December 2011

DROUGHT
Response Plan

DENVER WATER

TABLE OF CONTENTS

LIST OF APPENDICES

The Drought Response Plan Technical Appendices, which are bound separately, contain technical and background information that complements the Drought Response Plan. The contents of the Technical Appendices are as follows:

- Live on Inflow Analysis
- Cloud Seeding
- Water Allocation Program
- Weather Model
- Demand Hardening
- Drought Recurrence Intervals
- Supply Augmentation Alternatives
- Reducing Deliveries to Outside City Contracts
- Operating Rules Pertaining to Drought

EXECUTIVE SUMMARY

As adopted by the Denver Board of Water Commissioners in 2002, the goal of drought response is to preserve the quality of public life and economic activity to the extent possible in the face of water shortage.

Droughts occur with unpredictable frequency, intensity and duration. During a drought, water supplies will be below normal, requiring customers to reduce their water use for a period of time.

The Drought Response Plan is intended to assist the Denver Board of Water Commissioners in reacting to a drought. This plan is a product of lessons learned during the 2001-2007 drought (defined here as the year when reservoirs first failed to fill until the year that they refilled) in Denver Water's service area and will be updated regularly to ensure that it addresses current conditions.

The plan has three elements: drought severity indicators, response actions and communication activities.

Drought Severity Indicators

Water supply projections and hydrologic conditions are significant components in deciding when a drought response is needed. The amount of the water supply shortage contributes to the severity of drought declared and the necessary level of response from customers. This Drought Response Plan recommends a progressive response to worsening drought conditions. Recommended drought response actions are aimed at increasing water supply and reducing water use based on stream flow, precipitation, wind, weather forecasts, snowpack, soil moisture, predicted reservoir storage and other hydrologic indicators. In addition, political, social and economic conditions could influence which drought response actions are implemented.

During a drought, the Board will consider drought severity indicators in choosing the appropriate drought response actions. The Drought Response Actions chapter shows how the drought severity indicators align with the suggested drought responses.

An important drought indicator is predicted July 1 reservoir contents because that is the date when storage in Denver Water's system usually reaches its annual maximum level. Predicted reservoir contents, along with hydrologic conditions and social, political and economic indicators, will be used to determine what level of drought response will be recommended to the Board.

The following *available* reservoir content[1] ranges will be used, along with other indicators, in determining the appropriate level of drought response:

[1] The water we can legally and physically deliver to our customers' taps without dipping into our emergency water supply.

Potential Drought Stage	Indicator – Available Reservoir Contents
Drought Watch	Between 95 and 60 percent of capacity
Stage 2	Between 75 and 35 percent of capacity
Stage 3	Between 40 and 0 percent of capacity
Stage 4	Less than 20 percent of capacity

July 1 storage levels are predicted monthly from February through June each year, based on forecasts of natural stream flow, bypass requirements, water usage and other factors.

Drought Response Actions

This Drought Response Plan outlines various measures designed to either augment existing water supplies or reduce water use. Because every drought is different, the Board will adjust and refine drought response actions based on actual conditions.

A number of alternatives for augmenting existing water supplies are available to the Board during droughts. These alternatives, which are discussed in more detail in the Technical Appendices, include invoking the Shoshone relaxation agreement, withholding deliveries to the Big Lake Ditch, reducing minimum bypasses at diversion facilities, drilling nontributary wells and tapping into the emergency water supply.[2]

The primary response to drought available to the Board is to restrict customers' water use so that supplies will last as long as possible and be available for the most essential uses. The water use restrictions imposed during the 2001-2007 drought indicated that no single category of response was effective at encouraging all customers to reduce water use. Instead, a variety of water-saving measures was needed, including restrictions, surcharges, enforcement and incentives.

Water Use Restrictions

The following principles guided the development of drought restrictions:

- Avoid irretrievable loss of natural resources.
- Impact individuals or small groups before impacting large groups or the public as whole.
- Minimize adverse financial effects on the community and water-dependent industries.
- Eliminate water waste.
- Implement extensive public information and media relations programs.
- Implement an understandable, progressive drought response program.
- Assure equity and logic in applying drought surcharges.[3]

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[2] The emergency water supply, also known as the strategic water reserve, is water that Denver Water plans to keep in its reservoirs to provide some protection against unforeseen circumstances, such as a dam or tunnel failure, a water quality crisis, climate change or catastrophic drought. Currently, the emergency water supply is 50,000 acre-feet of yield, or approximately 200,000 acre-feet of reservoir contents. The Board has the option of making some or all of the emergency water supply available to customers during a drought.

[3] Drought surcharges are temporary charges applied to customers' water bills designed to reduce water use during droughts.

The basic demand reduction response to a Drought Watch is voluntary measures; to a Stage 2 Drought, mandatory use restrictions; to a Stage 3 Drought, a general prohibition on lawn watering; and to a Stage 4 Drought, rationing of water supplies for essential uses. Because Stage 2, Stage 3 and Stage 4 drought restrictions are mandatory, they must be incorporated into Denver Water's Operating Rules, where they become enforceable pursuant to the Denver City Charter, the Denver Revised Municipal Code and provisions in Denver Water's water service agreements and water leases.

Drought restrictions should not be confused with ongoing water conservation efforts. Restrictions may be harsh, cannot always be fair, and are not intended for long-term application. Water-dependent businesses will be negatively affected by water-use restrictions.

Surcharges

During a drought, Denver Water will consider implementing surcharges as part of an overall program to increase customer awareness of the drought's severity and the importance of saving water. Surcharges are separate from rates in that they are designed to raise awareness of the value of water, reduce water use and penalize those who don't comply with drought restrictions. Surcharges are temporary measures, and the Board must be clear in what criteria must be met in order to lift the surcharges.

Enforcement

Drought monitors are Denver Water employees who patrol the service area enforcing drought restrictions and water waste rules. The goal of the drought monitor program is to help customers comply with the rules, not merely to penalize violators.

Incentives and Education

To encourage immediate water savings during a drought, the Board may implement incentive programs, such as rebates, educational programs that teach water-saving skills, and clinics on drought-tolerant landscaping and watering practices.

Monitoring and Evaluation

When the Denver Water Board declares a drought, monitoring and evaluation activities are intensified. Water savings will be tracked and compared with normal water use and weather-adjusted expected use. If water savings goals are not being met, the drought response efforts may be modified.

Recommended Responses to a Drought Watch

The goal in a Drought Watch is to reduce water use by up to 10 percent. Adoption of a Drought Watch is meant to warn customers that water supplies are below average and that continued dry weather could trigger a Stage 2 Drought.

Recommended responses in a Drought Watch include:

- Request customers to voluntarily reduce their water use to decrease the possibility that water use restrictions will be intensified.
- Implement the water delivery reduction clauses in fixed-amount contracts associated with voluntary measures.

- Warn of and prepare for a Stage 2 Drought.
- Implement a public drought awareness campaign.

Recommended Responses to Stage 2 Drought

The goal in a Stage 2 Drought is to reduce water use by 20 percent and to increase water supply. A Stage 2 Drought activates mandatory water use restrictions and requires a significant effort on the part of customers.

Recommended responses to a Stage 2 Drought include:

- Allow irrigation only on specified days and for certain lengths of time.
- Restrict or eliminate nonessential water uses.
- Implement a water use reduction goal of 20 percent for large-volume customers.
- Consider exemptions or water budgets for public-use customers.
- Implement industry-specific water restriction programs.
- Activate the enforcement program.
- Implement the water delivery reduction clauses in contracts that are triggered by a Stage 2 Drought response.
- Implement a surcharge program as needed to support the mandatory drought restrictions.
- Implement a public awareness campaign.
- Consider making all or part of the emergency water supply available for use during the drought.
- Review the supply augmentation alternatives discussed in the Technical Appendices and implement those alternatives to the extent contracts, permits and finances allow.

Recommended Responses to Stage 3 Drought

The goal in a Stage 3 Drought is to reduce water use by 35 percent and to increase water supply. A Stage 3 Drought imposes more onerous mandatory water restrictions on Denver Water's customers. Stage 3 Drought restrictions are severe and may result in significant damage to landscapes.

Recommended responses to a Stage 3 Drought include:

- Allow one day of watering per week for trees and shrubs (no turf watering except on high-public-use areas).
- Limit watering time allowed per watering day.
- Eliminate all nonessential water uses.
- Implement a water use reduction goal of 35 percent for large-volume customers.
- Implement industry-specific water restriction programs.
- Implement the water delivery reduction clauses in contracts that are triggered by a Stage 3 Drought response.
- Consider making all or part of the emergency water supply available for use during the drought.
- Review the supply augmentation alternatives discussed in the Technical Appendices and implement those alternatives to the extent contracts, permits and finances allow.

Recommended Responses to Stage 4 Drought

The goal in a Stage 4 Drought is to reduce water use by 50 percent and to increase water supply. A Stage 4 Drought activates a rationing program for Denver Water's customers. Restrictions under a Stage 4 Drought are severe and will probably result in long-term damage to landscapes.

Though it is highly unlikely that conditions would ever warrant declaration of a Stage 4 Drought, recommended responses include:

- Limit outdoor watering to monthly tree watering.
- Eliminate nonessential water uses.
- Design a water-rationing program to provide customers water for essential uses for an indefinite period of extreme drought.
- Make the entire emergency water supply available for use during the drought.
- Review the supply augmentation alternatives discussed in the Technical Appendices and implement those alternatives to the extent contracts, permits and finances allow.

Communication

During a drought, Denver Water must communicate effectively with its customers, employees, community leaders and elected officials about the severity of the drought and why it is important for customers to restrict water use in order to gain support and cooperation from the people we serve. Drought affects a wide variety of water users, and Denver Water's ability to inform the public and employees of the water supply situation and need to act will determine the success of the plan.

The three major components of Denver Water's drought communication program are community outreach, customer relations and media relations. Communication among the Executive Team, Section Leaders and the Drought Response Committee is crucial to ensure that all activities at Denver Water support the drought response efforts.

INTRODUCTION

This Drought Response Plan is designed to maximize available water supplies and reduce water usage.

This Drought Response Plan outlines guidelines Denver Water will use to manage water supply and water use during drought, in addition to Denver Water's Policy Statement Regarding Drought Response, dated August 21, 2002. The guidelines are designed to avoid adverse impacts to public activity and quality of life for the community as a whole, while considering individual customer needs as much as possible. Because each drought is different, it is not practical to develop a set of hard-and-fast rules to apply to all droughts. These guidelines are intended to assist the Denver Board of Water Commissioners in making decisions throughout the course of a drought. The Board may adjust or refine the response based upon actual drought conditions.

Drought Response Plan History

Recognizing the need for a plan to deal with drought conditions, Denver Water created its first Drought Response Plan in 1993 with the help of a Citizens Advisory Committee task force. The 1993 plan was revised several times, and the most recent version prior to this document was dated May 2004. Because Denver Water's supply, demand and other conditions change continuously, the Drought Response Plan must be updated regularly to stay relevant to current conditions.

Before drafting the current Drought Response Plan, Denver Water staff thoroughly examined a range of drought scenarios, studied trends in water usage, quantified the severity of Colorado's past droughts, reviewed the lessons of past droughts and investigated options for obtaining additional water supplies in times of drought. Many of these reports and analyses are in the Technical Appendices.

Drought Response Plan Components

The Drought Response Plan consists of three interrelated sections:

- **Drought Severity Indicators –** The plan discusses a variety of factors that should be considered in choosing an appropriate drought stage and corresponding actions.
- **Drought Response Actions –** The plan provides guidelines for augmenting water supplies and reducing water use during times of drought.
- **Communication –** It is important to gather customer suggestions and involve them in decisions, as well as implement methods to keep customers and employees informed before, during and after a drought.

Defining Drought

Numerous drought definitions have been proposed by water resource professionals. For Denver Water, a drought is a condition of insufficient water supplies caused by a deficit in precipitation. Droughts occur in virtually all climatic zones, and they are a normal, recurring aspect of climate. When the amount of water flowing in streams and into reservoirs is less than average, Denver Water will more closely monitor its water supply outlook. If continued low stream flows stress water supplies, Denver Water will implement this Drought Response Plan.

Figure 1 depicts the variability of natural stream flows in Denver Water's raw water collection system. Troughs in the plot indicate that droughts are a recurring natural phenomenon.

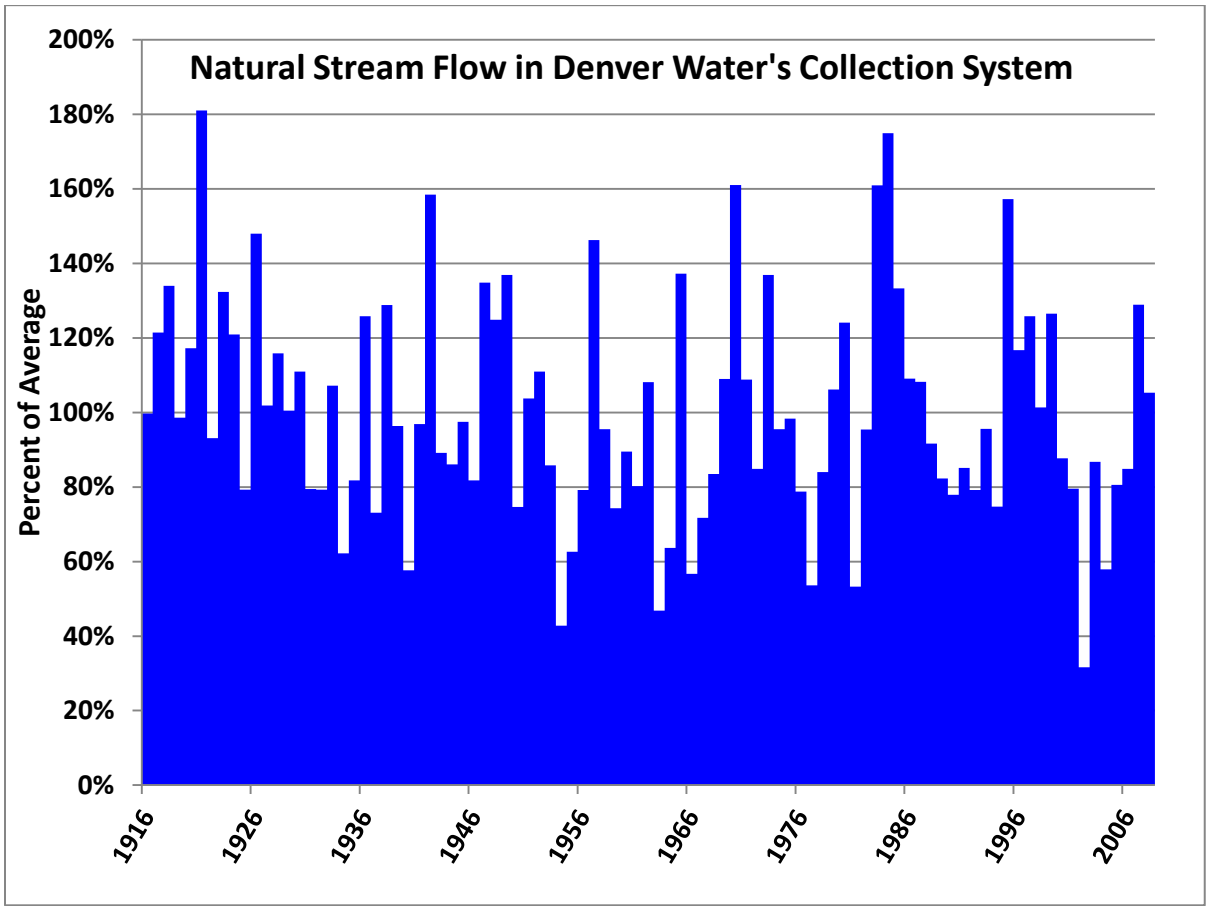


Figure 1. *Natural stream flow in Denver Water's collection system*

Denver Water's collection system is designed to dependably meet the needs of customers through hydrologic conditions similar to those of the past 377 years (1634 – 2010). Unfortunately, no one can predict how long drought conditions will continue once they begin. Timely response – not too early or too late – is Denver Water's goal.

