Assessing Drought Impacts and Vulnerabilities for Long-Term Planning and Mitigation Programs

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INTRODUCTION

The number of U.S. states that developed a drought plan or management process in the latter part of the 20th century grew from three in 1983 (Wilhite 2001) to at least thirty-five in 2004. This growth in state drought planning has occurred despite the absence of a federal mandate or incentive program. Numerous municipalities and regional and multi-state entities have also developed plans for managing drought and water shortages (National Drought Policy Commission 2000), but states have become the predominant political scale for the management of drought impacts.

The National Drought Mitigation Center (NDMC) has played a central role in the growth and maturation of drought planning in the United States and around the world by assisting directly with plan development and acting as the primary clearinghouse for guidance and information. Since the mid-1990s the NDMC has encouraged states to mitigate drought vulnerability "pro-actively" (Knutson et al. 1998, Hayes et al. 2004). This sentiment is echoed in a recent major review of hazard and disaster research, which concluded that hazard management and policy must begin incorporating more pre-hazard planning and mitigation programs aimed at reducing vulnerability (Mileti 1999). State drought planning activities are usually activated after conditions worsen beyond a defined threshold and rescinded shortly after drought conditions diminish. Planned activities typically involve enhancing the gathering and dissemination of drought information, assessing losses or deficits relative to pre-drought conditions (i.e., impacts), and organizing and deploying resources to effectively anticipate and respond to impacts.

NDMC guidance on impact and vulnerability assessments is found in the Center's "risk assessment and management" planning model (Knutson et al. 1998, Wilhite 2000, Wilhite 2001, Hayes et al. 2004). Drought risk is assessed through "an analysis of vulnerability to understand what people and sectors may be most affected by drought, why these impacts occur, and if these relationships are changing over time" (Hayes et al. 2004, pp. 107-108). Results of impact and vulnerability assessments are then used to guide pre-drought planning and mitigation programs that diminish the risk of future drought impacts, and in turn lessen the burden placed on response-oriented management.

Despite the diffusion of the NDMC's risk assessment and management model to state and local drought planning processes, a national survey on the ways states have thus far assessed drought risk and used assessments has yet to be conducted. Furthermore, it is unclear if states are sharing impact and vulnerability assessment methods, success stories, etc. This paper presents results of a national survey of state drought planning processes in the United States in 2004. The survey examined impact and vulnerability assessment methods, and how assessments were being used to develop and improve short- and long-term mitigation. How effectively are states assessing impacts and vulnerabilities? What kinds of assessments are more informative for pro-active mitigation? How could assessments be made more effective for long-term vulnerability mitigation programs?

By addressing these questions, the paper builds on existing drought planning guidance. The documentation and analysis of contemporary impact and vulnerability assessment methods within the context of state drought planning is important for at least two reasons. First, a baseline can be established focusing discussion on the design,

implementation, and application of impact and vulnerability assessments. Also, a clearer view of the "state of the art," including its shortcomings, will facilitate more progressive and targeted guidance. Second, state drought planners and policy makers need more examples of successful methods and more accessible guidance. There are too few sources of information to assist drought planners with assessment design, and very little of the academic literature on vulnerability assessments is targeted to this audience.

This paper builds on recent impact and vulnerability assessment guidance but articulates the alternative to short-term and reactive mitigation differently from the NDMC. Specifically, the term "pro-active" is substituted with the broader concept "long-term." The NDMC emphasis on pro-active mitigation is a critique of the dominance of reactive and short-term management and mitigation in state drought planning and the management of hazards and disasters in general. "Pro-active" in this sense is synonymous with "preventative," referring to the reduction or elimination of future drought impacts before the onset of a drought or intensification of drought conditions. Drought, however, is a normal, recurring aspect of climate variability. What may appear to be mitigation and planning before a drought may actually represent lessons learned from experiences with the previous drought. Rather than a linear model of pre- and post-drought mitigation, the paper employs a cyclical or continuous model of drought, drought impacts, and drought management and mitigation. In doing so, "pro-active" efforts become a component of "long-term" planning and mitigation that, in principle, have continuity and momentum irrespective of drought conditions.

Next, the paper reviews sources of drought planning guidance and research on vulnerability assessment. Survey methods are then introduced, followed by survey results summarized on a national scale, followed by a brief section highlighting the vulnerability assessments of four planning processes. The paper then discusses results of the national survey, which are compared and contrasted with hazard, disaster, and climate vulnerability research. Several recommendations are made to improve on contemporary state planning process structures, and ultimately improve the effectiveness of impact and vulnerability assessments for pro-active and sustained drought vulnerability reduction.

DROUGHT MANAGEMENT AND PLANNING IN THE UNITED STATES

A number of factors have contributed to the proliferation of state drought planning since the mid-1980s. The effects of New Federalism initiatives during the early 1980s redistributed a greater share of governmental capabilities to the states, providing incentives for states to act independently on drought management (Wilhite and Rhodes 1994). Since then, many state governments have developed or revised an existing drought plan after experiencing a significant drought. Many of these states have received assistance or guidance from the NDMC and the U.S. Bureau of Reclamation. Federal efforts to assist states with local and regional drought impacts have been limited to U.S. Department of Agriculture post-disaster financial aid, grants, and loans. As of 2004, other forms of federal involvement have yet to move beyond legislation or workgroups (e.g.,

Small Business Drought Relief Act of 2003, National Drought Preparedness Act of 2003, National Drought Policy Commission, Congressional Natural Hazards Caucus). Several states have, as a result, established grant or loan programs to assist communities in improving water system infrastructure or recovery from losses (National Drought Policy Commission 2000).

Many drought plans have become increasingly sophisticated during this period. Earlier state drought plans focused primarily on inter-agency coordination, emergency response management, and the declaration of disaster areas to qualify for federal assistance. Subsequent planning processes began to incorporate mitigation, although many efforts were short-term or emergency response-oriented (Wilhite 1997). More and more planning processes have established or leveraged existing climate monitoring programs (e.g., see Dupigny-Giroux 2001a) to track the onset of droughts. States have begun more recently to integrate climate data with impact data (e.g., reservoir levels, fire hazard indices) to develop quantitative thresholds often referred to as “triggers.” These triggers are then used as objective determinants of drought status that in turn set the levels of restrictions or initiate mitigation activities (e.g., see Dupigny-Giroux 2001b, Steinemann 2003).

