Overview of the Colorado Drought Vulnerability Assessment by Sector-

Methods, Results, Challenges and Opportunities

Graeme Aggett

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Why Assess Drought Vulnerability?

- New paradigm in disaster management
- Drought is costly!
- Decision makers need information to help prepare for droughts, allocate resources effectively, and reduce impacts
- Assessment of losses in time and space key to successful mitigation
- Understanding full risk picture requires understanding of vulnerability

Risk Assessment

Risk Assessment: The process of identifying the likelihood and consequences of an event to provide the basis for informed planning decisions on a course of action

Drought Risk =

Hazard x **VULNERABILITY**

Drought Hazard: a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area."

Vulnerability: The susceptibility to injury or damage from hazards." (Godschalk 1991, 132)

Previous work

- Few have presented methods to assess vulnerability empirically or spatially
- Ambiguity surrounds components of vulnerability - also operationalization and measurement of those components
- Some empirical studies use indicators to characterize vulnerability, although indicator values may not adequately reflect **impacts**, especially at the local level, and may not be relevant across multiple regions and sectors
- Project team decided what is needed are empirical assessments to understand how vulnerability is experienced “on the ground,” by those who are vulnerable
  - Elucidate causes and effects of vulnerability
  - Provide data based guidance to decision makers.

This Study..

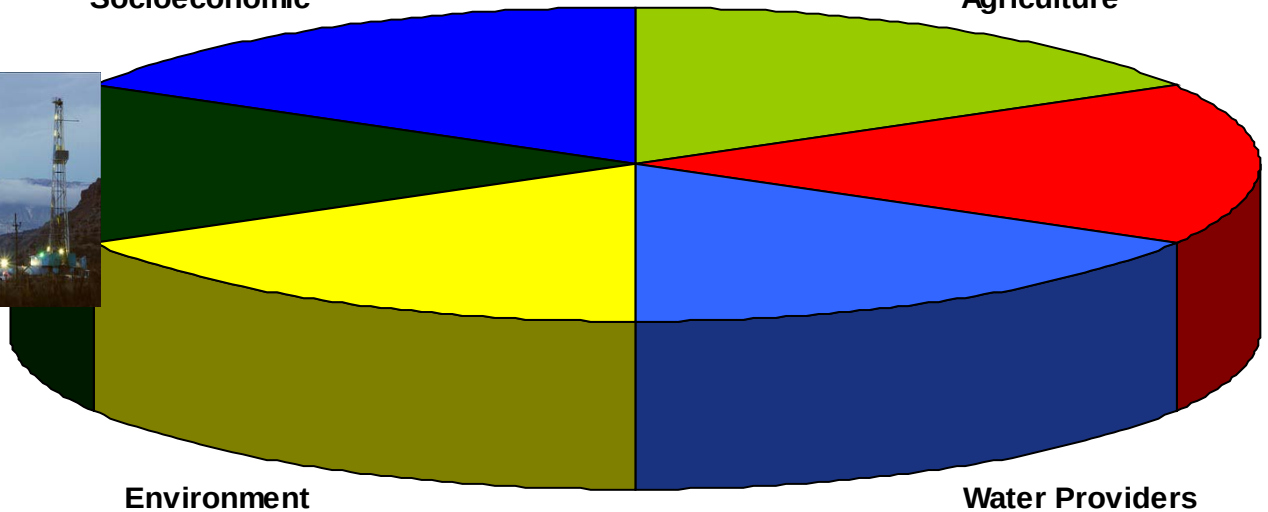
- Developed a new vulnerability assessment method that uses qualitative and quantitative impacts data, sector sensitivities, and adaptive capacities
- Acquisition of data and information from those who are vulnerable, which permits not only quantitative assessments, but also a deeper understanding of the factors that influence vulnerability
- Focus on spatial variability and presentation of results
- We then apply this method to the assessment of drought vulnerability for the entire state for 6 sectors and multiple sub-sectors

Study Sectors

Socioeconomic

Agriculture

Energy



Recreation

Environment

Water Providers

How do we assess Vulnerability?

- Cataloging assets and resources in a system and across sectors
- Assigning quantifiable value (or at least rank order) and importance to those resources
- Identifying the vulnerabilities or potential threats to each resource
- Assess IMPACTS

- Mitigating or eliminating the most serious vulnerabilities for the most valuable sectors/assets

How do we assess Vulnerability? – Importance of Drought IMPACTS data

- **Environmental**
  - Losses or destruction of fish and wildlife habitat
  - More wildfires
    - Erosion and WQ issues
- **Economic**
  - Ranchers may have to spend more money on feed and water for their animals
  - Timber industry affected when wildfires destroy stands of timber
  - Tourists stay away
- **Social**
  - Health problems related to dust/smoke
  - Loss of recreational opportunities
  - Mental health concerns

How do we assess Vulnerability? – Importance of Drought IMPACTS data

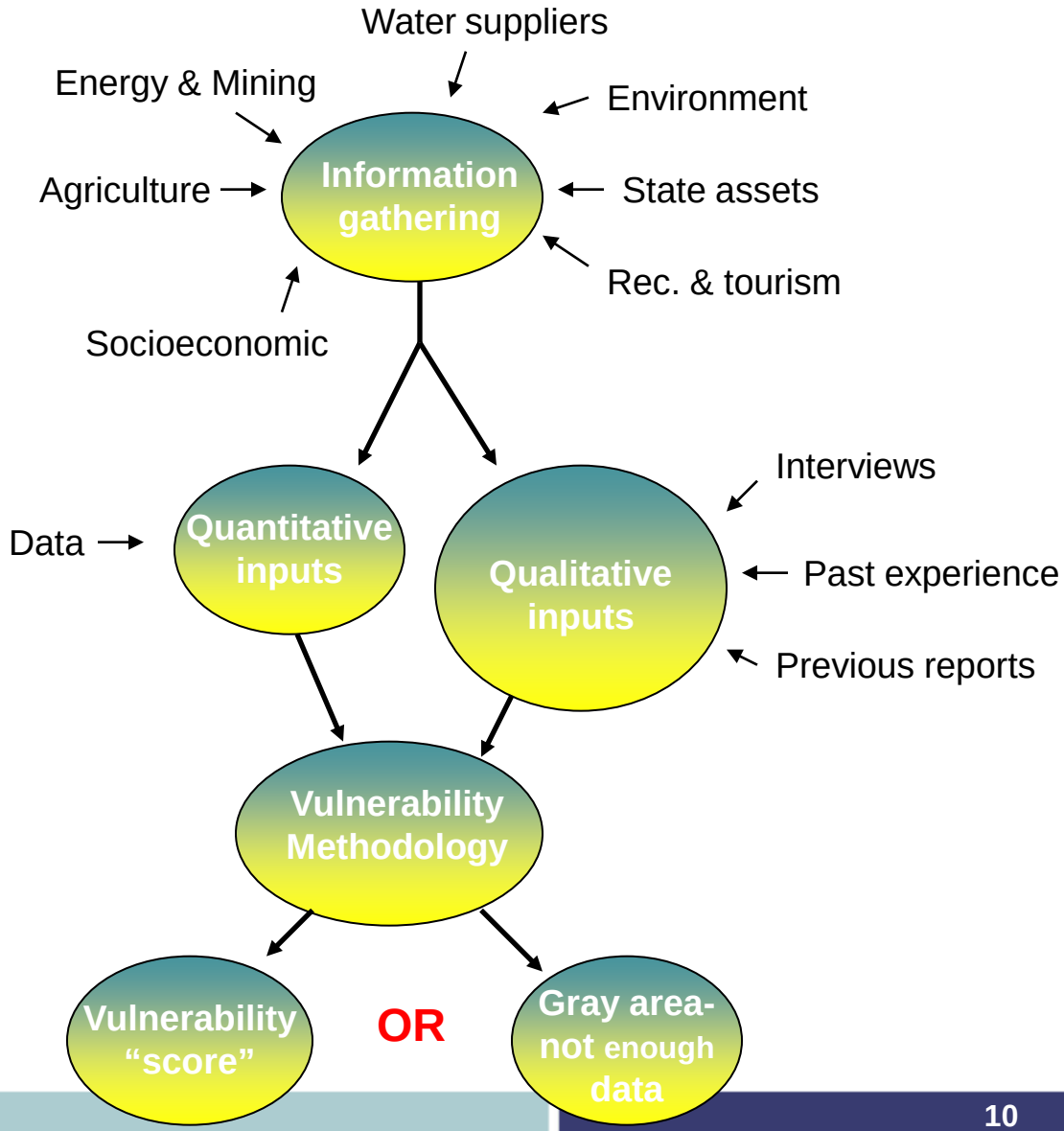
- Drought Impacts data collection…. versus other natural hazards
  - Earthquake risk assessment
  - Flood risk assessment

