing activity may match or exceed last year's record amount. Mortgage rates on a 30-year loan were recently at 6.15%, the lowest rate since reliable records have been kept. This will likely stimulate additional refinancing activity. However, the refinancing activity may not have the impact of last year. A shorter interval between peaks in refinancing means that cash-out amounts are only one-third of year-ago levels. Moreover, the percentage of cash-out equity that is spent is estimated at 40%, compared with 60% last year, according to estimates by Lehman Brothers. Housing indicators will likely suffer in upcoming months when interest rates begin to rise. However, housing should remain healthy overall.

The National Forecast. The following highlights summarize the national forecast. The detailed national economic forecast can be found in Table 7.

- Although the risks for a double-dip recession ebb and flow with each release of monthly economic statistics, the nation will likely avoid another near-term recession. Inflation-adjusted gross domestic product (GDP) will increase 2.3% in 2002, following a revised gain of a minuscule 0.3% for last year. The economy will improve even more in 2003 with a 3.1% increase for GDP. Low interest rates and special zero-interest rate financing for cars and light trucks will boost consumer spending by 3.1% in 2002, compared with 2.5% in 2001. Spending on durable goods in 2002 will compare favorably with 2001. While increases in durable and nondurable spending will tail off in 2003, a 4.0% increase in services spending will lead overall consumer spending to a 3.2% gain next year. The long slide in fixed investment will end in the fourth quarter of 2002 with a small gain. However, 2002 will end up with a 3.5% drop, following a 3.8% decline for fixed investment in 2001. 2003 will see a very welcome 2.4% increase, however, though still far below the rapid pace of the mid- to late-1990s.

- Increases in nonfarm employment will lag the general economic recovery. Jobs will decline by 0.8% in 2002, following a meager 0.2% gain last year. The economic recovery will gradually boost business confidence, leading nonfarm employment to a 1.1% gain in 2003. The unemployment rate will average 5.9% in 2002 and 2003.

- The weak national economy will hold the inflation rate to 1.6% in 2002. The national and world economies will likely have surplus capacity again in 2003. Thus, businesses will have little cause to raise prices, limiting the inflation rate to 2.0% next year.

Risks to the National Economy. Consumer spending constitutes two-thirds of the nation's economic output. The resilience of the consumer prevented the recession from being more severe. However, the resilience could come to an end if consumer confidence continues its recent three-month decline. Potential causes of further erosion of consumer confidence include an extension of the recent stock market slide and another terrorist attack. An on-going jobless recovery would further exacerbate the consumer debt load and the recent 30-year high for home foreclosures. A prolonged weakening of spending would raise the risk of a double-dip recession.

Business spending has declined for the past seven quarters. Business investment will continue to lag until corporate profits recover. Additionally, business spending is at risk if investors are troubled by additional accounting scandals.

Oil prices have risen in recent weeks, though remain in an acceptable range at this point. A war in Iraq would remove a significant amount of oil supply from the market and would likely boost oil prices significantly in the short run. Recovering economies could sustain a substantial shock under this scenario, placing further recovery in danger.

COLORADO ECONOMY

This section provides a review of the recent performance of the Colorado economy and the economic forecast for the state.

Recent performance. Anticipated improvement in the Colorado economy has yet to materialize. The state is mired in recession after seeing the fastest growing parts of the local economy in the 1990s take the biggest hits during the recession. With all of the major stock markets down again in the current year and unable to find any sustained gains, Colorado's financial sector has been hit hard again this year. The markets' pain has spread through other top sectors in Colorado. The technology-heavy NASDAQ market is down 70% from its peak two and one-half years ago. This has impacted both existing businesses in Colorado and potential startups. Venture capital has dried up in Colorado, falling 90% in this year's second quarter from its peak in the second quarter of 2000. Meanwhile, business investment in all sectors is very weak as businesses take a cautious wait-and-see attitude towards the economy. These factors, combined with tremendous over-capacity and accounting/regulatory problems in the telecommunications industry, have led to significant layoffs in the state as all of these sectors struggle to regain their footing.

In fact, the state now has the third-weakest job market in the nation. Colorado experienced a 2.0% decline in jobs through July 2002, compared with the same period in 2001. The state's jobless rate, while lower than the highs reached at the beginning of the year, still stood at 5.1% in August. The decline in jobs only tells a part of the picture, however. Not only have the job losses been primarily centered on the state's highest paying markets such as advanced technology, communications, and finance, many workers with jobs have found themselves working for reduced salaries.

Further pain is being inflicted on the state's economy by two sectors that have long been important – tourism and

agriculture. The combination of the worst drought since the 1930s and related forest fires have led to a sharp decrease in tourism to the state this summer. We anticipate that winter tourism will also be down significantly unless the state is able to report abundant early snowfall at the ski areas. Tourists typically make up 10% of the state's retail sales base and many of the state's businesses and governments have felt the loss in sales. Meanwhile, the agricultural sector has seen significant impacts from the drought as the state's winter wheat crop was devastated and many other crops felt the pain of a long dry summer.

