NSF Convergence Accelerator Workshop
Oct 25/31 & Nov 2/4, 2022

Session 1: Analyzing Community Input (Oct. 25th; 9am-11am)
Session 2: Identifying and Refining Societies Pressing Water Resource Issues (Oct 31st 9am -1pm)
Session 3: Crafting Solutions (Nov. 2nd; 9am -1pm)
Session 4: Messaging and Prioritization (Nov. 4th; 9am -1pm)
All times in PDT

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EXECUTIVE SUMMARY

Society faces multiple water quantity and quality challenges that threaten the economic, resource, and ecosystem security in the United States. Only holistic approaches can begin solving these problems in the face of climate change and attendant social disruption that we see today. Convergent science can bring scientists from a variety of disciplines together with local, state, and national partners that span various industries, government agencies, and nonprofits to determine how water is managed, allocated, and supplied, both for human use and for the ecosystems on which we depend. The “Managing Water for a Changing Planet” Convergence Accelerator Workshop identified some of the top challenges facing U.S. water resources. This report summarizes the findings of the workshop that took place virtually via Zoom on October 25, October 31, November 2 and November 4, 2022.

The workshop brought together 54 participants from academic institutions, national laboratories, government agencies, industries and non-profit organizations (see appendix 1). The workshop attendees discussed extensively the grand challenges and barriers facing water resources that could be addressed in a timeline of roughly 3-4 years. Seven themes for convergence were identified:

1. Building a Community of Learners and Professionals of Practice
2. Cost-effective, real-time monitoring technologies from headwater to tap
3. Cooperative Communities as a Catalyst for Change
4. Ecosystem services for safer communities
5. Big Data for Big Problems
6. Ensuring water supply for the future
7. Hydrologic disturbance frameworks for decision makers

From the seven themes discussed in the workshop ***we identified four tracks that were especially “convergence ready”***, given their expected key outcomes and high impact deliverables which are described within the report.

1. Cooperative communities as a catalyst for change: The objective of this track is to catalyze communities to find socially, politically, economically, and culturally acceptable solutions and to build (or implement policy for) sustainable water supply systems by delivering novel, effective, unbiased data-driven decision support tools.

2. Building a Community of Learners and Professionals of Practice: The objective of this track is to design community-based and user-inspired approaches and frameworks for workforce development that can address local/regional water resource challenges and related equity and policy issues. The foundation of these frameworks will be equitable partnerships between communities facing water access challenges and academics.

3. Ensuring Water Supply for the Future: The objective of this track is to ensure and enhance future water supplies through accelerating implementation of aquifer recharge projects, increased safe water access in underserved communities, identification and acceptance of new alternative water sources and the modification of existing regulatory frameworks to enable uptake.

4. Hydrologic disturbance frameworks for decision makers. The objective of this track is to develop a suite of tools that can be used by communities with varying levels of resources to manage for sustainable climate resilient watersheds. This community centric approach will bring a diversity of stakeholders together and elevate their collective knowledge.

Throughout the seven themes, several cross-cutting topics and community needs also emerged and may be threads that could be encouraged in a potential solicitation. These topics and needs include:

1. Community-based and user-inspired approaches and frameworks: community-based and use-inspired research and education interventions includes serving underserved and/or racialized communities by intentionally identifying critical needs and conducting research and education in equitable ways.

2. Rethinking communication pathways: effective communication, including how to deliver information to impacted communities and how to communicate in culturally meaningful ways is needed for collaborating across sectors and stakeholders.

3. Amplifying impact through transferable and scalable approaches: there is persistent need for frameworks, standards of practice and tool-kits that can be transferred across geographies, or applications.

4. Identifying and managing disturbances/disasters as priority: several themes identified disturbances as an area of research priorities based on increasing occurrence of extreme events (e.g. floods, drought, fires).

5. Big data and emerging technologies: big data and emerging technologies were identified as an independent theme in the workshop; however, this topic was also present throughout most of the other themes. Data-based solutions are important to improve communication pathways as well as for improving our monitoring networks.

