Western
Drought
Coordination
Council

How to Reduce Drought Risk

Preparedness and Mitigation
Working Group

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Purpose and Use of this Guide

This guide was developed as part of an action item addressed by the Preparedness and Mitigation Working Group of the Western Drought Coordination Council, prepared with input and review by members of the working group. It is designed to be a step-by-step process for users to identify actions that can be taken to reduce potential drought-related impacts before a drought occurs. This guide is a work in progress and will continue to evolve as new information and examples are identified. All comments concerning the guide are encouraged. Suggestions provided by users relating their experiences would be especially helpful. Plans to make the guide easier to use are already being considered, and the guide will be updated regularly.

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Abstract

This guide describes a practical step-by-step process for identifying actions that can be taken to reduce potential drought-related impacts before a drought occurs. Step 1 begins with making sure that the right people are brought together and supplied with adequate data to make informed and equitable decisions during the process. Steps 2 and 3 narrow the focus of the study by identifying high priority drought-related impacts that are relevant to the user's location or activity. Step 4 demonstrates that in order to reduce the potential for the identified impacts to occur in the future, it is necessary to understand the underlying environmental, economic, and social causes of the impacts. Finally, Steps 5 and 6 utilize all of the previous information to identify feasible, cost-effective, and equitable actions that can be taken to address the identified causes. In this manner, true drought vulnerabilities can be addressed that will subsequently reduce drought-related impacts and risk.

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> ***"Unfortunately, we tend to focus on drought when it is upon us. We're then forced to react -- to respond to immediate needs, to provide what are often more costly remedies, and to attempt to balance competing interests in a charged atmosphere. That's not good policy. It's not good resource management. And it certainly adds to the public's perception that government is not doing its job when it simply reacts when crises strike. To the contrary, we must take a proactive approach to dealing with drought. We must anticipate the inevitable -- that drought will come and go -- and take an approach that seeks to minimize the effects of drought when it inevitably occurs."***
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> -- James R. Lyons, Assistant Secretary of Agriculture for Natural Resources and the Environment, speaking at Drought Management in a Changing West: New Directions for Water Policy, a conference in Portland, Oregon, in May 1994.

In drought management, making the transition from crisis to risk management is difficult because little has been done to understand and address the risks associated with drought. To promote this process, the Western Drought Coordination Council has constructed this guide to assist individuals and organizations through a process of identifying specific actions that can be taken to reduce short- and long-term drought risks. Although based in natural hazards theory, this guide was designed to be flexible enough to be tailored to any particular region or location and a straightforward and practical tool for all drought managers.

The approach of this guide may be new to some natural hazard managers since traditional hazard risk assessment is often limited to comparisons of the likelihood of a disaster with the dollar value of potential losses or impacts. These comparisons are then used to decide whether it is economically favorable to prepare for certain disasters. This guide, however, recognizes that impact assessments and economic analyses only partially accomplish risk management. To be complete, risk management must also address issues of vulnerability and the equity, efficiency, cost, and urgency of possible actions.

Therefore, this guide focuses on identifying and ranking the priority of relevant drought impacts; examining the underlying environmental, economic, and social causes of these impacts; and then choosing actions that will address these underlying causes. In a sense, what makes this guide different and more helpful than previous methodologies is that it addresses the "whys" behind drought impacts, which are the true causes of vulnerability, rather than the specific impacts. Until now, almost all drought responses have been reactions to the impacts. This guide provides its users the opportunity to identify mitigation actions that can be taken to lessen vulnerability to future droughts.

Step 1. Getting Started

For this type of interdisciplinary analysis, it is essential to bring together the right group of people and supply them with adequate data to make fair, efficient, and informed decisions pertaining to drought risk. This group's knowledge will need to encompass several aspects of environmental, economic, and social topics. Any shortfall in information or perspective could lead to results that

fall far short of planning goals. Appendix B contains suggestions and relevant material that may provide some insight into some of these drought-related topics.

Also important is the need to include public input and consideration when dealing with the issues of appropriateness, urgency, equity, and cultural awareness in drought risk analysis. Public participation could be warranted in every step, but time and money may limit their involvement to key topics (public review vs. public participation). Therefore, the amount of public involvement is up to the discretion of the planning personnel. The advantage of publicly discussing questions and options is that the procedures used in making any decisions will be better understood, and it will also demonstrate a commitment to participatory management. At a minimum, decisions and reasoning should be openly documented to build public trust and understanding.

It would be best if this guide were incorporated into a larger drought planning process such as the Ten-Step Process developed by the National Drought Mitigation Center (NDMC) for long-term mitigation and short-term response planning. Using this guide is a natural way to incorporate mitigation into the development of new drought plans. For states, communities, and organizations that already have drought plans, the guide would help identify mitigation actions that could strengthen existing plans. Since most plans are limited to drought response, this guide would allow some of the emphasis of these plans to be shifted toward mitigation.

If feasible, it may be even more efficient to include drought planning as one section in an overall natural hazard plan. For example, the Federal Emergency Management Agency (FEMA) has put together a program called Project Impact aimed at building disaster-resistant communities. Combining this guide with FEMA's Project Impact would enhance a community's preparedness to all natural disasters, including drought.

Step 2. Drought Impact Assessment

Impact assessment examines the consequences of a given event or change. For example, drought is typically associated with a number of outcomes. Drought impact assessments begin by identifying direct consequences of the drought, such as reduced crop yields, livestock losses, and reservoir depletion. These direct outcomes can then be traced to secondary consequences (often social effects), such as the forced sale of household assets or land, dislocation, or physical and emotional stress (Ribot 1996:2). This initial assessment identifies drought impacts but does not identify the underlying reasons for these impacts.

Some of the more common types of drought impacts are listed on the following page (Box 1). For practical purposes, the impacts from drought can be classified as economic, environmental, or social, even though several of the impacts may actually span more than one sector. A detailed checklist of impacts that could affect a region or location is found in Appendix C. Impacts should be examined for their relevance in past or recent droughts, but consideration should also be given to the question "What drought impacts will be seen in the future?" This last question is crucial as populations shift and water demands change.

Box 1. Common Types of Drought Impacts

Economic Category
- ➞ Agricultural
- ➞ Industry
- ➞ Tourism and Recreation
- ➞ Energy
- ➞ Financial
- ➞Transportation

Social Category
- ➞ Stress and Health
- ➞ Nutrition
- ➞ Recreation
- ➞ Public Safety
- ➞ Cultural Values
- ➞ Aesthetic Values

Environmental Category
- ➞ Animal/Plant
- ➞ Wetland
- ➞ Water Quality

See Appendix C for a detailed list of impacts.

To perform an assessment using the checklist in Appendix C, check the box in front of each category that has been affected by drought in your study area. Depending on the kind of event you plan to base your impact reduction strategy on, your checklist selections can be based on either common or extreme droughts, or a combination of the two. If enough time, money, and personnel are available, it may be beneficial to conduct impact studies based on common droughts, extreme drought(s), and the "drought of record" for your region.

These analyses would yield a range of impacts related to the severity of drought. In addition, by highlighting past, current, and potential impacts, trends may become evident that will also be useful for planning purposes. These impacts highlight sectors, populations, or activities that are vulnerable to drought, and when evaluated with the probability of drought occurrence, identify varying levels of drought risk.

Step 3. Ranking the Impacts

Once the checklist in Appendix C has been completed, all of the categories that were checked should be made into a new list, with the unchecked categories omitted. This new list contains the drought impacts that are relevant to your location or activity.

From the new list, the "current" impacts should then be ranked according to the most important impacts. To be effective and equitable, the ranking should take into consideration concerns such as cost, areal extent, trends over time, public opinion, fairness, and the ability of the affected area to recover. The general public, community advisory committees, and groups of relevant scientists and policy makers can be included in the process of ranking, or it can be accomplished through some other method. However, it is recommended that, as in all decision-making activities, as many groups as possible be represented for informed and equitable policy formulation.

In choosing the highest priority impacts, it may be helpful to ask some of the following questions:

- Which impacts are important to the affected individual's or group's way of life?
- If impacts are not distributed evenly, should hard-hit groups receive greater attention?
- Is there a trend of particular impacts becoming more of a problem than others?

It may be also useful to develop some kind of a matrix, as shown in Table 1 below, to help organize the information used in your decision making.

Table 1. Drought impact decision matrix

Impact	Cost	Equally Distributed?	Growing?	Public Priority?	Equitable Recovery?	Impact Rank

From this list of prioritized impacts, you next need to decide which impacts should be addressed and which are too small to warrant attention in this forum. No impacts should be ignored, but they may be deferred to another forum for discussion or postponed until the higher priority impacts have been addressed. Again, the previously mentioned concerns (urgency, equity, etc.) should be taken into account.

The result of this step is the development of a list of the highest priority impacts that are relevant to your particular region or activity and supported by scientific researchers, policy makers, and the public. These impacts can then be investigated further (Step 4).