The Colorado forecast. The following highlights summarize the Colorado economic forecast. The detailed Colorado economic forecast can be found in Table 8.

- As previously mentioned, declines in the state's high technology, communications, and finance industries have combined with a dramatic slowdown in tourism and a weak agricultural sector to cause significant job losses during 2002. While we see the employment situation slowly turning around over the next two years, the state will end 2002 with a 1.8% decline in employment. The slow turnaround will lead to just 1.6% more jobs in 2003 followed by a more significant 3.1% increase in 2004. The unemployment rate will average 5.3% in 2002, after coming in at a low 3.7% in 2001 and just 2.7% in 2000. The rate will decline slowly over the next several years, falling to 5.0% in 2003, 4.8% in 2004, and 4.6% in 2005.

- The pressures on the job market will lead to a much slower rate of personal income growth during the next few years. Income will increase 1.4% in 2002 and 4.4% in 2003. During the latter half of the 1990s, income growth regularly exceeded the 8.0% level before slowing to just 3.8% in 2001. Wage and salary income, which makes up approximately 60% of personal income, will decline 1.0% in 2002. This results from the previously mentioned job losses and the number of people underemployed or working for smaller salaries.

- The recession and Colorado's relatively weak economy vis-a-vis the rest of the nation will cause migration to slow significantly over the next several years. As a result, population growth in the state will slow from a 2.2% pace in 2001 to 1.4% in 2002 and 1.5% in 2003. Falling wages, coupled with slowing population growth, will cause retail trade sales to drop 2.5% in 2002. As the economy slowly recovers in 2003, sales will increase 3.2% before strengthening further over the remainder of the forecast period.

- Inflation will also remain subdued over the next several years. Falling energy prices compared with last year, a slowdown in housing price appreciation, and slow retail sales growth that constrains retailers from raising prices will combine to keep inflation low in Colorado. The inflation rate will be just 1.9% in 2002 and 2.8% in 2003 after climbing 4.7% in 2001 and 4.0% in 2000. The only significant upward pressure on prices will result from accelerating costs of medical care. Low inflation, combined with the slow growth in population, will cause the state's limit on the TABOR revenue growth rate to remain quite low over the forecast horizon.

- Construction levels will decline significantly during 2002. The vacancy rates for most types of commercial property and apartments have increased significantly. Accordingly, rental rates have been declining in many markets, removing the incentive for new construction. Home prices have also come under considerable pressure recently as the number of homes on the market has been increasing dramatically. Many builders who could not put the product out fast enough in the 1990s are now finding themselves with inventories of unsold homes. Nonresidential building will decline 19.1% in 2002 and continue to decline slightly into 2003. The number of home permits will fall 18.7% in 2002.

Risks To the Forecast. We believe the world markets have substantially priced in the possibility of a war between the U.S. and Iraq. America's markets may be less prepared, however, and may take a short term hit if a war occurs. The risk to the forecast from war is twofold. First, if a war turns out to be more difficult or devastating for U.S. armed forces than expected, consumer confidence will fall dramatically and the budding recovery will likely disappear. Colorado would immediately feel a hit in its housing and construction markets that would flow over into retail sales and job growth. The second risk is related to oil prices. Other oil-producing nations seem ready to step up production and replace any oil supply that is lost because of a war. Oil prices would then stabilize. However, if this does not occur, we could see a spike in energy prices that would negatively impact the state's economy.

Any housing price bubble that bursts or a significant rise in mortgage rates would endanger the Colorado economic recovery. Housing prices have increased dramatically

in Colorado. Prices have continued to increase during the recession, albeit at a slower rate. If housing prices have become high relative to the underlying economic conditions, the state could see a drop in housing prices. This would have three deleterious effects: consumer spending would decrease as people would feel less wealthy; cash-out refinancing would be much lower and slow spending in the state; job growth in many industries that rely on home sales would be lower. Similar impacts would be felt from a rise in mortgage rates, especially with inflationary pressures. As other interest rates would be pushed up as well, bankruptcies would increase from already high levels and more homes would fall into default. The state's tourism industry would take another hit if the drought continues and the mountains do not have significant early snowfall to prop up the ski industry. In addition, if the state suffers another dry spring and large wildfires again scar the landscape, tourism spending in the state would dry up as well.

QUESTIONS

Q: I would like to ask Dick if he has any ideas about legislation requiring mitigation to rural communities if the buy-up/dry-up occurs?

There are some good examples of what can be done which have been done recently. One is the Northern Colorado Water Conservancy District, where they did compensatory storage to the Colorado River Water Conservation District which totaled out to $10.2 million. They also invested that well. It probably went up to $17 million in terms of the investment value. They then got money from the Water Board construction fund, about $17.5 million, and through the responsible relationship between the NCWCD and Denver Water, they worked out a 25-year lease. My point is, you can do a quid-pro quo where everybody gets something, which they did in this case. This is an example of what we can do. Everybody got something, and it resulted in the reservoir up by Kremmling that the River District now owns.