Finally, two bottlenecks for solving societal problems through this convergence accelerator mechanism were discussed multiple times by the participants. First, it takes time to develop partnerships and build the trust needed to make enduring relationships. While workshop participants understood that funding agencies wanted rapid action, they repeatedly stressed that it takes time to build community and trust to avoid (unintentional) exploitation and allow for meaningful and sustainable change over the long term. Second, long term measurements that capture the response of environmental systems seem undervalued. Monitoring is necessary to evaluate the long-term effectiveness of “solutions”. Short term funding mechanisms (e.g., 3-5 years) are not sufficient; lack of monitoring likely leaves both societies and ecosystems vulnerable.

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1. INTRODUCTION

"*The provision of adequate fresh-water resources for people and ecosystems will be one of the most critical and potentially contentious issues facing society and governments at all levels during the 21st century*" (American Meteorological Society, 2017).

Grave statements such as these are supported by too many predictions and even many real-world observations stemming from global change, population growth and migration, and changing and intensifying land-use practices. For example, global surface temperature in 2020-2021 was 0.99 °C higher than 1850-1900, and is projected to increase by 1.4-4.4 °C. These increased temperatures will lead to increased transpiration, decreasing soil moisture and stream flow. And in fact, streams in the United States have seen longer durations and higher frequencies of zero-flow between 1980 and 2017 (Zipper et al., 2021). A warming climate will also lead to higher frequency and intensity of droughts and floods and fire. And in fact, over the last several decades, megadroughts have led to the loss of municipal water supplies – in the Southeastern U.S. and in Chile where severe water scarcity led to rationing for 8.5 million inhabitants (Bartlett, 2022). North America's Southwest has now moved into a megadrought with the last 22-yr representing the driest period for this region since 800 AD (Williams et al., 2022). Already two-thirds of the global population (4.0 billion people) are experiencing water shortages at least one month per year (Mekonnen and Hoekstra, 2016); this number is projected to increase to 4.8-5.7 billion by 2050 (Burek et al., 2016). The sheer scale of these issues is daunting. For example, seventy-eight percent of large cities draw water from nearby or distant rivers and streams (McDonald et al., 2014). Further, while the world's largest cities (>750,000 population) occupy less than 1% of the Earth's land surface, their source watersheds occupy 41% of its surface (McDonald et al., 2014).

The multiple water quantity and quality challenges that society faces threaten economic, resource, and ecosystem security (for additional facts see appendix 8.2). Only holistic approaches will be sufficient to begin solving these problems in the face of climate change and attendant social disruption that we already see beginning today. Scientists can contribute to solving these issues by improving our understanding of physical hydrologic mechanisms and how these mechanisms influence water supply across different regions with different geologies and climates. However, improved knowledge alone will be insufficient for designing effective policy responses to the environmental challenges that humanity faces. In fact, differences in the cultural, political, and economic environments among regions may have as large an effect on the supply of water as do hydrologic mechanisms. Convergent science can bring scientists from a variety of disciplines together with local, state, and national partners that span various industries, government agencies, and nonprofits to determine how water is managed, allocated, and supplied, both for human use and for the ecosystems on which we depend.

2. MANAGING WATER FOR A CHANGING PLANET WORKSHOP

The Managing Water for a Changing Planet Workshop was conducted as a series of four progressive virtual meetings held between Oct 25th and Nov 4th (see appendix 8.3 for the full agenda). The event was facilitated by KnowInnovation and all materials related to the workshop will remain available to participants through their platform KIStorm (https://kistorm.com/ryqznG3yEO0QajwYTVr1/dSi5lMEYElj6MaXiVd8b). To create an inclusive workshop and ensure participation from multiple sectors the workshop was advertised across a series of listservs (e.g., CUAHSI, American Water Resources Association) and our website (https://sites.google.com/oregonstate.edu/managing-water-nsf-ca/home) which was circulated on twitter and other social media platforms. All registrants were asked to answer four questions, and those not able to participate during the workshop were also able to provide feedback for us to incorporate into our workshop development. The four question asked to both registrants and individuals providing input included:

1. What are the top challenges coming over the horizon in water resources?
2. What are the current barriers to addressing these challenges?
3. What emerging practices, technologies, or other applications have the potential to transform water resource solutions?
4. Who are the key stakeholders that must be at the table to solve these challenges?