- If we have robust impacts data ($), we are on our way to a full risk assessment

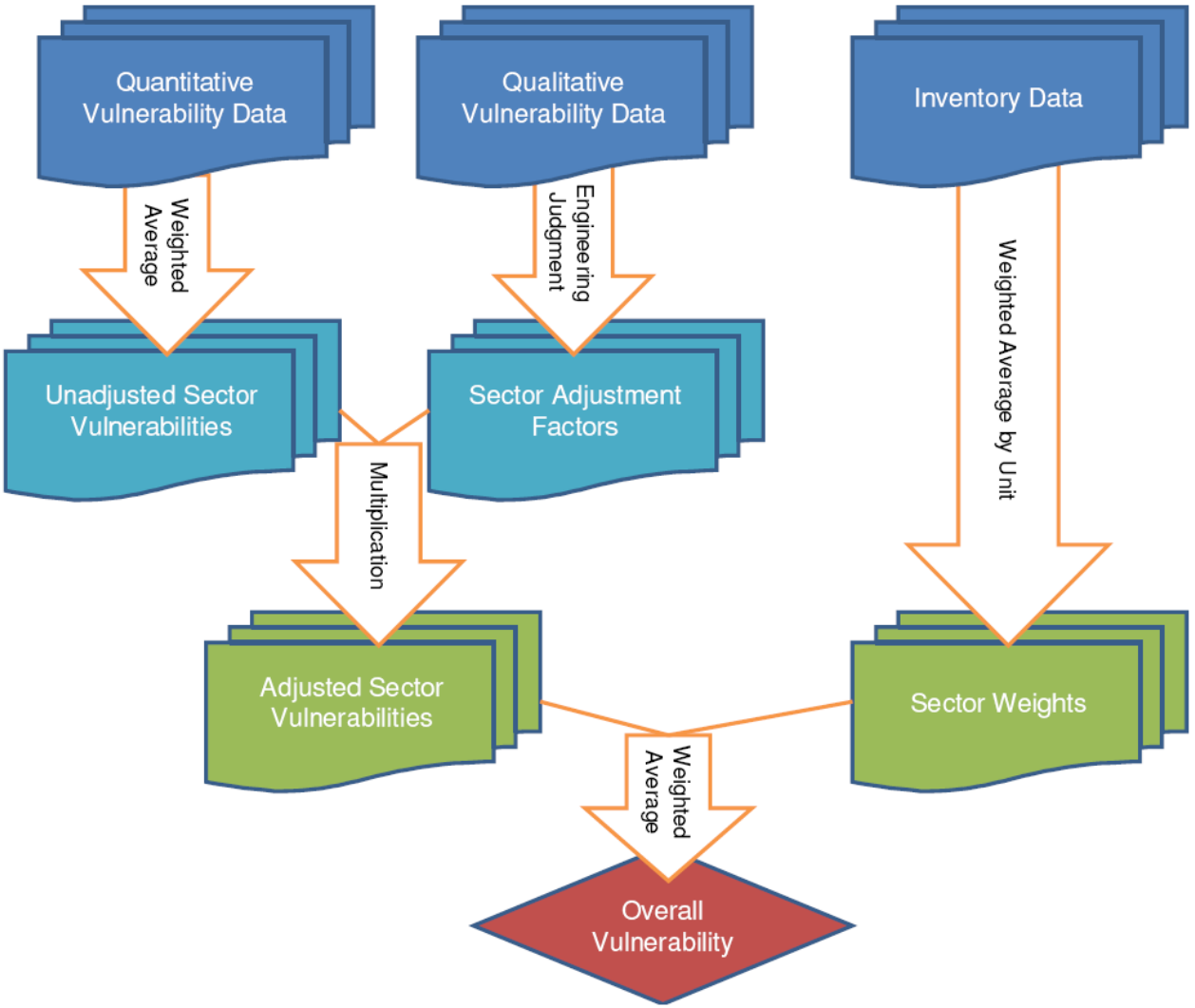
- Drought Impacts are most complex and not so readily or directly related to the hazard (magnitude, intensity, duration, location) in space or time

Methodological Framework

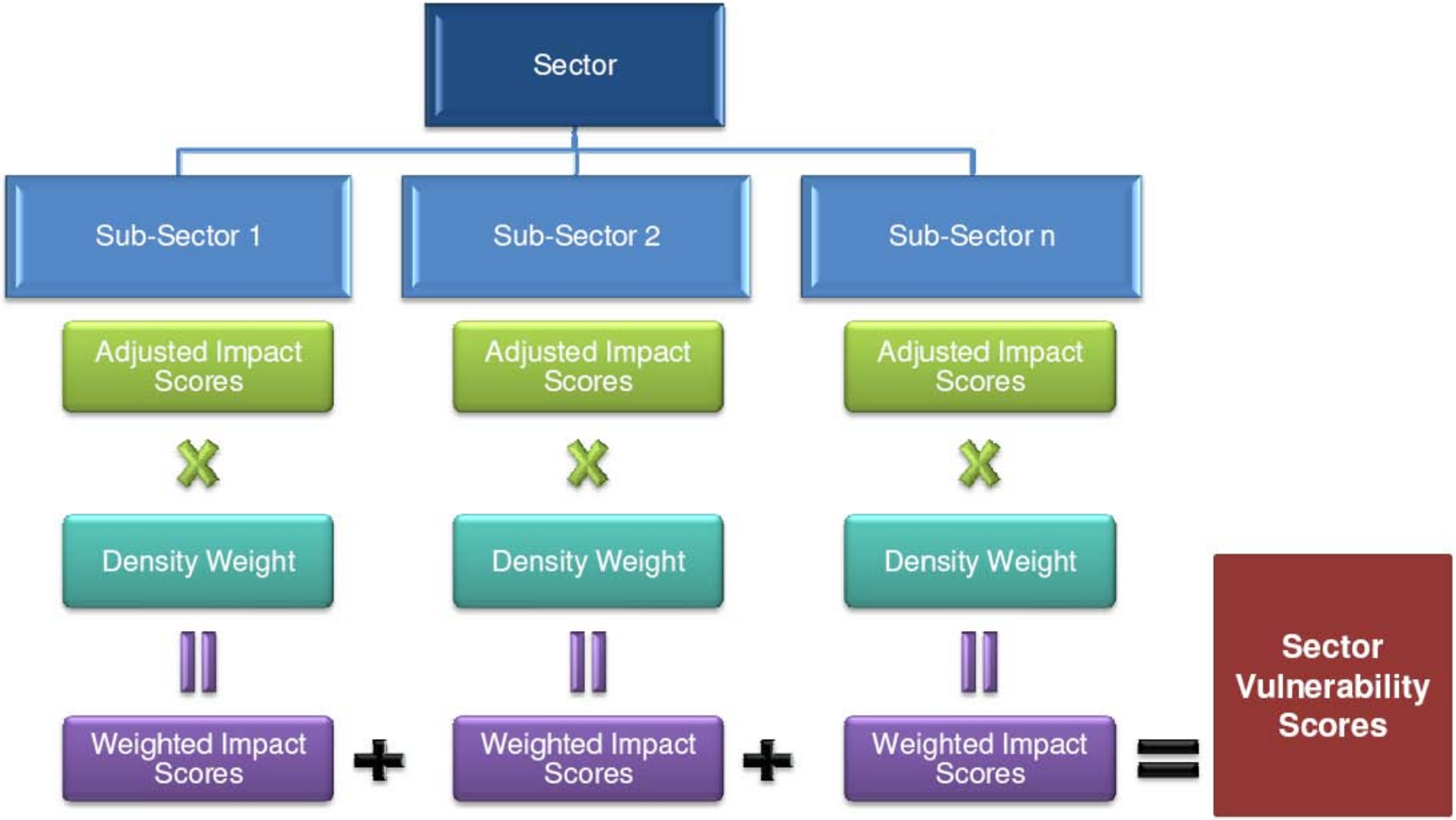
- Research sectors, publications, previous drought studies
- Quantitative data
  - What we have
  - What we need
- Qualitative
  - Interviews
  - Past experiences
  - Specific knowledge of the area
- Methodology
- Vulnerability “score” OR framework for future data collection