Q: Are you interested in supporting such legislation?

A: I am interested in anything where all my friends come together in a common effort to achieve something that is mutually beneficial to all sides.

Table 1
Colorado General Fund, Accrual Basis
September 2002 Revenue Estimates by Tax Category
(Dollars in millions)

Category	Preliminary FY 2001-02	Percent Change	Estimate FY 2002-03	Percent Change	Estimate FY 2003-04	Percent Change	Estimate FY 2004-05	Percent Change	Estimate FY 2005-06	Percent Change	Estimate FY 2006-07	Percent Change	Estimate FY 2007-08	Percent Change
Sales /A	$1,755.6	-3.1	$1,772.0	0.9	$1,866.5	5.3	$1,983.5	6.3	2,102.2	6.0	2,224.7	5.8	2,361.1	6.1
TABOR Overefund	0.0	(100.0)	(32.3)		0.0		0.0		0.0		0.0		0.0	
Use /A	140.6	-10.9	135.9	-3.3	143.9	5.8	153.2	6.4	160.9	5.1	169.1	5.1	178.4	5.5
Cigarette	58.2	-5.0	55.0	-5.6	54.1	-1.5	53.3	-1.5	52.5	-1.5	51.7	-1.5	51.0	-1.5
Tobacco Products	10.3	4.5	10.1	-1.9	10.9	7.0	11.3	3.8	11.7	3.9	12.2	4.1	12.7	4.2
Liquor	29.5	0.7	29.4	-0.4	30.2	2.8	31.0	2.6	31.8	2.6	32.6	2.6	33.4	2.4
TOTAL EXCISE	$1,991.3	-0.7	$1,970.1	-1.1	$2,105.6	6.9	$2,232.3	6.0	$2,359.1	5.7	$2,490.3	5.6	$2,636.5	5.9
Net Individual Income	$3,345.2	-16.7	$3,424.6	2.4	$3,732.3	9.0	$4,053.5	8.6	$4,373.0	7.9	$4,670.6	6.9	$5,031.9	7.6
Net Corporate Income	178.0	-46.0	219.6	23.4	239.9	9.2	297.4	24.0	350.3	17.8	371.1	5.9	389.5	4.9
TOTAL INCOME TAXES	$3,523.2	-19.0	$3,644.5	3.4	$3,972.1	9.0	$4,350.9	9.5	$4,723.3	8.6	$5,041.7	6.9	$5,421.3	7.4
Less: Portion directed to the State Education Fund /B	(272.9)	66.1	(273.4)	0.2	(297.6)	8.8	(329.5)	9.4	(353.6)	8.5	(377.0)	6.8	(404.5)	7.3
INCOME TAXES TO GENERAL FUND	$3,250.3	-22.3	$3,371.0	3.7	$3,674.5	9.0	$4,025.5	9.6	$4,370.3	8.6	$4,670.7	6.9	$5,016.8	7.4
Estate	$72.5	-12.2	$53.3	-26.5	$38.5	-27.8	$20.4	-46.9	$2.1	-89.6	$0.0	-100.0	$0.0	NA
Insurance	164.6	8.9	164.4	0.3	167.8	2.0	169.6	1.1	176.9	4.3	184.5	4.3	191.8	4.0
Pari Mutuel	5.7	-5.8	5.3	-7.7	5.3	0.0	5.2	-1.9	5.2	0.0	5.1	-1.9	5.1	0.0
Interest Income	23.3	-44.0	20.4	-12.4	25.3	24.0	29.3	15.8	34.6	18.0	40.2	15.9	35.0	-12.9
Court Receipts	23.3	4.4	25.5	9.5	26.3	3.0	27.0	2.8	27.7	2.8	28.5	2.7	29.2	2.5
Gaming /C	34.1	6.5	39.6	16.2	40.0	1.1	44.2	10.5	48.0	8.6	52.2	8.8	56.4	7.9
Medicaid (Intergovt. Transfer)	11.2	NA	10.7	-4.2	0.0	NA	0.0	NA	0.0	NA	0.0	NA	0.0	NA
Other Income	31.9	-4.4	25.3	-20.7	22.0	-13.2	22.8	3.8	23.7	3.8	24.6	3.7	25.4	3.5
TOTAL OTHER	$366.6	-1.2	$344.5	-3.9	$325.1	-5.6	$318.6	-2.0	$318.5	-0.0	$335.1	5.2	$342.9	2.3
GROSS GENERAL FUND	**$5,690.2**	**-14.5**	**$5,685.6**	**1.5**	**$6,185.2**	**7.4**	**$6,576.3**	**7.7**	**$7,048.9**	**7.2**	**$7,496.1**	**6.4**	**$7,996.2**	**6.7**
REBATES & EXPENDITURES														
Cigarette Rebate	$15.9	-3.0	$15.8	-0.4	$15.6	-1.5	$15.4	-1.5	$15.1	-1.5	$14.9	-1.5	$14.7	-1.5
Old-Age Pension Fund	72.9	0.5	76.0	4.2	80.2	5.6	85.1	6.2	90.5	6.3	96.4	6.5	103.6	7.4
Aged Property Tax & Heating Credit	23.6	40.5	23.5	-0.5	22.5	-4.0	22.3	-1.0	21.9	-1.7	22.2	1.4	22.0	-0.9
Fire/Police Pensions	28.9	0.7	28.9	0.0	28.9	0.0	28.9	0.0	28.9	0.0	28.9	0.0	28.9	0.0
TOTAL REBATES & EXPENDITURES	$141.3	9.5	$144.2	2.0	$147.2	2.1	$151.7	3.1	$156.5	3.1	$162.5	3.8	$169.2	4.1