A total of 140 people registered and an additional 13 people provided feedback only; collectively, we received approximately 100 responses to each of the four questions. Sixty-four of the registrants were invited to attend the workshop. Invitees were selected to ensure a diverse group of participants, based on professional sectors (private, government, non-profit, academic), career stage, and personal demographics.

Word cloud analysis shown in Figure 1 for each question highlights key terms that came up after implicit words to our theme (e.g., “water” and “climate change”) were removed. In addition, we used these data to generate a series of questions that could help motivate participants to move past the broad questions to a more creative space by posting a synthesis of the feedback for the registered participants on KIstorm.

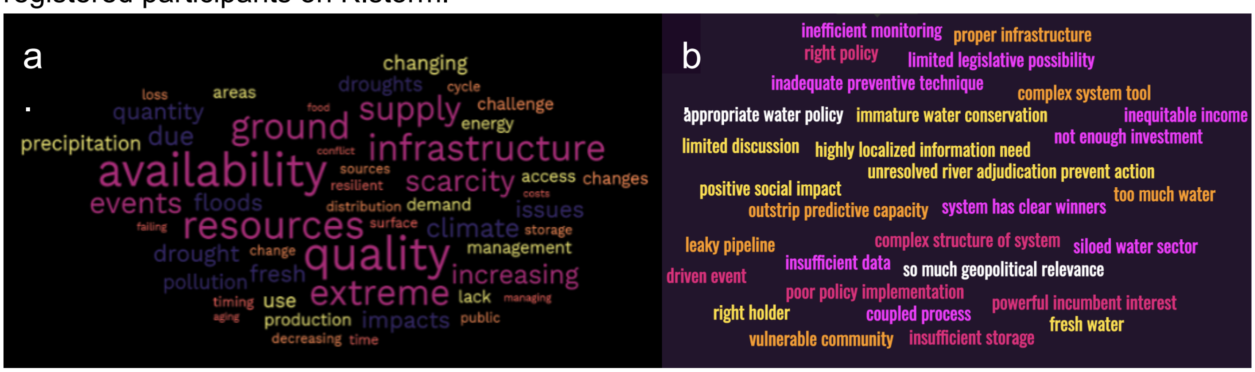

Figure 1. Word cloud generated from the first two questions posed in the survey about (a) challenges and (b) barriers in water resources.

From the challenges and barriers highlighted by the community, we synthesized eight provocative questions. We used these questions in **Session 1** to engage the participants and to simulate conversation.

1. How might we create the best prediction tools to allow our communities to deal with more variable weather conditions?
2. How do we develop new technologies, communication strategies, and investment solutions to really reduce disparity in access to clean water in the future?

3. How might we prevent places becoming inhabitable due to drier conditions (increased occurrence of drought or aridification)?
4. How might we prevent places becoming inhabitable due to wetter conditions (increased occurrence of flooding or sea level rise)?
5. How do we develop/create methods for delivering information to the public that will help solve water resource issues?
6. How might we enhance knowledge transfer between water sectors to provide the water resources needed to support humans and ecosystems alike?
7. How might we prevent limited access to clean water from threatening the viability of communities dependent on groundwater?
8. How might we change water law and other regulations to encourage long-term sustainable use and discourage unsustainable over consumption, in ways that better foster environmental justice (i.e., supply water for tribes, underrepresented, less-well off, and the environment)?

To further engage participants in **Session 1** around a large variety of water related challenges, we invited select participants to record a brief interview and shared it during the session. The video is available here https://youtu.be/xzM8bY1PRmA". During **Sessions 2-4** Knowinnovation facilitated the group through the divergence and convergence processes in a series of breakout groups. **Session 2** was focused on identifying all of the challenges and barriers in water resources that could be addressed in a timeline of roughly 3-4 years (see appendix 4). By **Session 3**, the participants distributed themselves into seven topical themes (listed below) based on interest and worked through a series of questions that the workshop organizers used to recommend convergent ready tracks (see *Section 5*). In **Session 4**, participants developed each theme into a "track" that could be addressed in a 3- to 5-year long research project, identified the key outcomes and listed several key deliverables. Participant input for each of the 7 themes is summarized below (*Section 3*. Overview and Findings). Across these themes, several cross-cutting topics also emerged which we highlight in *Section 4*.