Figure 1 presents the organizational structure of state drought planning processes based on the recommendations of the NDMC (Wilhite et al. 2004). Drought task forces

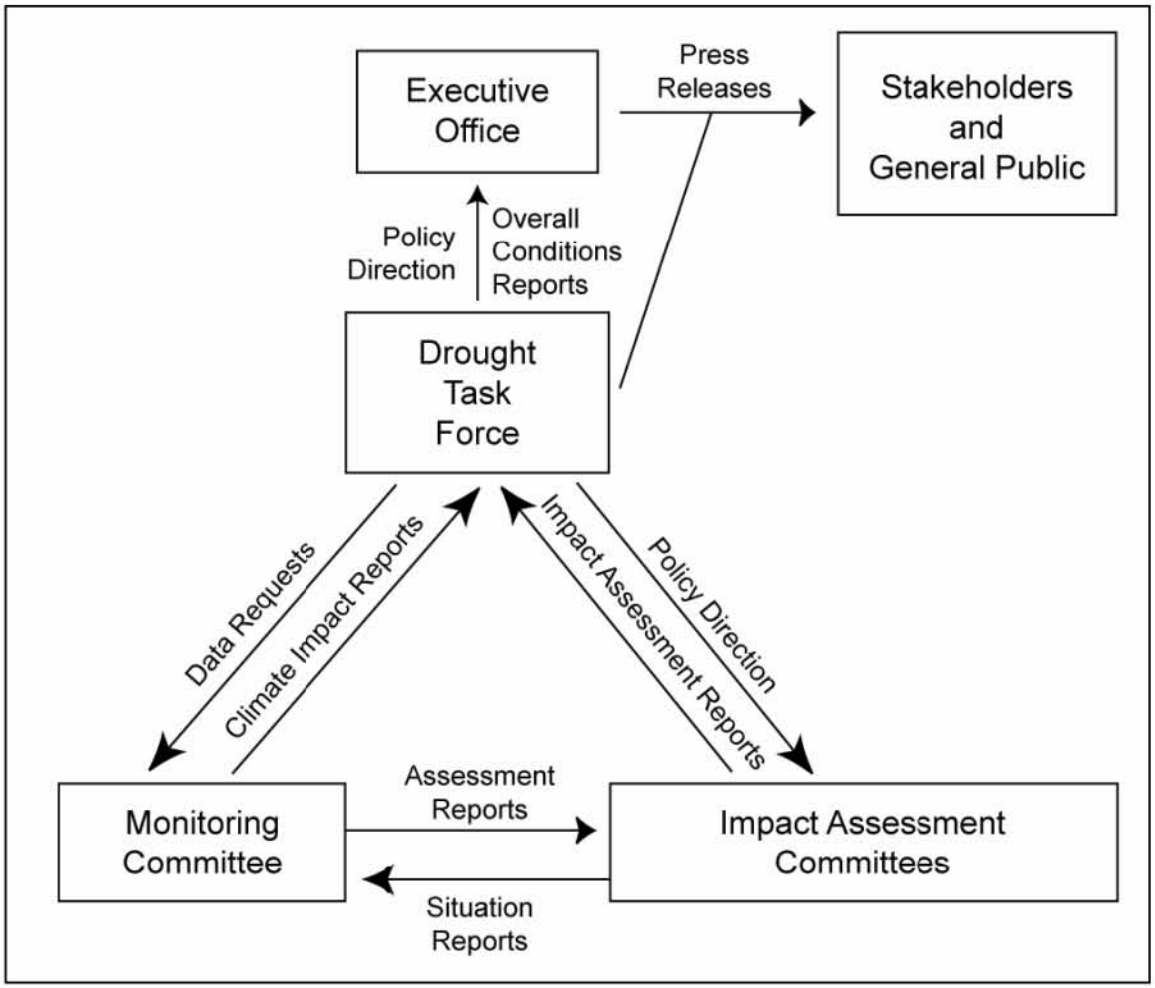

Figure 1. The organizational structure of state drought planning processes in the United States (adapted from Wilhite et al. 2004).

are typically composed of representatives or heads of state and federal agencies and departments, university researchers, and members of non-governmental organizations representing primary industries and public interest groups. Monitoring groups are typically composed of state, federal, and/or university scientists (e.g., climatologists, meteorologists, hydrologists, engineers, etc.). Activities of monitoring groups may include assessing recent and historical climate variability, establishing and supporting a data collection system that collects climate and first-order drought impact data (like precipitation, snowpack, stream flow, reservoir levels, soil moisture, etc.), and recommending changes to official drought stage levels. Impact assessment committees are often composed of government officials (e.g., program managers) and personnel that spend time in the field (e.g., agriculture extension agents) and collect data from local agencies, field representatives, and industry organizations. Impact assessment groups collect a wider variety of data, including second-, third-, etc. order impacts that reflect the permeation of first-order impacts into society via its appropriation and management of environmental systems and services (e.g., rangeland conditions, agricultural losses, forest fire hazard, aquatic habitat quality, municipal water shortages, tourism revenue losses). The three groups—drought task forces, monitoring groups, and impact assessment committees—produce and share information, and often respond to and support an executive branch of the state government (e.g., the governor's office) for disaster declarations and to support legislation or special funding requests.

States have managed drought primarily through short-term response-oriented processes (i.e., over days, weeks, months) focused on minimizing emergencies and

facilitating access to federal disaster relief programs. As a consequence of reactive drought management there has often been little or no planning to mitigate drought vulnerability during the sometimes lengthy periods between droughts. Although many state drought planning processes have become more organized and sophisticated over time, previous national assessments have revealed few instances where state programs have pro-actively identified and mitigated drought risk (Wilhite 1991, Wilhite and Rhodes 1994, Wilhite 1997). Thus, it is reasonable to conclude that in many states the management of drought risk has consisted of short-term, response-oriented mitigation of impacts.

Drought Risk Assessment and Management

Since the mid-1990s, the NDMC has advocated that states manage drought more often through pre-drought planning and mitigation. This emphasis on pre-hazard mitigation largely reflects concern over a growing vulnerability to hazards in the United States that has contributed to increasing losses despite no clear evidence that droughts or other hazards have actually become more extreme or frequent (Changnon et al. 2000). Recently the NDMC has proposed a two-step risk assessment and management model that has been adapted by several states and tribal governments (Hayes et al. 2004). In the first step, risk is assessed as the product of two contributing factors: exposure to drought ("hazard analysis"), and biophysical and social causes of drought impacts ("vulnerability

analysis”). Conducting hazard analysis includes evaluating climate forecasts and the history and spatial patterns of drought in the state and broader region. Thus, hazard analysis is likely to be conducted by monitoring committees. Vulnerability analysis begins with acquiring data on first-, second-, third-, etc. order impacts. The causes of impacts would then be explored by “tracing outwards from each impact the multiple environmental, social and economic underlying factors that contribute to the resulting impacts” (Hayes et al. 2004, p. 108). Thus, vulnerability analysis would likely be conducted or led by impact assessment committees. The NDMC advocates significant public involvement during the exploration of impact causality. In the second step of the risk assessment and management model, the results of impact and vulnerability assessments are used for developing and prioritizing targeted, long-term planning and mitigation programs.