Totals may not sum due to rounding.
NA: Not Applicable.
/A Sales and use taxes diverted to the Highway Users Tax Fund can be found in Table 5.
/B In November 2000, Colorado voters approved Amendment 23 that deposits an amount equal to 0.33 percent of Colorado taxable income into the State Education Fund. These revenues are exempt from the TABOR spending limit.
/C Includes only the amount credited to the General Fund.

Table 2
Cash Fund Revenue Estimates by Category, September 2002
Millions of Dollars

	Actual FY 01-02	Estimate FY 02-03	Estimate FY 03-04	Estimate FY 04-05	Estimate FY 05-06	Estimate FY 06-07	Estimate FY 07-08	FY 01-02 to FY 07-08 CAAGR*
Transportation-Related /A	$813.9	$833.4	$852.9	$877.4	$900.0	$924.8	$957.0	
% Change	4.2%	2.4%	2.3%	2.9%	2.6%	2.8%	3.5%	2.7%
Higher Education /B	$635.4	$686.8	$708.6	$746.9	$786.8	$827.3	$872.8	
% Change	-9.7%	8.1%	3.2%	5.4%	5.3%	5.2%	5.5%	6.4%
Unemployment Insurance /C	$196.1	$242.9	$348.7	$430.4	$492.2	$334.7	$286.9	
% Change	-2.4%	23.9%	43.6%	23.4%	14.4%	-32.0%	-14.3%	6.6%
Limited Gaming Fund	$99.1	$105.9	$114.9	$124.5	$134.2	$144.9	$155.4	
% Change	7.7%	6.8%	8.6%	8.3%	7.8%	8.0%	7.2%	7.8%
Capital Construction - Interest	$17.6	$8.9	$12.3	$14.4	$15.4	$10.8	$7.6	
% Change	-49.8%	-50.7%	76.3%	17.7%	6.7%	-30.0%	-29.7%	-13.0%
Controlled Maintenance Trust Fund - Interest** /E	$0.5	$0.0	$8.1	$20.4	$22.2	$22.2	$22.2	
% Change	-97.1%			151.7%	8.7%	-0.0%	-0.2%	86.5%
Insurance-Related	$66.3	$64.5	$68.0	$73.3	$79.0	$85.3	$92.2	
% Change	29.0%	-2.6%	5.4%	7.8%	7.8%	8.0%	8.0%	5.7%
Regulatory Agencies	$60.4	$62.1	$63.7	$65.2	$66.7	$68.4	$69.2	
% Change	-1.6%	3.2%	3.1%	2.8%	2.8%	3.0%	3.1%	3.0%
Severance Tax /D	$67.5	$51.4	$55.8	$56.8	$55.9	$59.0	$62.9	
% Change	-23.1%	-10.6%	8.6%	1.7%	-1.6%	5.6%	6.5%	1.8%
Employment Support Fund	$19.6	$19.8	$20.5	$21.7	$22.3	$23.3	$24.4	
% Change	-6.0%	0.7%	3.8%	5.7%	2.8%	4.6%	4.6%	3.7%
Petroleum Storage Tank Fund	$21.3	$20.3	$20.9	$10.1	$10.4	$10.8	$11.2	
% Change	-19.9%	-4.5%	3.0%	-51.5%	2.8%	3.3%	3.4%	-10.2%
Other Cash Funds	$254.8	$264.3	$281.0	$297.9	$315.8	$335.5	$356.7	
% Change	-2.8%	3.7%	6.3%	6.0%	6.0%	6.3%	6.3%	6.8%
Total Cash Fund Revenues Subject to the TABOR Limit	$2,232.4	$2,348.1	$2,545.5	$2,729.1	$2,890.9	$2,837.2	$2,909.3	
	-6.1%	5.2%	8.4%	7.2%	5.9%	-1.9%	2.5%	4.5%

Totals may not sum due to rounding.

* CAAGR: Compound Average Annual Growth Rate.

/A This includes the Highway Users Tax Fund, the State Highway Fund, and other transportation-related funds.

/B Higher Education tuition revenues are net of scholarship allowances.

/C Includes a 20% tax credit on unemployment insurance taxes during calendar years 2001 and 2002. Reflects the solvency tax that will be triggered in calendar years 2004 through 2006.

/D This figure includes total severance tax revenue and interest earnings before distribution to the Local Government Severance Tax Fund.