Themes that emerged from session 2 inputs on challenges and barriers (see appendix 4)

1. Building a Community of Learners and Professionals of Practice
2. Cost-effective, real-time monitoring technologies from headwater to tap
3. Cooperative Communities as Catalyst for Change
4. Ecosystem services for safer communities
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3. OVERVIEW AND FINDINGS

Below is the overview and findings that emerged from the seven themes identified by the participants. *Section 4* highlights cross-cutting topics and *Section 5* provides our recommendation for convergent ready tracks.

3.1. Building a Community of Learners and Professionals of Practice

A significant barrier to clean water for all is the high degree of water injustice and racialized and underrepresented groups that disproportionately face most of the water challenges. These groups often do not have agency or knowledge to take informed action. Outreach and engagement with academia is central toward building solutions, but relationships are often extractive and not founded in the local culture, thus burning social and cultural capital before solutions are realized. Finally, education and communication barriers hinder uptake of new information and potential solutions by communities and other professionals.

The main idea and outcome will be a process, structure, or generalized framework for community-based science and education partnerships that will i) enable historically under-represented communities to address local/regional water related issues, ii) provide pathways to increased exposure and on-ramps to career opportunities, civic engagement projects/volunteerism around water issues, and iii) generate awareness among higher education research and training in the field, thereby broadening participation, expanding diversity, and promoting inclusion. Through this, community members will gain knowledge of their local/regional water resource challenges, and related equity and policy issues and thus acquire specific competencies needed to engage with researchers, technicians, practitioners, policy makers, etc. and take action on water related issues. Likewise, academic specialists will acquire competencies on engagement and culturally-appropriate translation of their specialized knowledge and its application.

Convergence is realized through sequential building of essential social capital among residents, practitioners, academic specialists, among others that induce and maximize the talents and energies brought to bear on a common problem that needs to be solved.

High impact deliverables within 3-5 years include a systematically organized general framework that is tested on case-studies. The framework includes transferable ways of engaging communities and provides material for multiple pathways (or on-ramps) into water-related scientific research experiences, degree programs, and careers. These would be established for students and/or community members, especially those most often directly affected by inequity. Longer term deliverables include building social capital through long-term engagement built on trust that can be leveraged toward a more collective adaptation to multisector impacts of climate change, cultivation of a new generation of water scientists trained with new tool sets that reach beyond traditional academia (science communication, community engagement, storytelling, data visualizations etc.) and a robust workforce that reflects community composition.

A barrier to implementation can be traditional funding mechanisms that do not allow for intentional community and trust building and learning before a project has to be delivered. Further, metrics for success/impact are based on fast publications in specialized venues, instead of the number of authentic partnerships built, both requiring adjustment in funding structures and flexibility in leadership teams.

3.2. Cost-effective, real-time monitoring technologies from headwater to tap

Significant barriers: Solutions to water scarcity, quality, emerging concerns, and extreme events challenges can be informed by better monitoring built around a community. These opportunities have technological and community-based barriers. Technology to measure emergent issues and sensor networks with greater coverage increase costs. Private-public partnerships will be key to solving some of the sensor and network issues needed to create open-source resources. Intelligent design of monitoring systems that builds a community of users and supporters will be critical to the success and sustainability of such systems.

The main outcome is to catalyze the co-design of sustainable frameworks of federated assets for secure and cost-effective, real-time monitoring technologies for collection, curation of development of actionable water data and applications. Vastly increase the density, diversity, continuity, and longevity of monitoring capacity to facilitate rapid hazard detection, analysis and predictive modeling, and long-term environmental tracking. Support data-driven policy and management via use-inspired research. Provide common facts about valued water assets with which to engage communities of learners, historically excluded groups, and stakeholders.

Convergence is realized through the support for private-public partnerships and by connecting technical expertise to social scientists that can facilitate engagement with the community. The community-based group that forms to address a water challenge with improved monitoring is likely to have a wide variety of expertise: social science, data networks, sensor technologists, computer scientists, water scientists and policy experts, and financial expertise. We expect this community to span across physical, institutional, and policy boundaries with relationships to community change agents, like state and local water agencies, water conservation districts, state extension service, water utilities, homeowners, and others.