Step 4. Vulnerability Assessment

Vulnerability assessment provides a framework for identifying the social, economic, and environmental causes of drought impacts. It bridges the gap between impact assessment and policy formulation by directing policy attention to underlying causes of vulnerability rather than to its result, the negative impacts, which follow triggering events such as drought (Ribot et al. 1996: 4). For example, the direct impact of a lack of precipitation may be reduced crop yields. The underlying cause of this vulnerability, however, may be that the farmers did not use drought-resistant seeds, either because they did not believe in their usefulness, the costs were too high, or because of some commitment to cultural beliefs. Another example of an impact could be a farm

foreclosure. The underlying cause of this vulnerability could be many things, such as small farm size because of historical land appropriation policies, lack of credit for diversification options, farming on marginal lands, limited knowledge of possible farming options, a lack of local industry for off-farm supplemental income, or government politics (state, national, or international).

Therefore, for each of the identified impacts that are relevant to your application (from Appendix C), begin asking why have (might) these impacts occurred (occur). It is important to realize that a combination of factors might produce a given impact (i.e., environmental, economic, and social factors). It might be beneficial to diagram these causal relationships in some form of a tree diagram. Two examples are shown in Figures 1 and 2. Figure 1 demonstrates a typical agricultural example and Figure 2, a potential urban scenario. Depending on the level of analysis, this process can quickly become somewhat complicated. This is why it is necessary to have the right mix of people working on the project that have knowledge of the relevant topics. Appendix D lists many factors that typically make an area vulnerable to drought; these should be considered when forming your tree diagrams.

The tree diagrams illustrate the complexity of understanding drought impacts. The two examples provided are not meant to be comprehensive or represent an actual location. Basically, their main purpose is to demonstrate that impacts must be examined from several perspectives to expose their true underlying causes. For this assessment, the lowest causes on the tree diagrams, the items in boldface on the tree diagrams, will be referred to as basal causes. These basal causes are the items that have the potential to be acted on to reduce the associated impact. Of course, some of these impact causes should not be or cannot be acted on for a wide variety of reasons (discussed in Step 5 of this guide).

Step 5. Action Identification

Once drought impact priorities have been set and the corresponding underlying causes of vulnerability have been exposed, it is time to identify actions that are appropriate for reducing drought risk. In accordance with the overall goal of drought mitigation rather than drought response, we stress that mitigative actions should be identified before potential response actions.

Again, it may be useful to develop some kind of a matrix (like Table 2) in your decision making. This matrix expands on the impact of “income loss from crop failure” from the agricultural example in Step 4. The matrix lists the impact as well as the described basal causes of the impact. From this point, begin to investigate what actions could be taken to address each of these basal causes. The following sequence of questions may be helpful in identifying potential actions:

- First, can the basal cause be mitigated (can it be modified before a drought)? If yes, then how?
- Second, can the basal cause be responded to (can it be modified during or after a drought)? If so, then how?
- Is there some basal cause, or aspect of the basal cause, that cannot be modified and must be accepted as a drought-related risk for your activity or area?

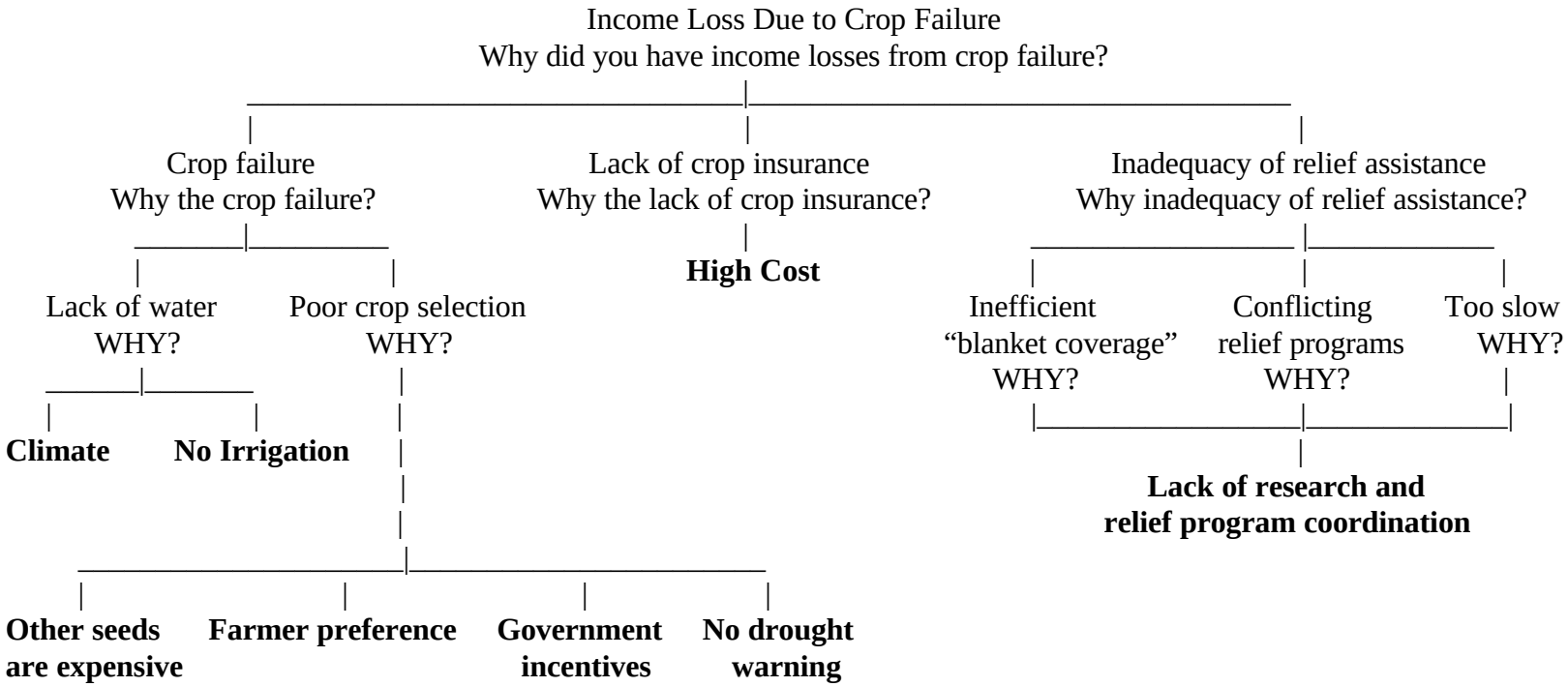


Figure 1. An example of a simplified agricultural impact tree diagram. Notice the boldface items represent the basal causes of the listed impact. Although these items may be broken down further, as in Appendix F, this example illustrates the vulnerability assessment process.

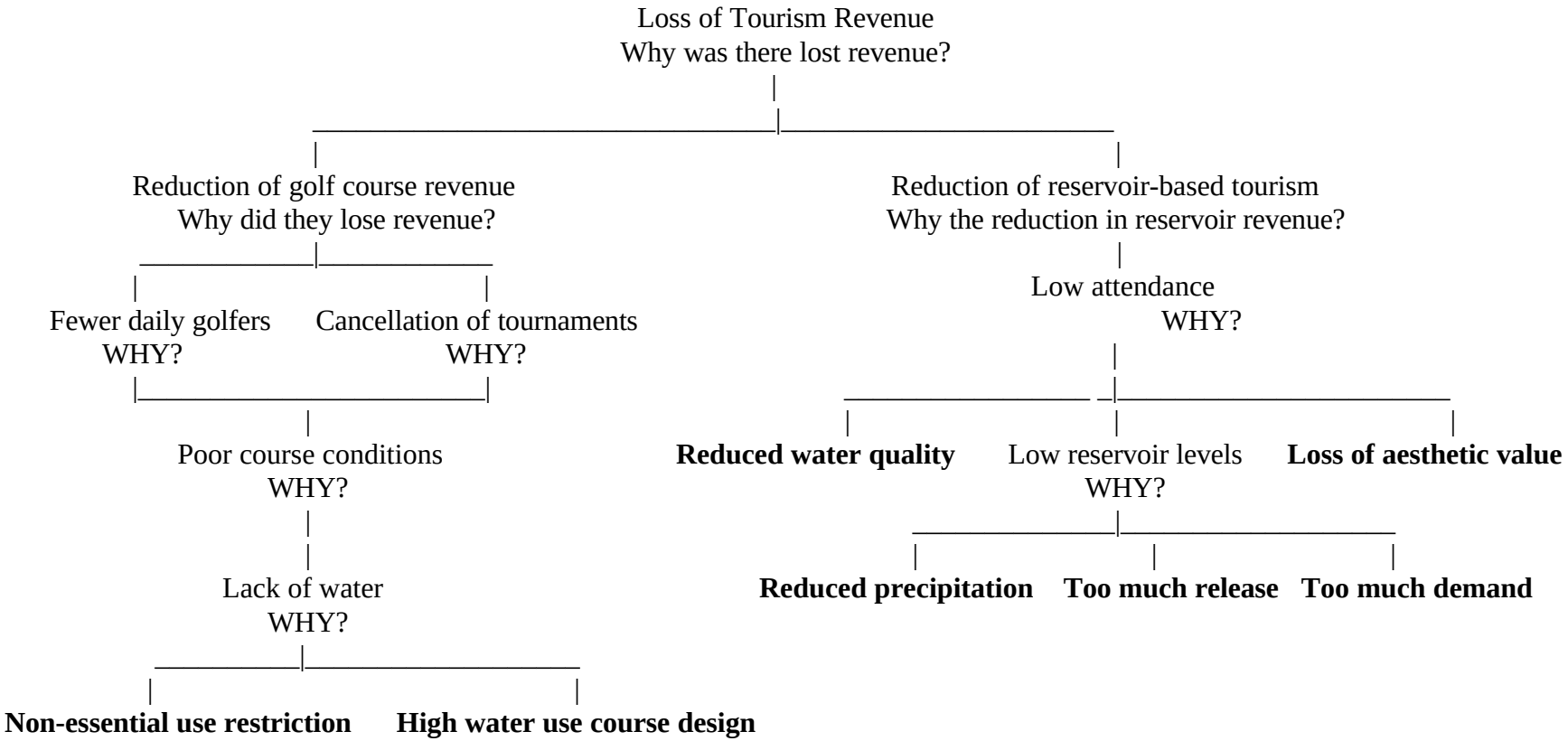


Figure 2. An example of a simplified urban impact tree diagram. Notice the boldface items represent the basal causes of the listed impact (in this case, the loss of tourism revenue). Although these items may be broken down further, as in Appendix G, this example illustrates the vulnerability assessment process.