Hazard, Disaster, and Climate Vulnerability

In recent decades, there has been a growing emphasis on the concept of vulnerability within the fields of hazards, disasters, and the human dimensions of global change (White et al. 2001, Wisner et al. 2004, Patt et al. 2005). NDMC vulnerability assessment guidance follows this broader trend. More specifically, NDMC guidance draws on a subset of the vulnerability literature that began in the late 1970s as a critique of popular explanations of disaster causality in the fields of hazards and disaster research

(Hewitt 1983). A brief review of this literature is provided as background for NDMC guidance, the discussion of survey results, and recommendations for improving vulnerability assessments.

In the late 1970s, mainstream hazard and disaster research and policy was critiqued for underemphasizing the role of socio-cultural structures and political and economic processes and institutions when explaining disaster losses. A large interdisciplinary body of research has since advanced the study of vulnerability, which in general examines how social, political decision-making, and economic processes and institutions result in people and places becoming differently vulnerable before, during, and after an extreme geophysical event (Varley 1994, Bohle et al. 1994, Ribot et al. 1996, Mileti 1999, Wisner et al. 2004). This research perspective has also been widely adapted to the study and assessment of climate change vulnerability (McCarthy et al. 2001, Liverman et al. 2004, Patt et al. 2005).

Although a number of definitions of vulnerability have been proposed (Cutter 1996), most recent definitions include variants of three factors: exposure, sensitivity, and adaptive capacity (McCarthy et al. 2001, Turner et al. 2003). Exposure refers to the probability of the occurrence of an extreme event influencing a defined area. Exposure is frequently expressed as the magnitude, spatial and temporal qualities, etc. of an extreme geophysical event. As a hypothetical or modeled concept, exposure can refer to specific areas that could be subject to extreme geophysical forces (e.g., floodplains, earthquake zones, areas below sea level). Drought exposure is often defined geographically by assigning a spatially averaged value within political, landscape, and watershed

boundaries. NDMC “hazard analysis” guidance is closely aligned with this description of exposure.

Broadly defined, sensitivity reflects how well a human or natural system can absorb the impacts of an event or manage them without much loss or expense. If sustained precipitation deficits have little effect on the productivity of an economic sector, for example, it is considered insensitive to drought exposure. Dryland farming and free-range livestock operations, in contrast, rely on adequate rainfall for crop and range quality and thus can be highly sensitive to drought exposure.

The third factor, adaptive capacity, refers to the “ability of a system to adjust to perturbations and changes in variability or system states to moderate potential losses, to take advantage of opportunities, or to cope with consequences” (McCarthy et al. 2001, p. 6). The term “system” refers to a variety of geographic scales: household, community, landscape, region, nation, and global. It can also refer to spatially disaggregated systems such as economic sectors, cultural groups, governments, and biomes. In terms of drought planning, adaptive capacity refers to how effective a system is at mitigating the consequences of first-, second-, third-, etc. order impacts. Adaptations can be pro-active or reactive. Effective adaptation is contingent on sufficient capacity to adapt, which in turn requires a broadening of vulnerability analyses to examine other factors, including household dynamics, community cohesion and health, social change, political and economic institutions, land-use change, and ecological dynamics.

Assessing Vulnerability

The assessment of vulnerability is an important theme in the aforementioned literature (McCarthy et al. 2001, Patt et al. 2005, Schroter et al. 2005). Where science can encourage and assist people to adapt in advance to project long-term environmental changes, the concept of vulnerability has taken on importance among the global change research community (Patt et al. 2005). “There are currently hundreds of vulnerability studies underway in countries and regions around the globe, delivering a variety of information packages” (ibid., p. 412). Assessments are attractive to decision makers because they can help them to significantly improve their decision-making process.

Given the diversity of disciplines that contribute to the research on hazards, disasters, and climate change, there are a variety of approaches to assessing vulnerability. Many vulnerability assessments have been conducted by academics and non-governmental organizations. The authors of most of these assessments focus on how policy can incorporate their results to reduce vulnerability. However, many other assessments, in particular those that critically address conceptual and methodological issues, are tailored to an academic audience and published in peer-reviewed scientific journals. This avenue for the dissemination of vulnerability assessment theory and methods, unfortunately, is not likely to be a popular outlet for the non-academic audiences that dominate the membership of state drought planning programs. The NDMC has begun to bridge this gap with its risk assessment framework, but more research is

clearly needed to link the academic advancements of vulnerability theory and assessment methods to the context of state and local government drought planning and assessments.

SURVEYING STATE DROUGHT PLANNING PROCESSES

I argue here that the integration of academic vulnerability research and state-run drought risk assessments will improve significantly if both are informed by the myriad ways states have thus far assessed impacts and vulnerabilities and used assessments to mitigate drought risk. A national survey of state drought planning processes would ground subsequent guidance on risk assessment and long-term planning in the "state of the art." A survey would also help apply vulnerability theory and methods, many of which have been formulated from case studies involving primary production in the Third World, to the state-sanctioned assessment of drought vulnerability in a capitalist and largely postindustrial society.

Motivated by these opportunities, a national survey was conducted of recent and ongoing state drought planning processes. The survey was conducted and completed in 2004, and sought to evaluate three issues. First, how have states assessed drought impacts and vulnerabilities? Second, how have states used assessments to guide and develop long-term planning and mitigation programs? Third, how can hazard vulnerability research be more effectively integrated into drought planning guidance? The survey included an email questionnaire, interviews with drought planners, and content analysis of drought planning documents, reports, and web pages.

Identifying Planning Processes, Survey Participants, and Survey Data

Initially, state drought planning contacts were identified using the NDMC state drought planning contact list (National Drought Mitigation Center 2004a). All survey participants received an email that included three elements: background information on the purpose of the study; a short questionnaire to determine if their state's drought planning process had included assessing drought impacts and the "causes of impacts" (vulnerabilities); and a request to conduct interviews with people that have had a direct role in the assessment of drought impacts and/or vulnerabilities in their state during the most recent active phase of the planning process. Concurrently, state drought planning documents and web sites were obtained and identified through the NDMC state drought plan web page (National Drought Mitigation Center 2004b) and performing keyword Internet searches (e.g., "Texas Drought Plan") using the Google® Internet search engine. Online plans, related planning documents and reports, and web pages were obtained and reviewed to help determine which planning processes were appropriate for the survey and to identify appropriate contacts to interview, and were included in the analysis of state planning processes as supplemental data. To ensure the survey was not omitting important state planning processes or contacts, drought planning experts with the NDMC were consulted throughout the survey.