High impact deliverables: This work would produce a variety of deliverables across different time horizons. At the end of the first year, the projects would develop a network of stakeholders and users, develop objectives for monitoring and measurement, establish governance mechanisms and principles, and develop a technology roadmap to lead to breakthroughs in cost and scalability. Another set of high impact deliverables could be achieved on the 3-5 year horizon: breakthroughs in cost and scalability, standardization of sensors, data collection, and curation, increased observation density and continuity, sustainable business plan, curriculum for lifelong learning, and an external assessment. At the 5-10 year horizon, the project could lead to replicated and expanded use of these systems, data-driven changes in policy and management, operationalized hazard warning systems, and more active communities of learners, especially of historically excluded users and supporters.

Barriers to implementation: One of the key barriers to success in these types are the lack of effective mechanisms to engage stakeholder and social networks to build and support. If this dynamic remains unsolved, already privileged groups and communities will be centered and receive support. There also needs to be sufficient planning to avoid overemphasizing technology as the outcome, build concrete private-public partnerships, and to make sustainable business plans to make long-term monitoring an attractive outcome for NSF.

3.3. Cooperative Communities as Catalysts for Change

Significant barriers: Society faces numerous challenges for the continued supply of water to meet domestic needs, yet, in many cases, communities lack the agency to address these challenges. Not only does current water law and policy often limit a community's decision space, but also many communities lack the information needed to make informed choices, the resources needed to make changes based on those choices, and further, the pathways to change are often obscured by competing interests among users with different needs and/or world views.

The main idea and outcome will be the development of a decision-support framework linked to informational support (see *section 3.1*), real-time monitoring (see *section 3.2*), and data / data analysis tools (see *section 3.5*). This framework would provide a transferable process that will help define the social, economic, and ecological connections of a community's "water-scape" to catalyze a community of governance for a holistic water management objective(s). This will require consideration of equity to address community-driven needs that will be addressed at commensurate spatial and temporal scales of management. Equitable community governance and expertise will leverage transdisciplinary and multi-sector perspectives to navigate conflict with respect and reciprocity.

Convergence is realized in two ways. First, actionable convergence comes from community development, improved governance, and implementation of holistic water management objectives. Second, within the scope of the proposal, success will require convergence among a variety of agents: i) sociologists to study decision making processes, ii) community developers and organizers to help develop effective community governance, iii) watershed advocacy groups to provide independent local leadership, oversight, and support new development, iv) engineers and tech specialists to design and develop sensor networks to provide real time data on water quantity and quality, v) water providers to identify specific local to regional scale data needs and other challenges, and vi) IT developers to build platforms that make this information readily available to both the public and decision makers in a transparent way.

High impact deliverables: The ultimate deliverable would be grassroots-driven, watershed-scale projects that are co-developed by diverse social groups with robust integration of private and public funding to support sustainable domestic water supplies. Approaches will include i) ecologically-driven restoration of streamflow and groundwater aquifers, ii) efficient agricultural irrigation and the iii) adoption of renewable energy resources. Building the foundation for realizing this vision would require a number of short, intermediate, and long-term deliverables. Over the shorter term (1-3 years) deliverables would include (1) a clear, co-developed decision-making processes including suggested processes for conflict resolution, code of conduct, establish communication norms, and accountability mechanisms, and (2) small proof-of-concept experiments, interventions, internships, or other tangible and inclusive "win-win" deliverables for early buy-in and stakeholder communication. Over the longer term (3-5 years) deliverables would include (3) additional case studies conducted at a variety of scales and in a variety of social landscapes, where transparency with perceived success and failure are both used to provide valuable insights, and (4) examples of varied communication of findings to diverse audiences (podcast, video, blogs, presentations). Finally, mature deliverables would include (5) a fully developed adaptive management strategy with implementation plans, a communication network of trained personnel that have successfully implemented community development strategies in the past and can provide transferable insights into process and comparisons to other ongoing or past projects.

Barriers to implementation: Policy and regulation, available resources, political conflict, and lack of information present barriers for communities, impeding their ability to find sustainable solutions to these challenges and secure sufficient high quality water for domestic uses. In some places, water rights and other policies that provide economic stability for users with senior water rights greatly limit a community's decision space. Even if it is possible to transfer or otherwise change these rights, doing so will be a slow and politically-fraught process. Communities must find other ways to solve water supply issues over the short term and in so doing, build the political capital necessary to address these problems sustainably for the longer-term. To do this, they will need information, resources, as well as guidance and examples of other success stories.