Table 2. Drought Risk Action Identification Matrix

Impact of Drought	Underlying Causes of Vulnerability (Basal Causes of the Why Questions)	Possible Actions	Mitigation (M), Response (R), or Accepted Risk (AR)	Feasible?	Effective for impact reduction?	Benefit / Cost ?	Equitable?	To Do?
Income loss from crop failure	Variable climate	Weather modification	M					
		Weather monitoring	M					
	No irrigation	Haul water during a drought	R					
		Provide government assistance for projects	M					
	Expensive seeds	Subsidize seed sales	M					
	Farmer preferences to plant specific seeds	Conduct workshops	M					
		Conduct research	M					
		Enhance communication	M					
	Government incentives to plant specific crops	Lobby for new incentives	M					
	No drought warning	Provide weather monitoring	M					
		Identify “triggers”	M					
	High cost of crop insurance	Government subsidies	R					
	Lack of research as to the efficiency of drought relief efforts	Identify target groups and conflicting relief program criteria and goals	M					
	Lack of drought relief program coordination	Streamline relief application and funding	M					

As a reference in identifying potential actions, Appendix E lists many actions that could be proposed for drought risk reduction planning. All of the listed items are not necessarily recommendations. As will be discussed (in Step 6), not all ideas are appropriate in all cases. Many of the ideas are more in the realm of short-term emergency response, or crisis management, rather than long-term mitigation, or risk management. Emergency response is an important component of drought planning, but should only be one part of a more comprehensive mitigation strategy.

Step 6. Developing the "To Do" List

Now that the impacts, causes, and relevant potential actions have been identified, the next step is to choose which actions to take in your risk reduction planning. This selection should be based on such concerns as feasibility, effectiveness, cost, and equity. Additionally, it will be equally important to review the impact tree diagrams when considering which groups of actions need to be considered together. For example, if you wanted to reduce crop losses by promoting the use of a different type of seed, it probably wouldn't be very effective to educate farmers on the benefits of the new variety if it is too expensive for them to use or there are high government incentives for planting other crops.

In choosing the appropriate actions, it might be helpful to ask some of the following questions:

- What are the cost/benefit ratios?
- Which actions are deemed feasible and appropriate by the general public?
- Which actions are sensitive to the local environment (i.e., sustainable practices)?
- Are your actions addressing the right combination of causes to adequately reduce the relevant impact?
- Are your actions addressing short-term and long-term solutions?
- Which actions would fairly represent the needs of affected individuals and groups?

Again, a matrix (such as Table 2) may be useful for organizing concerns regarding the relevant actions. Once the appropriate risk reduction actions have been chosen, they should be compiled in a comprehensive, explanatory form. It is suggested that the "To Do" list be split into actions that are to be done now versus those that are to be performed during or after a drought. In addition, it may be helpful to clarify the areas of vulnerability that you have identified as falling under the acceptable risk categories.

This process has the potential to lead to the identification of effective and appropriate drought risk reduction activities rather than ad-hoc responses or unresearched mitigation plans that may have little effect on reducing drought impact in the future.

Conclusion

Upon completion of Step 6, the risk analysis is finished. The user has gone through a process to identify drought impacts, vulnerabilities, and the underlying causes of those vulnerabilities. Perhaps most importantly, the user has identified a “to do” list of actions that can lead to long-term mitigation of these impacts. Drought mitigation actions have always been difficult to identify because of the lack of systematic approaches to do so. This guide stops short of suggesting methods of implementing any of the actions identified.

The development of a drought contingency plan provides an excellent opportunity to use this guide. In these cases, many of the people needed to complete the guide have already been assembled. In addition, completing this analysis will also provide important information useful in constructing a plan. For example, the mitigation actions identified using the guide can then be included within the plan. It could also be useful for those interested in reviewing and updating any drought plans. Completion of the analysis as part of a post-drought evaluation would be another valuable opportunity, providing information on how efforts of mitigation, response, and recovery can be improved before the next drought. Finally, because vulnerability is dynamic, it would be beneficial to periodically complete a drought risk analysis to assess how vulnerability is changing and to maintain an appropriate level of preparedness.

Appendix A. Glossary of Terms

Below are definitions for terms that appear within this guide. Several of these terms have other definitions that are commonly used elsewhere depending on the discipline or perspective. In this case, the definitions have been tailored to the natural hazard of drought.

Acceptable Risk: A level of vulnerability that is considered to be "acceptable," balancing factors such as cost, equity, public input, and the probability of drought.

Crisis Management: An approach for dealing with drought where responses and actions are made during the event with no prior planning, sometimes leading to ineffective, poorly coordinated, and untimely initiatives by individuals or governments.

Drought: A deficiency of precipitation from expected or "normal" that, when extended over a season or longer period of time, is insufficient to meet demands. This may result in economic, social, and environmental impacts. It should be considered a normal, recurrent feature of climate. Drought is a relative, rather than absolute, condition that should be defined for each region. Each drought differs in intensity, duration, and spatial extent.

Drought Contingency Plan: A document that identifies specific actions that can be taken before, during and after a drought to mitigate some of the impacts and conflicts that result. Frequently these actions are triggered by a monitoring system.

Hazard: A threatening event (in this case, a drought, a reduction in water supply, or an increase in water demand) that would make supply inadequate to meet demand.

Drought Impact: A specific effect of drought. People also tend to refer to impacts as "consequences" or "outcomes." Impacts are symptoms of vulnerability.

Drought Impact Assessment: The process of looking at the magnitude and distribution of drought's effects.

Mitigation: Short- and long-term actions, programs, or policies implemented in advance of drought, or in its early stages, to reduce the degree of risk to people, property, and productive capacity.

Preparedness: Pre-disaster activities designed to increase the level of readiness or improve operational capabilities for responding to a drought emergency. Preparedness is a mitigation action.

Response: Actions taken immediately before, during, or directly after a drought to reduce impacts and improve recovery. Response measures are an important part of drought preparedness but should only be one part of a more comprehensive mitigation strategy.

Risk: The potential adverse effects of drought as a product of both the frequency and severity of the hazard and corresponding vulnerability.

Risk Analysis: The process of identifying and understanding the relevant components associated with drought risk as well as the evaluation of alternative strategies to manage that risk.

Risk Management: The opposite of crisis management, where a proactive approach is taken well in advance of drought so that mitigation can reduce drought impacts, and so relief and recovery decisions are made in a timely, coordinated, and effective manner during a drought.

Vulnerability: Characteristics of populations, activities, or the environment that make them susceptible to the effects of drought. The degree of vulnerability depends on the environmental and social characteristics of the region and is measured by the ability to anticipate, cope with, resist, and recover from drought.

Vulnerability Assessment: Vulnerability assessment provides a framework for identifying or predicting the underlying causes of drought-related impacts. Drought may only be one factor along with other adverse social, economic, and environmental conditions that creates vulnerability.

Appendix B. Supplementary Information for Getting Started

- Environmental Information
- Economic Information
- Social Information
- Customizing Information to Your Local Area

- **Environmental Information**

Precipitation

Because precipitation is an important water resource supply component, an analysis of precipitation characteristics is a critical component of drought risk. First, it is important to identify and examine local and regional precipitation characteristics. To make this type of analysis, it is necessary to understand climatology. Climatology represents the composite of day-to-day weather over a long period of time and provides the method of reviewing the past to make predicitons of the future. Some initial questions that are important to consider are:

- What is the average annual precipitation?
- What is the seasonality of precipitation?
- What are the extremes and variability of precipitation?

The annual precipitation provides a starting point. Monthly mean precipitation totals are a next step in defining a region's climatology. In many parts of the United States, it is more important to understand the distribution, or seasonality, of precipitation throughout the year than the annual quantity of precipitation. However, it is the natural variability and the potential extremes of precipitation that can help identify the vulnerability. A region that experiences a larger precipitation variability and greater extremes could be more susceptible to an increased number of drought events. Droughts occur in almost every kind of climate, but the characteristics of drought differ depending on the region.

Climatology can also be used to provide important benchmarks, such as the drought of record. The drought of record is the drought remembered as having the greatest impact on a region. Some specific questions regarding drought should be asked, including:

- How often does drought occur in this region?
- How severe have the droughts been?
- How widespread have the droughts been?
- How long have the droughts lasted?
- What is the drought of record?