Supply

Denver Water's supply is the estimated amount of water available from its collection system to meet customer demand. To determine supply, the water system capabilities are modeled using stream flow estimates back to the year 1634. The model assumes that water restrictions would be imposed to reduce demand during droughts. An emergency water supply has been set aside for other unforeseen circumstances and drought conditions worse than we have seen since the early 1600s. Figure 2 shows how Denver Water's reservoirs would be stressed if the 1634 – 2007 hydrologic period were to repeat itself with an average annual demand of 318,000 acre-feet and water restrictions imposed according to the recommendations in this plan. The current average annual demand is 280,000 acre-feet. Shifts in weather patterns can

be substantial from year-to-year and decade-to-decade, affecting both water supply and water use.

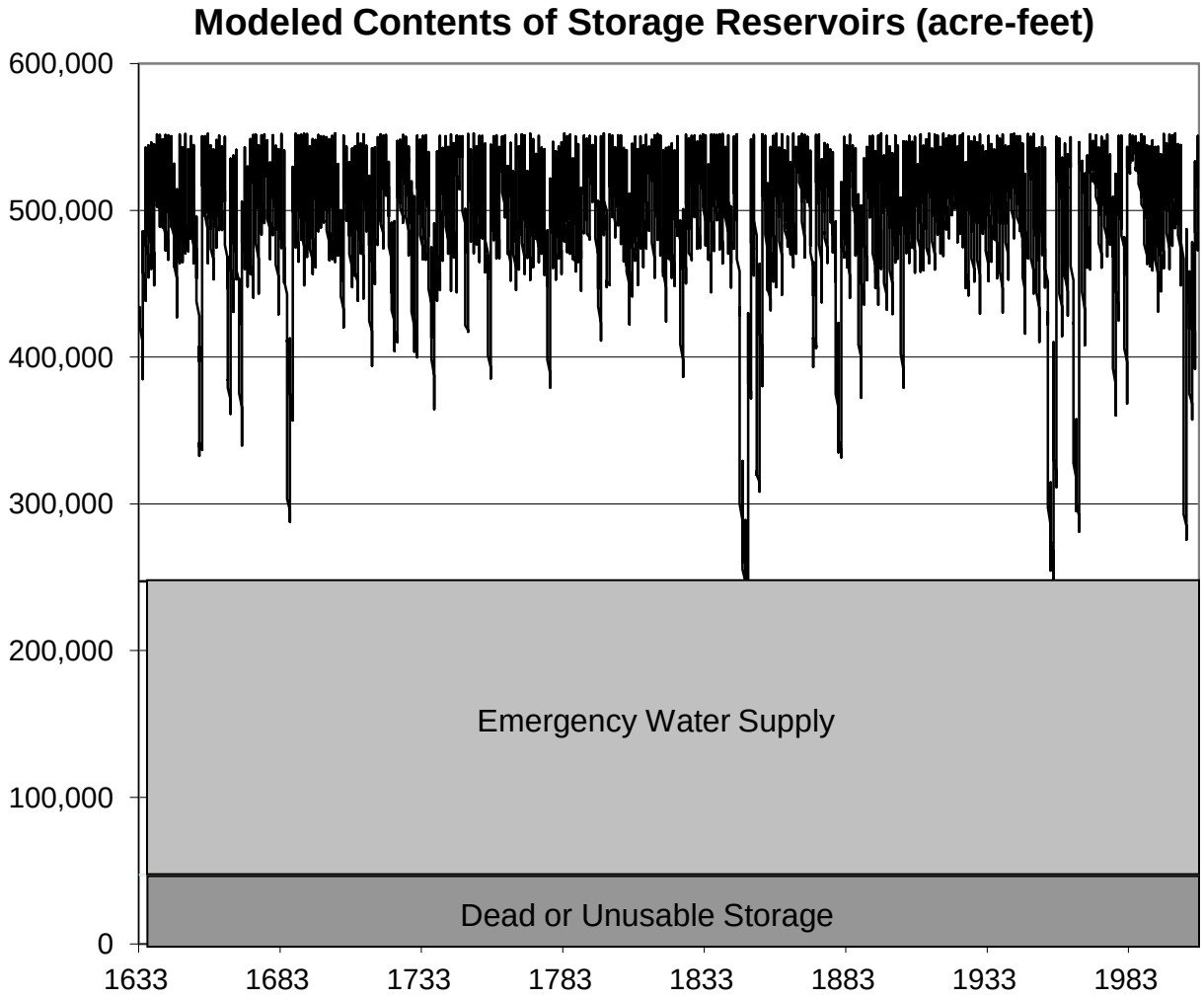


Figure 2. Modeled reservoir contents assuming a repeat of 1634-2007 stream flows and average annual demand of 318,000 acre feet.

Of the many factors that affect water supply estimates, weather is perhaps the most inexact. If the Denver area experienced a drought more severe than any ever recorded, the water supply system could be stressed even more than is accounted for in the estimated supply. Still, in relation to reasonable predictions based on nearly four centuries of estimated and measured stream flows, the supply calculation appears to be a reasonable way to view the water supply for drought planning purposes.

Long-term Conservation Efforts

Since the 2001-2007 drought, customer water use has stayed approximately 20 percent lower than water use levels prior to the drought. In 2007, Denver Water launched an aggressive conservation program to permanently reduce average customer water use from 1993 – 2001 levels 22 percent by 2016. Some restrictions used in the 2001-2007 drought, such as no lawn

watering from 10 a.m. to 6 p.m. and no watering more than three days per week, are now permanent water waste rules.

Because customers are already making conservation a permanent way of life, it will be harder to further reduce their water use during a future drought. Percentage reduction targets in each drought stage have been reduced to reflect this principle. Figure 3 shows the ongoing conservation efforts where demand has stayed relatively flat over the past 30 years while population continues to increase.

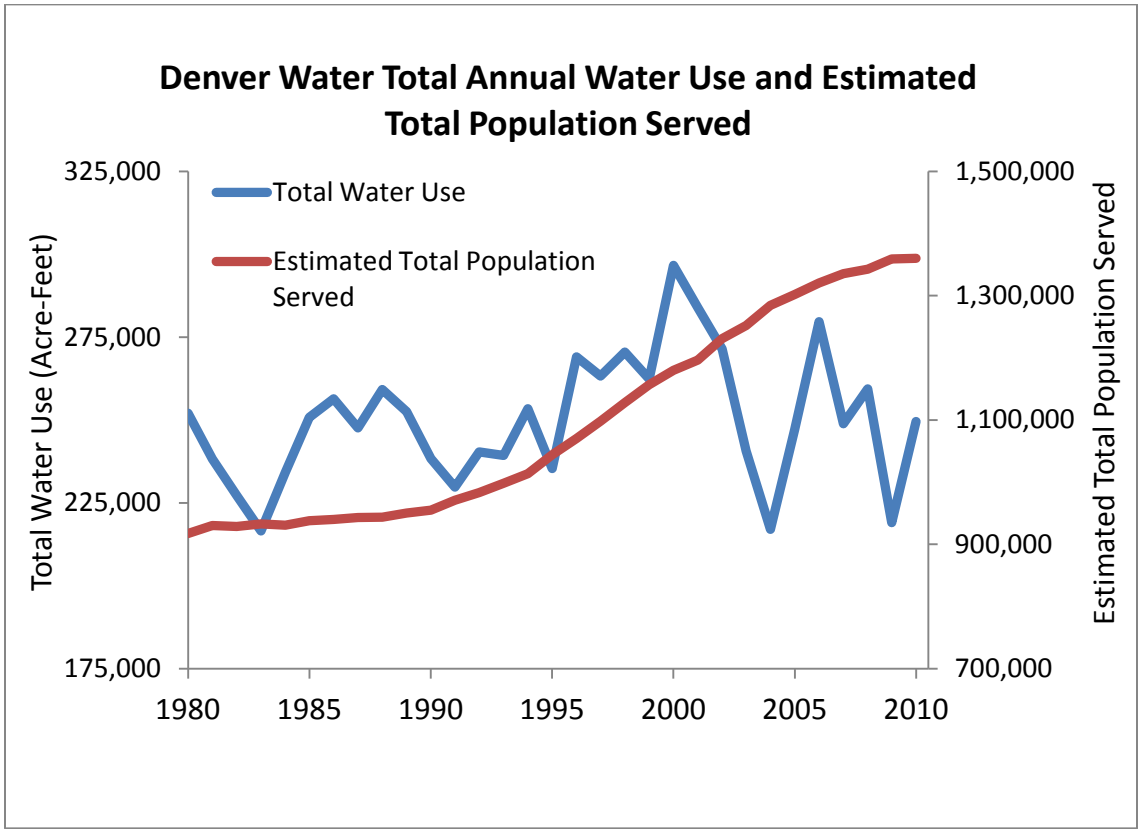


Figure 3. Customer water use and population growth.

DROUGHT SEVERITY INDICATORS

Drought severity indicators can generally be divided into two categories: (1) water supply indicators and, (2) political, social and economic indicators.

Water Supply Indicators

Water supply indicators include snowpack, precipitation, temperature, evaporation, stream flow, soil moisture and weather forecasts. Drought indices, such as the Surface Water Supply Index, the Standardized Precipitation Index and the Palmer Drought Severity Index, integrate multiple measurements and can also be used as drought severity indicators.

Because most of the water supply during drought comes from storage reservoirs, reservoir storage is an excellent indicator of a drought's impact on supplies. Reservoir storage is the bottom line result of the factors affecting supply, including weather, snowpack, soil moisture, runoff, water rights, bypass requirements, collection system limitations and water use.

Aggregate reservoir storage in Denver Water's system usually peaks in June or July just before water use becomes greater than water supply. For this reason, July 1 storage is a logical indicator for drought response.

July 1 storage levels are forecasted during the first weeks of February, March, April, May and June. Predictions are based on measurements of snowpack, stream flows, and the amount of water already in storage on the forecast date. The ability to predict July 1 storage improves as that date approaches. Since forecasts of July 1 reservoir storage prior to April are not very reliable, Denver Water would be reluctant to declare or alter a drought response before then.

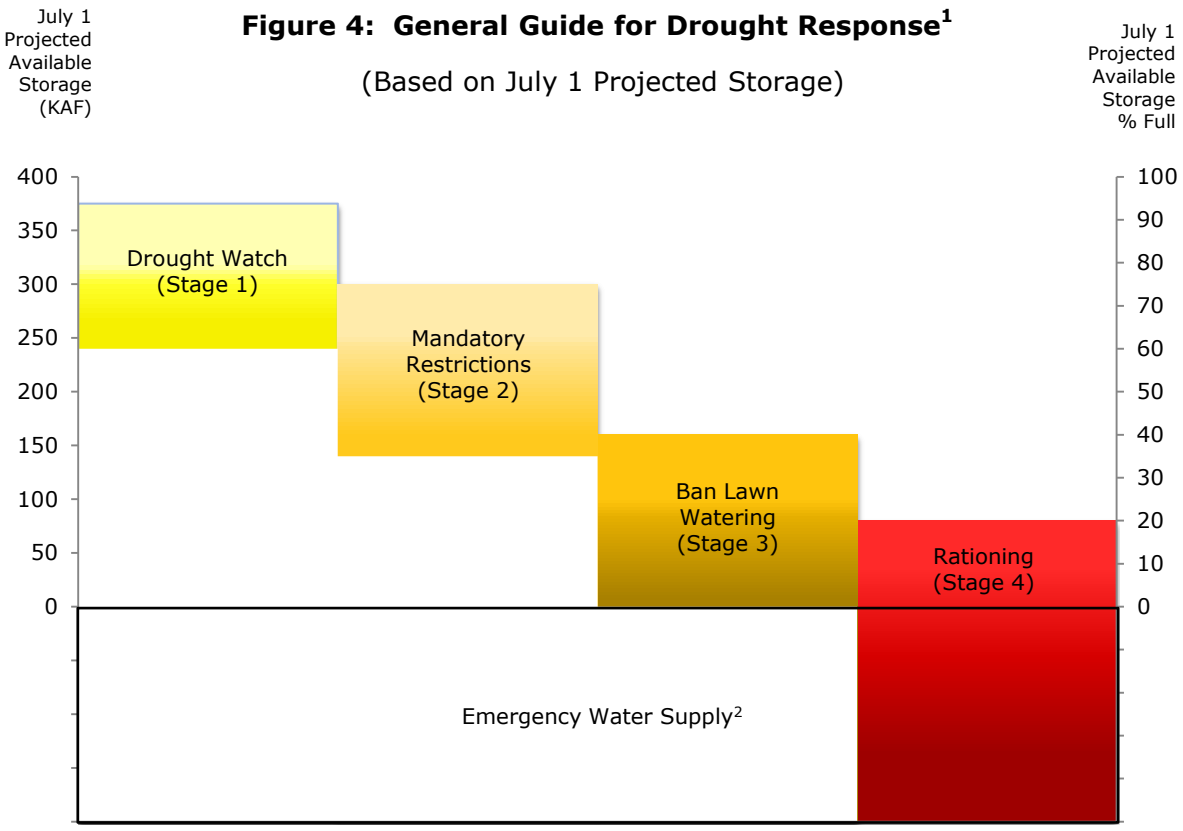
Regardless of the water supply situation, Denver Water staff monitors changes in snowpack, precipitation, temperature, evaporation, stream flow, soil moisture, weather forecasts and reservoir storage. This routine monitoring intensifies during dry periods.