3.4. Ecosystem services for safer communities

A significant barrier is the lack of standard practices for recognizing environmental, economic, and social/cultural value of ecosystem services and how current nature-based solutions achieve water quality, water quantity, and human health and safety goals. Consequently, many projects using nature-based solutions have only been implemented at the local scale and the pace of implementing projects and transferring knowledge at larger scales has been slow. Additionally, the economic and societal value of ecosystem services remains difficult to quantify.

The main idea and outcome is to develop integrated standards of practice for designing, implementing, incentivising, and monitoring nature-based solutions for addressing water resource and ecosystem challenges for communities (which interfaces with *3.6* and *3.7* below). An interdisciplinary group of practitioners, community partners, and project stakeholders will quantify socio-economic and environmental benefits from nature-based solutions, evaluate barriers to efficient application and implementation, and apply a new standard of practice ready for testing with a series of example ecosystem service projects. They will develop a mechanism for continued dissemination and engagement of stakeholders to refine the standard of practice for use in new projects in the future.

Convergence is realized through integration of: 1) environmental scientists providing critical process information to and working with, 2) environmental design and planning specialists to address, 3) community water quality and safety (e.g. flood protection) needs and 4) economists and social scientists who have experience with valuation of ecosystem services.

High impact deliverables include: 1) Tools for identifying better projects/solutions that benefit societal access to clean water and create resilient ecosystems and communities in the face of flood, drought, and climate change, 2) A new standard of practice ready for testing with a series of examples of ecosystem service projects, 3) Develop a systemic method for identifying and addressing barriers (knowledge gaps, evaluation of benefits, etc.) that slow implementation of nature-based solutions, and 4) Develop a mechanism for broader dissemination and engagement beyond project timeline.

Barriers to implementation included lack of application of science of team building and creating enduring/discoverable/translational tools. Given the complexity of stakeholders surrounding nature-based solutions questions were raised as to the best practices for engaging with different stakeholders to achieve realistic innovation. During the tool construction phase questions arose as to which data platforms and dissemination would actually endure over time and allow for tools to continue to be useful into the future. How do the tools themselve keep pace with the advances in technology?

3.5. Big Data for Big Problems

A significant barrier to solving pressing water issues is the ability to access, use, and translate 'Big Data' into solutions. There is a disconnect between groups that are generating the data, analyzing the data, and communicating the data and making it accessible in many areas. There is also a lack of resources to make these connections, particularly in places with a history of being underserved. There remain issues around privacy, long-term sustainability of data, and a large diversity of data types that further impede development around these ideas.

The main idea and outcome would be a scalable and transferable design toolkit that uses open science, open data and information to identify and help develop cooperative communities (e.g., geographic region that includes multiple communities and underrepresented peoples) to become literate about local water issues. This resource would support implementation of effective organizations and the development of projects to address local water issues including supply, quality, and reliability. The development of an iterative engagement model such as a digital extension service, would regularly conduct needs assessments, communicate data needs back to big data providers and inform and enable a science and data literate local and regional water management workforce.

Convergence is realized by connecting social scientists, data scientists, cloud computing, government agencies, and non-government groups. The projects should use social science to increase the likelihood of adoption by studying information flow, behavioral impacts, and how to make information culturally relevant. Existing data repositories supported by NSF and cloud services could be combined with necessary resources and expertise. Government agencies like the USGS and US Digital Service have responsibilities for data collection, stewardship, and accessibility. Non-government agencies, like The Nature Conservancy and World Resources Institute, could be collaborators or leaders using identified water security issues.

High impact deliverables in the first year of projects would focus on community building and need identification. Data and tools will identify regions and communities with needs (water quality, water price, underserved, etc.) and the challenges accessing water resource information. An assessment of water data, information technology and related assets at the community level with a focus on equity. Preliminary data/information products with local context as foundation for following deliverables. The projects would convene communities around discovery of their water issues and information needs (including visualization, ui/ux, modalities for use/distribution, etc.). These efforts would lead to three-year deliverables that would increase local data collection and sharing capacity, develop open data policies and tools, and develop prototypes that can quantify the ability to meet community needs.