Some regions are dependent on precipitation in other regions a long distance away. In these cases, a knowledge about the climatology of the source region is very helpful. A good example of this would be the Imperial Valley in southern California. Because most of the water supply for

irrigation of crops comes from the Colorado River, the Imperial Valley depends on the precipitation characteristics of the Upper Colorado River Basin.

It is also important to consider how your climate is changing over time. Droughts are a normal part of almost every climate. In the United States, droughts occur regularly in Alaska, Hawaii, Florida, Maine, and everywhere in between. Even though the precipitation for the country as a whole has increased during the recent decades, the evidence is that much of this increase is in the heavy rainfall events. During the same time, droughts have continued to occur throughout the country. Most of these droughts have been short-term, although California and Nevada experienced an extended drought from 1987 to1992.

One event that has captured recent national and international attention is the El Niño phenomenon. There is increasing understanding about El Niño and it's opposite phenomenon, La Niña, and the precipitation anomalies associated with them.[2] As the ability to forecast El Nino and La Niña events improves, it may become possible to have a better prediction of potential precipitation anomalies in the future.

Another issue capturing political and scientific attention is climate change. This issue could have potential impacts on regional precipitation characteristics in the future. Scientists are still working to identify regional changes in precipitation patterns as a result of human-induced warming.[3] Planners should be aware of some of the potential impacts that could result from climate change, but they should also understand that considerable research still needs to be done on precipitation changes, especially on a regional or local basis.

Notes:

1. For example, Sacramento (California) and Bismarck (North Dakota) both receive a little more than 15 inches of precipitation a year. It is the timing of the precipitation, however, that makes the two climates different and vulnerable to drought in different ways.

Sacramento receives most of its annual precipitation during the winter months. Dryness during the summer is normal, but less than expected precipitation during the winter can have large impacts, especially with water supplies. The same pattern is true in much of the West, where 75% of the precipitation is snowfall during the winter months. Without this snow, there is much less snowmelt to increase streamflows and fill reservoirs.

In Bismarck, and across the Great Plains, most of the precipitation falls during the summer. This precipitation is required by the vegetation, especially crops, so that if there is low precipitation during these months, the impacts could be severe.

In the eastern United States, the distribution of precipitation during the year is less variable. Richmond, Virginia, for example, receives an annual precipitation of 43 inches and each month averages more than 3.0 inches. These regions are vulnerable to a series of months with less than the expected rainfall at any time, but the impacts become visible more quickly during the summer months because of the increased demand by vegetation and the higher air temperatures.

2. At this stage, scientists agree that there is an increased chance of above-normal winter season precipitation in the region from California to the Gulf Coast during El Niño events and an increased chance of below-normal precipitation in the Pacific Northwest during winter. During La Niña events, the Pacific Northwest has an increased chance of above-normal winter season precipitation, while the Southwest has increased chances of below-normal precipitation both during the winter and in the region's summer "monsoon". There is also a slight increase in the chances of below-normal precipitation during the summer across the Corn Belt and Midwest with La Niña events. One should always be cautious with these expectations. For example, even with the increased chances for above-normal precipitation, California can still experience below-normal precipitation during an El Niño winter. Scientists continue working to identify other relationships between the climate across the United States and El Niño/La Niña events.

3. Scientists believe that one of the results of a human-induced global warming will be an intensification of the hydrological cycle. This means that the atmosphere will be able to hold more moisture because of the warmer temperatures, creating the potential for increased precipitation in some locations. The warmer temperatures will also increase the evapotranspiration from the surface, creating a potential for moisture deficits in regions where precipitation amounts do not balance this loss. A possible scenario for the central United States might be that annual precipitation will increase in a location, but summertime losses due to evapotranspiration will also increase, causing an increased potential for drought conditions during a time crucial for crop production. Another potential impact on water supplies in the United States would be that runoff from winter snows would take place earlier in the spring season, and that snowpacks may be decreased, causing a change in water management, especially in the western states.

Water Supply Sources

In drought planning, it is essential to have an adequate understanding of your water supply sources. A good start would be to categorize the supply sources into surface and ground water. Within the surface category, a further classification between storage and streams/rivers is suggested. Within the streams/rivers category, it may be significant to further divide the information between flows that are controlled by upstream structures and those that are not. If the surface water sources are located in different hydrologic basins or, in the case of groundwater, different geologic basins, this geographic distinction may be informative in terms of timing of the reduction of water supplies or different rates of recovery of supplies.

Information from previous drought events, in terms of timing, location, and duration, will be important for each of the categories listed above. This information can lead to an understanding of the linkage between a drought event and the impacts on supply.

Identification of trends in water supply is also important. Trends of specific concern that may have an effect on specific sources of supply might include: changes in watershed land management that affect runoff (timing, magnitude, or sediment loads); additional wells located in the aquifer or increased withdrawals; new diversions from the stream/river that might have a higher priority in times of emergency; critical habitat needs for endangered species, requiring the maintenance of minimum flows; or lower-than-normal maintenance of physical features (such as pumps and motors) that would reduce the availability of groundwater.

Effects of Drought on Soil/Sediment

The primary drought effect on soil and sediment is increased sheet erosion due to the loss of plant roots and wind. Brief thunderstorms remove soil from exposed ground surfaces, including channels. The increased deposition of sediment on deltas and into rivers increases turbidity that affects fish habitat. The loss of farm soil causes long-term loss in farm production, even after the drought is over. Wildfires remove vegetation, enhancing the potential for sheet erosion and soil removal. Soil is baked from wildfires, perhaps making them impermeable. Wildfire impacts create greater potential for debris floods and flows and for flash floods.

Effects of Drought on Surface and Ground Water Levels

Rivers and lakes drop to low levels during drought, while turbidity and salinity increase, affecting fish habitat. Mountain animals have less to drink and migrate to wetter areas or to places of water concentration. Ground water levels drop and spring flows decrease. Deeper aquifers may not be affected until some years later, if at all. Wetlands can become dry until moisture returns. Soil moisture can decrease, killing even the deeper plant root systems. Primary and secondary water systems lose pressure, creating potential for cross-connection contamination and potential illness. Low community water pressure makes firefighting difficult. More frequent wildfires may burn deeply, damaging root systems and future plant growth. Reservoir drawdowns and low stream flows affect recreation. The lack of water during drought can make it difficult to fight wildfires.

Effects on the Air

Air can become dry, warm, and dusty, further desiccating the soil and increasing evaporation from bodies of water. Respiratory ailments increase. Winds enhance sheet erosion from dried soils. Fields, yards, flower beds, and gardens become dry and parched, enhancing the potential for field and yard fires. Dust storms decrease visibility. More common wildfires will place smoke, ash, and dust into the air. When surface vegetation is removed or thinned during dry periods or after wildfires, “dust-devils” remove surface soil layers, reducing plant growth potential. Lack of precipitation and humidity increases concentration of dust and pollutants in air.

Effects on Wildlife and Plants

Ecosystems depending on soil moisture or the presence of open water become damaged. Fish and game habitat is reduced. If soil is lost due to wind, then damage may be semi-permanent. Wetland and riparian animal and plant life are displaced or die. Drier mountain slopes create vulnerability to forests from wildfire. Mountain burn areas damage game habitat and forage. Burn areas are unattractive for several years, decreasing property values and interest in development; tax bases also decrease. Dangerous animals may be attracted to developed areas for food and water. Depredation problems arise and competition between deer and elk and livestock for native forage and water increases. Deer and elk herds may migrate, affecting the hunting season. Endangered species populations are stressed further. Stressed vegetation and wildlife are more vulnerable to disease.

Drought and Catastrophic Fire

There are strong intuitive connections between drought and catastrophic wildfire potential in the West. For instance, many have drawn the conclusion that the record wildfire season of 1996 was connected to the drought that gripped much of the western United States.

However, it is far less clear, from a scientific viewpoint, what the real, verifiable impacts of

drought are on incidence and impacts of catastrophic wildfire. Further, it is not understood what role drought plays in facilitating beneficial, lower-intensity fires in healthy forest regimes. Specifically, the following questions are raised:

1. A vacuum exists in the scientific literature and assessment data in understanding drought and post-drought residual impacts on catastrophic fire risk and hazard. Research to address this need could include:

a. To what degree do wildfires in forest types change during and after periods of drought?
b. To what degree do catastrophic wildfire risk and hazard change during and after a drought?

2. The impact of urban sprawl in relation to fire potential in times of drought needs significant further exploration. Increasing attention is being paid to fire in the interface, but not as it correlates to drought. Some questions are:

a. What is the impact of mandatory community water conservation measures during drought on vegetation moisture levels in the interface?
b. What impact does this imposed dewatering have on fire risk, and what can be done to mitigate these increased risks?

3. Overall, the health of forests plays a major role in levels of catastrophic wildfire risks and hazards. The scientific community is in general agreement that standing and downed fuel loads, disease, and overcompetition for available moisture by dense overstory vegetative stands all contribute to reduced understory vigor, lowered streamflows, soil moisture recharge, etc.

An important missing information link for effective drought risk assessment, in relation to the overall forest condition, is the degree to which drought exacerbates adverse forest health symptoms. Important questions that should be considered include:

a. What is the effect of drought on vegetative moisture content and incidence of vegetation stress, insect infestation, and disease in healthy and unhealthy forests?
b. What is the effect on fuel load levels in healthy and unhealthy forests?