If conditions change after a drought has been declared, the declaration can be lifted or the level of drought response can be adjusted. Denver Water's drought response decisions must be adequate to deal with the lack of water without causing unnecessary hardships for its customers.

Figure 4 illustrates the relationship between storage levels and recommended drought response, but the Board will consider many factors other than reservoir storage in making its drought response decisions. The figure shows July 1 *available* storage, which is the water we can legally and physically deliver to our customers' taps without dipping into our emergency water supply. Our emergency water supply is water that we plan to keep in our reservoirs to provide protection against unforeseen circumstances, such as a dam or tunnel failure, a water quality crisis, climate change or a severe drought. Available storage also excludes water that cannot physically be sent to our customers, such as the water stored in Williams Fork Reservoir, and water that must be retained in our reservoirs for environmental, dam safety or water quality purposes.

Figure 4: General Guide for Drought Response[1]

(Based on July 1 Projected Storage)



[1] In addition to reservoir storage, the Board may consider other factors in determining drought response. These factors include snowpack, stream flow, precipitation, soil moisture, responses of other water suppliers, news media response, political response and long-range weather forecasts.

[2] The emergency water supply is water that Denver Water plans to keep in its reservoirs to protect against unforeseen circumstances such as a dam or tunnel failure, a water quality crisis, climate change or a catastrophic drought.

The recommended responses in the chart overlap each other because there are no hard-and-fast relationships between reservoir storage and appropriate drought response. Denver's Board of Water Commissioners will consider many factors other than reservoir storage in choosing an appropriate drought response.

Political, Social and Economic Indicators

How a drought affects people – plus public perceptions about how the drought should be addressed – will influence how customers respond to Denver Water's calls to save water. The drought response activities of other water suppliers in the metro area, as well as news media and political responses, will also affect customer reaction. Although political, social and economic indicators cannot be viewed in terms of simple formulas, they can be monitored and described for consideration in the Board's decisions about drought response.

Response of Other Water Suppliers

Droughts affect the supplies of metro-area water providers in different ways. Northern suburbs that rely on single watersheds may be better or worse off, depending on the localized effects of a drought. Other systems that have junior water rights could be affected sooner or

more severely than Denver's system. The Denver Board of Water Commissioners will weigh the importance of developing a unified metro-area response against potentially restricting our customers' water use either sooner or later than warranted by water supply conditions.

Media Response

Much of the information customers receive about drought comes from the media. Members of the media can be very helpful in conveying factual information to customers, and they also play a key role in shaping public perception of drought.

Political Response

Political response to the drought can take many forms and depends on the constituents affected. For example, the Board might be asked to save some of its water supply for providers with less reliable systems. Or communities in the mountains, near Denver Water's collection system, might pressure the East Slope to conserve as they watch nearby reservoirs drop throughout the drought.

Economic Impacts

Water restrictions imposed in response to drought affect businesses in different ways. During the 2001-2007 drought, some water-dependent industries, including landscape-related businesses and water bottling companies, felt that restriction programs unfairly affected them economically. As part of its public outreach efforts, Denver Water will continue to carefully coordinate restriction programs with these industries.

Environmental Effects

Reduced stream flows and lower reservoir levels caused by drought can affect the environment, recreation, fisheries, economic activity and surrounding communities. Denver Water will monitor stream and reservoir levels so that environmental effects are taken into account in drought response decisions.

Taking Action on Drought Indicators

Denver Water staff analyzed and debated the advantages and disadvantages of taking early action versus delaying action until drought conditions are clearer. Tradeoffs are shown in Table 1.

Table 1. *Tradeoffs of early versus delayed action in case of possible drought*

Early Action	Delayed Action
Customers are frequently asked or required to reduce water use.	Customers are infrequently asked or required to reduce water use.
Reservoirs stay relatively full.	Reservoirs are less full.
A more severe drought can be withstood before storage water runs out.	A less severe drought can be withstood before storage water runs out.

A primary focus in the debate over early action versus later action was the potential hardships caused by reducing water use and drawing reservoir storage to lower levels. Reducing water use could harm metro-area businesses and damage water-intensive landscapes. Low reservoirs may reduce or prevent recreation, degrade the environment and

create aesthetic problems. In the final analysis, Denver Water staff judged indicator levels and drought responses on the basis of three questions:

- How severe of a drought could Denver Water withstand?
- How often and to what degree would customers be asked to reduce water use?
- How low would storage levels get?

To answer these questions, staff analyzed the water system with the following assumptions:

1. Current average annual demand is 280,000 acre-feet.
2. The Board would adopt a Drought Watch when July 1 projected available reservoir storage is 75 percent full, a Stage 2 drought when storage is 55 percent full, and a Stage 3 drought when storage is 20 percent full. These declaration levels are roughly in the middle of each response block shown in Figure 4.
3. Denver Water and its customers would not save any water during a Drought Watch, but would save 14 percent during a Stage 2 Drought, 29 percent during a Stage 3 Drought and 57 percent during a Stage 4 Drought. Water use reductions were estimated on the basis of how customers use water during normal periods and how they have used it during past dry periods.

How severe of a drought could Denver Water's system withstand?

At current water use levels, the assumed indicator levels and corresponding water savings listed in the preceding paragraphs would enable Denver Water and its customers to endure a drought more severe than either the 1950s drought or the 2001–2007 drought without dipping into the emergency water supply. In fact, using recorded and estimated stream flow going back to the year 1634, staff did not find any dry periods that would have caused us to dip into our emergency water supply given the assumptions of the preceding paragraph.

How often and to what degree would customers be asked to cut water use?

At current usage amounts, the assumed trigger levels and corresponding water savings listed earlier would result in Denver Water's customers having no water use restrictions about 93 percent of the time, Drought Watch restrictions 4 percent of the time, Stage 2 restrictions 2 percent of the time and Stage 3 restrictions 1 percent of the time. We do not believe a repeat of any droughts in the past 377 years would necessitate water rationing. However, as water demand increases with population growth, Denver Water expects drought declarations to occur more frequently. System maintenance or repair activities that temporarily take a storage or conveyance facility out of service could also make drought declarations more likely.

Uncertainty Associated with Forecasts

Sometimes a drought appears to be imminent, but weather conditions can change rapidly. Figure 5 shows what happened in the South Platte River Basin in 1995. The South Platte basin is a major source of Denver Water's supply. From February through mid-April of that year, water supplies from this source were below normal and drought conditions looked probable. The situation changed, however, as a result of higher-than-average precipitation during late April and most of May.

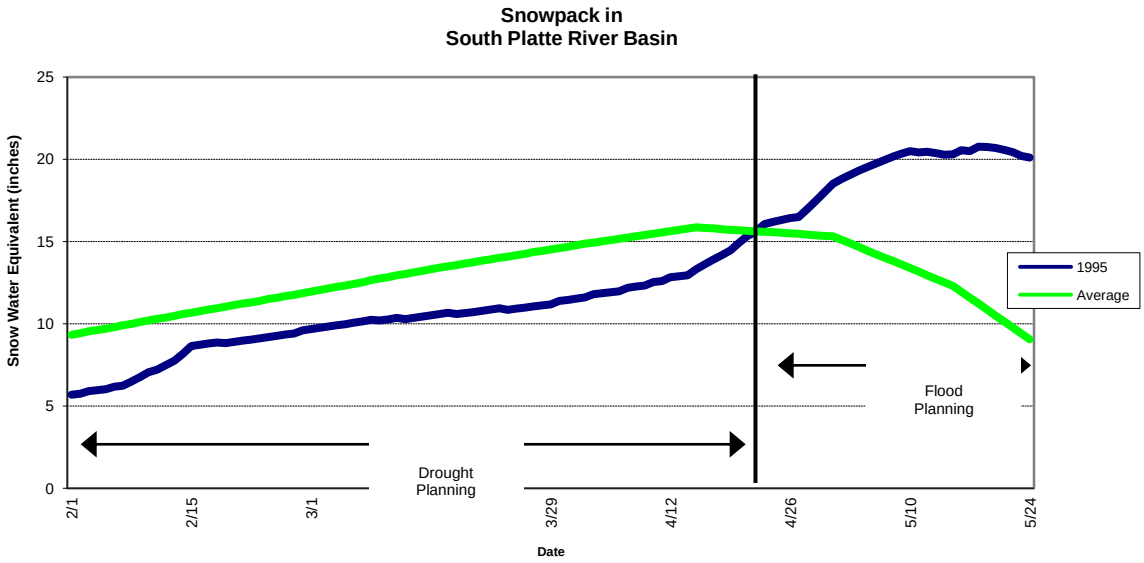


Figure 5. *Snowpack in the South Platte River Basin – 1995*

In 2002, on the other hand, an extremely dry spring and summer caused what would have been a moderately dry year to become the driest single year on record for Denver Water's collection system.

Unfortunately, Denver Water is no better at predicting weather than anyone else. Forecasting a drought – and knowing with certainty if one exists – can be difficult. When a dry year occurs, for example, we don't know whether we are in the first year of a three-, five- or 10-year drought, or if we are merely in a dry year somewhere in a series of average-to-wet years. Even though droughts cannot always be predicted, we will continue to advise customers of the latest water supply information so they can consider it in their own planning.

DROUGHT RESPONSE ACTIONS

As reservoir storage declines, efforts to add water supplies and reduce water use increase.

Denver Water's Drought Response Plan consists of two components – the **indicators** that help the Board decide which stage of drought to declare and the corresponding **actions** recommended for each stage. The plan delineates four stages of drought severity. Each stage is based on water supply indicators such as snowpack, precipitation, temperature, evaporation, stream flow, soil moisture and reservoir storage, as well as various political, social and economic indicators discussed in the Drought Severity Indicators chapter of this document. For each stage, progressively more stringent responses are recommended.

As reservoir storage declines, efforts to add to water supplies and reduce water use increase. Some drought response measures, particularly those designated for mild episodes of drought, require minimal customer effort. But measures become mandatory, more costly and sometimes intrusive as a drought intensifies. Basically, the recommended response to a Drought Watch is voluntary measures; to a Stage 2 drought, mandatory restrictions; to a Stage 3 drought, prohibitions on lawn watering; and to a Stage 4 drought, rationing of water supplies for essential uses.

To activate a particular drought response, the Board of Water Commissioners declares a drought stage and adopts an effective date for imposing applicable restrictions. Because Stage 2, Stage 3 and Stage 4 droughts involve mandatory restrictions, they are incorporated into Denver Water's Operating Rules and become enforceable pursuant to the Denver City Charter, the Denver Revised Municipal Code and provisions in Denver Water's water service agreements and water leases. Chapter 15 of the Operating Rules contains the restrictions that apply during a Stage 2, Stage 3 or Stage 4 drought, as declared by the Board.

Drought Response within Master Meter Districts

Master meter districts receiving water from Denver Water are governed by Denver Water's operating rules, including the drought response rules. Master meter districts can make and enforce their own rules, as long as they are not inconsistent with Denver Water's. These districts also must help enforce the operating rules.

Increasing Water Supply

In addition to managing water use during a drought, Denver Water will try to increase its supplies by gaining access to other sources. Each augmentation option listed below presents unique intergovernmental and technical issues.

- Invoke the Shoshone relaxation agreement.
- Reduce diversions by the Big Lake Ditch.
- Reduce deliveries to Englewood under the 1995 agreement.
- Waive minimum bypass requirements.
- Waive minimum reservoir pool requirements.
- Operate the Chatfield temporary pumps.
- Develop substitute water supply plans.
- Use the WISE water supply.
- Reduce the endangered fish delivery from Williams Fork Reservoir.

- Refrain from participating in the Coordinated Reservoir Operations program for the endangered fish.
- Reduce outflows from South Platte reservoirs below the minimums shown in the South Platte Protection Plan.
- Drill nontributary wells.
- Pump dead storage.

The Supply Augmentation Alternatives chapter in the Technical Appendices discusses the above options in detail.

Reducing Water Use

Denver Water's primary response to drought is to reduce water uses so that supplies will be available for the most essential uses for the duration of the drought. Mandatory drought restrictions were put in place in 2002, 2003 and 2004. Through that experience, we learned no single approach was effective at encouraging all customers to reduce their water use. A variety of actions proved more effective at creating an overall atmosphere that promotes water savings. The five actions discussed in the sections that follow include restrictions, surcharges, enforcement, incentives, and monitoring and evaluation. Generally speaking, restricting the number of days and times allowed for watering landscapes is the most effective method for reducing water use. Other methods, such as surcharges and public information efforts, complement those watering restrictions. Other restrictions may not substantially reduce water use but may eliminate discretionary uses of water or heighten awareness of drought severity.

Restrictions

Once the Board has declared a drought, Denver Water will activate the corresponding set of recommended responses. Denver Water's goal for drought response is to preserve the quality of public life and economic activity to the extent possible in the face of water shortage. In 2002, the Board adopted policy guidelines for developing a drought restriction program. Denver Water follows these principles in restricting water use during a drought.

Avoid irretrievable loss of natural resources.

- Allow watering of irreplaceable trees.
- Avoid damaging perennial landscaping if possible.
- Tailor water restrictions as much as possible to known landscape needs.

Restrict less essential uses before essential uses.

- Restrict water use for misters, fountains and other aesthetic water features first.
- Avoid using water as a substitute for something else (for example, cleaning impervious surfaces or washing personal vehicles).
- Curtail outdoor water use (except for watering trees and shrubs) and commercial use before restricting domestic indoor use.

Affect individuals or small groups before affecting large groups or the public as a whole, allowing as much public activity as possible to be unaffected.

- Preserve community pools rather than residential pools.
- Restrict golf courses before public parks.

