CHAPTER 2

Research Teams: Key Wicked Problem Focus Areas in Oklahoma

Authors

Maggie Leon-Corwin
Institute for Public Policy Research and Analysis
University of Oklahoma
Norman, OK

Carol L. Silva
Office of the Vice President for Research and Partnerships
University of Oklahoma
Norman, OK

Hank Jenkins-Smith
Institute for Public Policy Research and Analysis
University of Oklahoma
Norman, OK

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The S3OK research initiative brought together research teams across interrelated domains—Subseasonal-to-Seasonal Weather Patterns (S2S), Variable and Marginal Quality Water Supplies (V-MQW), Terrestrial Water and Carbon Dynamics (TWCD), and Sustainable Infrastructure (SI)—all anchored by a unifying Social Dynamics (SD) group. This integrated structure provided strategic coherence to the five-year effort, ensuring that each team's work contributed to a comprehensive understanding of the complex, interdependent natural and human systems shaping Oklahoma's most persistent challenges.

Each focus area addressed high-stakes issues central to Oklahoma's environmental and economic future: increasing variability in weather patterns, changing water quality and availability, changing patterns of land use, and growing challenges to infrastructure reliability. Historically, addressing these concerns in isolation has exacerbated social divisions and policy gridlock. By approaching them as interconnected, S3OK enabled a reframing of problem boundaries and fostered more constructive dialogue across stakeholder groups. This integrated model also offered a basis for negotiating value tradeoffs—balancing environmental, economic, and social priorities in pursuit of broadly supported, socially sustainable solutions.

Throughout the project, cross-sector collaboration was enriched with inputs from Oklahoma households (via the **M-SISNet),** strategic interdisciplinary exchanges within the EPSAN, and interactions with diverse opinion leaders through the OLAN. This approach created a continuous feedback loop that grounded research in lived realities and policymaking contexts in Oklahoma.

The Oklahoma Meso-Scale Integrated Socio-Geographic Network (M-SISNet) *is a panel survey of up to 2,500 households across Oklahoma that gathers insights on perceptions of key problem areas, feasibility of solutions, and willingness to support proposed solutions.*

These partnerships allowed the project to:

- Strengthen and enhance interdisciplinary collaboration within Oklahoma's research institutions
- Push the boundaries for innovative solutions to some of the region's most persistent societal issues
- Establish a visible testbed for integrating scientific research, community outreach, education, and collaborative problem-solving to address pressing challenges in an increasingly fragmented society.
- Position Oklahoma as a leader in developing and applying science-driven, inclusive solutions to urgent socio-environmental issues

This chapter will introduce the teams working throughout the five-year project and the focus of their research:

- Social Dynamics (SD)
- Changing Seasonal to Subseasonal Weather Patterns (S2S)
- Variable and Marginal Quality Water Supplies (V-MQW)
- Terrestrial Water and Carbon Dynamics (TWCD)
- Sustainable Infrastructure (SI)

Social Dynamics (SD) Team

THE SD TEAM FOCUSED ON PEOPLE'S PERCEPTIONS AND BELIEFS SURROUNDING WICKED PROBLEMS.

The Social Dynamics (SD) team examined the pivotal role of public perceptions and social narratives in shaping Oklahoma's ability to respond to wicked problems. These perceptions influence individual behaviors, collective decision-making, and the broader societal capacity to adapt to emerging threats across infrastructure, water systems, land use, and changing weather patterns. Drawing on data from the M-SISNet, the SD team:

- Measured and modeled the perceptions and beliefs underpinning social narratives that fueled debates among the public, opinion leaders, and scientists about the pressing issues identified in the project's focus areas.
- Evaluated how pervasive narratives hindered collective action toward convergent solutions that recognized the complex human-driven origins of these challenges.
- Assessed social valuation of potential solutions, including willingness to pay for sustainable options.

By providing a structured framework for understanding social dynamics, the SD team facilitated the identification of socially sustainable solutions aimed at Oklahoma's most critical challenges. S3OK's distinct yet interrelated focus areas were used to enhance understanding of overlapping dynamics that drive these issues. The team's objective was to identify overlapping problems and associated solution sets that fostered consensus and constructive engagement and to reframe (or steer clear of) the kinds of divisive narratives that often derail constructive problem-solving. Through this lens, the Social Dynamics team supported the identification of practical solution sets that aligned with public values and institutional capacities, contributing to more resilient governance structures across the state.

