CHAPTER 4

Project Engagement, Structure, and Process

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CHAPTER 4

Project Engagement, Structure, and Process

This chapter details the strategies for project engagement, overall project structure, and iterative processes developed to operationalize project vision and ensure that S3OK research remains both rigorous and relevant. Together, these elements illustrate how the S3OK project bridges research and practice.

This chapter will address:

- Initial engagement and ongoing cross-sector collaboration
- Project structure
- Project process

Initial Engagement and Ongoing Cross-Sector Collaboration

The project began with targeted initial engagement activities that explicitly brought together stakeholders from diverse sectors to focus on the specific goals of the project. These early interactions set the stage for deeper collaboration and created a platform for mutual learning across disciplines. As the project progressed, additional cross-sector collaborations emerged, expanding beyond the initial framework. These collaborations were often driven by shared interests and the recognition that complex problems require multifaceted solutions. The following sections will address examples of emergent collaborations and explain cross-sector communication.

Examples of Emergent Collaborations

Through continued cross-sector engagement and collaborations, S3OK scientists were able to identify the kinds of analyses that were most needed and useful in a practical domain while advancing key elements of the science proposed. These partnerships not only shaped the direction of scientific research over the course of the project but also empowered stakeholders to address critical issues within their domains, demonstrating the reciprocal nature of the project. While building these collaborations required significant time, effort, and alignment of interests, the resulting synergy and shared commitment are essential for tackling complex, "wicked" problems and advancing sustainable, impactful outcomes.

We partnered with existing Oklahoma organizations, such as utilities and water management groups, to help identify areas of need and work together towards solutions.

Examples of these emergent collaborations include:

- D&B Oilfield Services
- The Oklahoma Electric Cooperative and the Oklahoma Association of Electric Cooperatives
- Oklahoma Water Reuse Action Plan and the Oklahoma Comprehensive Water Plan

D&B Oilfield Services

D&B Oilfield Services partnered with S3OK researchers and was an invaluable private industry partner to the project, significantly advancing the development of an economically viable and scalable treatment train for produced water. In Oklahoma, the oil and gas industry operations generate billions of gallons of produced water annually, creating both a challenge and an opportunity for water reuse. D&B Oilfield Services provided critical feedback to S3OK researchers to help address this issue, supplied produced water samples for testing, and hosted a working group meeting with a tour of their facilities, offering firsthand insights into full-scale wastewater treatment and re-injection processes. Their guidance highlighted resource extraction opportunities, such as iodine recovery and non-potable agricultural uses like cultivating Bermuda grass for state highway landscaping, Oklahoma's largest consumer of the crop. This collaboration underscores the importance of cross-sector partnerships in driving innovative, practical solutions that balance environmental and economic goals.

The Oklahoma Electric Cooperative and the Oklahoma Association of Electric Cooperatives

S3OK researchers partnered with the Oklahoma Electric Cooperative (OEC) and the Oklahoma Association of Electric Cooperatives (OAEC) to establish a data-sharing agreement that enabled detailed analysis of the electric grid's performance during the October 2020 ice storm. Using fine-grained outage data, the study revealed critical vulnerabilities in traditional radial distribution systems and identified specific failure modes caused by icing and tree limb interference, providing actionable insights for OEC's resilience planning. This collaboration, rare due to the typical reluctance of utilities to share detailed data, fostered trust and innovation, allowing OEC to improve grid resilience while enabling S3OK scientists to develop a framework for analyzing interdependent infrastructure systems facing multiple hazards.

Oklahoma Water Reuse Action Plan and the Oklahoma Comprehensive Water Plan

The Oklahoma Water Reuse Action Plan (OWRAP) exemplifies cross-sector collaboration between OLAN and EPSAN, with S3OK researchers playing a leading role in developing key components of the plan. In particular, S3OK researchers supported OWRAP in survey design, data analysis, stakeholder engagement, and technical advancements. By integrating S3OK researchers into the development of OWRAP and the broader Oklahoma Comprehensive Water Plan (OCWP), the collaboration aimed to create actionable solutions for water reuse challenges while providing a sustainable framework for implementation. This process also helped inform and refine S3OK research, incorporating diverse perspectives and interdisciplinary expertise into ongoing scientific activities, including soil and agricultural sciences, to ensure impactful and symbiotic outcomes.

Cross-Sector Communication

It can be challenging to maintain effective communication across stakeholders with different backgrounds, schedules, and capacities. In response to these challenges, S3OK designed communication and collaboration processes to support successful communication. Successful communication depends on adapting processes to meet changing needs and avoid overwhelming stakeholders with irrelevant information. It is also important to leverage multiple channels of communication, like Slack, email, and in-person engagement.

Revisiting and revising communication processes over time as stakeholders expanded and new information became available was essential. For

We continuously refined our communication methods to improve stakeholder understanding and engagement.

example, S3OK used a "soft launch" approach to share updates and event invitations, allowing stakeholders to stay informed at a surface level without receiving excessive details.

Tailoring materials, such as offering concise fact sheets instead of full reports, and adjusting strategies based on the audience, improved communication and transparency. Established networks like EPSAN were leveraged to deliver targeted, less frequent updates, while embedded communication in meetings and verbal presentations helped engage stakeholders effectively. Continuous development and refining of communication processes, aligning strategies with stakeholder needs, and fostering informal channels have been central to S3OK's success, building trust and support to achieve shared goals.