/E The principal balance of the Controlled Maintenance Trust Fund, or $243.9 million, was transferred to the General Fund on July 1, 2001. The CMTF will be repaid in two installments on July 1, 2003 and July 1, 2004.

Table 3
September 2002 Forecast for the TABOR Revenue Limit and Emergency Reserve
(Dollars in millions)

	Preliminary FY 2001-02	Estimate FY 2002-03	Estimate FY 2003-04	Estimate FY 2004-05	Estimate FY 2005-06	Estimate FY 2006-07	Estimate FY 2007-08
TABOR Revenues:							
General Fund /A	$5,548.4	$5,632.2	$6,051.3	$6,518.2	$6,986.1	$7,430.1	$7,987.4
Cash Funds	2,232.4	2,348.1	2,545.5	2,729.1	2,890.9	2,837.2	2,909.3
Total TABOR Revenues	$7,780.8	$7,980.3	$8,596.8	$9,247.3	$9,877.0	$10,267.3	$10,896.7
LIMIT:							
Allowable TABOR Growth Rate	10.0%	6.9%	7.8%	5.8%	5.0%	5.1%	5.2%
Inflation	4.0%	4.7%	1.9%	2.8%	3.2%	3.2%	3.2%
Population Growth	6.0%	2.2%	1.4%	1.5%	1.8%	1.9%	2.0%
Population Adjustment for Growth Dividend	6% Carried Forward	0.0%	4.5%	1.5%	0.0%	0.0%	0.0%
Allowable TABOR Limit	**$8,125.2**	**$8,317.7**	**$8,602.8**	**$9,095.4**	**$9,550.2**	**$10,037.3**	**$10,559.2**
Revenues Above / (Below) TABOR Limit /B	**($337.1)**	**($337.4)**	**($6.0)**	**$151.9**	**$326.8**	**$230.0**	**$337.5**
EMERGENCY RESERVE:							
TABOR Emergency Reserve /C	$233.4	$239.4	$257.9	$272.9	$286.5	$301.1	$316.8

Totals may not sum due to rounding.

Note: TABOR broadly defines spending such that expenditures are equal to revenues. The statutory 6 percent limit applies to the General Fund appropriations only. Thus, the two concepts are not directly comparable.

/A These figures differ from the General Fund revenues reported in other tables because they net out revenues that are already in the Cash Funds to avoid double counting. For instance, the General Fund gaming revenues, unexpended prior-year Medicaid expenditures that are booked in "other revenue," and transfers of unclaimed property are netted out. These figures also include the net amount of sales and use tax, after the over-refund of excess TABOR revenues. Senate Bill 97-1 diverts 10.355% of the gross sales and use tax revenues to the Highway Users Tax Fund.

/B Includes $8.3 million in FY 2002-03 for understated revenue from a prior year.

/C In years where the projected revenues exceed the amount allowed by the Constitution, the reserve is calculated based on the limit, rather than on projected receipts. Given that the state will only retain the maximum allowed by the Constitution, it need only reserve three percent of such amount.

Table 4
Transfers to the General Fund
(dollars in millions)

Fund Name	Amount	Fund Name	Amount
Collection Agency Board	$0.5	Unclaimed Property Trust	$10.0
Uniform Consumer Credit Code	$0.2	Tobacco Settlement	$139.1
Petroleum Storage Tank	$4.0	Waste Tire Recycling	$0.6
Employment Support	$15.0	Regular Capital Construction	$17.5
Major Medical	$211.5	Hazardous Substances Response	$30.0
Trade Name	$0.4	Environmental Leadership	$0.5
Dealer License Board	$1.1	Children's Basic Health Plan	$0.9
Read-to-Achieve	$1.9	Species Conservation	$5.5
Fitzsimmons Trust	$18.4	Disabled Telephone Users	$0.5
Secretary of State Fees	$1.2	Persistent Drunk Driver	$0.5
Tobacco Litigation Settlement	$3.5	Support Registry	$0.4
Severance Tax Trust	$20.2	State Rail Bank	$0.5
		Total	**$482.7**

Table 5
September 2002 General Fund Overview
(Dollars in millions)