4. The incidence and potential positive benefits of drought-generated, lower-intensity wildfires in healthy forest ecosystems is also largely unexplored. For instance:

a. To what degree would reducing forest tree densities, incidence of insect infestation and disease, and fuel loading create a more positive drought-driven fire regime of benefit to natural resources, while reducing hazards?

In an effort to reduce adverse impacts of drought and fire, and produce positive environmental, social, and economic benefits, answering these questions is important to both understand the difficult and complex impacts associated with drought and catastrophic fire and arrive at a greater consensus for action.

- **Economic Information**

Understanding Economic Linkages and Trends

Droughts cause hardship on many different sectors of an area's economy. Multi-generation farms may go under financially. In the community, agriculture-dependent businesses conduct less business and lose money, thereby increasing their potential for bankruptcy. Therefore, banks may be reluctant to loan more money, extend loans, or waive payments to farmers/ranchers and agribusinesses.

Significant effects are not only felt in the agriculture-related sector. Tourists may be reluctant to visit drought-affected areas, reducing another source of community income. Use of forests for recreational purposes may be discouraged because of fire hazards. Water based recreation may also decrease. Businesses relying on these activities will suffer. Generally, in most sectors, people suffer economically, with some facing the potential for serious financial hardship.

Economic drought impacts are also influenced by many different sectors, including local households, businesses, and the community, as well as state and national policies and organizations. In addition, each of these entities and levels may influence the economic impact on the other sectors. Therefore, careful analysis is needed to understand linkages that may place a specific group or activity in economic risk.

Within the last few decades, several economic methodologies and models have been developed for the analysis of drought. These tools have been used to study several historical droughts throughout the United States in terms of specific economic impacts, along with management evaluations and recommendations to limit these impacts in the future. A review of such historical information could provide insight into issues that may be relevant to your local situation. In the United States, these impacts typically occur in the agricultural sector, although significant impacts can also be felt in many other areas, such as timber, fishery, recreation, manufacture, utility, banking, and transport sectors. It is important to remember that, no matter which sector is affected, the final impact is felt at the individual family level.

Knowledge of potential economic trends in your region may also be a valuable asset for identifying potential areas of drought risk. However, the identification of these trends requires a good knowledge of local, regional, and national economic capacities and policies. On the local level, one must determine a community's capacity to withstand the economic losses often associated with drought. This would require information on issues such as: family income, assets, credit flexibility and economic decision-making processes, local social welfare programs, and community planning. On the state and national level, policies and programs must be evaluated for their applicability to your local areas. These policies may affect national crop price fluctuations and export demands, while programs may aid in local development or drought relief.

Other Economic Topics

A. Conservation Reserve Program: The Conservation Reserve Program (CRP) was extended in 1997 for an additional ten years, setting aside up to 25 percent of crop land per county for soil conservation/stabilization and for wildlife use. This program does provide farmers with some income, which is helpful during drought years that may occur beyond the 10-year extension.

B. Drought Awareness Programs: There can be a lack of interaction between government and drought-affected individuals or entities, so that neither understands the other on drought issues. Programs including brochures and workshops could establish this relationship/interaction. Through this process, relevant individuals or groups might maintain a higher level of motivation to set aside drought-reserve funds, based on the knowledge of the realities and potential of drought impacts on them.

C. Low-Interest Loan Programs: Some agricultural loan programs were depleted of funds and not available for the drought year of 1996. Additionally, some low-interest drinking water loan programs were depleted of funds, making it difficult for communities that may have experienced shortages in drinking water, or wished to upgrade drinking water systems, to obtain loans.

D. Funding for Drought Response and Recovery: At the beginning of the 1996 drought year, federal drought assistance and planning grant funds, such as PL 102-250, were nearly depleted. Adequate funds to mitigate drought early on can reduce cascading affects before a drought enters its later stages.

E. Crop Insurance: Crop insurance has recently changed from the public to the private sector. Still, this is an insurance that can be applied during emergencies. A comparison should be made between the kinds of applications and effectiveness of crop insurance and, for example, the National Flood Insurance Program (NFIP). Farmers and government officials have said that crop insurance is not adequately effective during drought. A study should be done within the federal government to compare these various kinds of insurance that can be applied during natural disasters. They should provide somewhat equal relief during emergencies, and they should be self-funding.

- **Social Information**

Public Health and Safety

Drought affects human health, both physically and emotionally, in both rural and urban areas. Some examples of these effects are discussed in the following paragraphs.

A. Structure Fire: Water conservation measures in communities can result in the drying of lawns and landscaping. Dry trees and bushes are vulnerable to fire, which can, in turn, cause fire to spread to adjacent structures. Dry fields in communities are also vulnerable. This potential

increase in numbers of structure fires leads to greater community losses and increased risk to firefighters. Decreased water pressure in primary water lines (or, in some cases, secondary lines) is aggravated through structure fire fighting. Pumper trucks further decrease water pressure in the lines and further deplete available drinking water. In some cases, water pressure may not be adequate to fight structure fires and may inadvertently cause cross-connections.

B. Cross-Connections: Most communities do not require back-flow preventers/valves on residential structures. Low pressure in community drinking water lines can lead to back-flow from residential gray water into primary lines. This can lead to illness throughout the community. Conditions that can lead to cross connections include garden hoses left lying in pools of water, shower hoses in bath tubs, kitchen sink spray nozzles left lying in dirty dish water, and other situations. Fire trucks that pump water from hydrants can cause very low water pressure in drinking water lines and increase the amount of and potential for cross connections.

C. Mental/Physical Stress: Most drought situations lead to stress that can result in a variety of responses. There is the potential for serious emotional and mental health problems, and there is the potential for family distress and conflict, divorce, and even suicide. Conflicts over water between neighbors, or with governmental agencies/offices, can raise public safety concerns.

D. Wildlife: The decrease of wilderness forage and water drives animals into communities where food and water may be available to them. The presence of bears, cougars, bobcats, coyotes, and other animals in populated areas raises public safety concerns to adults, children, and pets. In addition, wild animals may bring disease into communities.

E. Wildfire: Drought increases wildfire potential and can cause unpredictable fire behavior, making them more dangerous to citizens and firefighters. Lack of water supplies during a drought can also make it difficult to fight wildfire, placing the lives of resident and firefighters at further risk.

An Individual's Perception of Drought

Many individuals can recall stories or experiences related to the 1930s drought in the United States. They can recall bankruptcies, migrations, dust storms, massive work subsidy programs sponsored by the Civilian Conservation Corp (CCC) or the Works Progress Administration (WPA), and probably many other effects. Such memories of drought help shape the way that people perceive, plan for, and respond to future droughts.

In addition to past experiences, how people perceive and deal with drought will depend on a wide variety of factors, including: available options, physical or social resources to deal with and recover from the drought, the amount of information available on which to base decisions, perceptions of cultural norms, their role in the drought, and trust in leadership. Basically, unique interpretations of drought characteristics may produce different attitudes and perceptions of how

to deal with drought. Research could be undertaken to identify these issues in your study area. Exposing and discussing these perceptions and forming a consensus on issues may bring about a more unified drought planning process.

Acknowledging Diversity

Drought will affect areas and groups differently based on variations in populations and cultural differences. Therefore, to better understand the relevant groups and their perspectives, it is essential to obtain information in many social categories such as occupation, socioeconomic group, ethnicity, age, gender, or seniority. Resources such as public surveys or community focus groups, citizen advisory councils, social scientists, extension agents, the clergy, and other public servants may provide much of the information required for this kind of analysis. The required data may include population statistics, socioeconomic data, environmental and cultural belief surveys, new legislation or regulation summaries, or any other relevant data that could identify socially relevant information.

Government/Nongovernment Interaction

There can also be a lack of interaction between the government and nongovernmental entities, so that neither understands the other on drought issues. Nongovernment entities may have much less awareness of drought threat and risk than does government, which generally has weather and soil science staff. It is important that both views are understood for effective policy formulation.

Political/Governmental Perspectives

The management of drought risk and impacts is largely affected by government decision making. Government addresses drought management issues from a multi-objective perspective. Each involved government agency has its own congressional or legislative mandates to oversee and implement, some of which may affect mitigation, preparedness, response, or recovery related to drought. These “multi-objectives” can work against each other during times when emergency issues arise, such as during drought periods. For example, it is the mandate of a Division of Wildlife Resources to maintain deer and elk herds in a drought-affected area. This agency may not have responsibilities to protect agricultural interests. A Department of Agriculture may have interests in assisting with the maintenance of agricultural production levels when depredation causes a serious production impact. Thus, there may be a variety of incompatible, yet individually important, objectives. Therefore, it is essential to have a working knowledge of various governmental institutions and their responsibilities for effective drought planning.

- **Customizing Information to Your Local Area**

As public officials address drought response and mitigation, it becomes apparent that drought emergencies are different from other emergencies. As a regional drought develops, the associated problems can vary from year to year, basin to basin, and local economy to local economy in many different ways. While some folks might be enjoying the "good weather," others are suffering financial losses; while some find the dry weather an opportunity to extend their normal recreation activities, others see their recreation activities lost from fish and wildlife kills and an increasing wildfire potential. Therefore, it is essential that information be available at a scale representative of the area experiencing drought and comprehensive enough to adequately examine corresponding impacts.