Project Structure

The S3OK project was structured around three primary stakeholder groups that remained engaged with one another throughout the project. These included the:

- Extended Peer Science Advisory Network (EPSAN)
- Opinion Leader Advisory Network (OLAN)
- Oklahoma Meso-Scale Integrated Socio-Geographic Network (M-SISNet)

These groups were composed of leaders from different sectors, scientists from several Oklahoma universities, and a representative sample from the public. EPSAN and OLAN interacted throughout the duration of the project and formed the core structure of the S3OK project in the effort to identify acceptable solutions for a diverse group of stakeholders and Oklahoma residents.

Extended Peer Science Advisory Network (EPSAN)

The Extended Peer Advisory Network panel consisted of approximately 100 scientists from several institutions across the state of Oklahoma. This included an "internal peer network" of project team members, including science-focus team area members, postdoctoral researchers, and graduate students. The internal network was complemented by "external peer network" scientists, leading experts in their fields who focused on Oklahoma and had a unique ability to advise the project. These individuals held academic positions, but their work strongly aligned with practice and policy, thereby bridging an important gap between the science efforts and policy priorities.

Members of the EPSAN were invited to attend the annual Academy meeting, where they interacted with other scientists across different focus areas and with OLAN members to help identify and build sustainable solutions. Combined, the EPSAN and OLAN created a holistic panel of experts uniquely positioned to tackle Oklahoma's "wicked" problems.

Opinion Leader Advisory Network (OLAN)

The S3OK Opinion Leader Advisory Network (OLAN) played a vital role in the EPSCoR project, serving as a practitioner advisory group of leaders from Oklahoma's public, private, and nonprofit sectors **(Figure 4.1)**. This network of opinion and thought leaders provided critical insights into how Oklahoma leaders perceived and responded to the state's complex, "wicked" problems. OLAN members offered constructive feedback—sometimes challenging researchers—on the direction and impact of S3OK research while helping integrate science and policy into

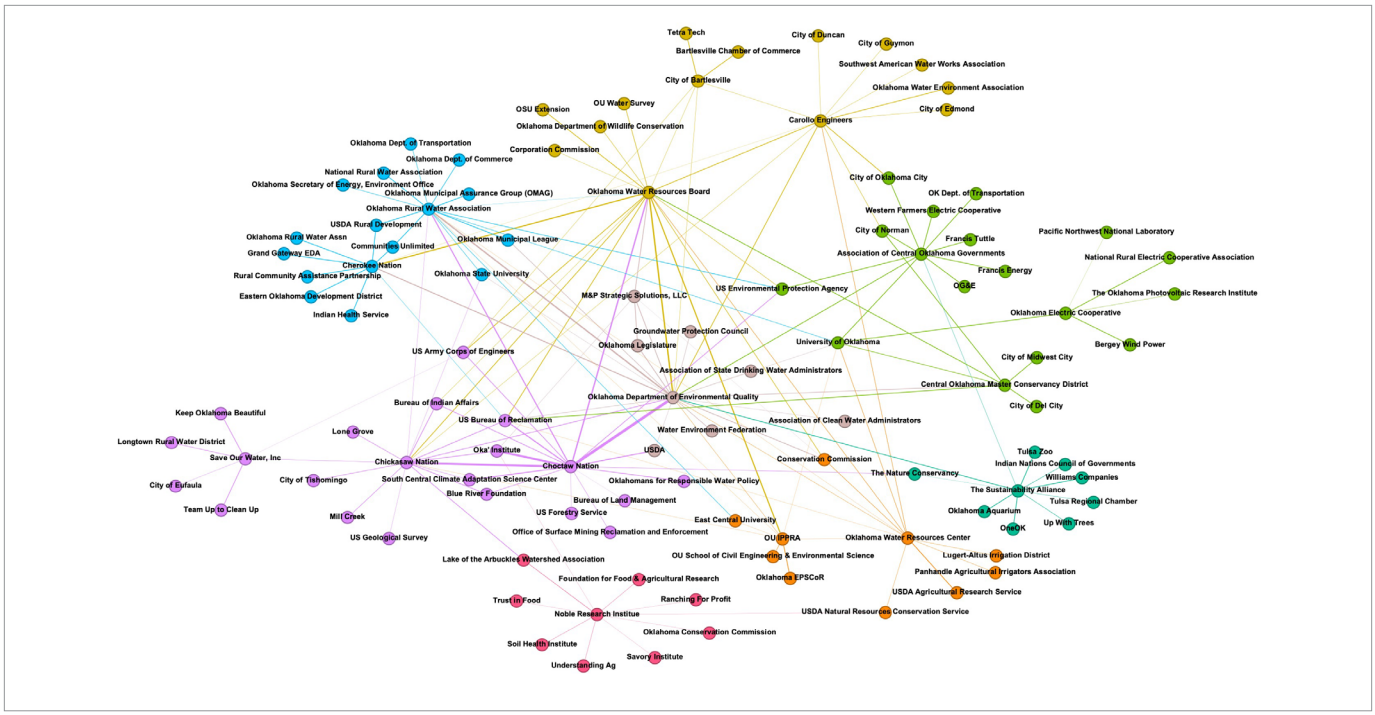

Figure 4.1. Map of the networks of collaborative relationships of OLAN-member organizations

strategic solutions for Oklahoma. Over time, they have advocated for implementing S3OK strategies and solutions in their respective fields. Conversely, OLAN members provided access to crucial data streams and resources that enabled S3OK research to advance in ways that would not have been possible without their support.

The OLAN was composed of over 70 individuals representing organizations across public, private, nonprofit, municipal, governmental, and tribal sectors. Recruitment was initially led by a community leader with over 30 years of experience in Oklahoma policy and politics, later augmented and continued by a key research practitioner with deep expertise in public and nonprofit collaboration. Particular effort was made to include a diverse array of groups, such as representatives from Tribal Nations and rural communities, to ensure diverse perspectives and equitable representation. The result was a dynamic advisory network that brought together individuals with varying experiences, interests, and organizational resources to collaboratively address Oklahoma's pressing challenges at the intersection of infrastructure, land use, and changing weather.