Vulnerability Calculations



Sector Vulnerability Calculations

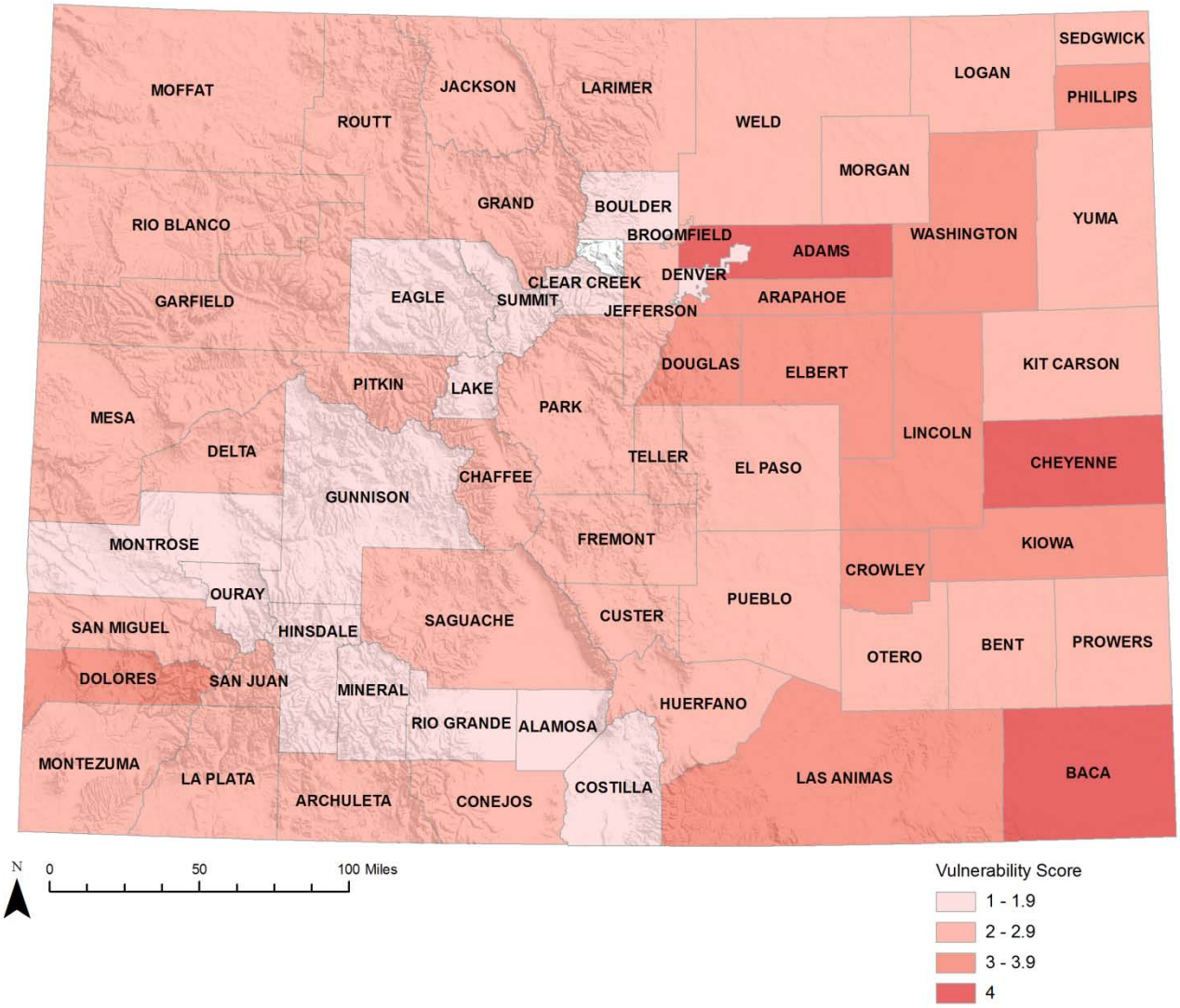


SUMMARY: Key Findings, Spatial Weightings, and Recommendations across Sectors

Agriculture: Key Findings

- Subsectors
  - Crops
  - Livestock
  - Green Industry
- Key drought vulnerabilities for crops include crop loss from lack of precipitation or insufficient irrigation, and possible damage to crops due to reduced quality of irrigation water
- The livestock sub-sector focuses on impacts to grazing cattle, which can be vulnerable to drought due to limited forage availability
- The green industry is vulnerable to municipal water restrictions as well as water-availability reductions that could cause plant loss