	Preliminary FY 2001-02	Estimate FY 2002-03	Estimate FY 2003-04	Estimate FY 2004-05	Estimate FY 2005-06	Estimate FY 2006-07	Estimate FY 2007-08
Beginning Reserve	$489.3	$165.3	($460.0)	($1,103.5)	($1,671.0)	($2,183.0)	($2,755.0)
Gross General Fund	5,600.2	5,685.6	6,105.2	6,576.3	7,048.0	7,490.1	7,996.2
Senate Bill 97-1 Diversion to the HUTF /A	****	0.0	0.0	0.0	(0.0)	0.0	0.0
Transfers from/(Paybacks to) Other Funds	536.3	(130.6)	0.0	0.0	0.0	0.0	0.0
Diversion of Sales Taxes to Other Funds /B	****	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
Transfer from the Controlled Maintenance Trust Fund /D	253.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Funds Available	$6,859.2	$5,717.4	$5,652.2	$5,469.9	$5,373.9	$5,310.1	$5,238.3
EXPENDITURES:							
General Fund Appropriations /C	$5,643.0	$5,950.4	$6,292.4	$6,671.2	$7,072.6	$7,495.2	$7,949.3
Medicaid Overexpenditure	NE	NE	NE	NE	NE	NE	NE
Rebates and Expenditures	141.3	144.2	147.2	151.7	156.5	162.5	169.2
Reimbursement for Senior Property Tax Cut	0.0	62.3	59.6	58.0	55.5	57.6	57.6
Capital and Prison Construction	****	10.6	101.2	101.8	100.4	0.0	0.0
Transfer for Highway Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transfer to the Controlled Maintenance Trust Fund /D	0.0	0.0	133.2	138.2	0.0	0.0	0.0
K-12 Settlement Funding Adds to GF Appropriation /C, E	10.0	0.0	20.0	20.0	20.0	20.0	20.0
TABOR Refund	927.2	0.0	0.0	0.0	151.9	326.8	230.0
Accounting Adjustments	(27.0)	NE	NE	NE	NE	NE	NE
Total Obligations	$6,693.9	$6,167.5	$6,755.6	$7,140.9	$7,557.0	$8,065.1	$8,426.1
YEAR-END GENERAL FUND RESERVE:	$165.3	($460.0)	($1,103.5)	($1,671.0)	($2,183.0)	($2,755.0)	($3,187.0)
STATUTORY RESERVE: 4.0% OF APPROPRIATIONS /F	0.0	119.0	252.6	267.6	283.7	300.7	318.8
GENERAL FUND EXCESS RESERVE	$165.3	($569.1)	($1,356.0)	($1,938.6)	($2,466.7)	($3,055.7)	($3,506.6)
Reserved Funds for Resumption of Accrual Accounting for TABOR Refund	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Funds in Excess Reserve to Highway Users Tax Fund	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Funds in Excess Reserve to Capital Construction	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
RESERVE AS A % OF APPROPRIATIONS	2.9%	-7.6%	-17.5%	-25.9%	-30.9%	-36.7%	-40.1%
TABOR RESERVE REQUIREMENT:							
General & Cash Fund Emergency Reserve Requirement	$233.4	$239.4	$257.9	$272.9	$286.5	$301.1	$316.8
Appropriations Growth /C	$303.4	$297.4	$362.0	$378.7	$401.5	$425.6	$451.1
Appropriations Growth Rate /C	5.67%	5.26%	6.08%	6.00%	6.00%	6.00%	6.00%
Addendum: Amount Directed to State Education Fund	($272.9)	($273.4)	($297.6)	($325.5)	($353.0)	($377.0)	($404.5)

NE: Not Estimated.
Totals may not sum due to rounding.
**** The diversion of sales and use tax revenues ($35.2 million) to the HUTF, the diversion ($3.0 million) to the Older Americans Fund, and the transfer ($83.3 million) to the Capital Construction Fund are contained in the General Fund appropriations amount.
/A 10.355% of sales and use taxes are diverted to the Highway Users Tax Fund when the full six percent General Fund appropriations limit can be attained. The amount was capped at $35.2 million for FY 2001-02 and does not occur thereafter due to General Fund revenue shortfalls.
/B Includes $1.0 million to the Supplemental Old Age Pension Health and Medical Care Fund and $2.0 million to the Older Americans Fund for FY 2002-03 and thereafter.
/C The amounts for the K-12 settlement funding attributable to Senate Bill 00-181 are also appropriations from the General Fund and should be added to the General Fund appropriations line to calculate total appropriations.
/D House Bill 01-1267 transferred the principal balance of the CMTF to the General Fund on July 1, 2001. HB 02-1446 transfers $133.2 million from the General Fund to the CMTF in FYs 2003-04 and 2004-05.
/E This settlement requires that the General Fund have at least $80 million in excess reserves for funding to take place. Because the General Assembly has funded the settlement in two budget years without reaching the $80 million threshold, it has been included in the overview for all years except FY 2002-03, when it is to be funded from the State Education Fund.
/F The four percent statutory reserve was eliminated for FY 2001-02. Fund transfers have been authorized for FY 2002-03 to prevent the reserve from falling below 2% so we are showing the reserve at that level in that year.