Interviews

At the national level there are myriad possible drought impacts, and consequently a wide range of frameworks and techniques that could be used to assess impacts. This was recognized before the survey, and interviews were conducted so as to be as inclusive as possible. Thus, definitions of what constitute a drought impact, impact assessment, and vulnerability assessment were similarly inclusive. Despite a variety of impacts and assessments, it is not possible to reflect this entirely in the present paper. Thus, the omission of impacts may, for example, be significant or widespread in some states but may not be represented by examples presented in the survey results and discussion.

Prospective interviewees were contacted before interviews to verify their responses to the email questionnaire and confirm their ability to provide information relevant to the study. Interviews were conducted by telephone, and each lasted approximately one hour. In most cases, one person per state or regional planning process was interviewed. In a few cases (i.e., California, North Carolina, Florida, Texas, Utah), two or more people were interviewed. Interviews were conducted using a semi-structured format and addressed three general questions: How have drought impacts been assessed in your state? Has your state process attempted to determine the causal nature of the identified impacts (i.e., vulnerabilities)? How have assessment results been used in the mitigation of drought impacts and vulnerabilities?

Broad definitions of “impacts,” “vulnerabilities,” and the “use of assessment results” were applied during interviews to encourage the inclusion of marginally relevant efforts. Results of the survey are presented here in qualitative format, and provide an

empirical basis for making recommendations to improve the effectiveness of assessments for long-term planning and mitigation programs, and for providing insight into how hazard vulnerability research can be more effectively integrated into and adopted by state drought planning processes.

SURVEY RESULTS

Representatives of 36 state drought planning processes responded to the initial email questionnaire. Of these, 24 contacts from 21 state and regional planning processes were interviewed for the survey (Figure 2, dark green shaded states). The remaining 15 states that responded to the questionnaire were excluded from the survey (light green shaded states). Questionnaire results and/or follow-up phone conversations revealed that in these states the planning process had either not included assessing impacts and/or vulnerability or that their state plan had yet to be implemented. Another 14 states did not reply to the email questionnaire despite multiple and varied solicitations. Thus, 29 states, many of which did not have a formal plan or had not implemented their plan as of October 2004, are not represented in the survey.

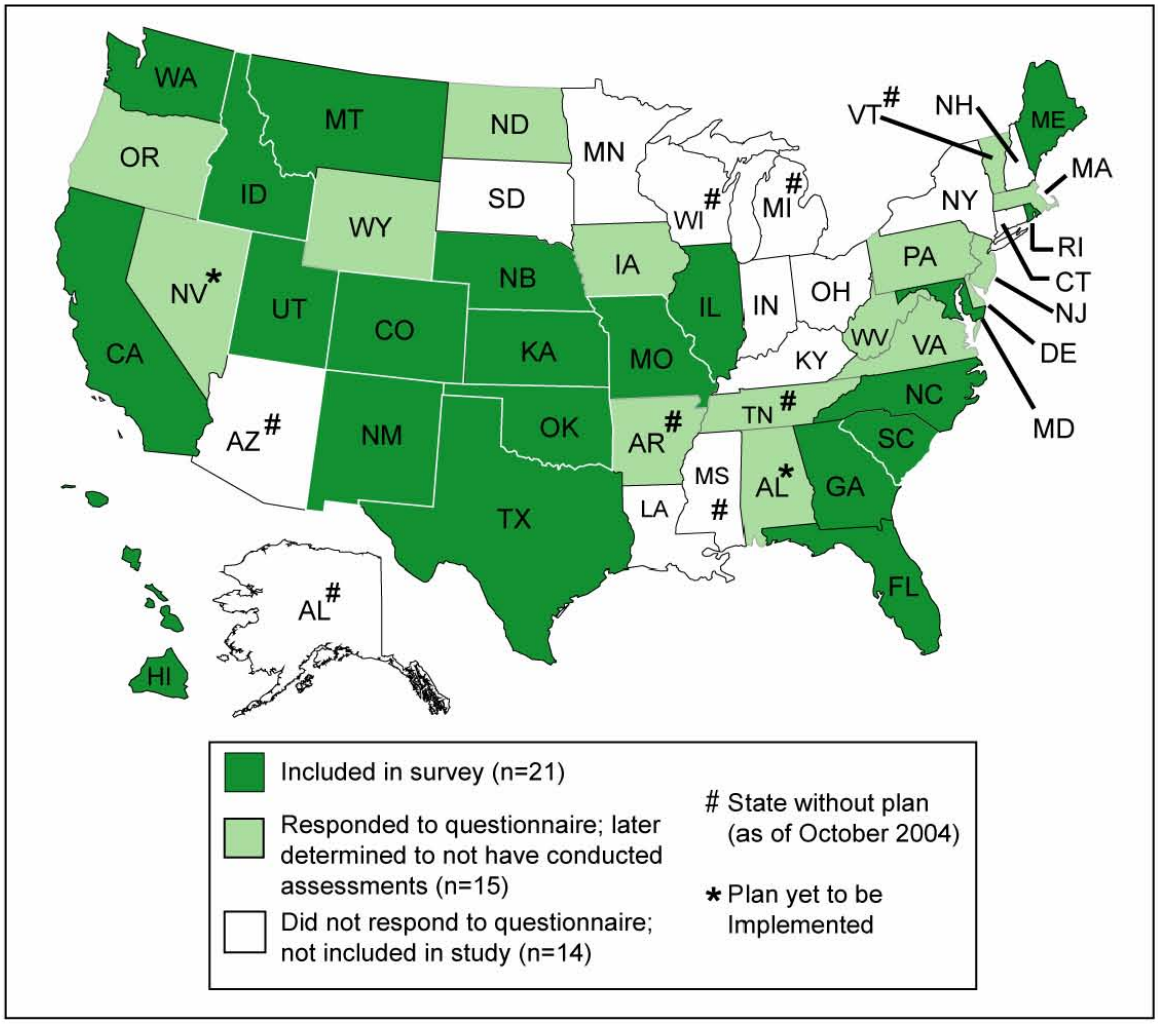

Figure 2. Results of the drought planning survey.

The measures taken to secure participation from people with the most experience and knowledge were effective. People with direct involvement in assessments were easily identified through post-email questionnaire/pre-interview screening. Questionnaire data were unfortunately of limited use for the main aims of the survey since most drought planning contacts provided “yes,” “no,” or very brief answers to questions about impact and vulnerability assessments. The questionnaire, however, was very useful as a starting point for identifying which states to include in the survey (i.e., states that had conducted impact and/or vulnerability assessments). In several states, the people who responded to the initial questionnaire (i.e., NDMC “drought planning contacts”) were appropriate interviewees. In other states, questionnaire respondents were helpful for identifying other officials with more direct experience with assessments.