Barriers to implementation include community-based, technological, and communication and accessibility concerns. Specifically, disconnected and nonuniform datasets that have different levels of accessibility are a hindrance to these approaches. For water related issues, the data quality and metadata information is critical and often poorly supported. In particular, vulnerable and marginalized community needs must be connected to datasets and the information must be accessible and disseminated.

3.6. Ensuring water supply for the future

A significant barrier for roughly 2.1 billion people living on Earth is water scarcity. Many of these communities are reliant on groundwater that is slow to recharge (e.g., decades, centuries, or even millennia). Within the water budget, groundwater storage tends to be one of the most poorly constrained quantities. Improved quantification of storage and withdrawals will improve our ability to predict risks to water security and help determine how much groundwater withdrawals need to be reduced, or groundwater recharge increased to maintain water security. There is a need to enhance our reliance on natural recharge zones such as floodplains, which are often disconnected from streams as a result of constructed features (e.g., levees) and to reduce the costs or modify the technologies associated with aquifer storage recovery wells to enable widespread adoption.

The main idea and outcome will be to develop a framework for flexible groundwater storage, that relies on assessment of local/regional groundwater availability, provides groundwater water credits to individuals, farmers, and industry for enhancing recharge and/or limiting extraction (e.g., more water efficient crops), and supports the development of low cost technologies that enhance aquifer recharge with potable water.

Convergence is realized through integration of: 1) local and regional water right holders and water treatment providers, 2) industries developing water quality sensors and recharge systems, 3) government agencies and nonprofit organizations that work toward improving natural recharge (e.g., reconnecting floodplains), and 4) economists and social scientists who have experience with valuation processes (e.g., carbon credit systems).

High impact deliverables include but are not limited to: 1) local and regional estimates of the amount of water that is available in aquifers that are available for use and for storage, 2) flexible recharge systems whose infrastructure and strategy can expand and contract to accommodate changing climate conditions, 2) sustainable, “do-no-harm” practices for using energy-extracting wastewater for groundwater recharge, 3) novel, low cost technologies that allow aquifer recharge to occur at the small scale (e.g., individual farmers), 4) ability to capture nuisance flood waters and use them for recharge, and 5) development of a groundwater credit system, which includes improved technologies for quantifying groundwater use (e.g., irrigation waters).

Barriers to implementation include difficulties in reaching the dispersed stakeholder groups (spread across diverse cultural and economic communities) and building trust among local/regional stakeholders who rely on a shared good. Enhancing communication, lessons learned, and advice/directive under a changing weather and climate conditions.

3.7. Hydrologic disturbance frameworks for decision makers

A significant barrier for decision makers is managing water given the numerous and compounding disturbances taking place. For example, drought accompanied by fire and followed by flooding and/or droughts that persist for record breaking periods and floods that occur more regularly. In many of these cases managers are being asked to make informed decisions and plans without always having the proper data to do so nor always knowing what the community values. Systems are currently changing faster than we can plan for, and there is a need to create "climate ready" watershed management plans.

The main idea and outcome is to generate a suite of tools to build and sustain climate resilient watersheds that can be usable by communities with varying levels of resources (multiple entry points for communities with varying levels of resources). Tools could be organized in following way:

1. Pre-project tools that help inform watershed scale risk, BMPs, nature-based solutions, prioritizing projects, identifying hydrologic extremes, novel interactions between multiple disturbances and climate stressors, and building climate resilient watersheds. Pre-project tools could build upon existing tools (e.g., Model my watershed, streamstats, and/or new tool that utilizes multiple existing datasets in a google earth format.) Pre-project tools could also include a gaming element (e.g., board game "Watershed Arizona"; TNC game; or add-ons to computer games like "Age of Empires" and "Civilization"), where participants would learn about post-disaster watershed impacts (simulate fires, floods, etc).
2. During and post project tools that could document project/management outcomes, understand impacts of issues/disasters as they occur and respond as appropriate (e.g., adaptive management framework tools)
3. Long term sustainability tools (organizational and collaboration tools, funding models for supporting long-term data collection, long-term project implementation funding, accessible work-force training and capacity building, etc.)