In monitoring local climatic conditions and water supply, it is necessary for a technical committee to break regional areas into basins or sub-basins. The boundaries should be determined by technical staff who have a knowledge of local climatic and hydrologic boundaries. An objective assessment should be made based on parameters such as streamflow, ground water levels, snowpack, precipitation, and reservoir storage. This information is often used in models that attempt to compare the current conditions to historical averages or to predict the likelihood of climatic events such as drought.

An example of a local technical data network for drought assessment is in Oregon. Technicians in Oregon collect data cooperatively through a number of state and federal agencies involved with a Drought Council (policy makers). The key tool is a customized Surface Water Supply Index (SWSI) developed for Oregon, reflecting earlier work in the state of Colorado. The supply index reflects Oregon’s reliance on snowpack.

These technical analyses must always be tempered with other environmental and social analyses that include input from local government, other organizations, and the public, so that a comprehensive assessment of environmental and social conditions is available for policy makers to consider. Accurate and comprehensive data is essential for sound decision making, public awareness and perception, and effective management of the resource. In addition, unnecessary declarations or inaccurate assessments destroy public confidence and make drought planning much more difficult.

Appendix C. Checklist of Historical, Current, and Potential Drought Impacts

To perform an assessment using this checklist, check the box in front of each category that has been affected by drought in your study area. Your checklist selections can be based on either common or extreme droughts, or a combination of the two. For example, if your drought planning was going to be based on the "drought of record", a historical review would need to be completed to identify the "drought of record" for your area and to assess the impacts of that drought. The impacts would then be recorded on this checklist by marking the appropriate boxes under the "Historical" column. Next, with the current knowledge that you have about your local area, if another "drought of record" were to occur tomorrow, speculate as to what the local impacts may be and record them on the checklist under the "Current" column. Finally, speculate what the impacts of the same drought would be for your area in five or ten years and record these in the "Potential" column.

If enough time, money, and personnel are available, it may be beneficial to conduct impact studies based on common droughts, extreme drought(s), and the "drought of record" for your region. These analyses would yield a range of impacts related to the severity of the drought, which could be useful for planning purposes and is necessary for conducting Step 3 of the guide.

H = Historical Drought
C = Current Drought
P = Potential Drought

H	C	P	**Economic**
			Loss from crop production
☐	☐	☐	Annual and perennial crop losses
☐	☐	☐	Damage to crop quality
☐	☐	☐	Reduced productivity of cropland (wind erosion, etc,)
☐	☐	☐	Insect infestation
☐	☐	☐	Plant disease
☐	☐	☐	Wildlife damage to crops
			Loss from dairy and livestock production
☐	☐	☐	Reduced productivity of rangeland
☐	☐	☐	Forced reduction of foundation stock
☐	☐	☐	Closure/limitation of public lands to grazing
☐	☐	☐	High cost/unavailability of water for livestock
☐	☐	☐	High cost/unavailability of feed for livestock
☐	☐	☐	High livestock mortality rates
☐	☐	☐	Disruption of reproduction cycles (breeding delays or unfilled pregnancies)
☐	☐	☐	Decreased stock weights
☐	☐	☐	Increased predation
☐	☐	☐	Range fires

H	C	P	**Economic** (continued)
			Loss from timber production
☐	☐	☐	Wildland fires
☐	☐	☐	Tree disease
☐	☐	☐	Insect infestation
☐	☐	☐	Impaired productivity of forest land
			Loss from fishery production
☐	☐	☐	Damage to fish habitat
☐	☐	☐	Loss of young fish due to decreased flows
☐	☐	☐	Income loss for farmers and others directly affected
☐	☐	☐	Loss of farmers through bankruptcy
☐	☐	☐	Unemployment from drought-related production declines
☐	☐	☐	Loss to recreational and tourism industry
☐	☐	☐	Loss to manufacturers and sellers of recreational equipment
☐	☐	☐	Increased energy demand and reduced supply because of drought-related power curtailments
☐	☐	☐	Costs to energy industry and consumers associated with substituting more expensive fuels (oil) for hydroelectric power
☐	☐	☐	Loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, etc.)
			Decline in food production/disrupted food supply
☐	☐	☐	Increase in food prices
☐	☐	☐	Increased importation of food (higher costs)
☐	☐	☐	Disruption of water supplies
			Revenue to water supply firms
☐	☐	☐	Revenue shortfalls
☐	☐	☐	Windfall profits
☐	☐	☐	Strain on financial institutions (foreclosures, greater credit risks, capital shortfalls, etc.)
☐	☐	☐	Revenue losses to federal, state, and local governments (from reduced tax base)
☐	☐	☐	Loss from impaired navigability of streams, rivers, and canals
☐	☐	☐	Cost of water transport or transfer
☐	☐	☐	Cost of new or supplemental water resource development
☐	☐	☐	Cost of increased ground water depletion (mining), land subsidence
☐	☐	☐	Reduction of economic development
☐	☐	☐	Decreased land prices

H	C	P	**Environmental**
			Damage to animal species
☐	☐	☐	Reduction and degradation of fish and wildlife habitat
☐	☐	☐	Lack of feed and drinking water
☐	☐	☐	Disease
☐	☐	☐	Increased vulnerability to predation (from species concentration near water)
☐	☐	☐	Migration and concentration (loss of wildlife in some areas and too many in others)
☐	☐	☐	Increased stress to endangered species
☐	☐	☐	Damage to plant species
☐	☐	☐	Increased number and severity of fires
☐	☐	☐	Loss of wetlands
☐	☐	☐	Estuarine impacts (e.g., changes in salinity levels)
☐	☐	☐	Increased ground water depletion, land subsidence
☐	☐	☐	Loss of biodiversity
☐	☐	☐	Wind and water erosion of soils
☐	☐	☐	Reservoir, lake and drawdown (including farm ponds)
☐	☐	☐	Reduced flow from springs
☐	☐	☐	Water quality effects (e.g., salt concentration, increased water temperature, pH, dissolved oxygen, turbidity)
☐	☐	☐	Air quality effects (e.g., dust, pollutants)
☐	☐	☐	Visual and landscape quality (e.g., dust, vegetative cover, etc.)

H	C	P	**Social Impacts**
☐	☐	☐	Mental and physical stress (e.g., anxiety, depression, loss of security, domestic violence)
☐	☐	☐	Health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations, reduced fire fighting capability, etc.)
☐	☐	☐	Reductions in nutrition (e.g., high-cost food limitations, stress-related dietary deficiencies)
☐	☐	☐	Loss of human life (e.g., from heat stress, suicides)
☐	☐	☐	Public safety from forest and range fires
☐	☐	☐	Increased respiratory ailments
☐	☐	☐	Increased disease caused by wildlife concentrations
			Increased conflicts
☐	☐	☐	Water user conflicts
☐	☐	☐	Political conflicts
☐	☐	☐	Management conflicts
☐	☐	☐	Other social conflicts (e.g., scientific, media-based)

H	C	P	**Social** (continued)
☐	☐	☐	Disruption of cultural belief systems (e.g., religious and scientific views of natural hazards)
☐	☐	☐	Reevaluation of social values (e.g., priorities, needs, rights)
☐	☐	☐	Reduction or modification of recreational activities
☐	☐	☐	Public dissatisfaction with government regarding drought response
☐	☐	☐	Inequity in the distribution of drought relief
☐	☐	☐	Inequity in drought impacts based on:
☐	☐	☐	Socioeconomic group
☐	☐	☐	Ethnicity
☐	☐	☐	Age
☐	☐	☐	Gender
☐	☐	☐	Seniority
☐	☐	☐	Loss of cultural sites
☐	☐	☐	Loss of aesthetic values
☐	☐	☐	Recognition of institutional restraints on water use
			Reduced quality of life, changes in lifestyle
☐	☐	☐	in rural areas
☐	☐	☐	in specific urban areas
☐	☐	☐	increased poverty in general
☐	☐	☐	Increased data/information needs, coordination of dissemination activities
☐	☐	☐	Population migrations (rural to urban areas, migrants into the U.S.)

Appendix D. Vulnerability Considerations

This section was developed by Deborah Braver. Ms. Braver is a Project Manager for the U.S. Bureau of Reclamation in Sacramento, CA.