Oklahoma Meso-Scale Integrated Socio-Geographic Network (M-SISNet)

The Oklahoma Meso-Scale Integrated Socio-Geographic Network (M-SISNet) is a cornerstone panel survey designed to collect valuable insights from a network of up to 2,500 Oklahoma households. Since its initial deployment in 2014, M-SISNet has provided essential data to support EPSCoR research initiatives[1]. The survey utilized an address-based random sampling approach, stratified by region, to ensure comprehensive geographic representation across both rural and urban areas of Oklahoma.

Administered biannually as part of the S3OK project since 2021, each iteration, or wave, of the survey sent to Oklahoma households was conducted online. The surveys collected data on public perceptions of weather, climate change, household resource use (e.g., water and energy), and other pressing topics. Core questions, such as those related to water, land use, and infrastructure, were repeated annually, while each wave also featured unique, thematic questions aligned with the science focus areas of the S3OK project.

The M-SISNet provided valuable insight from the public that informed ongoing S3OK research and was used to complement insights derived from other data components of the project. After the initial, wave 1 baseline survey, subsequent surveys included targeted sets of questions, or batteries, that addressed timely issues. To date, these have included topics related to S3OK such as modernization of the electrical grid, water reuse, and S2S weather products—among others. Each targeted set of questions offered actionable insights into public attitudes and willingness to support solutions, such as public willingness to pay for infrastructure improvements. These targeted question sets were constructed with insight from the science focus team areas and included:

- Wave 2: Modernization of the electrical grid
- Wave 3: Water re-use
- Wave 4: Eastern Red Cedar encroachment
- Wave 5: S2S weather products
- Wave 6: Infrastructure (energy and transportation infrastructure)
- Wave 7: Wildfire, water re-use, and produced water
- Wave 8: Water re-use

Data from each survey wave were made publicly available and shared with other science teams and the OLAN to ensure that research aligns with public priorities and stakeholder needs. Each wave of the survey was designed to reflect the ongoing research efforts, policy dynamics, and focusing events (like the 2021 cold air outbreak), as well as conversations across stakeholder groups. The M-SISNet provided input from the public that helped identify stakeholder perspectives on the causes and impacts of complex challenges, as well as acceptable pathways for resolution. This process ensured that survey data continually shaped project outcomes, aligning research and policy recommendations with the needs and values of Oklahoma citizens.

Student Leadership and Professional Development

A critical element of the S3OK initiative was the recognition of student researchers as key stakeholders, underscoring their essential role in driving and sustaining the project's objectives. Students were not merely participants but active contributors whose work formed a vital part of the project's outcomes. By engaging in hands-on research, students gained a deep understanding of the complexities associated with "wicked problems" in Oklahoma and developed the skills necessary to address them. They collaborated within interdisciplinary teams, bridging diverse fields of expertise to tackle challenges at the intersections of science, policy, and community engagement. Their contributions led to numerous peer-reviewed publications, presentations at National Science Foundation (NSF) site visits and EPSCoR events, and appearances at discipline-specific conferences and workshops, showcasing their work on local, regional, and national platforms **(Figure 4.2)**.

These opportunities not only advanced students' technical expertise and research capabilities but also trained them in interdisciplinary collaboration. This skill is increasingly critical for addressing complex societal issues that demand holistic, multifaceted solutions. Through their work on the project, students learned to integrate diverse perspectives, navigate institutional differences, and translate scientific findings into actionable recommendations for stakeholders.

Central to this initiative was the creation of a student-led, project-wide professional development group, supported by the Executive Board (EBoard). This group served as a cornerstone of the project's commitment to fostering the next generation of leaders. Students took ownership of their professional development by advocating for platforms to present their work, including oral and poster presentations, ensuring their research was visible and impactful. The group also spearheaded initiatives to create networking opportunities, allowing students to connect with peers across institutions and disciplines.

Student participation was a critical element of the project.

Figure 4.2. Student poster presentations at OK EPSCoR's Research Day at the Capitol.

These efforts were complemented by EBoard–supported, student-designed professional development events tailored to meet the unique needs and challenges of the student researchers. Faculty mentors provided guidance to ensure these events offered meaningful and relevant support, equipping students with the tools to succeed in their academic and professional careers.

The project's approach to student engagement extended beyond technical training to include leadership development. Students were empowered to assume leadership roles, organize events, and advocate for their own professional growth, reinforcing their confidence and capacity to influence the direction of interdisciplinary research. These experiences prepared students not only to excel in their current academic pursuits but also to become champions of interdisciplinary collaboration in their future careers.

In addition to advancing their individual growth, students contributed to the sustainability of the S3OK project by becoming part of a broader professional network that bridges academia and practice. By fostering meaningful connections with other researchers, policymakers, and community leaders, students played an integral role in translating project findings into actionable strategies for addressing Oklahoma's wicked problems. Their efforts created a foundation for continued interdisciplinary engagement and ensured that the lessons learned from the project would be carried forward into future initiatives.

These investments in student researchers have created a legacy of leadership, with emerging professionals who are equipped to advocate for evidence–based solutions, interdisciplinary approaches, and community–engaged science. Through their contributions to S3OK, students have become integral to the project's success, forming a network of champions committed to advancing innovative, sustainable solutions to pressing societal challenges. This legacy ensures that the project's impact will endure as these leaders carry forward its principles and approaches in their careers across academia, policy, and practice.