Overall Agriculture Vulnerability Scores



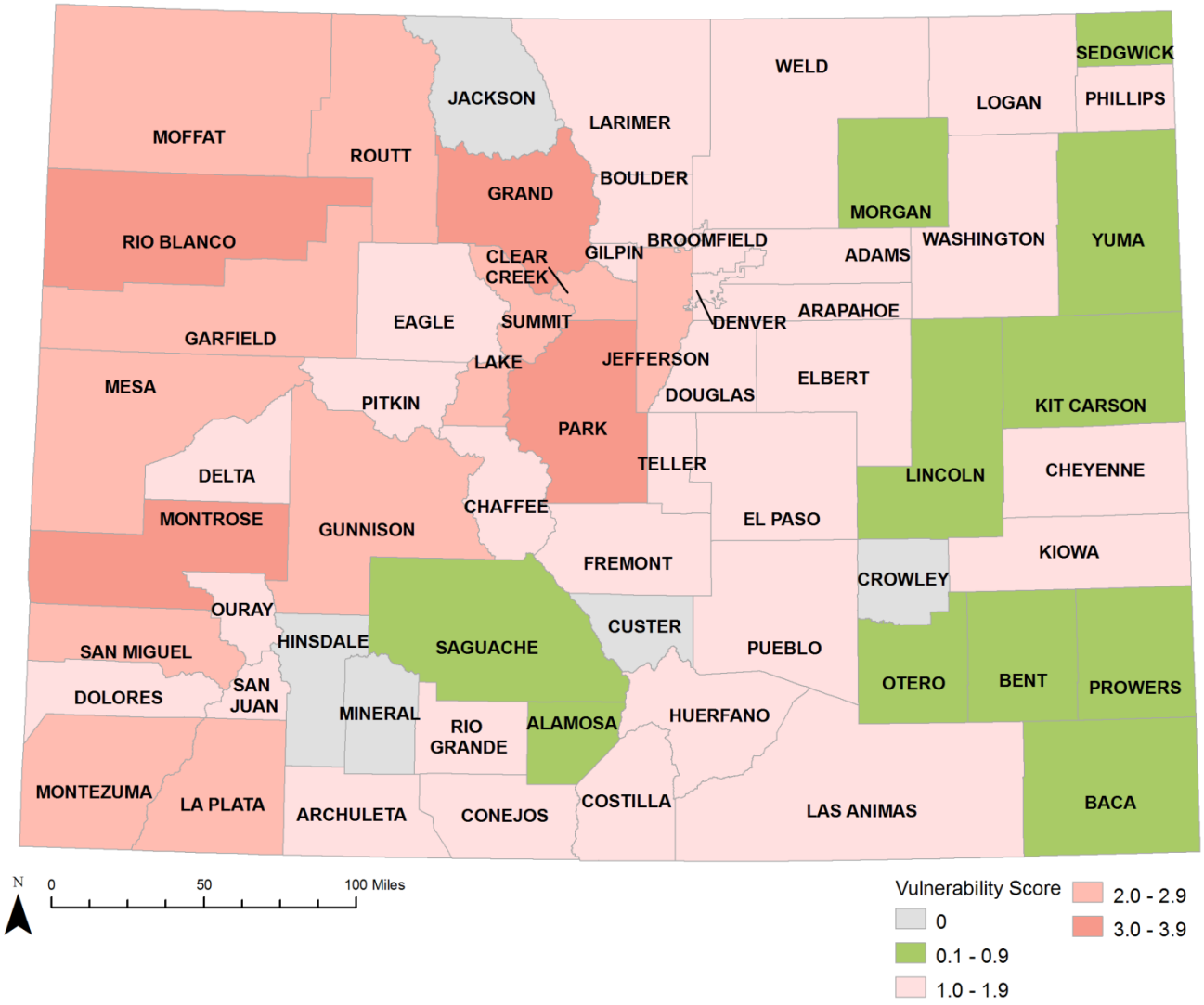
Agriculture: Key Recommendations

- Crop diversification and advanced planning for drought scenarios
- Best management practices developed by the green industry might have applications for irrigated crop producers, and a formal set of best management practices could be developed for dryland farmers
- Crop specific vulnerability assessments
- Additional data collection on the green industry

Energy: Key Findings

- Subsectors
  - Mining
  - Power Generation
- Thermoelectric power plants can be impacted by inadequate water supplies and increased cost of water during drought
- Hydropower generation capacity decreases as reservoir levels drop
- Mining operations can be impacted by increased costs of water for operations or limited water availability
- The energy sector is generally drought tolerant. Power providers and mining operations tend to have very senior water rights and some power providers already have conditional drought agreements in place

Overall Energy Vulnerability Scores



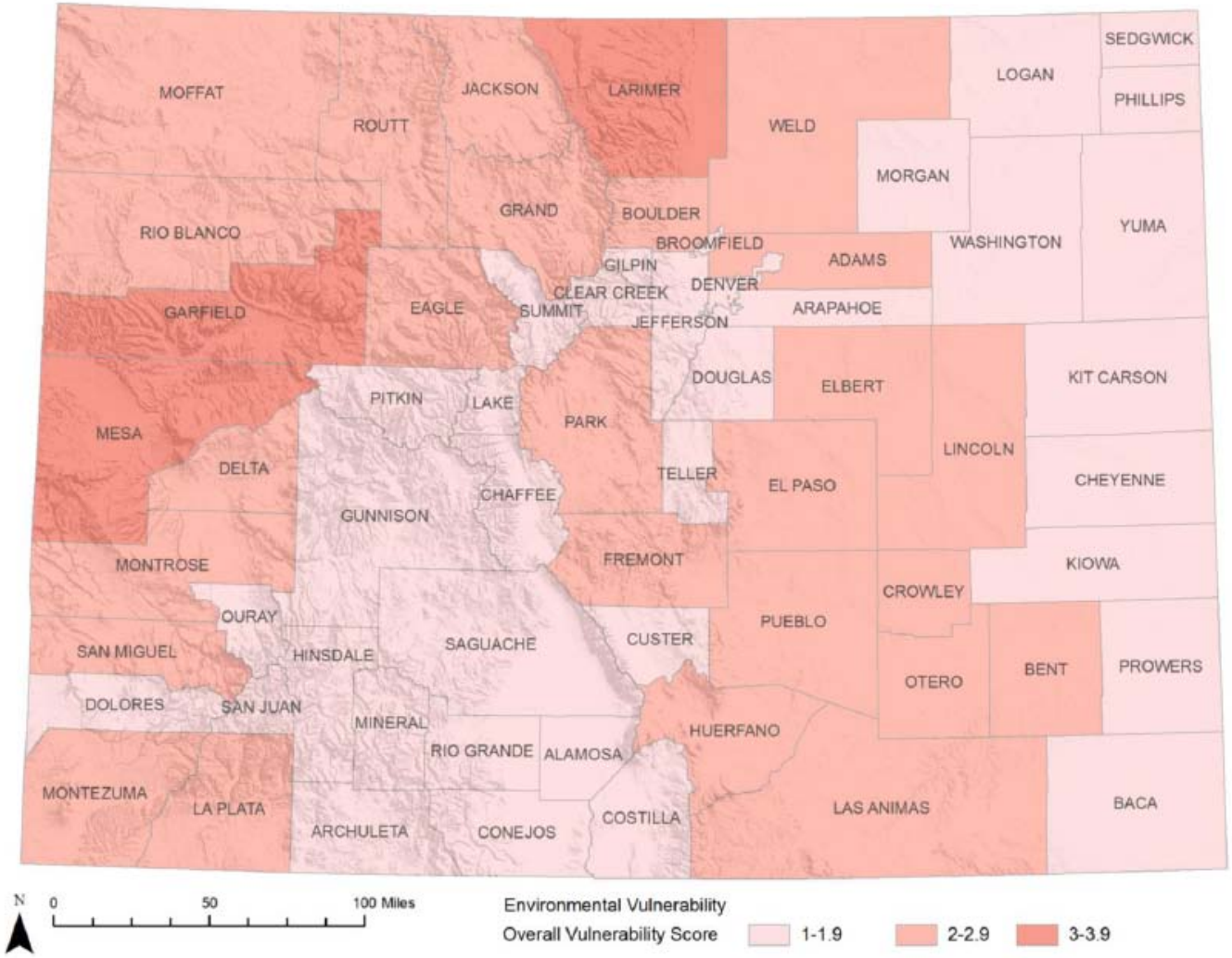
Energy: Key Recommendations

- Drought vulnerability for power providers may increase as population expands, power demand increases and competing demand on water resources intensifies
- Power providers should diversify their water rights portfolio and purchase additional water rights and conditional drought leases
- Renewable generation methods like wind and solar use negligible amounts of water and are part of the legislated goal of 30% renewable energy sources by 2020
- Transmission line capacity should be increased to facilitate flexibility during drought
- Mining companies should increase their drought awareness and consider technologies that are less drought intensive

Environment: Key Findings

- Colorado's natural environment is diverse and drought vulnerabilities are expected to vary spatially based on ecology and current precipitation regimes
- In the 2002 drought significant impacts to fish populations were noted
- Increased wildfires and beetle infestation are common secondary drought impacts
- Monitoring resources are limited and comprehensive impact information even for the most recent drought is not available