The professional backgrounds and job titles of interviewees varied. All interviewees, however, had been affiliated with or employed by state or regional government agencies and departments (e.g., water, natural resources, and planning departments). All interviewees were directly involved in their state’s most recent drought planning process, and were members of impact assessment groups and task forces or oversaw entire planning processes.

Survey results are summarized and discussed in two sections. In the first section, results of the entire survey are summarized to provide a national overview of impact and vulnerability assessments, and the application of assessments to long-term planning and mitigation programs. In the second section, four different state agencies’ drought planning efforts are presented: the Kansas Water Office, the Hawaii Commission on

Water Resource Management, the California Department of Water Resources, and the Colorado Water Conservation Board. The four examples reviewed in greater detail represent the only states determined to have conducted some type of a vulnerability assessment. Together, the national summary and the review of the four state processes offer both broad and focused analyses of drought planning in the United States, and facilitate discussion of issues pertinent on a national scale, while also highlighting innovative drought vulnerability assessment processes that have potential for application in other states.

National Overview

The survey revealed the limited amount of resources being devoted to state drought planning nationwide. Few states have permanent drought planning offices or coordinators, and all states rely on existing state agencies (e.g., department of natural resources, water, or emergency management) to lead or significantly support drought planning efforts. Task forces and monitoring and assessment groups are often composed of officials who must divert time and resources from regular job duties to attend to drought management. When a drought has been declared formally, task force and impact assessment groups mobilize and meet regularly (e.g., monthly) as long as drought conditions persist. In many states, drought planning efforts are coordinated with seasonal water, agriculture, and fire hazard management objectives and thus can be relatively

inactive during the winter part of the year. When droughts are declared to be over, task force and assessment groups typically dissolve and drought management processes remain relatively inactive until the next time a drought is declared. Monitoring groups, however, are responsible for assessing conditions on a regular basis to anticipate the development of drought conditions and thus are considered to be continually active. The prevalence of limited and short-term appropriation of resources for drought planning most likely limits opportunities for enhancing the assessment of impacts and vulnerabilities, and the development and implementation of long-term mitigation programs.

State drought planning processes have, however, developed a number of ways to assess drought impacts. The most common approach mentioned in survey responses involves formation of government agency-led impact assessment groups similar to those described by NDMC guidance. Groups were often categorized by resource area, such as agriculture, municipal and industrial water, forest health, etc. To collect information on drought impacts, assessment groups almost exclusively rely on leveraging and “tapping into” agency social networks and existing regulatory reporting requirements. Examples of agency networks and regulatory reporting requirements include agricultural extension services and other state and federal agricultural reporting programs, local agricultural and watershed management groups, annual or quarterly state fish and wildlife agency surveys and reports, existing reporting requirements of municipal and regional water management issues (e.g., water shortages, reservoir levels, water quality issues), and other existing state and federal natural resource management programs. Impact assessments, in most

cases, consist of summaries of quantitative first-order impact data on, for example, stream flow, reservoir levels, soil moisture deficits, forest fire risk, and other agricultural and natural resource parameters monitored regularly.

Several planning processes surveyed have also conducted novel impact assessments that establish new communication networks independent of existing regulatory reporting requirements. In all of these cases, public participation was necessary to obtain data. These assessments were also more likely to include a mixture of quantitative and qualitative data representing second-, third-, etc. order impacts such as residential water quality and quantity problems, lost business or income potential, community stress, and local conflicts regarding water allocation and management.

A variety of approaches were used by states to obtain impact data and public input. Several states organized “town hall” meetings where government officials traveled to different parts of the state to obtain input from the public and from industry representatives. Online and mail surveys were also used in a few states to target specific economic sectors and geographic regions. In two states, private research firms were contracted to conduct phone surveys and interviews with a variety of stakeholders. In one of these states, a large percentage of residents rely on private (and often shallow) wells, and a phone survey estimated the number of residents experiencing water shortages or quality problems. A third state set up a phone “hotline” during water shortages to answer questions, which also helped residents inform hotline operators of household water shortages and outages. Another state organized and supported local public drought

assessment groups throughout the state that provided information on local drought impacts.

The analysis of email questionnaire responses, state plans, and related planning documents indicated that many drought planning processes had assessed, or planned to assess, the causal nature of impacts (i.e., vulnerabilities). Subsequent screening and phone interviews, however, revealed that most of these claims were largely unfounded. In fact, only four of these planning processes had completed some version of a drought vulnerability assessment. These four planning processes are described below in greater detail.

Finally, the survey revealed that impact assessments have been used predominantly to enhance emergency response management. Assessments were used, for example, to help define boundaries of agricultural disaster areas; to internally coordinate distribution of state and federal resources for mitigation programs; and to provide content for press releases on drought conditions, impacts, resource use or land access restrictions, and government aid programs. The survey identified only four state processes, highlighted below, that had completed a vulnerability assessment of some kind. Three of the four had only recently completed the vulnerability assessment. In these cases, results of the assessment had not been finalized or acted on. The other state's assessment of vulnerable public water suppliers, however, was used to identify suppliers that qualified for assistance from state programs that would help address vulnerabilities identified in the study, such as basic source, distribution, treatment facility, and contractual limitations.

Case Studies

Kansas Water Office

Kansas has established an operations plan for a Governor's Drought Response Team charged with monitoring and evaluating drought conditions and implementing restrictions and emergency programs. The assessment and mitigation of drought vulnerability, however, has been integrated into the state's long-term water planning process. Since the 1970s, the Kansas Water Office has emphasized conservation, management, and protection of water resources. Ratified by the state government in 1985, the Kansas State Water Plan is updated regularly and includes a variety of preparedness and response programs.

In 1998 the Kansas State Water Plan included several goals to be reached by 2010, including a reduction in the number of "drought vulnerable" public water suppliers to fewer than 5% of all suppliers in the state. In a 1992 assessment of public water providers during the 1988-1991 drought, 181 water suppliers were determined to be drought vulnerable as a result of several supply, distribution, and treatment limitations. The Kansas Water Office updated the 1992 study in 2001, using a similar definition of drought-vulnerable water suppliers (adding a category for vulnerability due to purchase contract provisions), conducting a survey of public water suppliers, and relying on reporting requirements of local water managers in the Kansas Water Plan. The updated

study estimated that the number of drought-vulnerable water suppliers decreased from 181 in 1992 to 88 in 1998. Results of the study have been used to target state resources at the basin or local level to reduce drought vulnerability, including special efforts to achieve the 2010 objective of fewer than 5% of water suppliers vulnerable to drought.