Project Process

In addition to carefully curating a project structure to optimize the ability to meet project objectives, the S3OK project relied on a foundation of iterative engagement processes that facilitated the development of solution sets through select

touchpoints throughout the project's 5-year period. In this section, we outline:

- The engagement process
- Solution sets
- Solutions refinement process
- Working Group solutions refinement

Engagement Process

The S3OK engagement process was built around a dynamic, multifaceted approach that offered recurring opportunities for meaningful collaboration between project stakeholders. Initially centered on a three-pillar programmatic structure — Research Retreats, State Conferences, and Academies — this engagement process facilitated regular in-person interactions and fostered coordination and collaboration throughout the project.

In response to evolving stakeholder needs and emerging collective interests, the engagement process expanded in Years 3 through 5 to include topically oriented collaborative engagements. This evolution introduced focus-group-style Deep Dive discussions and Working Groups, which allowed concentrated stakeholder groups to explore specific cross-cutting themes in greater depth. These additions enhanced the project's capacity to address complex challenges and encouraged more focused, impactful collaborations.

By adapting to stakeholder input and evolving priorities while maintaining consistent communication, the S3OK Engagement Process exemplifies a responsive and inclusive approach, ensuring sustained engagement and meaningful outcomes for all involved.

Annual Research Retreats

As part of the initial three-pillar programmatic approach to engagement in the S3OK project, the S3OK Research Retreats were a cornerstone for fostering collaboration, advancing interdisciplinary research, and integrating education with research initiatives. Held each fall, these retreats were carefully designed to achieve multiple objectives:

1. **Collaboration and Knowledge Exchange:** The retreats provided a platform for researchers to share data, findings, and methodologies, facilitating the evolution of project goals and priorities. Student and early career researcher poster sessions and presentations highlighted ongoing work, while panel discussions and group engagements facilitated the exchange of ideas and the formation of new collaborations.
2. **Mentorship and Integration:** A key focus of the retreats was integrating students and postdoctoral researchers into the broader project team and providing structured mentorship for junior faculty. This approach ensured a talent pipeline and supported capacity building across career stages.
3. **Strategic Focus and Adaptation:** Each annual retreat emphasized a specific theme aligned with the project's evolving needs **(Figure 4.3)**. Themes have included strengthening networks within the scientific community, addressing state-specific research priorities, and fostering partnerships between academia and industry. These targeted efforts ensure that the retreats remain responsive to emerging challenges and opportunities, maximizing their impact on the project's goals.

In addition to these objectives, the retreats were instrumental in promoting the integration of research and education, developing strategies to increase funding opportunities, and positioning the project for sustained success. Moreover, research retreats provided the S3OK researchers with an opportunity to iterate on the evolution of the projects' focus and scope based on what insights had been obtained in the year prior.

State Conferences

The second avenue for bolstering engagement in the S3OK project was the annual State Conferences. These annual conferences provided an essential and additional platform for sharing research progress, fostering collaboration, and engaging with a diverse network of stakeholders. Held each spring, these conferences were distinct from the fall Research Retreats, offering a broader public-facing venue to highlight S3OK's

achievements and connect with the broader research and stakeholder community.

The conferences featured keynote presentations by nationally recognized researchers, poster sessions, and targeted discussions that facilitated networking and the exchange of ideas among participants. Attendees included S3OK principal investigators (PIs), researchers, postdoctoral scholars, students, and stakeholders, ensuring a multidisciplinary and inclusive atmosphere.

Focused on themes central to the S3OK mission—weather, water, land management, and infrastructure—the conferences showcased progress and ongoing objectives, reinforcing the project's relevance to state-specific challenges and national research priorities. Participants shared the most recent results from their research through scientific presentations and interactive poster sessions, offering opportunities for constructive feedback and collaboration.

These events also provided an avenue for NSF representatives and external evaluators to assess research outcomes and interact directly with the S3OK community, ensuring transparency and alignment with program goals. By bridging research and application, the State Conferences served as a dynamic space for engaging stakeholders, advancing project objectives, and strengthening the overall impact of the S3OK initiative.

Academies

A defining feature of the S3OK engagement structure, the S3OK Academies brought together S3OK researchers, EPSAN, and opinion leaders from the OLAN to connect and collaborate around tackling Oklahoma's "wicked problems." Held annually, these invitation-only events were aimed at providing a platform for researchers to share relevant findings from the year prior and collect data from participants that were used to guide the next iteration of research foci. This approach fostered interdisciplinary collaboration, advanced stakeholder engagement, and facilitated the development of actionable solutions for complex societal challenges.

Each Academy provided a unique, additional platform for the OLAN and EPSAN to engage with one another. They were mindfully designed to enable open dialogue, iterative knowledge exchange, and sustained participant engagement. By integrating diverse perspectives, the Academies served as a critical nexus for aligning scientific research with public priorities and policy feasibility. Key objectives of the S3OK Academies were**:**

- **Facilitating Face-to-Face Engagement**: Academies created opportunities for EPSAN and OLAN stakeholders to meet in person, strengthening collaborations and fostering trust.
- **Guiding Collaborative Research**: Discussions centered on ongoing collaborative research progress, sharing insights from previous Academies, and exploring new directions for addressing wicked problems.
- **Developing Sustainable Solutions**: The Academies were instrumental in crafting solutions-oriented scientific workflows to address complex, interconnected issues in Oklahoma.