- Restrict water use on less heavily used areas of parks where grass can go dormant before restricting use on formal and informal playing fields, where recreational activity would either kill the grass or have to be prohibited.

Minimize adverse financial effects.

- Be respectful of water-based businesses that will be financially affected by restrictions.
- Restrict seasonal commercial use, which is likely to be outdoors.
- Restrict nonessential uses of water in businesses before affecting fundamental business functions.
- Work with large-volume water users to reduce use in the least disruptive manner.
- Engage in ongoing dialogue with the green industry to obtain input and allow these businesses to plan for future months.

Eliminate waste.

- Enforce restrictions and permit limitations in an effective manner.
- Adopt restrictive criteria for exemptions from restrictions.
- Discourage or prohibit irrigation of medians.
- Prohibit installation of new landscaping if its survival next season is in doubt.
- Provide incentive programs to promote savings.
- Perform audits to identify water waste and recommend solutions.

Adopt extensive public information and media relations programs.

- Inform customers about the problems caused by drought and what they can do to help.
- Hold and attend public meetings as necessary to receive input.

Surcharges

When considering surcharges during drought conditions, Denver Water will consider several guiding principles in developing surcharges:

There is a relationship between price and demand. In theory, customers respond to an increase in price by reducing demand. But at what price level will customers reduce demand? The answer depends on a number of factors, especially uses of water. Indoor uses, such as bathing and drinking, are typically more essential than outdoor uses, such as lawn irrigation. Therefore, customers are more likely to reduce nonessential outdoor uses as the price increases than they are to reduce essential indoor uses.

*Surcharges will be incorporated into an overall program to increase customer awareness of the drought's severity and the importance of saving water***.** A variety of actions, including surcharges, cause customers to reduce their water use. Surcharges play a role in creating an environment in which customers recognize the importance of reducing water use.

Surcharges may apply to current water demands, new taps or other demands on the water supply. Some people disapprove of issuing new taps when existing customers are subject to surcharges during a drought. Applying various forms of surcharges to different types of demands on the water supply provides an equitable method allowing all customers to share the burden of preserving the supply.

Surcharges are less effective by themselves. Industry studies and Denver Water's customer surveys indicate that surcharges are more effective at reducing water use when combined with other restrictions to create an atmosphere of saving water. Customer response to surcharges varies depending on several factors, such as affluence, billing frequency and the normal cost of water. Empirical data show that customers respond to temporary water pricing strategies as part of a water savings environment.

Surcharges are separate from rates. Denver Water is a nonprofit governmental agency that sets rates based on the cost of providing service to customers. Drought surcharges, on the other hand, are designed to send a price signal to customers to raise awareness of the value of water, reduce water use and penalize those who don't comply with drought restrictions. These goals are better accomplished when surcharges are implemented as a temporary measure.

Surcharges should match the severity of the drought. Because every drought is different, each one may require a different set of responses. Surcharges must be structured to help create an atmosphere of appropriate water savings. Surcharges may include one or more of the following components:

- Increasing the unit rates for each customer class while retaining the existing structure.
- Modifying the block thresholds for single family residential and multifamily customers.
- Increasing the number of tiers for single family and multifamily customer classes.
- Increasing the number of seasonal periods for nonresidential customer classes (e.g. low, medium and high seasons).
- Changing the price ratios for tiered or seasonal rate structures. This would include single-family residential, multifamily (less than five units), and nonresidential customer classes.
- Developing individualized structures for metered irrigation-only customers.

These surcharge price or structure changes would be applied uniformly across the affected customer class. For example, if the single-family residential block 1 rate increased by 100 percent, all single family customers both inside city and outside city would be increased by 100 percent.

Surcharges must be feasible for computer systems to handle. Denver Water must be able to respond to drought conditions quickly and efficiently. Any change in water use charges must be manageable with only moderate modifications to existing computer systems.

Surcharges should be tailored for different customer groups. Commercial and industrial customers use water differently from residential customers. Large-volume public use customers may need some accommodation. The surcharge structure must be flexible enough to promote water savings while still addressing diverse customer needs and supporting drought restrictions.

Surcharges should reflect overall drought response philosophies. Because all surcharge structures divide customers into groups, no surcharge structure is 100 percent fair. Some customers may pay a surcharge even if they comply with the other restrictions.

Surcharges may need to be seasonally adjusted. In Colorado, water use is greater in summer than in winter. Outdoor use is more discretionary than indoor use, and surcharges should be adjusted to reflect this. Because restrictions to reduce indoor use are difficult to design, adjusting surcharge thresholds can be more effective at monitoring and reducing indoor water demand in winter.

Public information is important in helping customers understand surcharges. When surcharges are designed and implemented, the public must receive adequate information to fully understand the surcharge program.

Surharges are temporary measures. Denver Water must determine criteria for lifting the surcharges before implementing them. This way, customers understand that the surcharges are a temporary measure during a drought.

Equity issues related to removing the surcharge should be addressed in advance. Denver Water won't necessarily remove surcharges at the end of a billing period. Criteria for lifting the surcharge once the specified conditions occur should be considered ahead of time.

Enforcement

Denver Water has an enforcement program to help customers understand and obey water waste rules and drought restrictions. During a drought, monitors will patrol Denver Water's service area, looking for customers who are not complying with the rules. The primary mission of the drought monitors is to educate customers. Drought monitors will distribute educational materials, help customers reduce their water use and answer questions about the drought. Violators may receive written warnings and may be fined for repeat violations. Flow restrictors may be installed at properties with repeat violations.

Recruitment. Denver Water has been enforcing its water waste rules since 2008 and will use these seasonal employees to enforce drought restrictions. It may be necessary to press into service additional people from the Customer Service section.

Training. Drought monitors will undergo an intense training program to prepare them to enforce drought rules. Dispatchers and administrative staff will participate in the training program, which will address:

- Customer service standards
- Reading meters
- Understanding the drought restrictions
- Operating irrigation systems
- Knowing the boundaries of their patrol area
- Understanding the data entry equipment

Documentation. Drought monitors will utilize a system to track violations and enable him or her to issue the appropriate warning or ticket. Drought monitors also will track stops that were educational and did not result in a ticket or a written warning.

Appeals. Anyone fined for violating a drought restriction may appeal, but must pay the fine with the bill by the due date. If the Board grants the appeal, Denver Water will credit the disputed charge on the customer's next bill.

Incentives

An incentive program may be designed to encourage immediate reductions in water consumption. This program would be an extension of Denver Water's long-term water conservation program and may include features such as:

- Rebates
- Contests
- Drought hero awards
- Landscape clinics
- Conservation kits

Monitoring and Evaluation

When the Board declares a drought, staff will intensify its monitoring and evaluation activities. The monitoring and evaluation program will track information such as snowpack, soil moisture, streamflow, precipitation, water rights, reservoir levels and weather forecasts. In addition, water usage and its corresponding revenue will be compared to normal use and weather-adjusted expected use. If customers are not reducing their water use by the required amount, the Board may increase the level of drought restrictions.

Recycled Water

Denver Water has the right to reuse a major portion of its water imported from the West Slope, as well as a small portion of its East Slope supplies. Denver Water has a recycled water plant that treats wastewater and delivers non-potable water to customers for irrigation and industrial purposes. Recycled water has different characteristics than potable water. In periods of drought, reusable water may be more or less abundant than other water supplies. In recognition of these potential differing circumstances, the Board may adopt specific drought restrictions for recycled water customers.

Use of Water Not Provided by Denver Water

Some customers have access to water sources that are not owned, controlled or provided by Denver Water. Though the use of such water is not under the direct control of Denver Water, those customers still will be subject to restrictions in the Operating Rules related to signage, avoidance of contamination of the potable water system, and prevention of water waste.

Drought Watch (Stage 1) Response

Indicators:

1. Projected available reservoir contents between 60 percent and 95 percent full on July 1. (See Figure 4.)
2. Watershed characteristics such as precipitation, snowpack, stream flow, wind and soil moisture indicate prolonged dryness.
3. Service area precipitation indicates prolonged dryness.
4. Long-range weather forecasts indicate a drought watch response is appropriate.
5. Other metro-area water suppliers are preparing to respond to the dryness.
6. News media are sending messages that imply drought may be pending.
7. Customers believe a drought watch and its corresponding actions are appropriate.
8. Elected officials are suggesting Denver Water adopt a drought watch or similar response.

***Water Use Reduction Target*:** Up to 10 percent

Description

A Drought Watch will alert customers that water supplies are below average and continued dry weather could lead to a Stage 2 drought declaration. Recommended responses to a Drought Watch include:

- Request that customers voluntarily reduce their water use by 10 percent to reduce risk of progression to a Stage 2 Drought.
- Enact the Stage 1 Drought delivery reduction clause in contracts.
- Warn of and prepare for a Stage 2 Drought.
- Request business entities such as restaurants, hotels and car washes to implement suggested water-saving measures.
- Suggest water reduction measures to irrigators and large commercial and industrial users.
- Enhance enforcement of rules governing water waste.

As a part of the Drought Watch response, Denver Water will:

- Inform customers about measures they can expect if the drought continues or intensifies.
- Invite public discussion on water use priorities and ways to reduce water use.
- Contact groups that use large volumes of water, such as water recreation groups, to garner their ideas and support.
- Provide suggestions for temporarily reducing water use.
- Require master meter water distributors to activate similar programs with their customers.

At the onset of drought, an interdivisional Drought Response Committee will be formed. This committee will monitor drought conditions and evaluate the effectiveness of the Drought Watch response. Recommendations for adjusting the response will be submitted to the Board of Water Commissioners.

Fixed-Amount Water Contracts

Water deliveries to customers who receive nonpotable or potable water under fixed-amount contracts will be restricted as follows:

- For agreements that allow Denver Water to reduce deliveries during a drought, Denver Water will reduce deliveries 10 percent.
- For agreements that allow the lessee to adopt the same or similar water use restrictions as Denver Water, the lessee must implement the water use restrictions adopted by the Board.

Stage 2 Drought Response

Indicators:

1. Projected available reservoir contents between 35 percent and 75 percent full on July 1. (See Figure 4.)
2. Watershed characteristics such as precipitation, snowpack, stream flow, wind and soil moisture indicate unusual and prolonged dryness.
3. Long-range weather forecasts indicate the dryness could persist.
4. Other metro area water suppliers are planning to enact mandatory water use restrictions.
5. Customers believe that mandatory water use restrictions are appropriate.
6. State water officials are engaged in drought response activities.
7. Circumstances warrant some adverse impact on water-dependent businesses involved in outdoor water use.

Use Reduction Target: 20 percent

Description

A Stage 2 Drought imposes mandatory water use restrictions and requires a significant effort on the part of customers. Stage 2 water use restrictions will appear in the Operating Rules. The current drought rules in Chapter 15 are included in the Appendices.

Mandatory Restrictions

- Restaurants – Restaurants will be restricted to serving water with meals only on request.
- Lodging – Lodging establishments will be restricted from changing sheets more often than a prescribed number of days for guests staying more than one night.
- Turf Irrigation - Irrigation of turf will be limited to a certain number of minutes per zone. Watering will be limited to assigned days each week, unless the Board grants exemptions for specific uses of irrigation, such as installation of new turf, or by means of water budgets for large volume irrigators.
- Irrigation of Trees, Shrubs and Gardens – Irrigation of trees, shrubs and gardens with a hand-held hose or low-volume nonspray irrigation device will be permitted with different restrictions than irrigation of turf.
- Early Winterization and Spring Watch Programs – Outdoor lawn watering may be prohibited between October 1 and May 1, except for watering of turf areas that are heavily used by the community.

Outdoor Nonirrigation Uses

- Water Features – Customers must not operate existing outdoor water features that spray water into the air.
- Vehicle Washing – Washing of personal and fleet vehicles will be subject to restrictions on frequency and the type of equipment used. Commercial car washes will be subject to a certification process to ensure an appropriate level of water conservation.
- Power Washing – Individual power washing that is permitted by water waste rules will be restricted to certain days and hours. Commercial power washing will be restricted to high-efficiency equipment.

Surcharges

A surcharge program may be used to support water use restrictions and help reduce customer water use.

Emergency Water Reserve

The Board may make water from the Emergency Water Reserve available for use during a Stage 2 drought. Such action could reduce the severity of Stage 2 restrictions, or it could be used to delay or eliminate a Stage 3 drought response.

Fixed-Amount Water Contracts

Water deliveries to customers who receive nonpotable or potable water under fixed-amount contracts will be restricted as follows:

- For agreements with provisions allowing Denver Water to reduce deliveries under drought conditions, deliveries will be reduced by 20 percent.
- For agreements with provisions requiring the lessee to adopt the same or similar water use restrictions as Denver Water, the lessee must implement the water use restrictions adopted by the Board.
- For agreements without these provisions, the Board may adopt drought surcharges or other methods to reduce water consumption outside Denver as necessary to provide an adequate water supply to the people of Denver.

Enforcement

The customer (owner or occupant of the property) is responsible for complying with drought restrictions and exemption terms. Those who violate any Stage 2 Drought restriction will be subject to increasing penalties, including the possibility of a flow restrictor or suspension of water service.

Stage 3 Drought Response

Indicators:

1. Projected available reservoir contents between 0 percent and 40 percent full on July 1. (See Figure 4.)
2. Watershed characteristics such as precipitation, snowpack, stream flow, wind and soil moisture indicate severe dryness.
3. Long-range weather forecasts indicate that the dryness could persist.
4. Other metro area water suppliers have enacted or are considering severe restrictions on outdoor water use.
5. Customers believe that harsh water use restrictions are appropriate.
6. State water officials have declared a drought emergency.
7. Bans on most lawn watering justify prohibitions on some water-dependent businesses.

Use Reduction Target: 35 percent

Description

A Stage 3 Drought imposes mandatory water restrictions on Denver Water's customers. Stage 3 Drought restrictions are severe and will probably result in significant damage to or loss of landscapes. Stage 3 water use restrictions will appear in the Operating Rules. The current drought rules in Chapter 15 are included in the Technical Appendices.

Mandatory Restrictions

- Restaurants – Restaurants will be restricted to serving water with meals only on request.
- Lodging – Lodging establishments will be restricted from changing sheets more often than a prescribed number of days for guests staying more than one night.
- Turf Irrigation – Irrigation of most turf is prohibited.
- Installation of New Turf – Installation of new turf is prohibited.
- Water Budgets for Large-Volume Users – The Board may permit irrigation by high-public-use, large-volume irrigators if they can manage water use in a way that reduces their seasonal water use by 50 percent.
- Irrigation of Trees and Shrubs – Existing trees and shrubs may be watered by means of a hand-held hose or low-volume nonspray irrigation device no more than one assigned day per week.
- Irrigation of Flowers and Vegetables – Existing gardens may be watered any except Monday by means of a hand held hose or low volume nonspray irrigation.
- New plantings are not allowed.