Hawaii Commission on Water Resource Management

Drought planning and management in Hawaii has leveraged resources for administering the state water code as well as for developing and implementing the state hazard mitigation plan. In 2003, revisions to the first phase of the Hawaii drought plan completed in 2000 included a quantitative assessment of drought risk that used the NDMC definition of risk as the product of exposure and vulnerability. The Drought Risk and Vulnerability Assessment and GIS Mapping Project was funded through a Federal Emergency Management Agency pre-disaster mitigation planning grant and was conducted primarily by researchers at the University of Hawaii (Hawaii Commission on Water Resource Management 2003). A GIS was developed to produce a statewide assessment of drought risk by integrating spatially modeled drought frequency and severity with spatial measures of vulnerability. Spatially interpolated Standard Precipitation Index (SPI) and historical rainfall data were used to create ordinal drought intensity maps (i.e., moderate, severe, and extreme) using 3- and 12-month SPI timescales. Vulnerability was represented by data on land use, population, past wildfire

frequency and spatial extent, water resources (wells, rainfall catchment), and agricultural designation (irrigated and dryland). Relative risk maps were created by overlaying the exposure and vulnerability components. Separate maps were created for each SPI timescale, drought severity level, and sector (water supply, agriculture and commerce, and environment and public safety), and are provided in the pre-final draft of the Hawaii Drought Plan (Hawaii Commission on Water Resource Management 2004).

Although no public participation or input was involved in the development of the risk maps, the maps will be evaluated locally. Specifically, the risk maps are being used as an initial assessment of vulnerability that will undergo local re-interpretation in the development of local natural hazard mitigation plans and programs. County drought mitigation projects are developed through the coordination of local and/or county drought committees, the Hawaii Drought Council, and the State Drought Coordinator as part of the Hawaii multi-hazard mitigation program. According to the pre-final draft of the Hawaii Drought Plan (Hawaii Commission on Water Resource Management 2004, p. 66), the maps:

> …should be reviewed by county agencies and local stakeholders to verify that they accurately represent drought risk areas on each of the islands. As part of these follow-on actions, residents and businesses affected by drought should also be interviewed to determine the magnitude of past drought impacts, identify existing response mechanisms used to address drought occurrences, and assess what type of mitigation measures worked best and were the most effective.

California Department of Water Resources

Currently, there is no statewide drought plan or planning process in California. The state delegates drought planning to all public water providers with more than 3,000 connections or that deliver more than 3,000 acre-feet per year. In 1983 the California state legislature passed the Urban Water Management Planning Act, partly in response to drought impacts in the state in 1976 and 1977. Amended several times since 1983, the act encourages the approximately 300-400 public water providers in the state to develop and submit updated water management plans every five years to the state Department of Water Resources. One California Department of Water Resources official who was interviewed estimated that, as of 2004, more than 90% of all public water providers that fall within the 3,000 connection/3,000 acre-foot criteria have submitted an updated plan to the state.

Although no formal process has been established at the state level to assess and document drought impacts, public water providers in California are required to assess certain drought vulnerabilities when creating and updating local water management plans. Based on demographic and customer base data, water providers must analyze past, current, and future demand for water (up to 20 years in advance), identify and quantify current and future surface and groundwater supplies and water rights, analyze the reliability of current and future water supplies based on several short- and long-term drought scenarios, and document existing and planned conservation and demand management measures. As a result, local water providers furnish the state with

periodically updated information to help identify local vulnerabilities to short- and long-term drought, and become eligible for state assistance to improve system resilience to drought. Additionally, it allows the Department of Water Resources to identify common local issues and inadequacies that may be addressed with legislation at the state level.

Colorado Water Conservation Board

Since 1981, the Colorado drought mitigation and response plan has been revised three times. Impact assessments were conducted and published in 2002 and 2003 by the state's eight sector-based impact assessment groups (IAGs) and a water availability task force (WATF) (Colorado Water Availability Task Force 2002, 2003). Both reports include qualitative and quantitative descriptions and analyses of sector-based impacts, and recommend specific mitigation programs. The 2003 report also details governmental entities responsible for the mitigation programs identified.

In addition to the WATF and the IAGs, the Colorado Water Conservation Board (CWCB) has been involved in drought assessment, planning, and mitigation efforts in Colorado. Created in 1937, the CWCB is one of four Department of Natural Resources sub-agencies focusing on water quantity issues, and is the state executive branch agency responsible for supporting state and local water and drought planning. In 2004, the CWCB completed a drought and water supply assessment (Colorado Water Conservation Board 2004) that involved the participation of numerous local, state, and federal

government agencies and collaboration with various consulting firms. The assessment involved interviewing and surveying more than 500 local, state, and federal stakeholders on several issues pertaining to drought impacts and water management: current water use and carry-over storage, current limitations on water supply, drought and water conservation planning, drought impacts, concerns for meeting future water demands, structural and non-structural project needs for drought mitigation, funding needs, use of cooperative agreements, and the role of the state in future drought planning and mitigation efforts. Participants were surveyed in person, over the phone, and on the Internet using a web-based survey instrument. In addition to the large-scale survey, a more in-depth, interview-based study was conducted with five persons in different parts of the state. Results of the survey supported a set of recommendations for mitigating drought vulnerabilities and improving long-term water management.

DISCUSSION

The national survey revealed that, as of 2004, at least twenty-one state planning processes had assessed impacts, but only four had assessed vulnerabilities and only one had used impact and vulnerability assessments to inform or develop long-term planning and mitigation programs. This finding is almost certainly influenced by a lack of political support for long-term drought planning and mitigation programs after a drought has diminished, rather than an inability to produce informative assessments. The issue of sustained political and public support is certainly important for implementing long-term

drought planning and mitigation programs. The survey, however, was not intended to explore this issue and it is not discussed in detail here. Nevertheless, the survey revealed several issues worthy of discussion.

In general, there has been a lack of documentation, organization, and public access to impact assessments. In several instances, assessment results were documented as appendices in voluminous drought planning documents, buried in lengthy web pages, or never published or made available to the public outside of press releases. In several cases, hardcopy or electronic versions of assessments were not readily accessible (e.g., “on someone’s computer”), or had been lost, and were revealed by interviewees only through repeated requests. Also, very few assessment reports or summaries that were available on websites or obtained in hardcopy included descriptions of assessment methods, assumptions, discussion of findings, or recommendations for action. Assessment groups may be composed of people not involved in previous drought planning processes. In cases where there was significant turnover from one task force to the next, it is expected that past “lessons learned” had to have been re-learned by subsequent drought task forces. To address this institutional memory loss, drought planning processes must be much more diligent by publishing any and all reports in both hardcopy and electronic format and archiving reports in multiple places. Such a requirement would be helpful for compiling data and information on impact and vulnerability assessments, coordinating those involved to comment on experiences, and making clear recommendations for what measures need to be taken to mitigate vulnerabilities before the next drought develops.