Water Shortage Vulnerability Continuum (by Deborah Braver, 11/97)		
	Higher Vulnerability	**Lower Vulnerability**
Meteorological Drought	Wide Precipitation Variation	Stable Precipitation Pattern
	Lack of Data/Single Source Data	Good Long-Term Data / Multiple Sources of Data
	Passive Drought "Acceptance"	Advance Warning
	Longer Duration	Shorter Duration
	Higher Severity Shortage	Lower Severity Shortage
	Sudden Change in Supply	Gradual Changes in Supply
Supply/Demand Balance or "Institutional Drought"	Single Water Source or Low Supply Reliability	Multiple Water Sources or High Supply Reliability
	Low Priority Water Rights or Low Contractual Rights	Senior Water Rights or High Contractual Rights
	Water Supply at Risk from Contamination	Protected Water Supply
	Imported Water Supply(ies)	Local Supply(ies) and Locally Controlled
	Subject to Other Natural Disasters	Low Likelihood of Other Natural Disasters
Water Use Patterns	High Growth Area/High Additional Demand	Stable or Decreasing Water Demand
	High Percent Water Use Improvements Requires EARLIER Demand Management Response	Low Percent Water Use / Efficiency Improves "Slack" in System = Requires MORE Demand Management Response
	Landscape/Ag Irrigation Usual Practices OR Landscape/Ag Dependence on Precipitation	"Climate Appropriate" Plants OR Non-irrigated Agriculture/grazing

Preparedness	Wait Until Shortage is "Declared" (or beyond...)	Early Shortage Response
	Lack of Political Will	Leadership
	Ignoring Situation/Abdicating Responsibility	Preparedness/Actions to Protect Community / Economy / Environment
	Non-interconnected Water Supply Systems OR Non-Collaborative Approach with Neighbors	Coordination with Others (i.e., Neighboring Water, Disaster Response and Fire Agencies, Mutual Aid Agreements, etc.)
	Revenue/Rate Instability	Rate Stabilization Fund
	"Knee Jerk" Rationing	Pre-determined and Equitable Allocation Methods
	Little Public Awareness	High Community Involvement (from all social and economic sectors)

Appendix E. Potential Risk Reduction Actions

The following grab bag of drought mitigation measures is based on two surveys, one published in 1993 and one that is ongoing. The 1993 survey was undertaken as part of a cooperative agreement between the U.S. Soil Conservation Service (now the Natural Resource Conservation Service) and the National Drought Mitigation Center. The current survey is part of the NDMC's ongoing communication with drought planners around the country. Many ideas naturally fit into more than one category, but each is listed only once.

Caution: These activities are not necessarily recommendations. Not all ideas are appropriate in all cases. Some of the ideas are more in the realm of short-term emergency response, or crisis management, rather than long-term mitigation, or risk management. Emergency response is an important component of drought planning if it is coupled with appropriate mitigation measures.

<u>Assessment</u>

- Develop criteria -- "triggers" -- for drought-related actions
- Develop early warning systems
- Inventory water bank contracts to find new water supplies for drought-stricken areas
- Evaluate water quantity and quality from new sources
- Evaluate use of ground water
- Establish new data collection networks
- Study public willingness to pay more for more reliable water supplies
- Study effectiveness of conservation measures
- Monitor vulnerable public water suppliers
- Improve the accuracy of seasonal runoff and water supply forecasts
- Establish alert procedures for water quality problems
- Investigate business and farm/ranch diversification strategies
- Evaluate capacities to withstand losses associated with drought such as incomes, assets, credit flexibility and decision-making processes, subsidy, loan, and welfare program applicability and the effect of government programs and policies
- Conduct public surveys on environmental, economic, and cultural beliefs for appropriate policy formulation
- Research drought impacts on various groups (i.e., occupation, socioeconomic group, ethnicity, age, gender, or seniority) to select appropriate "target groups"
- Inventory and monitor natural resources within the relevant areas
- Conduct further research into the relationship between drought and fires
- Evaluate the use of marginally productive farm and rangelands

<u>Legislation and Public Policy</u>

- Prepare position papers for legislature on public policy issues
- Examine statutes governing water rights for possible modification during water shortages
- Establish a state water bank
- Pass legislation to protect instream flows
- Pass legislation to protect and manage groundwater
- Pass legislation providing guaranteed low-interest loans to farmers

- Impose limits on urban development
- Develop a state water plan
- Pass legislation requiring water agencies to develop contingency plans
- Enact legislation to facilitate water recycling
- Establish standards for safe residential use of gray water
- Make decision-making authority relating to wildlife during drought conditions available in local offices of federal and state agencies

Water Conservation/Demand Reduction

- Establish stronger economic incentives for private investment in water conservation
- Encourage voluntary water conservation
- Require water users to decrease reliance on ground water and implement conservation measures
- Improve water use and conveyance efficiencies
- Implement water metering and leak detection programs
- Support local development of conservation programs
- Improve water scheduling
- Reduce consumptive use by changing the type of water application system or using water meters
- Institute conjunctive use of surface and ground water

Water-saving measures for urban areas:

- Modify rate structure to influence consumer water use, including:
  - shifting from decreasing block rates to uniform block rates
  - shifting from uniform rates to increasing block rates
  - increasing rates during summer months
  - imposing excess-use charges during times of water shortage
- Modify plumbing system, including:
  - distributing water-saving kits, including replacement showerheads and flow restrictors
  - changing plumbing standards
  - requiring or offering rebates for ultra-low-flow toilets
- Reduce water-system losses, including:
  - using watermain-leak-detection survey teams followed by watermain repair or replacement as necessary to reduce system losses
  - monitoring unaccounted-for water
  - conducting indoor-outdoor audits
  - starting a meter-replacement program
  - recycling filter plant backwash water
  - recharging groundwater supplies
- Reduce water use for landscaping, including:
  - imposing lawn watering and other landscape-irrigation restrictions
  - developing a demonstration garden
  - publishing a xeriscape manual
  - using nonpotable water for irrigation
  - imposing mandatory water-use restrictions during times of water shortage

- Conduct water-conservation education of the public and of school children, including special emphasis during times of water shortage
- Meter all water sales and replace aging or defective meters in a timely way

Water-saving measures for farms:
- Use lasers for accurate land leveling
- Install return-flow systems
- Line canals or install piping to control seepage
- Control exotic phreatophytes
- Use sprinkler and drip irrigation systems
- Schedule irrigation by demand
- Use soil-moisture monitoring
- Use deep pre-irrigation during periods when surplus water is available
- Improve tillage practices
- Use evaporation suppressants
- Use lower-quality water
- Install underground pipelines
- Grow drought- or salinity-tolerant crops

<u>Increasing Water Supply/Supply Augmentation</u>
- Issue emergency permits for water use
- Provide pumps and pipes for distribution
- Propose and implement programs to rehabilitate reservoirs to operate at design capacity
- Undertake water supply vulnerability assessments
- Inventory self-supplied industrial water users for possible use of their supplies for emergency public water supplies
- Inventory and review reservoir operation plans
- Provide funds for water recycling projects
- Provide onstream storage of excess water
- Implement water quality management and wastewater reuse
- Use carryover storage in a reservoir to "bank" a conserved water supply
- Use ground-water banking concepts to allocate and store surplus, inactive, or reclaimed water
- Establish water banks for voluntary sale, transfer, or exchange of water
- Establish water banks and transfers in conjunction with voluntary farmland idling programs
- Temporarily authorize deliveries of water outside service areas and/or for unauthorized project purposes when project water is available and with the consent of project water users
- Temporarily use project facilities for storage and distribution of non-project water
- Implement minor structural measures to obtain temporary water supplies from inactive or dead storage or from ground water sources

<u>Economic Development</u>
- Provide incentives for farm and business diversification
- Promote off-farm industry to diversify wage-earning strategies
- Enhance information flow between bankers, farmers/ranchers, businesses, and government agencies

Public Education and Participation

- Establish a public advisory committee
- Include public participation in drought planning
- Organize drought information meetings for the public and the media
- Implement water conservation awareness programs
- Publish and distribute pamphlets on water conservation techniques and drought management strategies
- Organize workshops on special drought-related topics
- Prepare sample ordinances on water conservation
- Establish a drought information center
- Set up a demonstration of on-site treatment technology at visitor center
- Include the media in drought planning
- Establish tuition assistance so farmers can enroll in farm management classes
- Develop training materials in several languages
- Provide education on different cultural perspectives of water resources
- Consult a marketing firm for strategies to draw public attention
- Employ public participation and public information specialists

Health and Nutrition

- Establish crisis counseling centers and hotlines (especially in rural areas)
- Establish food subsidy programs for drought-affected individuals
- Establish shelters for domestic violence cases
- Conduct workshops on stress management and basic nutrition strategies
- Conduct public information campaigns on the health dangers of drought (e.g., heat stress, low-flow cross-connections, fire risk, reduced water quality, etc).