Outdoor Nonirrigation Uses

- Water Features – Customers may not operate existing water features that spray water into the air. No new outdoor water feature may be put into operation during a Stage 3 Drought.
- Vehicle Washing – Washing personal vehicles is prohibited except at commercial car washes certified by Denver Water. Fleet vehicles may be washed only once a month using car washes or washing equipment certified by Denver Water. Commercial car

washes must be certified as achieving 50 percent water savings compared with nonrecycling car washes.

- Power Washing – Individual and commercial power washing are prohibited except for immediate public health or safety reasons. Commercial power washing may use only Denver Water-certified high-efficiency equipment.
- Swimming Pools – Single-family residential pools may not be filled or refilled. Operation of community pools may be permitted.
- Hydrant Permits – Water obtained with a hydrant permit may not be used to clean equipment or for any other use prohibited during a Stage 3 Drought.

Surcharges

A surcharge program may be used to support water use restrictions and help reduce customer water use. For example, each consumption block for residential customers could be increased by the same percentage, or by an increasing percentage.

Emergency Water Reserve

The Board may make water from the Emergency Water Reserve available for use during a Stage 3 drought. Such action could reduce the severity of Stage 3 restrictions, or it could be used to delay or eliminate a Stage 4 drought response.

Fixed-Amount Water Contracts

Water deliveries to customers who receive untreated water, nonpotable water or potable water under fixed-amount contracts will be restricted as follows:

- For agreements with provisions allowing reduced deliveries under drought conditions, the amount delivered shall be reduced by 35 percent.
- For agreements with provisions requiring the lessee to adopt the same or similar water use restrictions as Denver Water, the lessee must implement the water use restrictions adopted by the Board.
- For agreements without these provisions, the Board may adopt drought surcharges or other methods to reduce water consumption outside Denver as necessary to provide an adequate supply of water to the people of Denver.
- Any water delivered by Denver Water between May 1 and October 1 shall not be used for otherwise permissible irrigation between the hours of 10 a.m. and 6 p.m.

Enforcement

The customer (owner or occupant of the property) is responsible for complying with the drought restrictions and with the terms of any exemption. Those who violate Stage 3 Drought restrictions will be subject to increasing penalties at levels higher than in a Stage 2 Drought, including the possibility of a flow restrictor or suspension of water service.

Stage 4 Drought Response

Indicators:

1. Projected available reservoir contents less than 20 percent full on July 1.
2. Watershed characteristics such as precipitation, snowpack, streamflow, wind and soil moisture indicate severe and prolonged dryness.
3. Long-range weather forecasts indicate that the dryness could persist.
4. Other water suppliers are rationing water.
5. News media are sending message that we are in a crisis situation.
6. Customers believe we are in a crisis situation.
7. Elected officials are saying that water rationing is appropriate.
8. The situation suggests that severe impacts to water-dependent businesses are unavoidable.

Use Reduction Target: 50 percent reduction

Description

A Stage 4 Drought activates a rationing program for Denver Water's customers. **Conditions that would lead to a Stage 4 Drought are highly unlikely.** However, if conditions warrant, Denver Water may implement a rationing program for an indefinite period of time to ensure, to the extent possible, that there is adequate water for essential uses. No outdoor watering will be allowed, and indoor water use will be restricted. Stage 4 Drought restrictions will be damaging the quality of life in Denver Water's service area, including the long-term loss of landscapes.

Mandatory Restrictions

- Turf Irrigation – Irrigation of turf is prohibited.
- Irrigation of Trees and Shrubs – Outdoor watering may be limited to monthly tree watering or prohibited completely.
- Outdoor Nonirrrigation Uses – Nonessential water uses will be prohibited.
- Indoor Water Use – A rationing program will be designed to minimize indoor water use.

Emergency Water Reserve

Due to the severity of the situation, the Board will probably make any water remaining in the Emergency Water Reserve available for use during a Stage 4 drought.

COMMUNICATION

During a drought, Denver Water must communicate effectively with its customers, employees, community leaders and elected officials to increase understanding of the severity of the drought and gain support and cooperation for the needed water use restriction levels from the people it serves.

Drought affects a wide variety of water users, and Denver Water's ability to inform the public and employees of the water supply situation will determine the success of the plan. The more people understand the drought's severity, the more likely they are to support the actions called for in the plan.

Communication During a Drought

A communications program designed for a drought must target employees, customers, distributors, media, general public, elected officials and community leaders.

The level of drought severity determines the level of communication efforts. If the drought is severe and requires the Board to impose mandatory drought restrictions, Denver Water's Public Affairs Division will employ aggressive public information tactics. Numerous tools are available for such efforts, including direct mail, Web updates, bill inserts, electronic newsletters, internal newsletters, social media, public meetings, Citizen Advisory Committee meetings, advertisements, press releases and media interviews.

Customer Care's call center representatives are another important communications tool. They handle 800 to 1,400 calls a day and can provide drought messages on every call. They also can adjust the automated phone attendant to communicate drought-related messages.

Another important task is communication with other utilities and industries. Denver Water would work with other utilities to help relay drought messages to the entire Denver-metro area. The Conservation Section could reach out to commercial customers, GreenCo (irrigators, sod farmers, landscape contractors and nurseries) and others to expand delivery of drought messages.

The Public Affairs Division will also notify local public officials and other community leaders of the drought's severity and steps necessary to offset the drought's effects. The Public Affairs Division will maintain a list of elected officials and community leaders who need to be notified and kept aware of the drought's progress and Denver Water's expected response.

At the same time, the Public Affairs Division will provide timely and accurate information to employees. Because Denver Water employees live and work in the community and have daily contact with customers, they are in a position to serve as communicators and ambassadors. This role requires that employees receive timely information about drought conditions and Denver Water's response plan and activities.

On Denver Water's intranet site, *Inflow,* employees would be able check reservoir status, consumption information, latest enforcement procedures and messages to relay to customers.

Outline for a Drought Communication Plan

Once the Board has identified a specific drought stage, Denver Water's Public Affairs staff will develop a tactical plan appropriate to the conditions and circumstances of that stage. A drought that has lasted several years, for example, will require a different communications strategy than a mild drought in its first year. Public Affairs must be resilient and flexible with its plan, but it's important that the division is notified of drought status early so the communications strategy can reflect changing conditions. The overall communications strategy would resemble the following:

Spring

- Work with the Executive Team, the Drought Response Committee and the committee's designated internal drought coordinator to establish key messages. Using those messages, develop strategies for educating the public and employees. Compile employee feedback about what's resonating with customers and adjust messages accordingly.
- Formalize a communications plan depending on the circumstances of the drought.
- Respond to and pitch relevant news stories.
- Determine whether the advertising agency's contract needs to be adjusted to accommodate a drought campaign.
- Use appropriate tools (website, direct mail, bill inserts, etc.) to communicate with customers and distributors about the seriousness of the drought and ask them to take actions to reduce water use if needed. Provide status information to public officials, stakeholders and key leaders.
- Stay in touch with other utilities and discuss appropriate ways to issue joint messages.
- Internally, use communication tools such as *PipeLine, Conduit,* newsflashes, conference calls, *Inflow,* and brown bag meetings to provide timely and accurate information about drought conditions and drought messages to employees.

Summer

- Use Water Savers to educate customers face-to-face about the severity of the drought and their role in drought response. Also use Customer Care to relay drought messages to customers. Use the Distributors Forum, mailings and other vehicles to help reach suburban providers and customers.
- Promote relevant news stories to media and respond to media inquiries.
- Use relevant tools (website, direct mail, bill inserts, public meetings, advertisements, etc.) to inform customers of the severity of the drought and what actions we need them to take, and to notify customers of drought surcharges and other measures the Board approves.
- Meet with public officials and community leaders to discuss the drought, key messages, Denver Water's response and why we need to respond.
- Contact relevant customers and industries, such as landscape contractors, tree nurseries, sod farmers and commercial customers to keep them posted on the drought's severity and why we are responding a certain way.
- Internally, use communication tools such as *PipeLine*, *Conduit*, newsflashes, *Inflow,* and brown bag lunches to keep employees posted about drought conditions, Denver

Water's response and why we are responding in a certain fashion. Public Affairs staff will help train employees on how to answer customers' questions about the drought and where to go for more information.

Fall

- As conditions warrant, conduct a customer survey to help understand what programs and strategies worked and what didn't, as appropriate.
- As conditions warrant, conduct a separate survey of commercial customers who depend heavily on water, such as bottling companies, food processing companies, GreenCo and laundry businesses.
- Debrief with Executive Team, Section Leaders and the Drought Response Committee and determine necessary changes or adjustments.
- Debrief with employees to determine the level of contact with customers, the nature of questions asked by customers and overall success of the summer's program.
- Develop messages about how customers should respond to the drought during the winter. Should they water their trees? Make landscape changes in the case of a prolonged drought? Involve GreenCO and Colorado State University's Cooperative Extension in creating these messages.

Weather conditions can change rapidly in Colorado, and Public Affairs must be flexible and adaptable with those changing circumstances in order to have a successful communications strategy.

December 2011

DROUGHT RESPONSE PLAN

Technical Appendices

DENVER WATER

◇ TABLE OF CONTENTS

◇ LIVE ON INFLOW ANALYSIS

An important question in formulating Denver Water's drought response plan is: "How much supply would Denver Water have if it entered a drought without any storage water?" The answer to this question provides drought planners with a possible worst-case scenario.

We addressed this question by analyzing municipal water year 2002, which is the time period from April 1, 2002 through March 31, 2003. This 12-month period was the driest on record for Denver Water's collection system.

The approximate supply Denver Water would have had for its customers during municipal water year 2002 if reservoirs were empty on April 1, 2002 is show in the table below:

South Platte direct rights:	30,996 acre-feet
Cheesman Reservoir storage rights:	9,866 acre-feet
Moffat Tunnel diversions during free river:	19,742 acre-feet
Meadow Creek Reservoir storage rights:	846 acre-feet
Bear Creek Rights:	588 acre-feet
Beery plus Four Mile No. 9 transferred rights:	130 acre-feet
Wolford Mountain Reservoir rights:	1,566 acre-feet [1]
Reusable Effluent:	1,737 acre-feet [2]
Williams Fork Reservoir storage rights:	7,050 acre-feet
Carriage and evaporation losses (assume 3%):	(2,176) acre-feet
Total:	70,345 acre-feet

[1] Assumes Denver would have received the first 613 acre-feet of storable inflow plus 40 percent of the remainder. Storable inflow figure provided by the Colorado River Water Conservation District.

[2] Estimated as the reusable effluent actually used times the ratio of Roberts Tunnel water that would have been available in 2002 had reservoirs started empty to the amount of Roberts Tunnel water actually diverted in municipal year 2002.

The table above tells us that our customers would have been forced to live on about 70,000 acre-feet of water for the 12-month period beginning April 1, 2002 had our reservoirs been empty on that date. The Williams Fork and Wolford rights were included because they would have made it possible to divert an equivalent amount of water through Roberts Tunnel. The majority of effluent exchanges and deliveries exercised during municipal year 2002 would not have been possible had our reservoirs been empty at the beginning of the year. This is because most of Denver's reusable effluent comes from Roberts Tunnel and reusable water released from storage.

Some might consider the 70,000 acre-feet figure pessimistic as a worst-case scenario; others would consider it optimistic. Those who consider this figure pessimistic argue that Denver Water would never allow the raw water reservoirs to go completely dry. Therefore, the assumption of no reservoir storage on April 1, 2002 is unrealistic. Those who consider 70,000 acre-feet an optimistic figure as a worst-case scenario argue that there is a risk that a future year could be even drier than 2002.

For more information on this analysis, see the Excel workbook
"Live on Inflow Analysis 2.xlsx."

CLOUD SEEDING

What is cloud seeding?

People have tried to modify the weather for centuries, but it wasn't until the 1950s that modern cloud seeding began. Cloud seeding, also known as weather modification, is the deliberate treatment of certain clouds or cloud systems with the intent of affecting the precipitation processes within those clouds. This process has been used worldwide and practiced in the United States for decades. Cloud seeding is mainly used to increase precipitation, which can help increase water supply in times of drought, but it is also used to abate hail storms and fog at airports.

How did cloud seeding begin?

In the late 1940s, a researcher at the General Electric labs in Schenectady, New York noticed that dry ice shavings could convert super cooled water droplets (those existing as water at temperatures lower than freezing) to ice crystals. This discovery led to more laboratory experiments that confirmed the nucleating properties of various materials in cold cloud conditions. The laboratory results were promising and trials in the atmosphere soon began. Operational cloud seeding as we know it began in 1950.

How does it work and how is it done today?

In clouds, tiny water droplets that form during condensation grow as they collide with one another. Cloud seeding introduces additional nuclei (e.g., silver iodide or salt). which causes more water drops to condense within the cloud and then fall to earth. Cloud seeding can be carried out with generators on the ground that disperse the particles upward, or by dropping it out of planes, directly into the cloud system. This produces precipitation that falls to the ground as snowflakes if temperatures are below freezing, and as rain if it is warmer. The seeding materials are applied to the clouds (sometimes targeted very carefully into very specific portions of the clouds) so that the material has adequate time to affect the precipitation process. The affected clouds then pass over the intended geographic area.

Is cloud seeding effective?

Not everyone agrees. It is difficult to prove the effectiveness of cloud seeding because of the natural variablity of the weather. The National Academy of Science found that scientific proof of the effectiveness of cloud seeding was lacking. However, the American Meteorological Society and the World Meteorological Organization have issued policy statements that attest to the efficacy of existing technology to enhance precipitation. The publication, "Guidelines for Cloud Seeding to Augment Precipitation" (American Society of Civil Engineers, 2006) states that, "Recent evaluations have shown that precipitation increases from 5% to 20% can be achieved through effectively operated cloud seeding programs." A study of the 1977-2005 cloud seeding program at the Vail Ski Resort showed a statistically significant increase in streamflow due to seeding (Silverman, April 2009).

Does cloud seeding pose health or environmental risks?