Table 6
September 2002 General Fund Overview with Appropriations Reductions
(Dollars in millions)

	Preliminary FY 2001-02	Estimate FY 2002-03	Estimate FY 2003-04	Estimate FY 2004-05	Estimate FY 2005-06	Estimate FY 2006-07	Estimate FY 2007-08
Beginning Reserve	$469.3	$165.3	$108.2	$221.8	$235.1	$249.2	$264.2
Gross General Fund	5,600.2	5,685.6	6,105.2	6,576.3	7,046.0	7,498.1	7,995.2
Senate Bill 97-1 Diversion to the HUTF /A	****	0.0	0.0	(221.3)	(234.3)	(247.9)	(263.0)
Transfers from/(Paybacks to) Other Funds	538.3	(130.6)	0.0	(11.0)	(56.6)	0.0	0.0
Capital Construction Freeze Savings to General Fund		15.1					
Diversion of Sales Taxes to Other Funds /B	****	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
Transfer from the Controlled Maintenance Trust Fund /D	253.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Funds Available	$6,859.2	$5,735.5	$6,210.4	$6,562.9	$6,987.1	$7,494.5	$7,994.4
EXPENDITURES:							
General Fund Appropriations /C	$5,643.0	$5,950.4	$5,719.9	$5,659.1	$6,210.8	$6,584.6	$6,980.9
Governor's Budget Restrictions		($151.9)					
Necessary Additional Reductions		($388.3)	($194.5)				
Medicaid Overexpenditure	NE	NE	NE	NE	NE	NE	NE
Rebates and Expenditures	141.3	144.2	147.2	151.7	156.5	162.5	169.2
Reimbursement for Senior Property Tax Cut	0.0	62.3	58.6	58.0	55.5	57.6	57.6
Capital and Prison Construction	****	10.6	101.2	101.8	100.4	0.0	0.0
Transfer for Highway Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transfer to the Controlled Maintenance Trust Fund /D	0.0	0.0	138.2	138.2	0.0	0.0	0.0
K-12 Settlement Funding Adds to GF Appropriation /C, E	10.0	0.0	20.0	20.0	20.0	20.0	20.0
TABOR Refund	927.2	0.0	0.0	0.0	151.9	328.8	230.0
Accounting Adjustments	(27.6)	NE	NE	NE	NE	NE	NE
Total Obligations	$6,693.9	$5,627.3	$5,988.5	$6,327.8	$6,695.1	$7,151.5	$7,457.7
YEAR-END GENERAL FUND RESERVE:	**$165.3**	**$108.2**	**$221.9**	**$235.1**	**$292.0**	**$343.0**	**$536.6**
STATUTORY RESERVE: 4.0% OF APPROPRIATIONS /F	**0.0**	**108.2**	**221.8**	**235.1**	**249.2**	**264.2**	**280.0**
GENERAL FUND EXCESS RESERVE	**$165.3**	**($0.0)**	**$0.0**	**($0.0)**	**$42.8**	**$78.8**	**$256.7**
Reserved Funds for Resumption of Accrual Accounting for TABOR Refund	**$0.0**	**$0.0**	**$0.0**	**$0.0**	**$25.0**	**$25.0**	**$25.0**
Funds in Excess Reserve to Highway Users Tax Fund	**$0.0**	**$0.0**	**$0.0**	**$0.0**	**$11.9**	**$35.9**	**$154.6**
Funds in Excess Reserve to Capital Construction	**$0.0**	**$0.0**	**$0.0**	**$0.0**	**$5.9**	**$17.9**	**$77.2**
RESERVE AS A % OF APPROPRIATIONS	**2.9%**	**1.8%**	**3.9%**	**4.0%**	**4.7%**	**5.2%**	**7.7%**
TABOR RESERVE REQUIREMENT:							
General & Cash Fund Emergency Reserve Requirement	$233.4	$239.4	$257.9	$272.9	$289.5	$301.1	$316.8
Appropriations Growth /C	$303.4	($242.8)	$135.1	$332.7	$352.7	$373.6	$396.3
Appropriations Growth Rate /C	5.67%	-4.29%	2.50%	6.00%	6.00%	6.00%	6.00%
Addendum: Amount Directed to State Education Fund	($272.9)	($273.4)	($297.6)	($325.5)	($353.0)	($377.0)	($404.5)

NE: Not Estimated.
Totals may not sum due to rounding.
**** The diversion of sales and use tax revenues ($35.2 million) to the HUTF, the diversion ($3.0 million) to the Older Americans Fund, and the transfer ($63.3 million) to the Capital Construction Fund are contained in the General Fund appropriations amount.

/A 10.355% of sales and use taxes are directed to the Highway Users Tax Fund when the full six percent General Fund appropriations limit can be attained. The amount was capped at $35.2 million for FY 2001-02.

/B Includes $1.0 million to the Supplemental Old Age Pension Health and Medical Care Fund and $2.0 million to the Older Americans Fund for FY 2002-03 and thereafter.

/C The amounts for the K-12 settlement funding attributable to Senate Bill 00-181 are also appropriations from the General Fund and should be added to the General Fund appropriations line to calculate total appropriations.

/D House Bill 01-1267 transferred the principal balance of the CMTF to the General Fund on July 1, 2001. HB 02-1446 transfers $138.2 million from the General Fund to the CMTF in FYs 2003-04 and 2004-05.

/E The settlement requires that the General Fund have at least $80 million in excess reserves for funding to take place. Because the General Assembly has funded the settlement in two budget years without reaching the $80 million threshold, it has been included in this overview for all years except FY 2002-03, when it is to be funded from the State Education Fund.