Overall Environmental Vulnerability Scores



Environment: Key Recommendations

- Identification of critical areas and additional monitoring
- Cross agency collaboration on monitoring efforts
- Additional analysis of previous studies conducted in the Colorado
- Future work should, where possible, build on the foundation of previous studies that have been conducted
- As additional data becomes available the drought vulnerability metrics used in this analysis should be updated

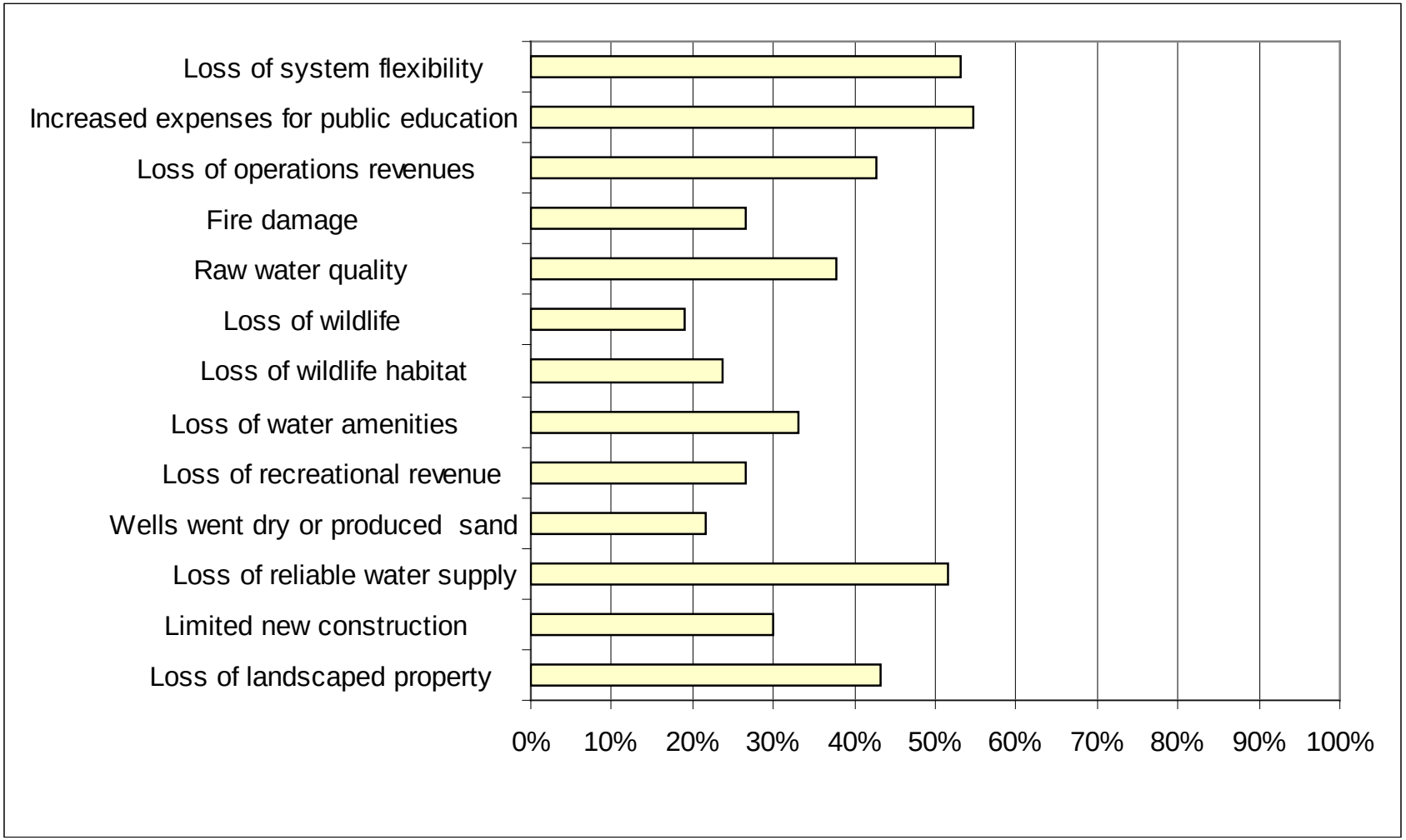
M&I: Key Findings

- Drought vulnerability depends on the reliability of a water supply system during a drought and the ability to effectively respond
- Vulnerability can vary greatly based on the following categories:
  - Water supply
  - Water distribution
  - Water demand
  - Adaptive capacity
- A quantitative vulnerability assessment would require consideration of the uniqueness of each M&I provider (beyond the scope of this study)
- A qualitative assessment of M&I vulnerability at regional basin-wide level was found to be appropriate for this study

M&I: Key Recommendations

- Encourage local policy that enforces the development or acquisition of reliable water supplies for growing communities
- Develop state policy requiring/encouraging M&I providers to develop drought plans
- Continue to provide technical and financial assistance to M&I providers
- Incorporate a review of river administration and historical call data in future M&I drought vulnerability studies
- Develop a database(s) that records individual M&I providers' historical drought impacts, and mitigation and planned response actions

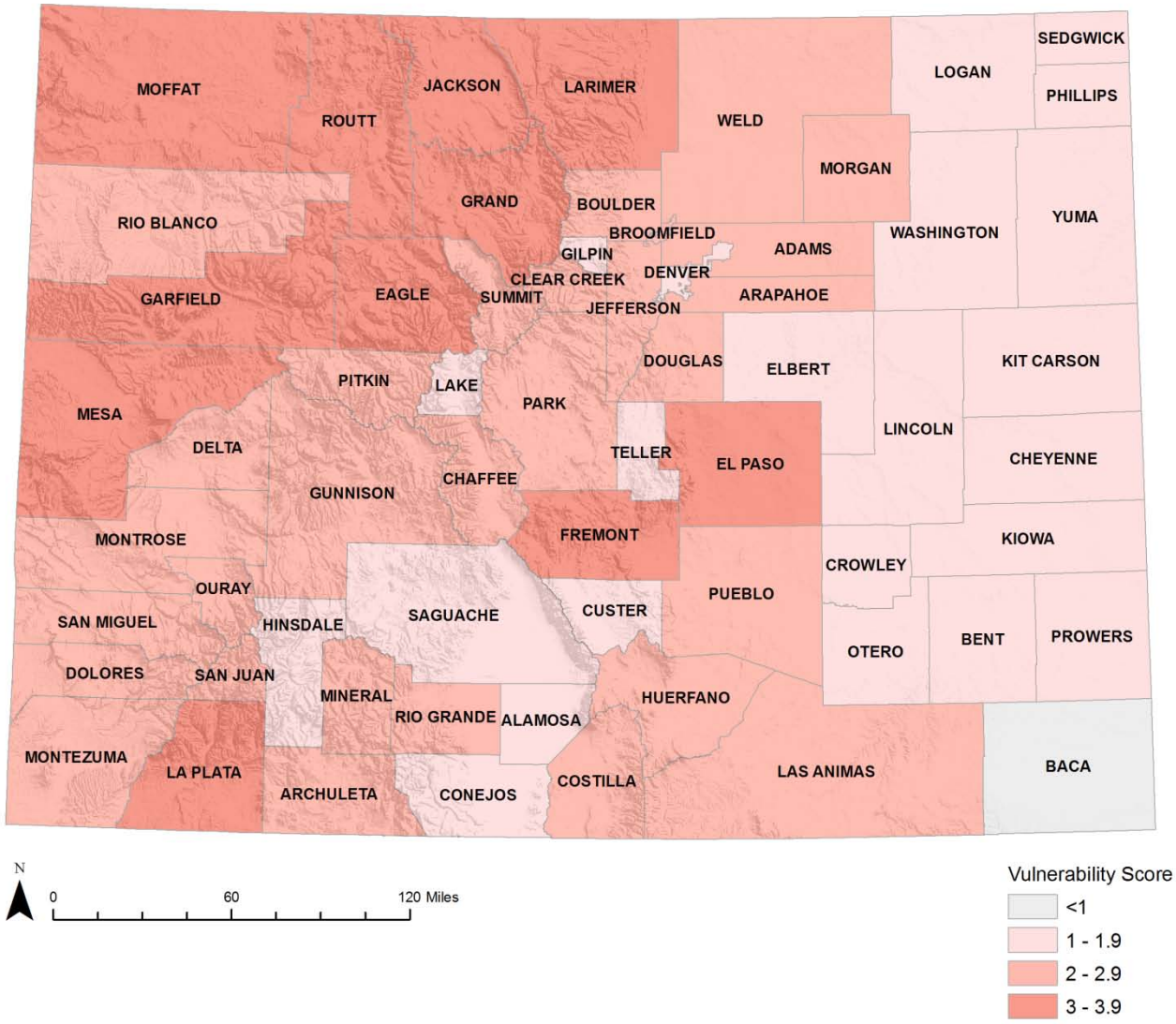
2001 Drought Impacts to M&I Providers from 2004 DWSA Survey Results