The Social Dynamics Team advanced six goals throughout the project:

1. **Evaluate and Model Narrative Mechanisms**: The SD team aimed to deeply understand the drivers behind attachment to competing social narratives, particularly how these narratives shape public opinion, influence decision-making, and contribute to social polarization. By analyzing these factors, the SD team sought pathways to reduce tensions and foster more constructive and collaborative discourse around pressing issues in Oklahoma.

2. **Collaborate Across Focus Areas**: Recognizing that the project's focus areas are interconnected, the Social Dynamics team worked closely with other teams to ensure that insights from each area informed a holistic approach. This collaboration enabled the integration of diverse perspectives, helping to align strategies for addressing complex and intersecting challenges.

3. **Leverage New Research**: Utilizing data from the M-SISNet, EPSAN, and OLAN, the team employed advanced analytic methods to capture evolving public sentiment across different Oklahoma stakeholder groups (the public, scientists, and opinion leader practitioners), enabling the refinement of engagement strategies and solution design in near real-time.

4. **Support Inclusive Problem Definition**: Through robust data collection and analysis, the team sought to develop more inclusive and nuanced problem definitions that considered the diverse experiences and perspectives of Oklahoma's communities. This inclusivity was aimed at fostering a comprehensive understanding of issues that would resonate with and engage a broader range of stakeholders.

5. **Systematically Evaluate Solution Sets**: The team conducted a rigorous evaluation of potential solutions, assessing each for practical feasibility, long-term sustainability, and social acceptance. This goal was essential for identifying solutions that not only addressed technical aspects but also aligned with community values and were adaptable to Oklahoma's diverse needs.

6. **Assess Sustainable Policy Mechanisms**: By studying policy mechanisms, the team aimed to identify approaches that could realistically implement socially sustainable solutions to wicked problems. This involved assessing policy durability, stakeholder buy-in, and environmental impact to ensure that selected policies supported resilience and sustainability in Oklahoma's communities.

Changing Subseasonal to Seasonal Weather Patterns (S2S) Team

THE S2S TEAM FOCUSED ON CHANGING WEATHER PATTERNS AND THE WICKED PROBLEMS ARISING FROM THOSE CHANGES.

The S2S Team addressed the shifting weather patterns driving transformation across both natural and human systems in Oklahoma **(Figure 2.1)**. These subseasonal to seasonal shifts, occurring on scales of 10–90 days, included fluctuations in average and extreme precipitation and temperature. With such changes arising in the context of competing social narratives about the impacts of human activity on the climate, recognizing and responding to these evolving S2S patterns presented unique challenges. To address these changing weather patterns, the S2S focus area team conducted comprehensive research to:

a. Deepen understanding of the atmospheric and land processes driving changes in S2S patterns
b. Refine models and improve the predictability of S2S events
c. Generate critical data for managing Oklahoma's water, carbon, and infrastructure systems

By advancing basic science and predictive capabilities around S2S events, the team aimed to support Oklahoma opinion leaders (through the OLAN) and households (via M-SISNet) in developing socially sustainable solutions to the increasingly frequent and diverse threats impacting communities across the state. The primary objective of the S2S team was to improve knowledge of S2S-related atmospheric and land processes and enhance predictive accuracy, ultimately enabling the development of outlook forecasts that could better equip Oklahomans to respond to and manage climate-related risks.

Throughout the project, the S2S team advanced five goals:

- **Enhance Knowledge of Atmospheric and Land Processes**: The S2S team aimed to deepen understanding of the atmospheric and land processes driving subseasonal to seasonal (S2S) events in Oklahoma, with particular attention to "weather whiplash" events. This research provided insights into the mechanisms contributing to changes in precipitation and temperature patterns and identified factors that impact predictive accuracy in the region.
- **Improve Predictive Skill for S2S Events**: The team worked to improve forecasting models, enabling the development of "outlook" forecasts for S2S events that included measures of certainty. These advances offered Oklahoma communities and stakeholders tools for more reliable weather projections and future preparedness.
- **Support Cross-Domain Data Sharing and Utilization**: Data from S2S outlook forecasts generated throughout the project were integrated across team collaborations with TWCD, VMQW, SD, and SI groups. These data sets and insights provided valuable S2S context that underlies cross-cutting challenge areas while informing modeling of water availability, infrastructure vulnerability, wildfire risk, and land management strategies.
- **Engage with Focus Areas to Address Infrastructure, Water, and Land Needs**: By working with other focus area teams, the S2S team contributed to an integrated understanding of infrastructure, water, and land use challenges in Oklahoma. This collaboration enhanced the capacity for addressing the impacts of S2S events on these critical systems.
- **Provide Inputs for Socially Sustainable Solutions Modeling**: S2S outcomes delivered essential inputs to the social dynamics team, supporting their work in modeling potential socially sustainable solutions at the intersections of land use, water availability, and infrastructure. These results laid a foundation for community-driven strategies to navigate and mitigate Oklahoma's climate challenges.