In addition to explaining and discussing the science central to these issues, the Academies provided the OLAN and EPSAN an opportunity to focus and guide the project in a way that facilitates informed policymaking. The OLAN provided feedback that guided the EPSAN's efforts towards areas that had the most public salience or political feasibility. Over five years, this included:

- **2021 S3OK Academy:** Focused on the collective definition and prioritization of wicked problems. Participants engaged in roundtable discussions to identify areas of consensus and disagreement, establishing a foundation for future collaborative efforts.
- **2022 S3OK Academy:** Introduced Group Model Building (GMB) to refine problem definitions collaboratively. Pre-distributed

research summaries enabled attendees to maximize their networking and focus discussions on actionable goals. Engagement was further supported through Slack channels for ongoing collaboration and communication online to augment scheduled in-person programming. *For detailed analysis, see Olofsson et al. 2023*[2].

- **2023 S3OK Academy:** Achieved four key objectives, including disseminating concise updates on research progress, collecting data to refine solution sets, and strengthening connections within the S3OK network. This Academy deepened the iterative feedback process between OLAN and EPSAN members.
- **2024 S3OK Academy:** Marked a shift toward actionable solutions, debuting working groups to stakeholders. The Academy emphasized fostering lasting networks and preparing to implement research outcomes beyond the project's duration.
- **2025 S3OK Academy:** This capstone event focused on reviewing the project's achievements and facilitating discussions on future collaborations. It provided a comprehensive summary of S3OK's contributions and served as a launchpad for ongoing research and collaborations inspired by the initiative.

Through these annual Academies, S3OK combined diverse expertise to address Oklahoma's most pressing challenges. The events exemplified the project's commitment to fostering meaningful collaboration and advancing science-driven solutions with a lasting impact on policy and practice.

Year Three Deep Dives

Throughout the S3OK project and particularly at the May 2022 S3OK Academy meeting, OLAN and EPSAN members emphasized the need to develop cross-cutting understanding and approaches to S3OK advancements toward sustainable solutions to Oklahoma's wicked problems. This feedback led to the development of the Year Three S3OK Deep Dive discussion sessions, which were a strategic initiative to address five critical cross-cutting challenge areas identified through collaborative discussions with S3OK researchers and OLAN. Each in-person, focus-group-style discussion session was held in strategic locations across the state. Each deep dive was aimed at developing integrated understandings and innovative approaches to tackle key environmental and infrastructural challenges in Oklahoma around five cross-cutting topic areas:

- Implementing Land Management Strategies for Water Use Efficiency in the Context of Agricultural Systems: Explored barriers and opportunities in implementing various land management strategies for water use efficiency, including red cedar management, soil health, and related plant and livestock management practices.
- Unique Challenges for Small Water Systems: Focused on the unique challenges small water systems in Oklahoma face, including infrastructure maintenance and implementation of new technologies, revenue/funding sources for small system projects, and workforce and training needs.
- Stakeholder Engagement: Explored existing Oklahoma stakeholder networks and strategies for enhancing current collaborations that address key environmental problem areas in Oklahoma.
- Water Availability and Challenges in the Regulatory Environment: Focused on challenges and opportunities posed by overlapping jurisdictions and competing interests in water-related outcomes in Oklahoma, with an eye toward how the regulatory environment influences the feasibility and timeframe for potential solutions.
- Extreme Weather and Oklahoma Infrastructure Interactions (Wildfire Focus): Focused on the interactions of wildfires and infrastructure systems in Oklahoma within the context of rapidly changing climatological trends and increased wildfire risk.

By curating focus-group-style discussions with relevant and interested stakeholders from across

Figure 4.3. Deep Dives provided the opportunity for more dedicated engagement around cross-cutting areas of interest.

sectors, the S3OK Deep Dives provided a single, standalone touchpoint for more dedicated engagement oriented around a range of cross-cutting areas of interest. These events marked a significant refinement and conceptual turning point for identifying pathways for potential solution refinement.

Working Groups

S3OK researchers established three topically oriented working groups focused on broader problem areas as a result of iterative analysis of findings from the S3OK Deep Dives and in response to feedback from OLAN and EPSAN members throughout the first three years of the project. These working groups reflected areas of agreement and were designed to maximize synergistic efforts, broaden awareness of experimental successes and challenges, and provide a forum for discussing future funded collaborations. They also focused on aligning research directions with community and stakeholder needs and enhancing access to data and evidence-based outputs. The working groups target three key problem areas **(Figure 4.4)**:

- **Novel Hybrid Treatment and Reuse Options for Stormwater and Municipal Wastewater**: Explored innovative approaches to treating and reusing stormwater and municipal wastewater, with a focus on sustainability and efficiency.
- **Produced Water Reuse Potential for Oilfield and Agricultural Applications**: Investigated opportunities for repurposing produced water to support oilfield and agricultural needs, aiming to reduce waste and enhance resource sustainability.
- **Natural Hazards & Utility Resilience**: Focused on addressing challenges associated with infrastructure resilience and disaster preparedness in the face of natural hazards, ensuring utility systems can withstand and adapt to increasing risks.

Working groups met at regular intervals, both at in-person and online working group meetings, across years four and five of the project. These working groups provided a dynamic platform for researchers and stakeholders to co-develop