Of the impact assessments that were obtained or discussed in the survey, the most common approach to collecting data for impact assessments was through the leveraging of existing reporting requirements intended for planning and regulatory programs other than drought impact assessment. Most of the data from these assessments were quantitative, instrumental measurements that represented first-order drought impacts. This approach to gathering data is quite practical for states faced with limited funding, and has been most efficient when impact assessment group members and their contacts received training or other guidance for documenting impacts as comprehensively as possible. Several interviewees, for example, mentioned agricultural extension agents and other field-based officials who played key roles in soliciting for and providing information on the agricultural impacts of drought.

In general, the data obtained by leveraging existing data reporting requirements was limited to first-order drought impact data such as reduced snowpack, lower reservoir levels, reduced stream flow, reduced soil moisture, increased vegetation stress, depreciated water quality, and increased wildfire risk. In several cases, impact assessments consisted of mostly instrumental monitoring data, some of which was also used by drought monitoring groups for determining drought triggers, stages, and inter-annual and decadal climate variability.

First-order impact data is important for assessing drought exposure. Data were reportedly most useful for developing and implementing short-term, reactive drought management options. Drought planning contacts from several states indicated that assessment data derived from leveraging existing reporting requirements were used

primarily to coordinate and appropriate resources for short-term drought management objectives (i.e., avoiding or addressing emergencies).

The leveraging of existing data reporting requirements, however, should not be considered a sufficient data collection process for assessing vulnerability. Leveraging existing reporting requirements is effective for assessing drought exposure, but is inadequate for assessing system sensitivity or adaptive capacity. The assessment of drought sensitivity is particularly challenging without, for example, data on crop failures, lost tourism revenue, fire management expenditures, or community water system shortages. Such data would be necessary to establish sensitivity-based relationships between drought exposure and exposed biological, economic, and other systems. Also, many of the assessment data cited in interviews and in drought planning documents were inappropriate for analyzing how decision making, planning, policies, rules, or other socio-economic and political institutions affect impacts. Thus, assessments that draw conclusions exclusively from first-order impact data are not likely to accurately characterize sensitivity and, thus, vulnerability. Such assessments would provide little insight into how existing policy, social practices, and social change contribute to second-, third-, etc. order impacts such as water shortages, crop failures, economic losses, community stress, and ecological degradation.

The Kansas Water Office example demonstrates the value of considering non-physical determinants of drought sensitivity. Surface water level data for rivers, streams, and reservoirs were useful for determining the amount of water remaining in a storage system. Also, the effects of climate variability on water availability (i.e., physically

determined sensitivity) could be ascertained when these data were evaluated against precipitation, soil moisture, and other environmental data. This information, however, was insufficient for articulating public water system vulnerability. Which systems would have priority rights to below-average surface water during a drought? Which systems would not? When would these latter systems begin to experience shortages? To answer these and other supply-side questions, Kansas Water Office officials considered system water rights, contractual agreements, state and federal environmental law, and other institutional arrangements and entitlements. In doing so, systems most likely to experience shortages during a drought were probably more accurately identified than if this data were not considered. The statewide vulnerability assessment conducted by the Kansas Water Office has since been used to assist the most vulnerable systems with source, distribution, and treatment capacity limitations. As a result, the state claims there were fewer drought-vulnerable public water providers in the late 1990s compared to the late 1980s.

The Kansas Water Office, however, did not adequately incorporate adaptive capacity into its assessment. To do so would have required a much closer examination of how individual systems and system customers would adapt to less-than-adequate water supply, and what factors would enable and limit the kinds of adaptations possible. The CWCB drought and water supply assessment included five brief case studies that attempted to reveal these kinds of issues. Social scientists participating in the study interviewed an owner of a rafting company, a farmer and calf-cow rancher, a dryland farmer, an owner of a plant nursery, and a “truck” farmer (Charney et al. 2004). Each

case study revealed specific information on local and regional second-, third-, etc. order impacts, how each person adapted to these impacts, and how their adaptations were either constrained or enabled by particular opportunities or entitlements. In one of the case studies, the authors report what was described as “a ripple effect” that extended and dispersed the effects of drought along modes of production. Sustained precipitation deficits were traced through farm product commodity chains revealing a nested ordering of impacts. Lower-order impacts were described as outcomes of higher-order impacts, of the ways in which higher-order impacts were mediated by social, political, and economic systems, and of how groups and individuals in turn adapted. The case studies, while limited to fairly specific situations and parts of the state, illuminated the importance of considering adaptive capacity in the overall characterization of vulnerability. The CWCB assessment did not indicate how the case studies were being used to formulate policy to reduce vulnerability, but nonetheless represents an example of a more complete assessment of vulnerability.

The CWCB assessment also highlights another important consideration for assessing vulnerability. Few state agencies involved with state drought planning have staff social scientists capable of conducting in-depth case studies, surveys, focus groups, and other methods of data collection from human subjects. In the Colorado case, private consultants experienced in social science study design, data collection, and analysis conducted the five case studies. The collection and analysis of data from surveys, focus groups, interviews, and other social science methodologies requires specific experience and training that is rare or absent in many government agencies charged with, for

example, managing natural resources or commerce. The study of adaptation, in particular, often requires collecting and analyzing qualitative data. The CWCB accomplished this by drawing on expertise from outside government agencies.

Given the limited membership of social scientists in state drought planning processes, it is expected that many impact assessment groups have lacked the capacity to conduct focus groups, interviews, and large-scale surveys. Planning processes that include social scientists or officials trained to design and conduct interviews, focus groups, and surveys, I argue, are more likely to effectively analyze drought sensitivity and, in particular, adaptive capacity. Additionally, such planning processes are far more likely to collect more and higher quality second-, third-, etc. order impact data.

Thus, state drought planning processes need to actively incorporate social science research into the assessment of impacts and vulnerability. To do so would improve the assessment of impacts and vulnerability, and arguably improve the relevance of such studies for developing long-term mitigation programs. To continue neglecting this issue will constrain future efforts to assess vulnerability. In most states, universities and colleges include programs, faculty, and graduate students capable of filling this methodological gap in state drought planning. Many non-profit and non-governmental agencies employ social scientists that could do so as well. At the University of Arizona, for example, the Climate Assessment for the Southwest (CLIMAS) project has conducted numerous studies on the sensitivity of human systems to climate variability and climate change (Morehouse et al. 2002, Finan et al. 2002, Vasquez-Leon et al. 2003, Bales et al. 2004, Lemos and Morehouse 2005). CLIMAS is one of eight Regional Integrated Science

Assessment programs in the United States funded by the U.S. National Oceanic and Atmospheric Administration. In addition to several physical scientists, CLIMAS includes faculty and graduate student anthropologists, agricultural economists, and geographers. Social scientists have greatly improved the understanding of climate vulnerability in Arizona and New Mexico, and they have participated in numerous studies driven by national, state, and local policy agendas.