Variable- and Marginal- Quality Water Supplies (V-MQW) Team

THE V-MQW TEAM FOCUSED ON WICKED WATER PROBLEMS SUCH AS WATER AVAILABILITY AND DEMAND.

The V-MQW focus area addressed issues surrounding Oklahoma's water demands, which are projected to increase by 600,000 acre-feet per year between 2007-2060[1]. Reliable water supplies are needed to provide for these demands while meeting the state's goal of capping freshwater use to 2010 levels.

However, freshwater supplies are declining due to reservoir sedimentation and groundwater overdraft and are increasingly vulnerable to S2S variability[2]. Concurrently, volumes of oil and gas "produced water," municipal wastewater, and stormwater are increasing with continued oil and gas development and urbanization. Disposal of produced waters has been correlated with seismicity, potentially impacting infrastructure and resulting in energy production curtailment in some regions.

Marginal-quality water (MQW) *refers to water of lower quality than fresh, potable water but can still be used for certain purposes with appropriate management and precautions. In Oklahoma, source of MQW include stormwater runoff, produced water from oil and gas, and treated wastewater.*

The challenge is finding a mix of solutions that allow Oklahoma's diverse array of **marginal-quality waters (MQW)** to be economically treated for beneficial use to address S2S-related water scarcity, waste disposal, and infrastructure risk while supporting continued energy production and economic growth. Moreover, water treatment solutions must also receive broad support from relevant stakeholders and elicit wide-ranging support from the public for implementation across Oklahoma's diverse water systems.

Our researchers hypothesized that the quality of Oklahoma's MQW can be improved by developing and deploying solutions based on chemical, biotechnological, hydrological, engineering, and sociological principles, with a focus on expanding opportunities for MQW reuse. The reuse of MQW has the potential to provide substantial quantities of water for the industrial, energy, agricultural, and municipal sectors, making communities and economies more resilient to increasing S2S variability.

Quantities of MQW are estimated to far exceed consumption in Oklahoma, which makes it a vast, under-tapped resource if it can be handled safely. The V-MQW Team therefore focused initial efforts on addressing the following uncertainties:

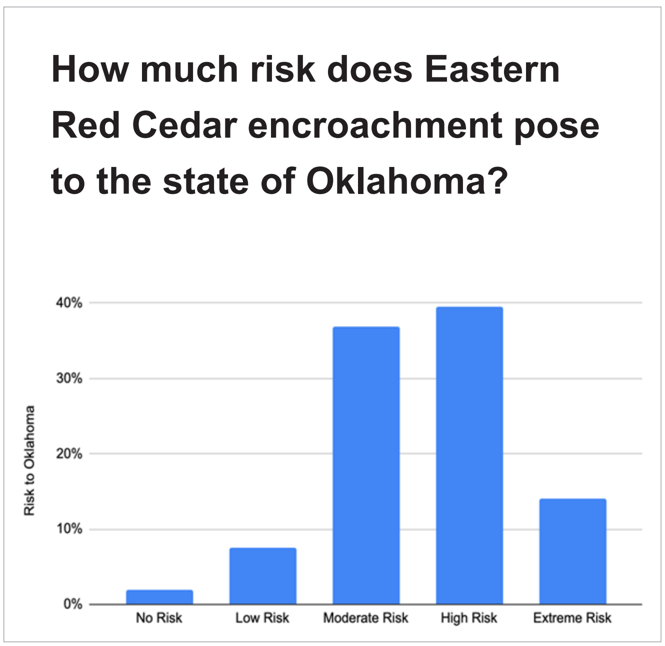
a. What happens to the leftover pollutants in MQW trace pharmaceuticals, hydrocarbons, and other emerging chemicals)? What risks do they pose, and how can they be removed?
b. What is the level of public, industry, and regulatory acceptance of using reclaimed water?
c. What are the energy and carbon footprints and related economic costs associated with conventional and new, innovative water treatment systems?
d. What are the impacts of S2S variability on the infrastructure and operations of reuse systems?