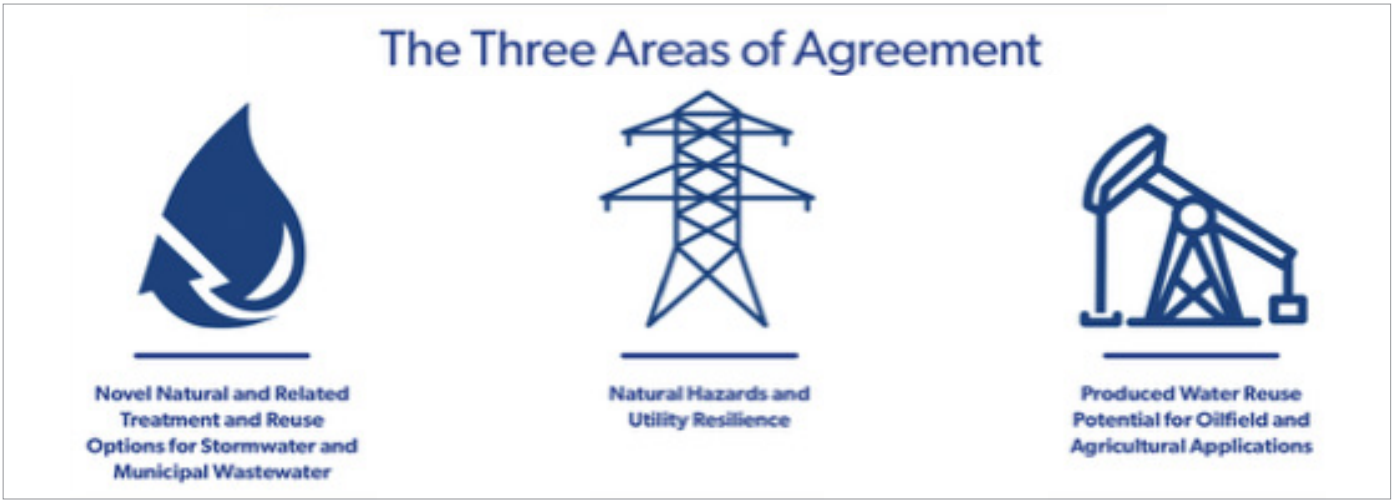

Figure 4.4. Three areas were identified for advancing research.

solutions, refine collaborative approaches, and identify actionable steps for addressing Oklahoma's environmental and infrastructural challenges as the project came to a close. Through these efforts, the working groups laid the foundation for impactful post–S3OK collaborations. Working groups served to:

- Maximize opportunities for synergistic efforts
- Provide broader awareness of experimental successes and challenges
- Serve as a platform for discussing the potential for future funded collaborations
- Shape future directional steps toward implementation with community and stakeholder needs in mind
- Enhance access to existing data, data systems, and other evidence-based outputs
- Serve as a springboard for post–S3OK collaboration

Solution Sets

The S3OK engagement process set the stage for the iterative feedback to be provided by OLAN to S3OK scientists during the project's midpoint at the Year 3 Academy. Here, attendees were provided with an overview of key scientific solutions to S3OK challenges in three domains:

1. Addressing the Impacts of Land Management Practices and Changing Weather Conditions on Water Availability for Agricultural Use/Land Management (ILM)
2. Evaluating Water Availability and Quality Under Changing Weather and Climate Conditions, with a Municipal Focus (WAQ)
3. Investigating Electric Infrastructure Impacts Resulting from Changing Land Cover, Weather, and Climate Conditions (EII)

During the session, participants in each breakout room were presented with 8–10 preliminary components of potential solutions designed to address problems within S3OK challenge areas. Each of the solutions presented is either currently being researched or planned as an area for future inquiry. Science team representatives provided breakout room attendees with a broad understanding of each solution component by presenting a brief, verbal overview of the research activities associated with each component.

Addressing the Impacts of Land Management Practices and Changing Weather Conditions on Water Availability for Agricultural Use/Land Management (ILM)

The ILM breakout room zeroed in on the challenges associated with land management and the dynamic weather and climate patterns affecting water availability for agricultural purposes. This breakout room served as a platform for the S3OK science team to present their progress on eight potential solution components for these challenges to the OLAN and ESPAN across the project **(Table 4.1)**.

Evaluating Water Availability and Quality Under Changing Weather and Climate Conditions, with a Municipal Focus (WAQ)

Participants in the WAQ breakout room focused on 10 preliminary S3OK solution components aimed at addressing the impacts of changing weather and climate conditions on water availability and quantity, with a municipal focus **(Table 4.2)**.

Investigating Electric Infrastructure Impacts Resulting from Changing Land Cover, Weather, and Climate Conditions (EII)

In this breakout room, participants reviewed nine prospective solution components designed to address two S3OK challenges associated with changing land cover and climate conditions' impact on electrical infrastructure **(Table 4.3)**.

Table 4.1: S3OK Solutions Presentation to the ILM group at the Year 3 Academy

Addressing Impacts of Land Management Practices and Changing Weather Conditions on Water Availability for Agricultural Use	
S3OK Challenge Addressed	**Potential Solution**
Increasing Eastern Red Cedar encroachment, coupled with increasing frequency of drought/ flash drought, leads to surface water depletion.	Quantify how restored native prairie improves water availability using ongoing monitoring; utilize these data to improve modeling and predictions.
	Understand and quantify social acceptance/public willingness to support Eastern Red Cedar, removal programs, particularly using controlled burns for smaller trees.
Reduced soil health due to land management practices and changing climate conditions, limiting water retention and rangeland resilience to drought.	Implement regenerative livestock grazing to improve soil water infiltration, as well as drought resiliency and soil health. EPSCoR supports research to compare two grazing management systems, adaptive and prescriptive, to determine the best method for improving soil health and overall sustainability.
Reduced water availability due to changing weather/climate conditions limits producers' ability to plan for optimal crop selection and maximize yields and creates a need for increased water efficiency and re-use.	Better meet long-term agricultural water needs and create the potential for year-round production by cleaning produced water using solar distillation to remove salinity and making it available for irrigation.
	Better meet long-term agricultural water needs and create the potential for year-round production by cleaning produced water using membrane distillation to remove salinity and making it.
	Identify instances and timing of extreme weather conditions, including flash drought, and improve future predictability of these events to assist producers in crop choice and irrigation planning.
	Utilize satellite data to monitor vegetation health and crop growth under varying water availability conditions in order to improve yield forecasting and support data-driven decision-making.
	Understand public risk perceptions and experiences related to water availability and related phenomena, such as drought, as an input into seeking water availability solutions that can receive public support.