Recreation and Tourism: Key Findings

- Subsectors
  - Skiing
  - Wildlife Viewing
  - Hunting/fishing/camping
  - Golfing
  - Boating
  - Rafting
- Higher operating costs for the ski industry and decreased visitation
- Animals may move away from traditional viewing/hunting areas due to lack of water, loss of vegetative cover, and/or heat
- Fishing areas can be impacted by lower reservoir and lake levels, decreased stream flow, and fish decline

Overall Recreation and Tourism Vulnerability Scores



Recreation and Tourism: Key Findings

- Forced closure of campsites and surrounding forest due to risk of wildfires and/or hazard trees
- Golf courses are impacted if municipalities impose watering restrictions or if water rights become out of priority due to low stream flows
- Lower reservoir and lake levels can render boat ramps unusable; and lower water levels can deter potential boaters
- Rafting companies suffer impacts as a result of low flows and negative public perception

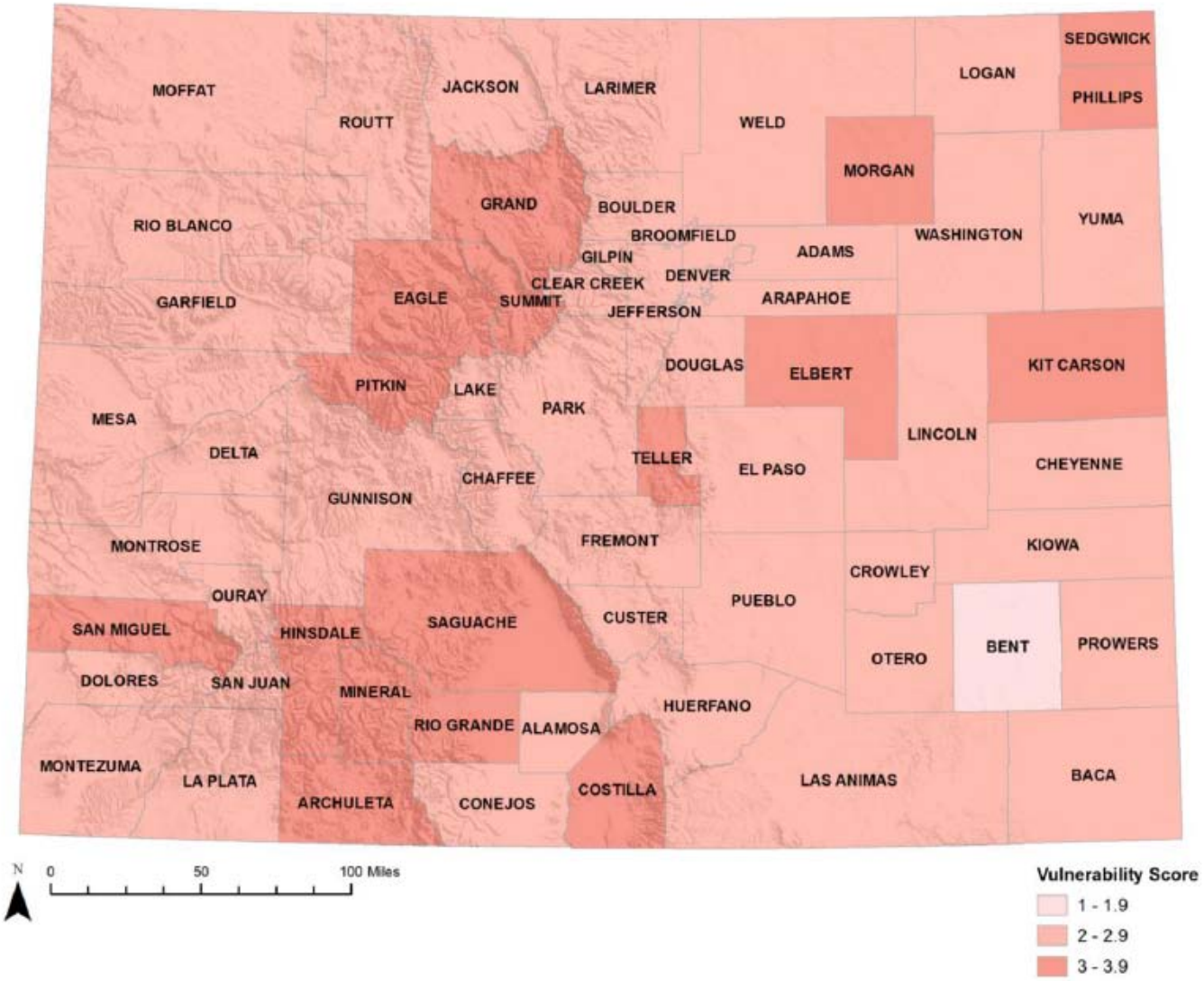
Recreation: Key Recommendations

- Public perception is a primary concern among all recreation sub-sectors. Public relations plans and strategies can help mitigate or prevent negative public perception during drought
- Adjusting the seasonality and variety of offerings increase the adaptive capacity of recreation companies
- Diversification and communication with the public, media, and local governments was found to be the most widely-repeated strategy for adapting to drought conditions

Socioeconomic: Key Findings

- Subsectors
  - Secondary economic impacts
  - Mental health impacts
  - Public health concerns
- The economic reliance of some counties on particularly drought vulnerable industries (agriculture, recreation) increases the vulnerability of the county as a whole
- Counties identified as having a mental health manpower shortage will have a difficult time responding to the increased mental health issues that can occur during drought
- Drought induced public health issues can include; impaired drinking water quality, increased incidence of mosquito born illness and respiratory complications resulting from impaired air quality

Overall Socioeconomic Vulnerability Scores



Socioeconomic: Key Recommendations

- Economic diversification
- Cooperative alliances and community planning
- Statewide agencies should increase their understanding of societal impacts of drought and focus on collaborative opportunities to mitigate drought impacts
- Significant data gathering and additional monitoring is required to spatially characterize social vulnerability

Opportunities

- Drought impact recording (NDMC and others)
- Water rights and spatial-data modeling (NCAR - Olga Wilhelmi)
- Collecting impacts and adaptive capacities information via drought gaming
- Social networks
- More detailed sector studies (e.g. CU Denver on Recreation-Tourism)