In response to these uncertainties, the V-MQW team's objective was to develop new natural and engineering technologies and modeling schemes for more effective reuse. By extension, this generated an improved understanding of water treatment efficiencies, which are beneficial to utility end users. Throughout the project, the V-MQW team sought to advance three key goals:

1. **Identify Sustainable Treatment Solutions**: The V-MQW team explored innovative active, passive, and hybrid treatment systems for stormwater, wastewater, and produced water to address the competing interests surrounding the use of MQW. This exploration sought to uncover socially sustainable solutions that balanced the needs of different stakeholders.

2. **Develop Advanced Treatment Technologies and Models**: V-MQW research led to the development of state-of-the-art basic science and natural and engineered technologies, along with advanced modeling schemes that advanced understanding needed to consider water reuse practices. These advancements contributed to more effective strategies for treating and reusing water resources.

3. **Improve Understanding of Treatment Efficiencies**: V-MQW research provided key insights into the efficiencies of different treatment methods, focusing on factors such as contaminant fate and removal, flow rate, energy use, and carbon emissions. These findings offered valuable guidance for utility sectors, policymakers, regulators and end-users. They also supported more informed system designs, technology and program decisions, and risk communication regarding water management practices.



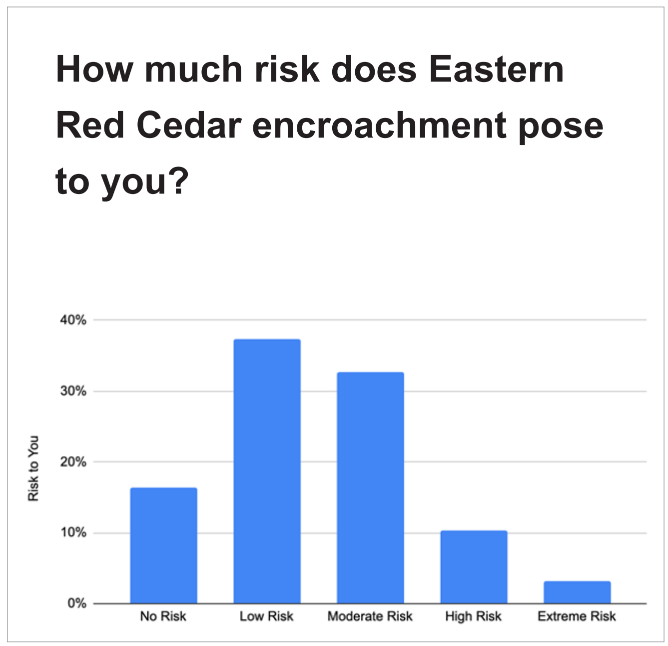


Figure 2.1. Results from Wave 4 survey of the M-SISNet focused on the public's concern about land management in Oklahoma.

Terrestrial Water and Carbon Dynamics (TWCD) Team

THE TWCD TEAM COLLECTED DATA REGARDING WICKED PROBLEMS AFFECTING LAND MANAGEMENT, A CENTRAL FOCUS OF THE S30K PROJECT. THIS TEAM WAS ALSO A CRUCIAL LINK BETWEEN OTHER PROJECT DOMAINS WHICH OFTEN OVERLAPPED.

The TWCD (Terrestrial Water and Carbon Dynamics) focus area was central to addressing the complex problems within the S3OK project scope, particularly due to conflicting policy narratives surrounding carbon management and the impacts from various land management practices, such as increased risk of impacts from wildfire. This focus area played a pivotal role by fostering linkages with other project domains, creating opportunities for engaging key stakeholder groups in discussions aimed at both defining these critical problems and identifying potential sustainable solutions. The interplay between land use and carbon cycle issues was especially important since terrestrial ecosystems and the cycling of carbon and water were integral to the broader environmental and infrastructural challenges addressed in the S3OK project.

The primary objective was to collect and calibrate essential data to inform management decisions that could impact ecosystem productivity, carbon storage, and water yield for agricultural, municipal, industrial, and ecological purposes **(Figure 2.1)**. These insights helped shape strategies for managing Oklahoma's land and water resources in a way that balanced competing demands while enhancing long-term sustainability.