Table 4.2: S3OK Solutions Presentation to the WAQ group at the Year 3 Academy

Water Availability and Quality Under Changing Weather and Climate Conditions: Municipal Focus	
S3OK Challenge Addressed	**Potential Solution**
Runoff from urban areas following pluvial events, coupled with inadequate water diversion infrastructure, results in contaminated water.	Improve predictions of frequency and severity of flash floods and pluvial events in order to better inform planners working to improve water diversion infrastructure.
	Identify/map flood-vulnerable locations and critical system components, and engage in spatial and temporal scale system monitoring to help prioritize stormwater system improvements and reduce cascading infrastructure failures.
Growing prevalence/requirements/ standards around removal of PFAS and other CECs.	Utilize wetland treatment units post-wastewater treatment and prior to water entry into another water body in order to reduce contaminant concentrations that are not addressed in traditional water treatment systems.
	Use chemical catalysts to destroy CECs in drinking water treatment systems with oxidation-based technologies.
	Understand public perceptions, acceptance, and trust of natural water treatment systems as opposed to engineered systems to assess feasibility.,
Risk of changing weather/climate conditions to reduce available water sources	Improve predictions of frequency and severity of flash and persistent drought in the short and medium term as an input into infrastructure planning, as entities seek to reduce water losses/reduce infrastructure inefficiencies.
	Understand public risk perceptions and experiences related to water availability and related phenomena, such as drought, as an input into seeking water availability solutions that can receive public support.
	Model potential reservoir management techniques are given for changing precipitation and temperature that may lead to increased water availability.
Public Hesitation Regarding Wastewater Re-use	Understand public willingness to accept wastewater under various re-use applications to assess the feasibility of projects.
	Design water treatment/re-use systems to minimize environmental impacts in construction, maintenance, and operations, thereby increasing the potential for public acceptance

Table 4.3: S3OK Solutions Presentation to the EII group at the Year 3 Academy

Water Availability and Quality Under Changing Weather and Climate Conditions: Municipal Focus	
S3OK Challenge Addressed	**Potential Solution**
Increasing Eastern Red Cedar, Encroachment, coupled with the increasing frequency of extreme weather (drought, heat, electrical storms, etc.) leads to increased wildfire risk.	Improve projections of future fire frequency and severity in the Southern Great Plains under changing weather/climate and fuel load conditions, in order to better inform decision-making and risk mitigation.
	Increase the predictability of the weather conditions that drive wildfire occurrence (including drought, electrical storms, heat), therefore increasing predictive ability for short and medium-term wildfire risks and aiding in decision-making.
	Assess economic impacts of the introduction of new ERC-based bioproducts industries (i.e., particleboard, mulch, and cedar oil) in Oklahoma through an integrated approach of spatial and economic impact analysis, in order to encourage mechanical removal and fire fuel load reduction.
	Understand and quantify social acceptance/public willingness to support Eastern Red Cedar, removal programs, particularly using controlled burns for smaller trees.
Need for increased physical resiliency of the electrical grid to mitigate the impacts of increasingly extreme weather/climate conditions.	Development of hazard maps that identify fire-vulnerable locations as they align with critical system components, and engage in spatial and temporal scale system monitoring to help prioritize system hardening, such as fire retardant for poles
	Model fragility of electric system components to extreme Conditions, including heat, cold, fire, and smoke, in order to prioritize system-hardening strategies
	Create network models of transmission and distribution systems to better understand cascading effects after failures and provide informational inputs into prioritization of mitigation strategies such as automatic switching/ rerouting measures
	Increase predictability of future frequency and severity of extreme weather that threatens the grid, including cold snaps and heat waves
	Understand public risk perceptions and experiences related to extreme weather and electric outages, and measure public willingness to pay for system improvements so as to best understand which approaches may receive public support

Solutions Refinement Process

Refinement of S3OK Solutions was advanced using inputs from the Year 3 Academy Solutions Assessment Discussion and in the Working Groups. Following the presentation of each solution component discussed in the previous sections, open discussions allowed for feedback and clarifying questions prior to the quantitative evaluation of each solution component via scorecard (details below). Criteria for assessing solution components were iteratively developed through feedback from previous project meetings, focus-group style Deep Dive Conversations, and OLAN survey responses.

Ultimately, this process generated evaluation criteria for solution components that included the following dimensions:

- Urgency (1–low, 3–medium, 5–high)
- Effectiveness (1–low, 3–medium, 5–high)
- Social acceptability (1–low, 3–medium, 5–high)
- Technical Feasibility (1–low, 3–medium, 5–high)
- Cost (low, medium, high)
- Timeframe for Development/Implementation (Under 5 years, 5–10 years, 11+ years)

OLAN and EPSAN participants completed scorecards ranking each prospective solution component based on the criteria outlined above. Data from completed scorecards were de-identified, entered into a spreadsheet, and shared with breakout room participants at the end of the session.

After the Academy, information from the scorecards was used alongside transcripts from breakout room discussions as the basis for preliminary evaluation and analysis of prospective S3OK solutions. During analysis following the event, researchers created an overall ranking for each component by averaging the ranks across the four main dimensions. These summary rankings are shown in **Table 4.4** below. These three most highly rated solutions across each breakout room had common characteristics, in that all were rated as having a low (under 5 years) timeframe for development/implementation and were perceived to have a low or medium cost of implementation.