Many detailed studies, including chemistry-focused testing to intensive environmental investigations, have been conducted to address health and environmental concerns. Seeding materials are applied in very small amounts relative to the size of the geographic areas being affected, so the concentrations of the seeding materials in rainwater and snow are extremely low. Using silver iodide as an example, the typical concentration observed is less than 0.1 micrograms per liter of rainwater or snow. This is much below the U.S. Public Health Service's stated acceptable concentration of 50 micrograms per liter.

What is Denver Water's experience with cloud seeding?

Denver Water contributed to cloud seeding activities in the upper South Platte River basin in the winters of 1950-1951 and 1981-1982. From 2002 to 2004, Denver Water contracted with experts to perform cloud-seeding activities in response to the drought. The program focused on seeding the watersheds within the Board's water collection system. This target area included potions of the Blue, Fraser, Williams Fork and South Platte rivers and their tributaries above 9,000 feet elevation. Several ski areas and metropolitan water providers contributed to the effort. The program was on standby from 2005-2008. In the winters of 2009-2010 and 2010-2011, Denver Water and Winter Park Resorts jointly contracted with experts to perform cloud seeding. The target area was and is the Winter Park area within Denver Water's Moffat Collection System. In coordination with this program, the Colorado Water Conservation Board and the lower Colorado River Basin States (California, Arizon and Nevada) shared the costs of two other weather modification efforts in the Winter Park area. The Colorado Water Conservation Board and the basin states extended the Denver Water-Winter Park cloud seeding program activities into the early spring, and contracted with an additional expert to operate two high-elevation remotely controlled generators throughout the winter.

◇ WATER ALLOCATION PROGRAM

While irrigation restrictions during times of drought are effective for most of Denver Water's customers, the Water Allocation Program is designed to elicit emergency drought response from properties that irrigate large areas. These properties, typical of homeowners' association common areas, parks, golf courses and commercial businesses, cannot effectively irrigate within the timeframe permitted for most Denver Water customers during droughts because of the size of the irrigated area.

Properties that can participate in the Water Allocation Program are defined as any property that is managed or owned by the same group or individual that irrigates more than 20,000 square-feet of landscape. These properties are considered one entity for the purpose of water restriction administration regardless of the number of meters serving the property. These properties are designated as a commercial or irrigation-only account in the Customer Care and Billing system.

The Water Allocation Program allocates a set amount of water to certain customers and allows them to decide how and where to apply it to landscape. Denver Water provides these customers a baseline budget based on historical water usage from corresponding billing cycles in previous year(s) and/or a calculation of what the landscape irrigation requirements are for the property. A corresponding drought stage factor is then applied to determine the Water Allocation Budget.

Stage 1 – Water Allocation Program participants asked to reduce their use voluntarily by 10%

Stage 2 – Mandatory Savings Goal of 30 percent (Baseline Budget – 20% = Water Allocation Budget)

Stage 3 – No irrigation allowed

If a property exceeds their Water Allocation Program budget, that customer is subject to a drought surcharge.
Water Allocation Program properties are prohibited from irrigating between 10 a.m. and 6 p.m. Because these properties are large enough that they cannot effectively irrigate the entire property within the number of days per week allocated during drought restrictions, these properties are not limited to irrigation on specific days of the week, but each zone must not be watered in excess of the prescribed number of times per week. If limits on irrigation times per zone are in effect, these properties are exempt as long as they are in compliance with the other provisions of this program.

Appropriate signs that say the property is being irrigated through the Water Allocation Program must be displayed in a prominent area throughout the irrigation season.

Any large property that wants to be a part of the Water Allocation Program must submit an application. If this application is not received and approved, the property must comply with the Non-Residential/Multi-Unit/Other Schedule and days and times of irrigation system operation will apply along with the applicable requirements of the Water Waste Rule.

◇ WEATHER MODEL

Objectives

Denver Water developed a model to predict expected water use based on weather conditions. This model determines the impact of water restrictions on typical habits of customers. The impacts of water restrictions are defined as the difference in water use during a period of restriction compared with water use under the same weather conditions during an unrestricted period.

Approach

The goal of the weather model is to fit the consumption curve to predict expected water use during a given time period. The function of demand over a typical year shows a normal parabolic distribution of water consumption as a function of month of the year. However, there is more to the consumption story than merely time. Seasonal changes in weather are the underlying reasons for changes in consumption. To determine which weather variables were the most influential on consumption, a statistical analysis was performed on available weather data. The statistically significant variables were then used to create a multiple linear regression model. This model assigns a coefficient to each significant variable that indicates the direction and magnitude that the particular variable will tend to have on consumption.

Weather variables were entered into an Excel spreadsheet and the statistics function was then used to determine the significant variables. A multiple linear function was developed to combine these significant variables. Backcasts were then developed to look at how close the model got to actual demand during a given year.

Variables

Variables had to meet the following set of criteria before being considered for the model:
A consistent historical data set
Readily available
Collected on a daily basis.

A description of each variable in the weather model is provided below.

Accounts

Denver Water's customer base varies during the year. The weather model incorporates the variance in demand that is directly related to the number of customers during the given period.

Temperature

During periods of hot warm weather, especially over 70 degrees, water use will go up.
The plot of high historical average temperature versus month shows the same normal parabolic distribution noted for water consumption. The similarities in these functions over the same time period indicate a directly proportional relationship between demand and high temperature.

Precipitation

Seasonal water use is intuitively dependent upon weather conditions. During periods of dry weather, water use will go up in order to supplement the water requirements of landscapes. Conversely, during wet periods water use will go down. Water use is also related to the timing of rain events. A stretch of rainy days will impact water use in a different manner than isolated rain events of the same intensity

The statistical analysis showed that the timing of rainfall had more of an impact on water consumption than how much rain fell in a given time period. The weather model includes a variable for the days since the last significant rainfall.

Cloud Cover

The human interpretation of weather conditions influences the perception of water need. Typically, overcast days result in less water usage. A slight reduction in water consumption will be noted even on days with temperature conditions that would indicate an increase in water usage. This variable will dampen down some of the expected water usage predicted by the other three variables.

Statistics

The t-test was performed on each variable in relation to demand. Each statistically significant variable has a historically evident impact on either increasing or lowering the water consumption. The two most significant variables were number of accounts and high temperature. The multiple linear formula has the form:

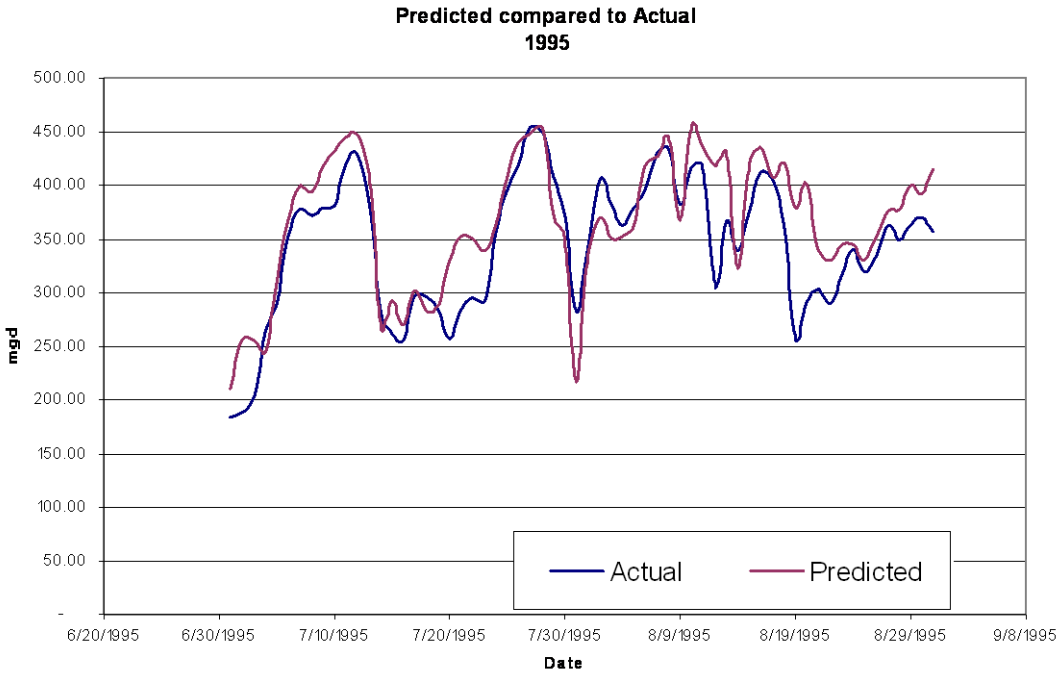
Demand (mgd) = 0.00075333(Accounts) + 5.15807787(Temp > 70ºF) + 6.52388115 (Days since 0.1 inches of rain) + 0.29242646 (PSBL).

	Coefficients	Standard Error	t Stat
Intercept	0	#N/A	#N/A
Accounts	0.00075333	2.75869E-05	27.307544
Temp > 70	5.15807787	0.302845222	17.03206
Days since .1 rain	6.52388115	0.480678358	13.572238
PSBL	0.29242646	0.103914982	2.8140933

Regression Statistics	
Multiple R	0.78919165
R Square	0.62282347
Adjusted R Square	0.61932916
Standard Error	47.0802828
Observations	614

Data

The model was developed from a dataset made up of June, July and August values from 1995 to 2001. Including the number of accounts as a variable in the regression model incorporated the effects of growth on demand. The figures below illustrate the predicted and actual demands over portions of the dataset period. It is noted that this model is only intended to predict demand during June, July and August.



◇ DEMAND HARDENING

Like many other southwestern water utilities, Denver Water's supplies suffer drastic reduction during a drought. Therefore, Denver Water has historically relied heavily on customer water use restrictions in a drought to reduce the drain on its reservoir contents.

Demand reductions from water use restrictions have proven very successful in extending Denver Water's ability to cope with droughts. The demand reductions effectively aid Denver Water's ability to serve its customers through the uncertain duration of drought.
The reliance on water use restrictions is logical because demand is really the only factor that a utility can control in a drought (vs. controlling Mother Nature in the watersheds). And customers expect and accept water use restrictions in a drought. Denver Water's customers simply prefer to preemptively hedge the risk of more onerous future water scarcity by reducing their current water use.

On the other hand, there is an obvious interaction between the demand reductions that occur from water use restrictions in a drought and long-term water conservation. Though the current realities of the interaction are really quite complex, generally, as Denver Water's customers become more efficient, it is more difficult for them to reduce their usage in a drought, than when they were less efficient.

This is not to say that Denver Water encourages its customers to remain inefficient so that greater savings can be attained with restrictions in a drought. Rather, the interrelationship of savings in a drought with long-term conservation implies careful consideration of how best to use the savings from conservations, including whether they should be used to supply water for new population growth or reserved within the water system as buffer against severe drought and other future risks.

In the 2007 Supplement to the Board's Resource Statement, the Board reinforced its commitment to a diverse portfolio of resources to serve future need and to minimize risks, including the risk of severse drought restrictions. For the near-term, the Board determined that water conserved under the enhnaced conservation program will be used to fortify the Strategic Water Reserve which is the buffer against future uncertainties including the risk of severe drought. This has the ancillary enviromental benefit of more water in streams and reservoirs for a period of time. Therefore the Board chose to use a portion of the saving from conservation to supply future demand growth and reserved a portion as a buffer against future risks including severe drought.

◇ DROUGHT RECURRENCE INTERVALS

Introduction:

The purpose of this chapter is to summarize and explain various estimates of drought recurrence intervals (a.k.a. return periods) made during the last seven years. The reader will see that return period estimates vary considerably depending upon the method used, the definition of "drought", and whether drought duration is allowed to vary.

Results:

The results of the various methods are shown in Table 1. All the methods used to obtain the figures in Table 1 are valid, but it is vital that those who use the figures fully understand what they mean and how they were derived. A discussion of the various methods follows:

Riverside Technology Incorporated (a.k.a. Riverside and RTi)

See "Drought Analysis of the Denver Water Supply System", by Jose D. Salas and Paul Weiss, February, 2004.

This consultant's approach was to develop a 100,000 year synthetic streamflow record based on the 1916 – 2002 record of virgin flows for the Blue River below Dillon Dam, the Fraser River near Winter Park, the Williams Fork River near Leal, and the South Platte River at South Platte. For simplicity, the virgin flows for the 4 gauges were summed to create one composite virgin streamflow record. (See "virgin4.xls") The 100,000 year synthetic record mimics the statistical characteristics of the 1916 – 2002 record, and can be found in "kaf_sequence.xls" and its derivatives.

Riverside defines "deficit" as the amount by which the streamflow for a given year is below the long-term mean of 632.5 kaf. The cumulative deficit of two 1954s would be 748.6 kaf, which is twice the difference between the long-term mean and 1954's streamflow (258.2 kaf). Riverside assumes that any year above the long-term mean ends the drought.

Table 1: Recurrence Interval Estimates (Years)

March 2004

1	2	3	4	5	6	7	8	9
Drought	Rti (Case 1, constrained by duration) (threshhold=LT avg)	Rti (Case 2, not constrained by duration) (threshold=LT avg)	Exponent (constrained by duration)	Peters, Dechant and Steger Using 1916-02 (Constrained by Duration) [3]	2002 DRP (constrained by duration) [4]	Steger Method (not constrained by duration) [1] [2]	Steger method using 450 kaf threshhold	Steger method using 550 kaf threshhold
1, 1954	71	6		69	29	31	44	25
2, 1954s	559	21		651	140	155	277	77
3, 1954s	4,545	68		6,790	600	641	1,639	220
4, 1954s	>100,000	205		55,405	2,000	2,381	7,692	578
5, 1954s	>100,000	621				11,111	50,000	1,515
6, 1954s	>100,000					100,000	>100,000	3,448
1, 2002	241	7		312		45	79	32
2, 2002s	4,167	30		8,451		299	735	117
3, 2002s	33,333	109		278,858		1,515	5,556	400
4, 2002s	>100,000	380		6,518,464		6,667	50,000	1,205
5, 2002s	>100,000	1408				>100,000	>100,000	3,226
1954-55			30 - 50	106	37	56	64	44
1953-55			30 - 50	59	22	42	24	45
1953-56			30 - 50	62	16	48	18	58

[1] Method made possible only with Peters' programming assistance.

[2] Makes use of Rti's 100,000 year synthetic record, but "counts" differently, and uses 500 kaf threshhold.

[3] Used square root transformations, because it provided a better fit to normal distribution than untransformed data.