Drought and Water Rights

Data

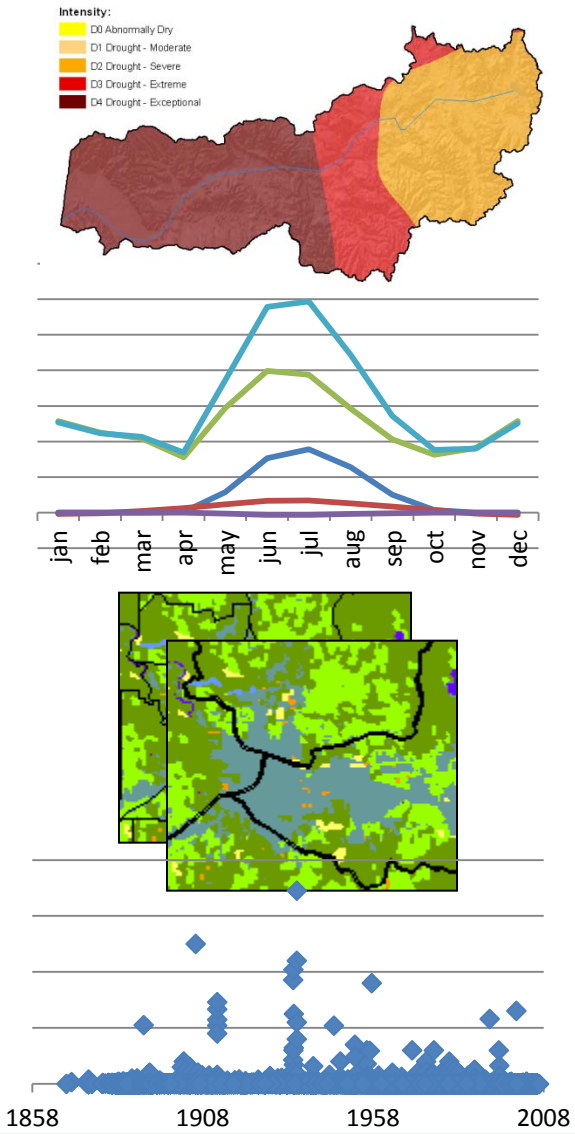
Drought Monitor

NHD Plus Watersheds

Bureau of Reclamation CU

USGS LULC (30m)

CWCB – CDWR HydroBase



Process

Identify drought area

Identify downstream sections affected

Analyze demand for time period

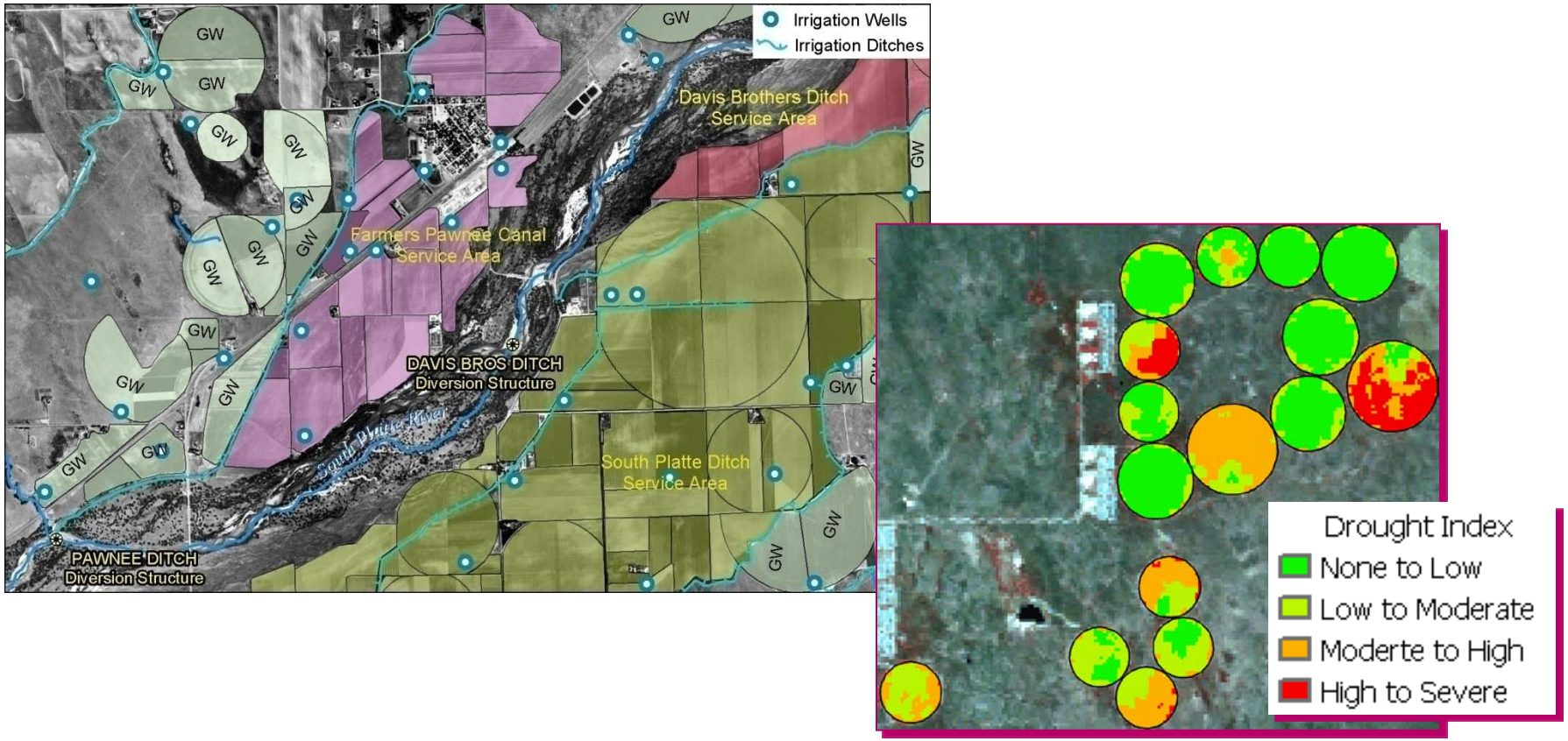
Land use analysis

Seniority analysis

Vulnerability

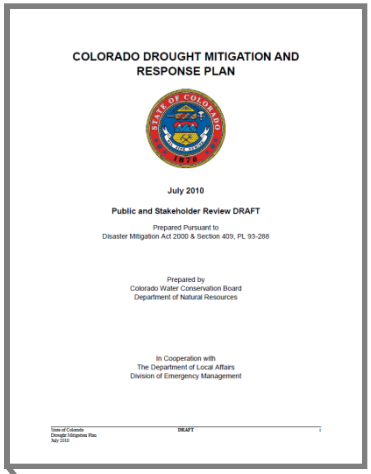
The National Center for Atmospheric Research NCAR sponsored by NSF

Agricultural Drought Hindcasting and Impacts Assessment



Conclusions

- Assessment of sector's ability to withstand a hazard is as important as assessment of the hazard itself
  - both hazard and vulnerability aspects need to be handled thoughtfully and within the same assessment framework
- Incorporation of differential susceptibility and differential impacts of the drought hazard – enabled Drought Plan revision to incorporate both the negative and positive attributes from the physical and social environments that increase risk and susceptibility and/or limit resistance and resilience to drought events
- Results provide an empirical basis for reporting vulnerability across sectors.
- Results analyzed spatially and used to make recommendations for drought planning and mitigation.