Figure 3 presents a modified organizational structure that incorporates these recommendations. The structure is adapted from NDMC guidance presented in Figure 1. The primary difference is the addition of vulnerability assessment teams (VATs) that maintain research relationships with impact assessment groups and the public. Impact assessment groups primarily collect quantitative, first-order impact data that is provided to the Drought Task Force and VATs as necessary. VATs, however, focus on the use of social science methods to collect both quantitative and qualitative second-, third-, etc. order impact data, and study drought sensitivity and adaptive capacity. Additionally, VATs are responsible for synthesizing assessments of vulnerability by incorporating data from impact assessment groups. Importantly, the addition of VATs to the organizational structure presented in Figure 1 does not jeopardize the effectiveness of existing roles of the Drought Task Force and monitoring and impact groups. Thus, depending on the resources available to a state drought planning process, VATs can be quite small and focused on narrowly targeted projects, or have large memberships and multiple projects and drive policy formation. It is also important to note that, despite the predominance of

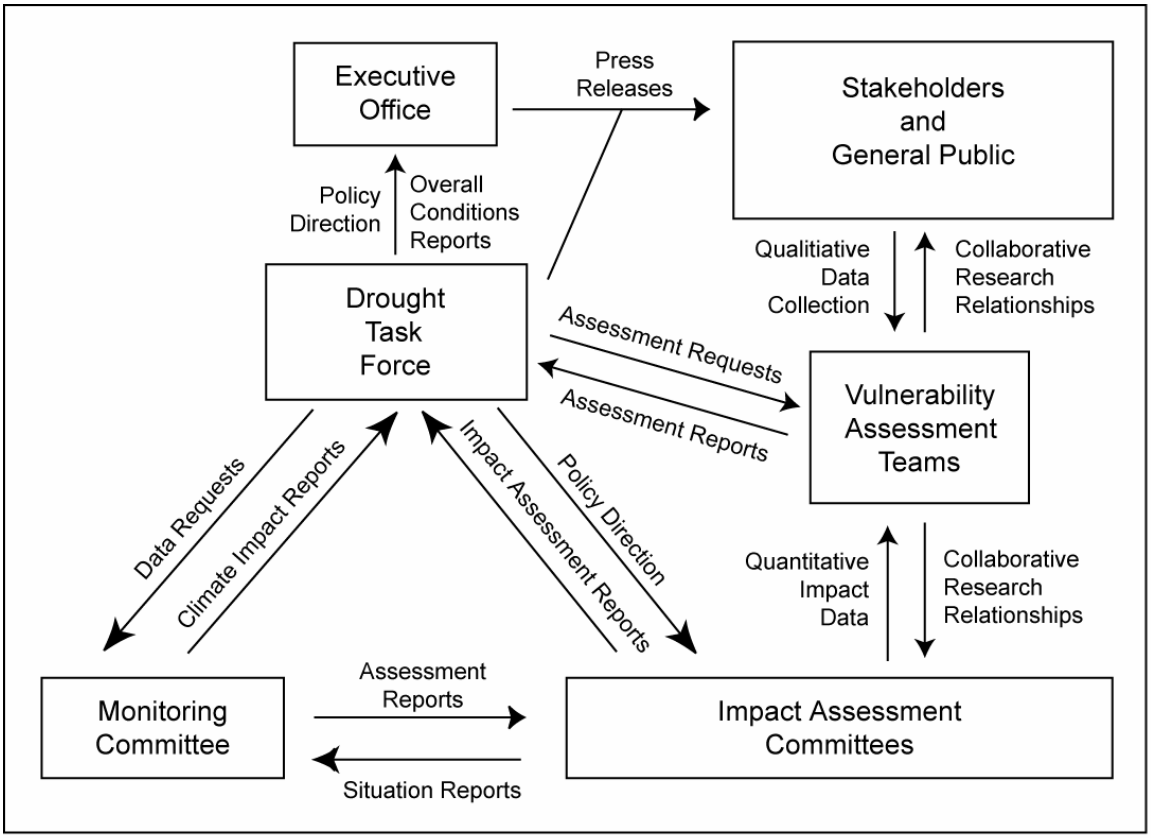

Figure 3. A proposed organizational structure of state drought planning to improve vulnerability assessment.

limited post-drought task force activity, VATs can act as an anchor for enhancing the long-term lifecycle of drought planning processes.

In addition to the proposed VATs, the survey revealed other effective strategies for improving the collection of second-, third-, etc. order impact data. During and after drought, task forces often create “wish lists” of data that, if available, would greatly improve their ability to assess conditions, improve reactive management, and formulate effective long-term programs. However, it is often unlikely that drought planning will receive committed, multi-year funding to collect this data in-house. As a compromise,

existing data reporting requirements are modified to include reporting some of the data from the wish lists. In California, Department of Water Resources officials involved in local drought management issues have had data requirements added to the Urban Water Management Planning Act several times since the Act's inception. The addition of these data requirements, it was argued, improved the state's capacity to assess the drought vulnerability of local water providers.

CONCLUSIONS

This paper presented results of a national survey of state drought planning processes in the United States. Given the substantial growth in the numbers of state planning processes in the United States during the past two decades, it is important to periodically survey the field to determine the current trajectory of drought management and evaluate this trajectory against recent research and planning guidance. This paper provides results of a first-ever survey of how states have thus far assessed impacts and vulnerabilities. Although states have been largely effective at assessing first-order impacts, as a whole they have been far less successful at assessing second-, third-, etc. order impacts and vulnerabilities. Impact assessments are argued to be marginally effective for assessing vulnerability, and vulnerability assessments have been conducted by fewer than 15% of states with drought plans. The survey, however, illuminated several areas for improvement, including documentation and publication of assessments, the

recruitment of social scientists to participate in vulnerability assessments, and modification of conceptual organization of drought planning to include vulnerability assessment teams.

The results of the survey suggest that, despite consistent interest, communication between state planning processes is low. A number of states were are unaware of innovative approaches that other states have developed, yet indicated enthusiastically their interest in what other states were doing. That said, future efforts to improve state drought planning in the United States should include organizing regional and national meetings where state planning representatives can share ideas and present results of recent assessments.

Finally, there is a need for greater integration and cross-fertilization between drought planners and hazard and disaster vulnerability researchers. Impact and vulnerability assessment guidance will only improve with increased collaboration between hazard planners and managers and researchers studying hazard impact and vulnerability assessment. In turn, hazard and disaster vulnerability research needs to be more responsive to agendas driven by theoretical and methodological shortcomings of hazard planners and managers. In addition, future hazard vulnerability research should include more active participation in state and local impact and vulnerability assessments. Social scientists, in particular, are most likely to significantly contribute as members of vulnerability assessment teams.

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