[4] Investigators did not transform data because untransformed data passed test for normality. Used 1710-1983.

Riverside, Case 1

Riverside's "Case 1" requires that the droughts being quantified only be compared to droughts of equal duration. For example, when Riverside says that the recurrence interval for two consecutive 1954s is 559 years (Column 2 of Table 1), they mean that one can expect a *two year* period as bad or worse than two 1954s to occur, *on the average*, every 559 years. Basically, Riverside came up with a return period of 559 years by identifying every 2-year period in the 100,000 year sequence with a cumulative deficit greater than or equal to two 1954s. The average interval between the beginnings of droughts meeting this requirement is 559 years.

Riverside, Case 2

Riverside's "Case 2" allows the droughts being quantified to be compared to *all* droughts, regardless of duration. For example, when Riverside says that the recurrence interval for 3 consecutive 2002s is 109 years (Column 3 of Table 1), they mean that one can expect a drought "worse" than 3 consecutive 2002s to occur, *on the average*, every 109 years.

Exponent

One should read Exponent's report, "Planning Period Assessment Study" (January 29, 1999), for a thorough explanation of that company's methods for quantifying drought severity. Exponent used annual virgin flows from 1916 – 1997 from both sides of the Continental Divide, and worked with some composite (East and West Slope) virgin flows as well.

Peters, Dechant and Steger, 2003

Bob Peters, Becky Dechant and Bob Steger worked with the same 1916 – 2002 dataset of virgin flow provided to Riverside. They first transformed the annual flows by taking their square roots. The transformations were made because they caused the data to more accurately fit a normal distribution. Without the transformations, the data "passed" various tests for normality, but the year 2002 did not fit the rest of the data very well. The investigators used the properties of the normal distribution to quantify various hypothetical droughts. See "return_periods.xls" for more information.

Steger, 1997, 2002

Bob Steger used the sum of the annual virgin flows at the following four gauges: South Platte at South Platte, Blue River below Green Mountain Reservoir, Williams Fork at Leal and Fraser River at mouth. Resource Consultants and Engineers Incorporated (RCI) provided him a sequence of aggregate flows from 1710 – 1983. RCI was able to develop this long streamflow record by correlating a relatively short record of measured flows with tree rings and back estimating streamflow. After testing the (untransformed) data for normality, Steger used the properties of the normal distribution to estimate return periods for the 1950s drought as well as for 2, 3, and 4 consecutive 1954s. His results were published in the 1997 and 2002 Drought

Response Plan Technical Appendices, and were in general agreement with the results published in the Two Forks Environmental Impact Statement (U.S. Army Corps of Engineers, 1985).

Steger and Peters, 2004

Bob Peters and Bob Steger used Riverside's 100,000 year synthetic sequence of composite virgin flow to quantify recurrence intervals for various droughts. In contrast to Riverside, Steger and Peters defined drought years as years where the sum of the virgin streamflows at the four gauges was less than 500 kaf. Figure 1 illustrates why 500 kaf was selected as the threshold annual flow below which Denver Water's reservoirs would drop *if average annual demand is 285 kaf*. (The investigators also tried thresholds of 450 kaf and 550 kaf to test the sensitivity of their assumption that flows below 500 kaf cause Denver's reservoirs to lose storage while flows above 500 kaf allow reservoirs to recover.) Steger and Peters kept track of a cumulative deficit, which is the cumulative amount by which annual streamflow is less than 500 kaf. The cumulative deficit was allowed to decrease if a given year's streamflow was above 500 kaf, but it was not allowed to become negative. They defined droughts as those periods between cumulative deficits of zero. The investigator's calculations and results can be found in "kaf_sequence_rsp.xls".

Conclusions and Recommendations:

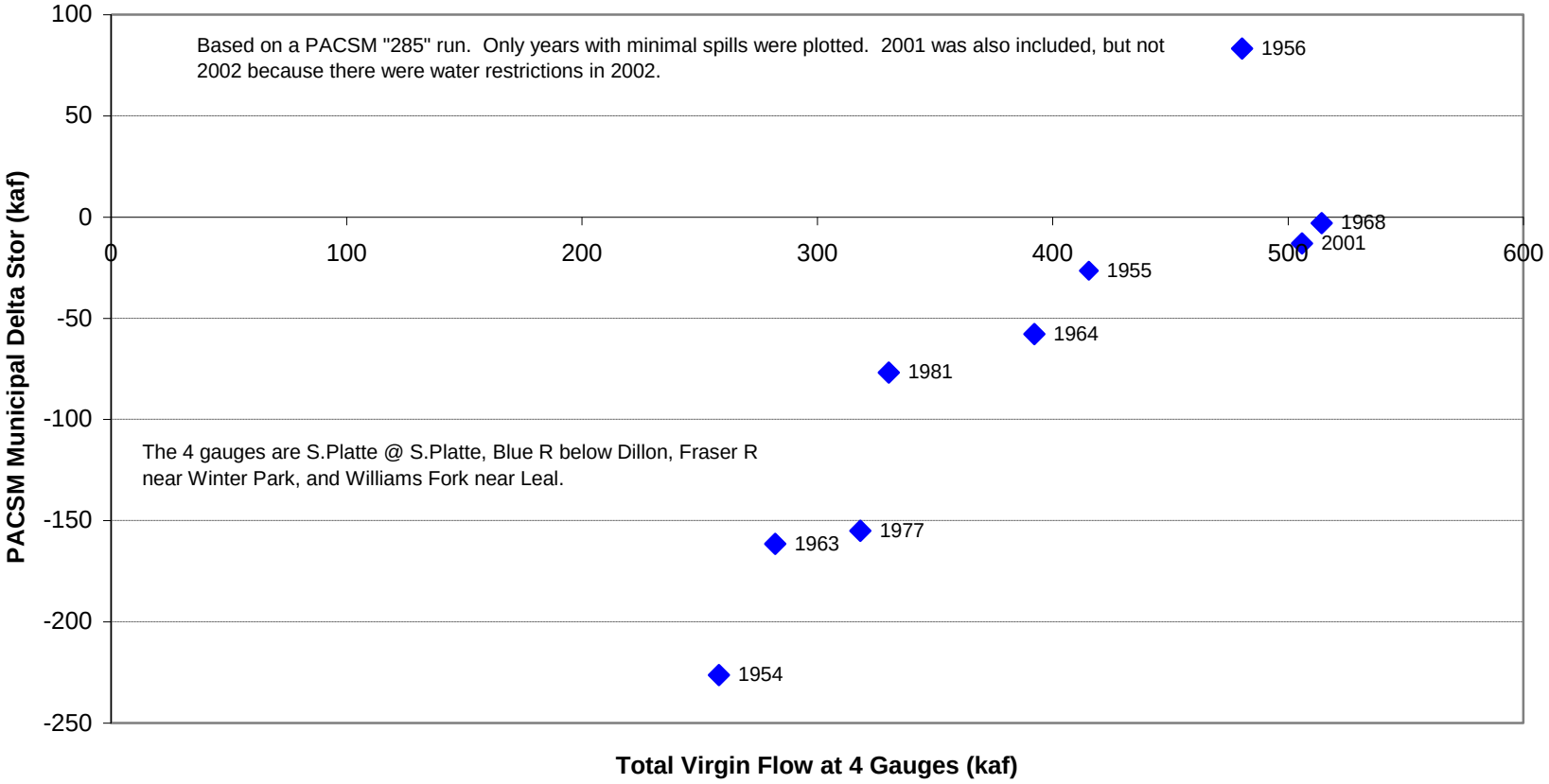
The numbers shown in Column 7 of Table 1 best represent the return periods for droughts as bad as or worse than the hypothetical droughts in Column 1. Columns 8 and 9 provide a sort of confidence interval for the numbers in Column 7, because one cannot say for certain that streamflows below 500 kaf cause our reservoirs to drop and those above 500 kaf allow our reservoirs to rise. For a water system that relies heavily on reservoir storage to withstand droughts (such as Denver Water's), it usually makes sense to compare a given hypothetical drought to *all* droughts, regardless of duration.

Riverside's methods do a good job of quantifying hydrologic droughts, but are problematic for quantifying water supply droughts for the following reasons:

1. Years in which the composite streamflow is below the long-term mean are considered drought years. It follows from this assumption that a long series of years between 500 kaf and 632.5 kaf could be a severe drought, yet we believe that our reservoirs would still be full.

2. Assuming that the drought is over when a given year's streamflow exceeds the long-term mean is problematic. If, for example, reservoir storage at the end of a given year is 300 kaf below full and the following year's streamflow is 640 kaf, Riverside's assumption says the drought is over. However, for Denver's system, the drought would not be over because our system would not have refilled.

Figure 1: Effect of Streamflow on Storage



For these reasons, we do not feel that Riverside's results are reasonable for water systems with large amounts of reservoir capacity. Exception: For *single year droughts* with constrained duration, the shortcomings of Riverside's assumptions do not come into play.

At times it might be desirable to constrain drought duration when quantifying drought severity. Suppose the question is asked, "What is the return period for a single year as dry or drier than 2002?" This question implies that we are comparing 2002 only to single years. It is proposed that the return period for a single year as dry as or drier than 2002 is about 250 - 300 years. (See Columns 2 and 5 of Table 1.)

If a given discussion of drought recurrence intervals suggests that drought duration should be constrained, then the figures in Column 5 of Table 1 should be used rather than those in Column 6. Intuitively, the figures in Column 6 should be considerably larger than those in Column 7; the fact that they are not suggests the figures in Column 6 might be too small. Column 5 is also preferred over Column 6 because the square root transformation used to compute the numbers in Column 5 caused the 1916 – 2002 dataset to more closely match a normal distribution than the untransformed data used in Column 6. Finally, Column 5 uses actual data whereas the majority of the data used for Column 6 was estimated from correlations between tree rings and streamflow.

When quantifying the severity of droughts affecting the Denver Water collection system, duration should, in most cases, be allowed to vary. A short, intense drought that causes reservoirs to drop X acre feet is essentially equal in severity to a longer, less intense drought that causes the same drop in reservoir storage. When analyzing droughts to plan new water supply projects or to impose water use restrictions, decision-makers need to know how low reservoirs would drop under various dry weather scenarios. For these analyses, drought duration does not matter, but drought severity does matter. For most of Denver Water's purposes, there is no reason to constrain drought duration when quantifying drought severity.

Summary:

When questioned about the severity of various droughts, Denver Water personnel use the figures in Table 2.

Table 2:
Recommended Recurrence Interval Estimates
March 2004

	Recurrence Interval (Years)	
Drought	Constrained by Duration	Not Constrained by Duration
1, 1954	70	30
2, 1954s	600	150
3, 1954s	7,000	600
4, 1954s	50,000	2,000
5, 1954s	>100,000	10,000
6, 1954s	>100,000	100,000
1, 2002	300	50
2, 2002s	8,000	300
3, 2002s	>100,000	1,500
4, 2002s	>100,000	7,000
5, 2002s	>100,000	>100,000
1954-55	100	50
1953-55	60	40
1953-56	60	30

◇ SUPPLY AUGMENTATION ALTERNATIVES

Many possibilities exist to temporarily increase water supply for Denver Water customers during a drought. In this appendix, we discuss some of the supply augmentation alternatives:

- invoke the Shoshone relaxation agreement
- withhold deliveries to the Big Lake Ditch and Coberly Ditch
- reduce deliveries to Englewood under the 1995 agreement
- waivers of minimum bypasses
- waivers of minimum pool requirements
- Chatfield temporary pumps
- substitute supply plans
- us the "WISE" water supply
- drill nontributary wells
- pump dead storage

Invoke the Shoshone relaxation agreement

Denver Water and Xcel Energy are parties to an agreement (the Shoshone agreement, Denver Water contract number 10266A) which became effective on January 1, 2007 and which, absent a renewal, expires on February 28, 2032. During times of a water shortage, as defined in the agreement, the flow threshold necessary for a Shoshone "call" on the river changes from 1250 cfs to 704 cfs.

This relaxation of the Shoshone call under the terms of the agreement allows Denver Water and other entities to increase their diversions from the Upper Colorado River Basin during the period from March 14 through May 20. Denver Water agreed to deliver Xcel and the Western Slope 15% and 10%, respectively, of the additional "net water" it is able to divert under the terms of the agreement while retaining the remaining 75% . Denver Water agreed to reimburse Xcel for lost power revenue resulting from the call relaxation.

Denver Water may invoke the Shoshone call relaxation agreement when the following two conditions are met:

1. Based on the "normal" weather scenario, Denver Water predicts its system reservoir storage on July 1 will be 80% full or less; and

2. The forecast of April through July undepleted flow at the Kremmling gauge is 85% of average or less.

In the agreement, there are additional provisions for longer call relaxation of the Shoshone call when water supplies are more severely impacted than described above. These provisions should be exercised as approporiate.

Withhold Deliveries to the Big Lake Ditch and Coberly Ditch

Through the year 2013, Denver Water has agreed to allow certain ranchers to use its Big Lake Ditch water rights to irrigate lands in Grand County. The Big Lake Ditch diverts water out of the Williams Fork River above Denver's Williams Fork Reservoir. The agreement allows Denver Water to "call back" its water rights under certain conditions in water short years. If Denver's "most probable" projections of fill levels at Dillon and Williams Fork Reservoirs, based on April 1 snowpack, show Dillon not filling above 95% of capacity and Williams Fork not filling above 90% of capacity, then Denver Water has the option of preventing these ranchers from diverting water into the Big Lake Ditch. Exercising this option would cause more water to flow into Williams Fork Reservoir. We must exercise this option to realize our current firm yield.

Denver is discussing with west slope entities the possibilty of participating in a joint study of how to best maintain the uses of the Big Lake Ditch while optimizing environmental benefits and preserving the yield that Denver is counting on by retiring the Big Lake Ditch demand.

Denver also owns the Coberly Ditch water rights which are diverted through the Big Lake Ditch. The water is used to irrigate the Lawrence Ranch. The property lease for this ranch provides that water may not be used from the Coberly Ditch or any other source without written approval from Denver Water. After a long period since 2002, beginning in 2010, Denver Water changed its approach on the Coberly Ditch and issued a letter allowing use for 2010 only. This is the reverse of the protocol for the Big Lake Ditch. Use of the Coberly should not occur unless Denver Water specifically approves it in writing. Staff recommends that approval letters only allow use for a single, ensuing irrigation season.