Table 4.4: Top Solution Components, by Average Ranking Across Dimensions

Breakout Room	Potential Solution	Rank*
ILM	Understand public risk perceptions and experiences related to water availability and related phenomena such as drought as an input into seeking water availability solutions that can receive public support.	4.08
ILM	Understand and quantify social acceptance/public willingness to support Eastern Red Cedar removal programs, particularly using controlled burns for smaller trees.	4.03
ILM	Quantify how restored native prairie improves water availability using ongoing monitoring; utilize these data to improve modeling and predictions.	3.87
EII	Understand public risk perceptions and experiences related to extreme weather and electric outages, and measure public willingness to pay for system improvements so as to best understand which approaches may receive public support.	3.96
EII	Understand and quantify social acceptance/public willingness to support Eastern Red Cedar removal programs, particularly using controlled burns for smaller trees.	3.93

Breakout Room	Potential Solution	Rank*
EII	Increase predictability of the weather conditions that drive wildfire occurrence (including drought, electrical storms, heat), therefore increasing predictive ability for short and medium-term wildfire risks and aiding in decision making.	3.85
WAQ	Understand public risk perceptions and experiences related to water availability and related phenomena, such as drought, as an input into seeking water availability solutions that can receive public support.	4.31
WAQ	Understand public willingness to accept wastewater under various re-use applications to assess feasibility of projects.	4.26
WAQ	Identify/map flood-vulnerable locations and critical system components, and engage in spatial and temporal scale system monitoring to help prioritize stormwater system improvements and reduce cascading infrastructure failures.	4.14

* Scores range from 1-Low to 5-High

In addition to considering the quantitative evaluation of potential solutions, the research team also analyzed transcripts from breakout room discussions, identifying key themes that informed the development of effective solutions. These included:

1. **Enhanced Technical Tools and Insights**: Participants emphasized the need for improved forecasting models, particularly for flash droughts, and fine-grained, localized data to support short- and long-term planning in land management, infrastructure, and agriculture. Expedited access to accurate information was noted as a way to mitigate risks like wildfires and support adaptive strategies, even with trade-offs such as power quality adjustments.
2. **Integration of Economic, Legal, and Policy Considerations**: Discussions highlighted the importance of incorporating regulatory and policy frameworks into technical solutions. Participants underscored the value of leveraging case studies and aligning with compliance needs, particularly in water management and infrastructure, to avoid redundant efforts and guide decision-making effectively.
3. **Scalable, Context-Appropriate Solutions**: Participants called for tailored approaches to address region-specific challenges, such as outdated rural infrastructure and varying water availability. Updated resources like floodplain maps based on current conditions were identified as essential for effective planning.
4. **Public Awareness and Engagement**: Effective communication and public input were deemed crucial, especially for water management. Participants stressed the importance of educating communities on water conservation, addressing fairness and costs, and using public surveys to guide solutions. Public opinion was recognized as a key factor in ensuring the successful implementation of initiatives.

These themes underscored the need for interdisciplinary, localized, and community-informed approaches to address environmental challenges in Oklahoma that were carried over into topically oriented Working Groups.

Working Group Solution Refinement

Drawing on the critical insights and lessons from the Year 3 Academy, working groups were

strategically organized around key challenge areas identified as priorities for advancing innovative solutions. Each group was tasked with translating complex challenges into actionable strategies, leveraging interdisciplinary collaboration to design, test, and refine solutions that addressed specific needs within their domains.

The working group development process emphasized an iterative and inclusive approach, bringing together diverse expertise from across disciplines and fields of practice. Through this collaborative effort, working groups developed impactful solutions that informed the creation of practical 'products'—such as actionable insights, innovative technologies, or optimized processes. These products were carefully crafted to deliver measurable outcomes while aligning with S3OK's overarching goals of sustainability, scalability, and real-world implementation.

The selection of solutions for refinement was driven by a dynamic combination of inputs, including:

- **Quantitative Evaluations**: Data-driven insights derived from rigorous analysis during the Year 3 Academy.
- **Collaborative Conversations**: Ongoing dialogue throughout the project to surface emerging needs and refine challenges.
- **Collective Effervescence**: The energetic exchange of ideas within the three problem area domains, fostering creativity and sparking actionable strategies.

By synthesizing these inputs, the working groups ensured that their solutions were not only technically robust but also context-appropriate and impactful, paving the way for meaningful advancements in the identified challenge areas of Novel Hybrid Treatment and Reuse Options for Stormwater and Municipal Wastewater, Produced Water Reuse Potential for Oilfield and Agricultural Applications, and Natural Hazards and Utility Resilience **(Figure 4.4)**. Each of these working groups, and the corresponding challenge areas they addressed, is discussed in detail in subsequent chapters.

References

[1] Jenkins-Smith, Hank, Joe Ripberger, Carol Silva, Nina Carlson, Kuhika Gupta, Matt Henderson, and Amy Goodin. 2017. "The Oklahoma Meso-Scale Integrated Socio-Geographic Network: A Technical Overview." *Journal of Atmospheric and Oceanic Technology* 34 (11): 2431–41. https://doi.org/10.1175/jtech-d-17-0088.1.

[2] Olofsson, Kristin L., Pavithra Priyadarshini Selvakumar, Kaitlin Peach, Maggie Leon-Corwin, Sam A. Stormer, Kuhika Gupta, Nina Carlson, and Martha Sibley. 2023. "Effective Stakeholder Engagement in Environmental Problem-Solving Though Group Model Building: An Oklahoma Case Study." *Environmental Challenges* 13 (December): 100755. https://doi.org/10.1016/j.envc.2023.100755.