Media Participation

- Select official representatives for media contacts
- Establish a list of authorities regarding drought issues
- Organize education activities for the media
- Write reports for the media early in the event
- Include media personnel in drought planning
- Keep the media updated about new conditions and plans

Conflict Resolution

- Resolve emerging water use conflicts
- Investigate complaints of irrigation wells interfering with domestic wells
- Negotiate with irrigators to gain voluntary restrictions on irrigation in areas where domestic wells are likely to be affected
- Clarify state law regarding sale of water
- Clarify state law on changes in water rights
- Suspend water use permits in watersheds with low water levels
- Work with community-based organizations to promote public participation in conservation programs
- Maintain communication between the public, policy makers, scientists, and the media

Drought Contingency Plans

- Adopt an emergency water allocation strategy to be implemented during severe drought
- Recommend water suppliers develop drought plans
- Evaluate worst-case drought scenarios for possible further actions
- Establish a natural hazard mitigation council
- Establish a public advisory committee

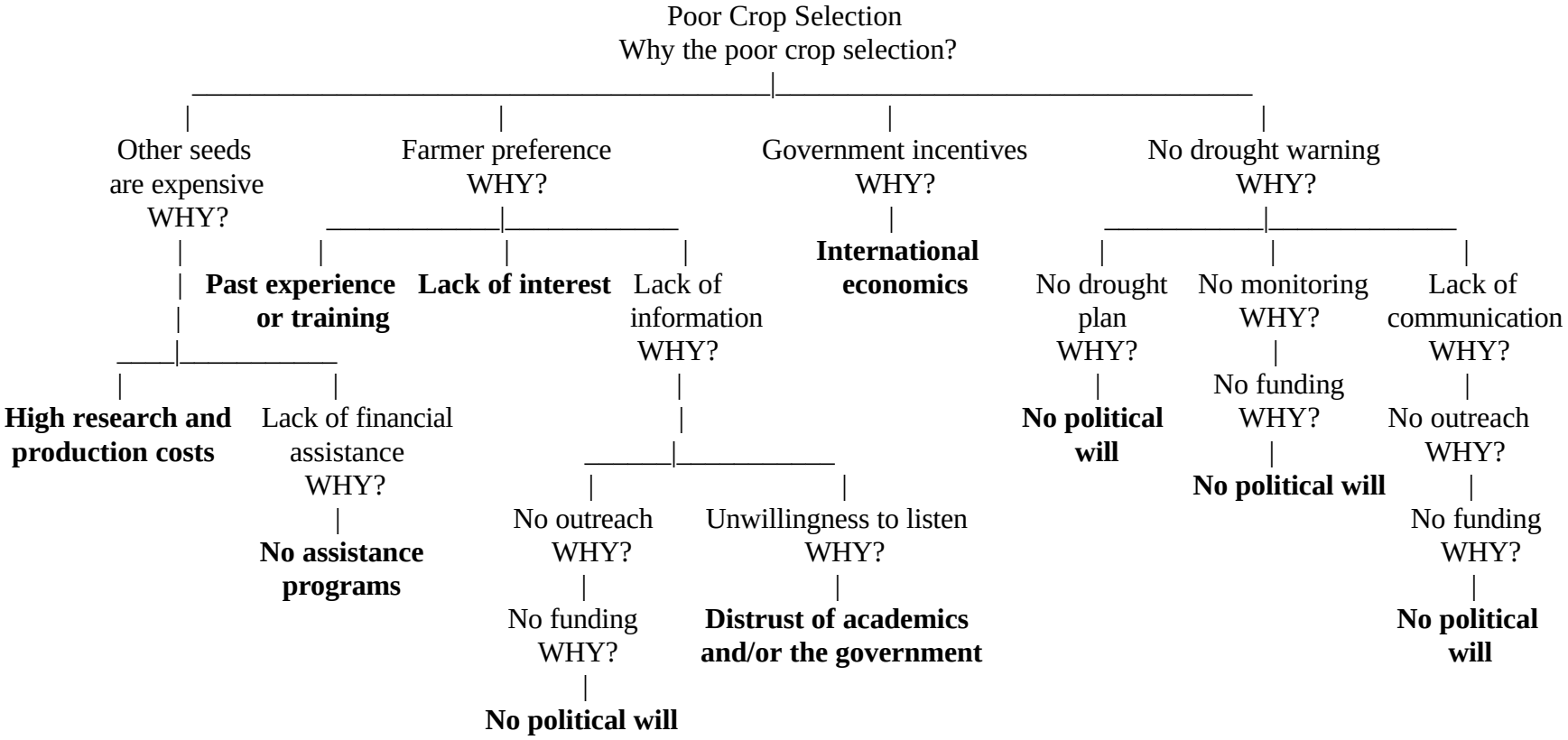
Technical Assistance

- Advise people on potential sources of water
- Provide additional training to natural resource personnel
- Advise water suppliers on assessing vulnerability of existing supply systems
- Recommend adopting water conservation measures
- Help water agencies develop contingency plans
- Form a drought information center and distribute real-time weather data
- Conduct workshops on various drought topics, including crop survival during drought
- Conduct workshops on design and implementation of water rationing programs
- Develop and market innovative technologies such as irrigation system improvements, waterless urinals, and monitoring technologies
- Develop and distribute software for irrigators and urban water suppliers
- Establish special plans to protect the values associated with wetlands, wildlife refuges, or exchange of water

Emergency Response

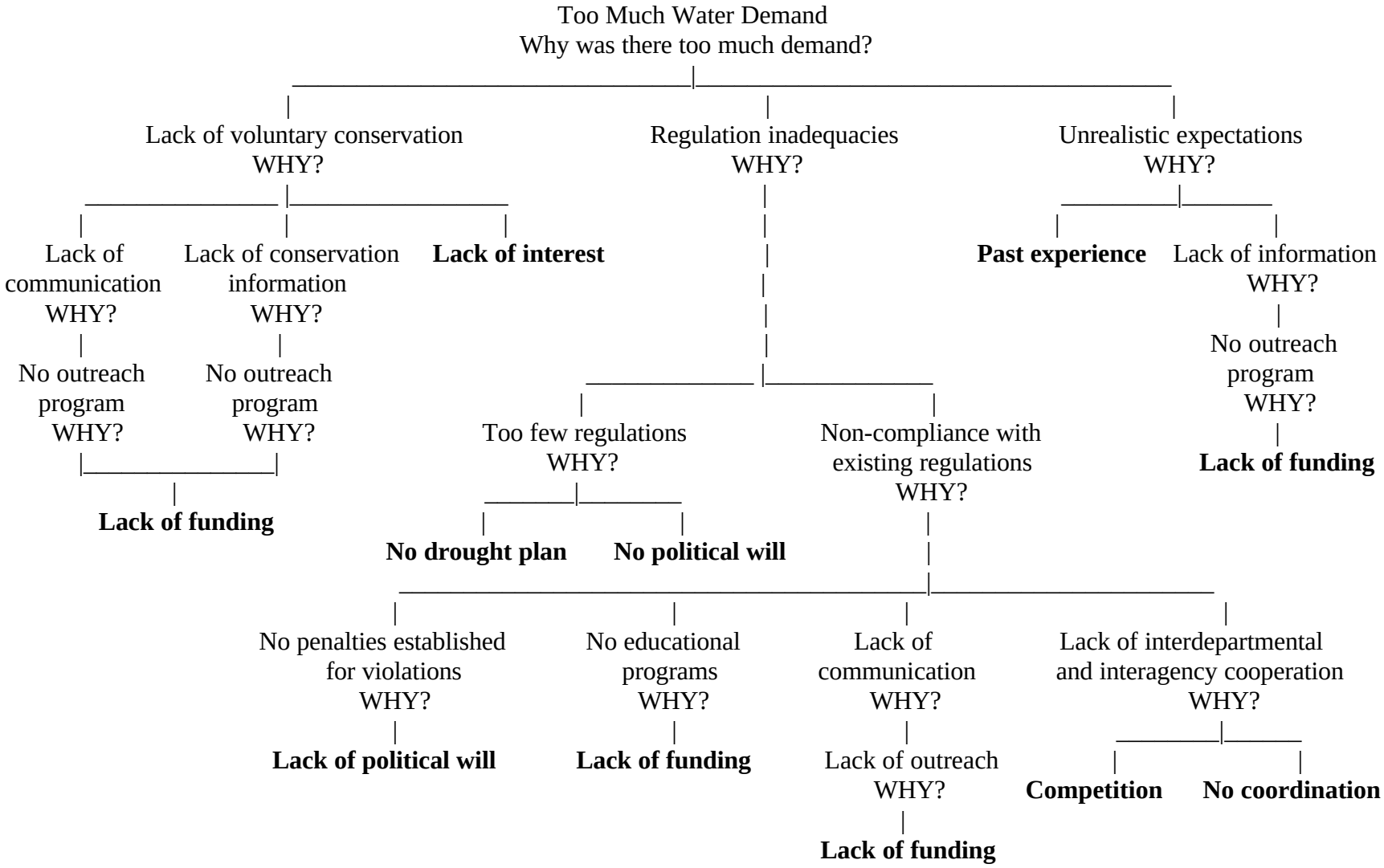
- Stockpile pumps, pipes, water filters, and other equipment
- Establish water hauling programs for livestock
- List livestock watering spots
- Establish hay hotline and provide emergency shipments
- Fund water system improvements, new systems, and new wells
- Fund drought recovery program
- Lower well intakes on reservoirs for rural water supplies
- Extend boat ramps and docks for recreation
- Issue emergency irrigation permits for using state waters for irrigation
- Create low-interest loan and aid programs for agriculture
- Create drought property tax credit program for farmers
- Tell farmers about sources of federal assistance

Appendix F. An Example of a Detailed Agricultural Impact Tree Diagram



(Depending on your situation, it may even be possible to break these causes down further)

Appendix G. An Example of a Detailed Urban Impact Tree Diagram



(Depending on your situation, it may even be possible to break these causes down further)

Appendix H. References and Resources

Resource Personnel

Drought management information, including contact names and technical information, can be found on the web site of the Western Drought Coordination Council at http://enso.unl.edu/wdcc/.

More information on drought planning can be found at the National Drought Mitigation Center's (NDMC's) web site at http://enso.unl.edu/ndmc/, or write the NDMC at the University of Nebraska-Lincoln, 239 LW Chase Hall, Lincoln, NE, 68583-0749. The NDMC also maintains a list of state and regional drought management contacts for the entire United States. These offices may be able to provide information that is more applicable to your local area. The list may also be viewed on the NDMC web site, or they will provide one to you on request.

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