Reduce Deliveries to Englewood under the 1995 Agreement

Under an August 11, 1995 agreement, Denver Water delivers South Platte River water to the City of Englewood in exchange for the right to divert the latter's water from the Cabin- Meadow Creek system in Grand County. Article III of the agreement describes how Denver may reduce its normal deliveries to Englewood during dry years.

Waivers of Minimum Bypasses

In some instances, Denver Water has the right to reduce minimum bypasses at its structures during a drought. However, we must always honor senior water rights downstream of our structures. The decision on whether to waive a minimum bypass during a drought must always consider possible damage to the downstream fishery. Locations at which Denver Water may be able to waive a minimum bypass requirement are:

Fraser System (excluding Englewood's Meadow Creek System)

On April 22, 1970, Denver Water agreed to stipulations with the Bureau of Sport Fisheries and Wildlife, later renamed the U.S. Fish and Wildlife Service. These stipulations were modified by the Clinton Reservoir–Fraser River Agreement dated July 21, 1992. The modifications provide for reducing minimum bypasses from the Fraser system under either of the following circumstances:

1. If there are mandatory restrictions on indoor use in the Denver Water service area; or
2. If there are mandatory restrictions of any kind in the Denver Water service area and bypass reductions would not cause restrictions on "indoor municipal and fire fighting use" in Grand County.

It is possible that one of the circumstances above could exist during a drought, thereby increasing the amount of water Denver Water could bring through the Moffat Tunnel. The minimum bypasses in the Fraser System under normal circumstances are:

Normal Minimum Bypasses (cfs)*

Diversion Point	Sept. 16 to May 14	May 15 to Sept. 15
St. Louis Creek	3	10
Vasquez Creek	3	8
Fraser River	4	10
Ranch Creek	2	4

* bypasses for downstream senior water rights are not included in this table.

Minimum Release from Dillon Reservoir to the Blue River

On August 9, 1966, the Denver Water Board approved stipulations with the Bureau of Sport Fisheries and Wildlife, later named the U.S. Fish and Wildlife Service. The stipulations allow the normal minimum release of 50 cfs to be reduced in any of the following situations:

1. "… during an emergency or during temporary periods of time involving maintenance or repairs on the water facilities involved;" or

2. If the combined contents of Cheesman, Eleven Mile, Antero and Dillon is less than or equal to the annual water use of Denver's customers; or

3. If the space available for storage of water at Dillon Reservoir exceeds 100,000 acre feet; or

4. "If at any time it becomes necessary for the Board to impose restrictions on the use of water in the area served by the Board due to insufficient water supply, the releases … may be reduced in accordance with the severity of the restrictions."

Denver Water has been discussing with west slope entities adding additonal criteria to the conditions under which it may reduce the minimum bypass flows.

Waterton Canyon

Paragraph I of the "Water Management Plan for the South Platte River Canyon Below Strontia Springs Dam," prepared in conjunction with the Foothills Project, indicates that Denver Water is obligated to provide 30 cfs from Strontia Springs Dam to Chatfield Reservoir during the September 16 through May 14 period ("winter") and 60 cfs from May 15 through September 15 ("summer"). There is an exception that Denver Water may divert up to 15 cfsof the winter flow at the old diversion point of the Platte Canyon–Last Chance Ditch; Denver refurbished the diversion structure in 2002 and began diverting water to Conduit 20 via the Kassler Pump Station in January 2003.

Paragraph II of the plan provides a means by which Denver Water could augment its supply during a drought. This paragraph states:

"In the event of severe drought conditions or operational emergency, Denver may reduce bypasses at its Strontia Springs Dam point of diversion below the amounts described in paragraph I above upon approval of the Bureau of Land Management and the Forest Service."

On April 15, 2004 Denver Water and the U.S. Forest Service signed an easement amendment whereby Denver received the right to reduce bypass flows below the Last Chance diversion during the "summer" season as follows:

"During Stage 1 drought response, as defined by voluntary water restrictions, the Grantee may divert and recover 15 cfs of the 60 cfs at the Old Last Chance Ditch diversion, leaving 45 cfs in the stream channel."

"During Stage 2 drought response, defined by mandatory watering restrictions, the Grantee may divert and recover 30 cfs of the 60 cfs at Old Last Chance Ditch diversion, leaving 30 cfs in the stream channel."

"During Stage 3 response, as defined by the total constraint of outdoor lawn watering, the Grantee may recover 45 cfs of the 60 cfs at the Old Last Chance Ditch diversion, leaving 15 cfs in the stream channel."

Waivers of Minimum Pool Requirements

Chatfield Reservoir

According to the April 3, 1979, contract between the State of Colorado and the City and County of Denver, Denver Water may use the storage between elevations 5,432 feet and 5,423 feet (paragraph 1a). Because these elevations correspond to storages of 27,428 and 16,294 acre feet, respectively, (as detailed in the 1998 reservoir survey) Denver Water has 11,134 acre feet of active storage in Chatfield. The contract also obligates Denver to try to keep the storage above 20,000 acre feet from May 1 through August 31 (paragraph 1b).

The contract allows these requirements to be relaxed in a drought situation. Paragraph 1a(2) of the contract states that:

"... the goal of maintaining 20,000 acre-feet of water in storage every year may not be continually attainable and the amount of water in storage may be allowed to fluctuate as these conditions require, but not above elevation 5,432 feet nor below elevation 5,423 feet, except as severe and prolonged drought conditions, as such drought conditions are reasonably determined by the Colorado Water Conservation Board may require the Contractor unavoidably to cause the level of storage to decrease below elevation 5,423 feet in order to satisfy its charter obligations to provide municipal water supply."

Denver Water intends to construct a pump station at Chatfield that would allow it to access all of its supplies in Chatfield, including the water below elevation 5423 during times of severe and prolonged droughts. Denver Water staff is involved in on-going negotiations with the Colorado Department of Natural Resources to determine the conditions under which water below elevation 5423 could be used by Denver.

During the Drought of 2002, Denver Water staff negotiated an operations agreement with CWCB to reduce storage below 5,423 feet. Staff is currently negotianig to make this agreement permanent.

Dillon Reservoir

On August 9, 1966, the Denver Water Board approved stipulations with the Bureau of Sport Fisheries and Wildlife, later named the U.S. Fish and Wildlife Service. The stipulations say that Denver Water shall not draw Dillon down below the invert of the Roberts Tunnel (elevation 8846.25, storage 12,700 acre-feet) except for repairs or emergency operational requirements (paragraph 1).

This bottom 12,700 acre-feet of water could not be diverted to Denver without construction of a pump station. However, approximately 4,900 of the 12,700 acre-feet of water could be released to the Blue River as replacement water for Moffat Tunnel if a drought is considered an emergency and water rights administrators allow the exchange.

Chatfield Temporary Pumps

In addition to the future pump station discussed in the preceding section, Denver Water owns pumps that can be installed at the reservoir on a temporary basis. The pumps draw water from the eastern side of the reservoir and discharge to Conduit 20. They have a capacity of about 21 cfs and are capable of drawing the water level down to roughly elevation 5427. During droughts, Chatfield Reservoir may stay relatively full due to a lack of exchange potential. The Chatfield temporary pumps can send water to Marston Reservoir that would otherwise “spill” from Denver Water’s pool in Chatfield.

Substitute Supply Plans

In a substitute supply plan, an entity may temporarily increase its water diversion at one point by introducing water at a different point. An example: Suppose a senior water "call" in eastern Colorado reduced Denver Water's ability to divert water at its intake on the South Platte. A possible substitute supply plan would be for Denver Water to drill a nontributary well and discharge the groundwater into the South Platte as a substitute for bypassing water at the intake for the senior call. Substitute supply plans must be approved by the Colorado Division of Water Resources.

Use the "WISE" Water Supply

Denver Water is trying to develop a 15,000 acre-foot water supply through the WISE Partnership. As contemplated, Denver's use of WISE would be as part of its Strategic Water Reserve (SWR). The supply could be called on during system emergencies or during times of drought. Denver's WISE supplies would be available primarily from October – April. It is anticipated that Denver would be able to take delivery of approximatley 20 – 30 mgd of treated water from the Aurora Binney Advanced Treatment facility, and blend that water into deliveries from Conduit 27. Denver's use of WISE would not be available before 2017.

Reduce the "5412" Delivery from Williams Fork Reservoir

As part of the recovery program for endangered fish in the "15-Mile Reach", Denver Water has agreed to release 5412 acre-feet of water from Williams Fork Reservoir. This water is released in the late summer and early fall at the request of the U.S. Fish and Wildlife Service. The 2010 contract for the release of this water expires on June 30, 2013. After that date, staff anticipates that a permanent, non Denver Water source of storage water will be available for the recovery program.

During a drought, the 2010 contract allows the releases to be reduced by 10, 30 and 50 percent for Stage 1, 2 and 3 drought declarations, respectively.

Elect to not Participate in "CROS" Bypasses for Endangered Fish

Since the 1990s, Denver Water has been participating in a voluntary program to help the Colorado River endangered fish by enhancing the peak flows in the "15-Mile Reach" during spring runoff. Essentially, reservoir managers who are confident their facilities will fill, voluntary bypass reservoir inflow during a 7 – 10 day period when the flow at the Cameo gauge on the Colorado River is expected to peak. These voluntary bypasses enhance the peak flows.

During drought periods, Denver Water should strongly consider not participating in this voluntary program in order to increase the amount of water stored during spring runoff.

Reduce Outflows from South Platte Reservoirs Below SPPP Optimums and Minimums

In the June, 2003 South Platte Protection Plan (SPPP), during non-drought periods, Denver Water committed to optimum and minimum streamflows below Eleven Mile and Cheesman Reservoirs as follows:

Eleven Mile:	Optimum: 50 – 100 cfs Minimum: The lesser of 32 cfs or inflow
Cheesman (August – March):	Optimum: 50 – 150 cfs Minimum: The lesser of 35 cfs or inflow
Cheesman (April – July):	Optimum: 100 – 225 cfs Minimum: The lesser of 40 cfs or inflow

However, the SPPP guiding principles say that water supply facilities will not be operated in ways that cause participants to lose water supply. One consequence of the guiding principles is that, during periods of drought, it is possible that neither the optimum flows nor the minimum flows will be achieved. Furthermore, the SPPP has a drought clause (Appendix C, page 2) that states, *"When Denver Water's customers are on mandatory water use restrictions and the combined contents of Denver Water's major storage reservoirs are less than 50 percent full, the minumum outflow requirement at Eleven Mile and Cheesman reservoirs will be 20 cfs or the reservoir inflow (as defined in the Streamflow Plan), whichever is less."*

Drill Nontributary Wells

Nontributary well drilling is a method of augmenting water supply during a time of shortage. The four steps needed to put a nontributary well on-line are:

- obtain water rights
- perform an engineering analysis
- obtain a well permit
- construct the well

Denver Water has obtained the legal right to use the nontributary groundwater beneath our city. Engineering analyses and well permits would normally take three to six months, and constructing the well could take another three to six months. If water rights and engineering analyses are completed beforehand, a "fast track" approach could probably get a well on-line in six months.

Pump Dead Storage

Pumping dead storage may be a viable supply augmentation alternative. Possible problems include cost, loss of fisheries, water quality (pollutants may become concentrated as reservoir storage decreases) and uncertain dead storage volumes due to sedimentation.

◇ REDUCING DELIVERIES TO OUTSIDE CITY CONTRACTS

Background

Denver Water has sold water outside the limits of the City and County of Denver since the early part of the last century. Even before the City Charter created the Denver Board of Water Comissioners in 1918, the early water companies sold some water by contract to others. Some of the contracts had provisions dealing with raw or non-potable water, and others dealt only with treated or potable water. Since each contract is different, there are different impacts on contract holders during drought.

Reducing Deliveries to Non-Potable Contract Holders

Currently, Denver Water supplies non-potable water (also known as raw water) to many customers outside the city limits. Some of these contracts contain language allowing Denver Water to reduce or discontinue deliveries during a drought. Reducing or discontinuing deliveries could cause serious hardship to these customers, and Denver Water would carefully consider the impacts of any delivery reductions before taking action.

Denver Water currently has approximately 50 active raw water delivery contracts. Most of these allow for some level of water restrictions during drought periods. However, there is a lack of consistency in restriction language throughout the contracts. The newer contracts include specific delivery restriction language consistent with this Drought Response Plan. Older contracts are not specific, and may contain only general language regarding delivery curtailments during droughts, system outages, and other unforeseen occurrences. Some contracts do not mention anything about restrictions or curtailment, other than through reference to the Denver City Charter, which talks about making sure there is sufficient water to serve the City.

Reducing Deliveries to Potable Water Contract Holders

Most of Denver Water's customers outside the City limits receive water only from Denver Water. There are about 65 water distributors, approximately 350 individual connectors and several special bulk sales contracts. The 65 Distributors serve 150,000 accounts under three types of contracts:

- Total Service
- Read and Bill
- Master Meter

About 90% of these accounts are served by a new (1993) form of Distributor Contract which applies drought restrictions uniformly to Denver residents and distributor contract customers. The older distributor contracts (pre-1993) include a series of increasingly restrictive prohibitions that can lead to a termination of service. The bulk sales contracts in this category include percentage reductions set forth in the contract. The methods of meeting the stated reductions are decided by the customer.

There are several special contracts that take Denver potable water and blend it with water from other sources. These customers are required to meet percentage reduction targets adopted by the Board.

In summary, the following administrative policies apply for each type of customer:

1) **Water Budget Customers.** Customers with drought delivery restrictions in their lease are on a water budget. For stage 2, Denver Water will not deliver more than 70% of the maximum contract amount. Customers on water budgets are not subject to all the operating rules, except: A) no watering 10 am to 6 pm and B) no water on Mondays (unless specified by a Board action). Other than these two restrictions, customers can decide how to use water so long as the use complies with the terms of the lease. Since Denver Water controls the delivery to these customers, no more than 70% will be delivered to them. Therefore, drought surcharges would not apply to these customers.

2) **Denver Parks.** They will be managed in a manner consistent with the treated water budget method .

3) **Restricted Use Customers.** These customers will continue to be subject to all the operating rules, including the Drought Restrictions. They are also subject to the raw water drought surcharge on use over 70% of their 2001 use.

4) **Carrier Facilities.** These are independently operated facilities. The amount of water delivered depends on the water right for the facility and the contract terms. The Board decided that no use restriction should be applied to carrier facilities.