/F The four percent statutory reserve was eliminated for FY 2001-02. Fund transfers have been authorized for FY 2002-03 to prevent the reserve from falling below 2% so we are showing the reserve at that level in that year.

Table 7
National Economic Indicators, September 2002 Forecast
(Dollar amounts in billions)

	1998	1999	2000	2001	Forecast 2002	Forecast 2003	Forecast 2004	Forecast 2005	Forecast 2006
Gross Domestic Product (GDP) percent change	$8,781.5 5.6%	$9,274.3 5.6%	$9,824.7 5.9%	$10,082.1 2.6%	$10,437.2 3.5%	$10,959.7 5.0%	$11,649.5 6.3%	$12,286.9 5.5%	$12,971.8 5.6%
Inflation-adjusted GDP percent change	$8,508.9 4.3%	$8,858.9 4.1%	$9,191.4 3.8%	$9,214.6 0.3%	$9,426.5 2.3%	$9,716.8 3.1%	$10,068.1 3.6%	$10,380.6 2.9%	$10,733.6 3.4%
Nonagricultural Employment (millions) percent change	125.9 2.6%	128.9 2.4%	131.8 2.2%	131.9 0.1%	130.8 -0.8%	132.3 1.1%	135.3 2.3%	137.4 1.5%	139.1 1.3%
Unemployment Rate	4.5%	4.2%	4.0%	4.8%	5.9%	5.9%	5.7%	5.4%	5.2%
Personal Income percent change	$7,426.0 7.0%	$7,796.5 4.9%	$8,406.6 8.0%	$8,685.3 3.3%	$8,963.0 3.2%	$9,339.8 4.2%	$9,813.9 5.1%	$10,290.7 4.9%	$10,797.0 4.9%
Inflation (Consumer Price Index)	1.6%	2.2%	3.4%	2.8%	1.6%	2.0%	2.3%	2.4%	2.4%
Prime Rate	8.4%	8.0%	9.2%	7.0%	4.8%	5.7%	8.0%	8.3%	8.1%

For historical data, see Appendix A.

Table 8
Colorado Economic Indicators, September 2002 Forecast
(Calendar Years)

	1998	1999	2000	2001	Forecast 2002	Forecast 2003	Forecast 2004	Forecast 2005	Forecast 2006	Forecast 2007
Population (thousands), July 1 /A percent change /A	3,969.0 2.0%	4,056.1 2.2%	4,323.4 6.6%	4,417.7 2.2%	4,479.5 1.4%	4,548.7 1.5%	4,628.6 1.8%	4,716.5 1.9%	4,810.9 2.0%	4,907.1 2.0%
Nonagricultural Employment (thousands) percent change	2,057.0 3.9%	2,131.9 3.6%	2,212.9 3.8%	2,231.9 0.9%	2,191.7 -1.8%	2,226.8 1.6%	2,295.8 3.1%	2,360.1 2.8%	2,426.2 2.8%	2,499.0 3.0%
Unemployment Rate	3.8%	2.9%	2.7%	3.7%	5.3%	5.0%	4.6%	4.6%	4.4%	4.3%
Personal Income (millions) percent change	$118,413 8.9%	$127,653 7.8%	$140,224 9.8%	$145,593 3.8%	$147,631 1.4%	$154,127 4.4%	$163,221 5.9%	$173,177 6.1%	$183,566 6.0%	$194,765 6.1%
Wage and Salary Income (millions) percent change	$69,604 11.3%	$76,358 9.7%	$86,002 12.6%	$89,070 3.6%	$88,179 -1.0%	$91,266 3.5%	$97,107 6.4%	$104,068 7.2%	$110,969 6.6%	$118,515 6.8%
Retail Trade Sales (millions) percent change	$48,131 6.6%	$52,209 8.5%	$58,018 11.1%	$58,947 1.6%	$57,473 -2.5%	$59,312 3.2%	$62,337 5.1%	$66,202 6.2%	$70,373 6.3%	$74,877 6.4%
Home Permits (thousands) percent change	49.5 16.5%	48.9 -1.3%	53.7 10.0%	54.5 1.5%	44.3 -18.7%	46.6 5.0%	50.5 8.5%	49.1 -2.7%	49.4 0.6%	49.4 -0.1%
Nonresidential Building (millions) percent change	$2,617 -12.4%	$3,544 35.4%	$3,339 -5.8%	$3,325 -0.4%	$2,690 -19.1%	$2,652 -1.4%	$2,785 5.0%	$2,979 7.0%	$3,173 6.5%	$3,360 5.9%
Denver-Boulder Inflation Rate	2.4%	2.9%	4.0%	4.7%	1.9%	2.6%	3.2%	3.2%	3.2%	3.3%

/A Colorado's population on April 1, 2000, was 4,301,261 according to the U.S. Bureau of the Census. The 6.0% change in the population reflects the change from the July 1999 estimate to April 1, 2000, and is used for calculation of the state's TABOR revenue limit.

For more historical data, see Appendix A.

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