COLORADO DROUGHT MITIGATION AND RESPONSE PLAN

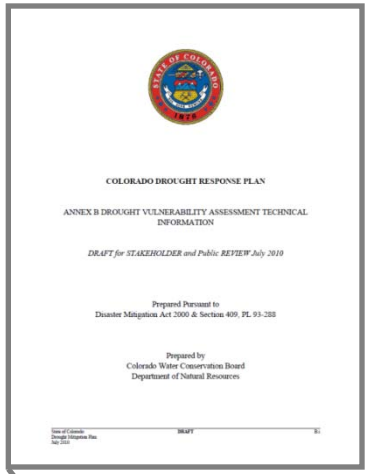
July 2010

Public and Stakeholder Review DRAFT

Prepared Pursuant to
Disaster Mitigation Act 2000 & Section 409, PL 93-288

Prepared by
Colorado Water Conservation Board
Department of Natural Resources

In Cooperation with
The Department of Local Affairs
Division of Emergency Management


COLORADO DROUGHT RESPONSE PLAN

ANNEX B DROUGHT VULNERABILITY ASSESSMENT TECHNICAL INFORMATION

DRAFT for STAKEHOLDER and Public REVIEW July 2010

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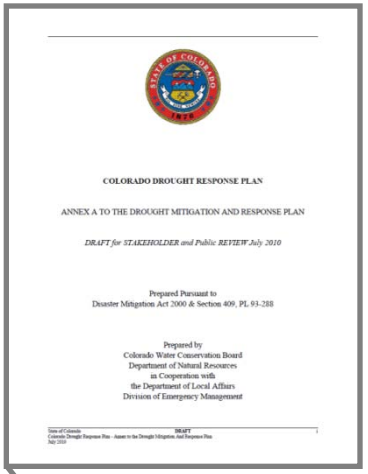
COLORADO DROUGHT RESPONSE PLAN

ANNEX A TO THE DROUGHT MITIGATION AND RESPONSE PLAN

DRAFT for STAKEHOLDER and Public REVIEW July 2010

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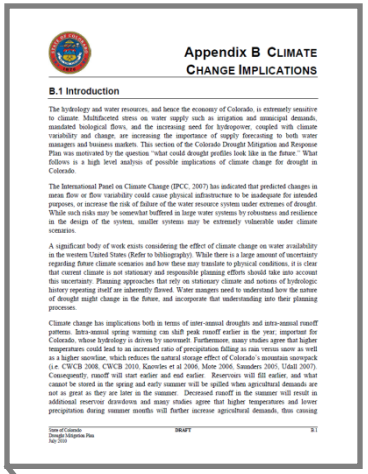

Appendix B Climate Change Implications

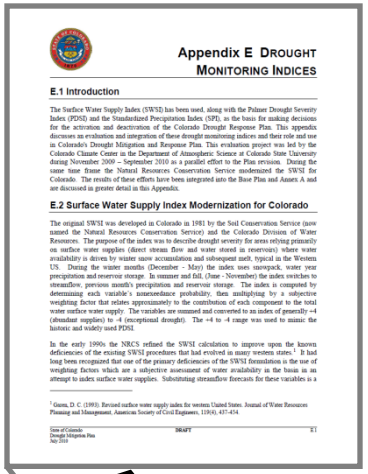
B.1 Introduction

The hydrology and water resources, and hence the economy of Colorado, is extremely sensitive to climate. Multifaceted stress on water supply such as irrigation and municipal demands, mandated biological flows, and the increasing need for hydropower, coupled with climate variability and change, are increasing the importance of supply forecasting to both water managers and business markets. This section of the Colorado Drought Mitigation and Response Plan was motivated by the question "what could drought profiles look like in the future." What follows is a high level analysis of possible implications of climate change for drought in Colorado.

The International Panel on Climate Change (IPCC, 2007) has indicated that predicted changes in mean flow or flow variability could cause physical infrastructure to be inadequate for intended purposes, or increase the risk of failure of the water resource system under extremes of drought. While such risks may be somewhat buffered in large water systems by robustness and resilience in the design of the system, smaller systems may be extremely vulnerable under climate scenarios.

A significant body of work exists considering the effect of climate change on water availability in the western United States (Refer to bibliography). While there is a large amount of uncertainty regarding future climate scenarios and how these may translate to physical conditions, it is clear that current climate is not stationary and responsible planning efforts should take into account this uncertainty. Planning approaches that rely on stationary climate and notions of hydrologic history repeating itself are inherently flawed. Water managers need to understand how the nature of drought might change in the future, and incorporate that understanding into their planning processes.

Climate change has implications both in terms of inter-annual droughts and intra-annual runoff patterns. Intra-annual spring warming can shift peak runoff earlier in the year, important for Colorado, whose hydrology is driven by snowmelt. Furthermore, many studies agree that higher temperatures could lead to an increased ratio of precipitation falling as rain versus snow as well as a higher snowline, which reduces the natural storage effect of Colorado's mountain snowpack (i.e. CWCB 2008, CWCB 2010, Knowles et al 2006, Mote 2006, Saunders 2005, Udall 2007). Consequently, runoff will start earlier and end earlier. Reservoirs will fill earlier, and what cannot be stored in the spring and early summer will be spilled when agricultural demands are not as great as they are later in the summer. Decreased runoff in the summer will result in additional reservoir drawdown and many studies agree that higher temperatures and lower precipitation during summer months will further increase agricultural demands, thus causing


Appendix E Drought Monitoring Indices

E.1 Introduction

The Surface Water Supply Index (SWSI) has been used, along with the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI), as the basis for making decisions for the activation and deactivation of the Colorado Drought Response Plan. This appendix discusses an evaluation and integration of these drought monitoring indices and their role and use in Colorado's Drought Mitigation and Response Plan. This evaluation project was led by the Colorado Climate Center in the Department of Atmospheric Science at Colorado State University during November 2009 – September 2010 as a parallel effort to the Plan revision. During the same time frame the Natural Resources Conservation Service modernized the SWSI for Colorado. The results of these efforts have been integrated into the Base Plan and Annex A and are discussed in greater detail in this Appendix.

E.2 Surface Water Supply Index Modernization for Colorado

The original SWSI was developed in Colorado in 1981 by the Soil Conservation Service (now named the Natural Resources Conservation Service) and the Colorado Division of Water Resources. The purpose of the index was to describe drought severity for areas relying primarily on surface water supplies (direct stream flow and water stored in reservoirs) where water availability is driven by winter snow accumulation and subsequent melt, typical in the Western US. During the winter months (December – May) the index uses snowpack, water year precipitation and reservoir storage. In summer and fall, (June - November) the index switches to streamflow, previous month's precipitation and reservoir storage. The index is computed by determining each variable's nonexceedance probability, then multiplying by a subjective weighting factor that relates approximately to the contribution of each component to the total water surface water supply. The variables are summed and converted to an index of generally +4 (abundant supplies) to -4 (exceptional drought). The +4 to -4 range was used to mimic the historic and widely used PDSI.

In the early 1990s the NRCS refined the SWSI calculation to improve upon the known deficiencies of the existing SWSI procedures that had evolved in many western states.[1] It had long been recognized that one of the primary deficiencies of the SWSI formulation is the use of weighting factors which are a subjective assessment of water availability as the basis in an attempt to index surface water supplies. Substituting streamflow forecasts for these variables is a

[1] Garen, D. C. (1993). Revised surface water supply index for western United States. Journal of Water Resources Planning and Management, American Society of Civil Engineers, 119(4), 437-454.

Drought Mitigation and Response Plan

Annex A: Drou Response Plan

Annex B: Vi ility Assessment

Appendix B e Change

Appendix E: Drought Indices

Annex B: Vulnerability Assessment

Thankyou - Questions

Soooo booooring!!