The TWCD team worked to advance four primary goals throughout the project:

1. **Inform Stakeholders on Carbon and Water Dynamics:** The Land/Water Observatory and Land/Water forecasting efforts associated with TWCD were designed to inform Oklahoma households (via M-SISNet), the peer science advisory network (EPSAN), and Oklahoma opinion leaders (OLAN) about new ways to understand broad-scale carbon and water dynamics as they relate to climate change and resource management.

2. **Inform Stakeholders on the Impacts of Land Use and Climate Management Decisions:** Insights from TWCD research provided a deeper understanding of the mechanisms underlying ecosystem carbon and water dynamics, as well as the tradeoffs involved in managing these resources. These results addressed globally relevant scientific questions and helped calibrate the Land/Water Observatory initiatives. The process and outcomes also informed diverse stakeholders about how land-use and climate-management decisions impacted ecosystem productivity, carbon storage, and water availability for agricultural, municipal, industrial, and ecological uses.

3. **Support Sustainable Water and Carbon Management:** The tradeoffs identified in these studies became essential inputs for shaping socially sustainable solutions focused on water use, reuse, and carbon reduction. Given the significant footprint of grazing and cropland in Oklahoma, it was important to understand how different management strategies affected soil carbon and water. These results were modeled for different plant species and systems to inform predictive models (Earth-system, crop, economic, and others), guiding future land-use decisions.

4. **Develop Models that Balance Economic, Environmental, and Social Needs:** TWCD research fed insights developed throughout the project into models designed to balance

long-term economic, environmental, and social needs through socially sustainable solutions. Recognizing that strategies increasing soil carbon sequestration might also enhance soil water-holding capacity and agricultural productivity, the scenarios developed for climate, water management, and agriculture provided stakeholders with critical information to reframe complex challenges. This helped alleviate social barriers, moving stakeholders closer to essential solutions.

Sustainable Infrastructure (SI) Team

THE SI TEAM FOCUSED ON HOW WICKED PROBLEMS AFFECT WATER AND ENERGY INFRASTRUCTURES.

The Sustainable Infrastructure (SI) team aimed to advance a comprehensive understanding of how Oklahoma's interdependent water and energy infrastructures were affected by severe weather and subseasonal-to-seasonal (S2S) extremes throughout the project. This includes events within and outside of the subseasonal-to-seasonal scale, such as pluvial events (periods of extreme precipitation) and droughts. The SI Team, in tandem with the TWCD Team (see above), also focused on important carbon cycle dynamics (including changing land use and increasing wildfires), and evolving water management/reuse practices (encompassing both surface and subsurface systems, and accounting for changes in storage and pipeline capacities).

The objective of the SI team was to construct an aggregated resilience model that captures the effects of stakeholder decision-making on the functionality and interconnectivity of Oklahoma's critical infrastructure systems. By developing an aggregated resilience model, this research provided critical insights into the interactions between these factors, offering a foundation for devising a broad spectrum of solutions that strengthened infrastructure resilience across the key project domains: weather, water, and land use. The model also supported the creation of socially sustainable strategies to enhance the state's resilience.

The SI research team had four overarching goals throughout the project:

1. Advance Understanding of Infrastructure Vulnerabilities: The SI team used the results from the S2S, V-MQW, and TWCD teams' modeling efforts, along with recorded and projected data on induced seismicity in Oklahoma, to assess the effects of and uncertainties surrounding severe weather events, S2S extremes, wildfires, and induced seismicity on both current and future infrastructure components. This included analyzing critical elements such as individual pipelines, transmission towers, bridges, and broader infrastructure networks (water, electric power grid, transportation), as well as the interdependencies between these networks.

2. Develop an Aggregated Resilience Model: The SI team developed an aggregated resilience model to integrate these insights, highlighting how the combined impacts of weather extremes, environmental hazards, and infrastructure interdependencies influenced the overall resilience of Oklahoma's systems. This model was a key tool for understanding how interdependent infrastructure systems responded to current and future disruptions.

3. Incorporate Stakeholder Decision-Making: The project characterized how the decision-making behaviors of diverse Oklahoma

stakeholders affected the performance and resilience of interdependent infrastructure systems. It explored how different stakeholder priorities and choices influenced infrastructure functionality and the development of sustainable solutions.

4. Formulate Socially Sustainable Solutions: The aggregated resilience model was used to design solutions that were not only technically viable but also socially sustainable. These solutions aimed to enhance the long-term resilience of Oklahoma's interconnected infrastructure systems, ensuring they could withstand and recover from future challenges while accounting for social equity and environmental sustainability.

References

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