Convergence is realized by melding decision-making science, geophysical science, ecosystem science, planning, and engineering (team with expertise in multiple areas) and by developing metrics for social & ecological resilience in decision-making models (complex systems & operations research expertise). Implementing frameworks vs. development frameworks will require different combinations of stakeholders including government agencies, academic communities, water users, non-profits, utility providers, local water boards, tiber/agriculture/local landowners, and insurance agencies.

High impact deliverables include: 1) “Standard” way/set of guidelines for how to manage uncertainty around extreme events. Usable by communities with a range of resources (three-tier system). 2) Advances in computational tools/modeling approaches that can be used to predict extreme events and represent novel processes/interactions. 3) Emergence of a new field/discipline called “uncertainty science” (how do we quantify uncertainty in past and in future, and 4) “Operational hydrology” - advance/build a field of research around operations (e.g., feedback loops; operational decisions drive research, adaptive management strategies).

Barriers to implementation surrounded: 1) defining and quantifying resilience in a consistent, but locally-relevant manner, 2) identifying the appropriate scale of this tool/framework - some contexts it will be very local, some it will be state level, 3) providing helpful and actionable solutions for community with low/med/high capacity, and, 4) providing helpful technical support for disadvantaged communities.

4. MAJOR CROSS-CUTTING TOPICS

4.1. Community-based and user-inspired approaches and frameworks: two groups identified this theme as a main focus (i.e., *3.1* and *3.3* above), however, the need for community-based and use-inspired research (and often education) interventions is apparent in a number of other themes. This includes the need to serve communities that are currently underserved and/or racialized by intentionally identifying critical needs and conducting research and education in equitable ways (e.g., *3.2, 3.4, 3.5, 3.7*). User-inspired research is a version of this theme (e.g., *3.2*).

4.2. Rethinking communication pathways: several groups identified the need for effective communication, which includes identifying how to deliver information to impacted communities and how to communicate in culturally meaningful ways. For example, data-based solutions including network analyses can support identification of information flow (e.g., *3.5*) and digital extension services can conduct needs assessments and communicate data needs back to providers. The need for a common basis for communicating and collaborating across sectors was mentioned across themes, especially partnerships that include culturally responsive ways of engaging communities of learners, historically excluded groups, and stakeholders.

4.3. Amplifying impact through transferable and scalable approaches: Several groups identified the need for frameworks, standards of practice and tool-kits that can be transferred across needs, geographies, or applications. This includes frameworks for real-time monitoring technologies for collection, curation and development of actionable water data and applications (*3.2*) and scalable design processes (or toolkits) based on open science and data (*3.5*). The development of standards of practice for designing, implementing, incentivizing, and monitoring was emphasized for nature-based solutions (*3.4*), but this approach is overarching and can serve other themes as well (e.g., "scalable and replicable science, technology and collaboration" under *3.7*).

4.4. Identifying and managing disturbances/disasters as priority: several groups identified disturbances as a focal theme, most explicitly *3.7*, where tools are suggested for identification of research priorities based on extremes. However data-based solutions (*3.5*) considers extremes/disturbances/disasters as a focal point and nature based solutions are suggested for carbon/hazard (flood, storm, wildfire) mitigation projects (*3.4*). Even though not explicitly mentioned, most groups implicitly consider disturbances (floods, droughts, fire) the main threat to water security and water justice.

4.5. Big data and emerging technologies: Big data and emerging technologies were identified as an independent theme in the workshop (see *section 3.5*). However, this topic was also a critical component of several other themes that rely heavily on need-inspired, iterative engagement models including digital extension services. Making data and data analysis tools readily available will help inform and enable a science and data literate local and regional water management workforce (*3.1*). Data-based solutions were also suggested to identify communication pathways (i.e., network analyses) to make data accessible when and where it is needed. This data/information infrastructure should be a foundational community service (*3.3*), can include ad hoc support groups, networked by communities to support implementation and management as well as reports identifying available datasets and data gaps necessary to address issues identified by communities. This will include improved real-time monitoring technologies for collection, curation of development of actionable water data and applications to facilitate rapid hazard detection, analysis and predictive modeling, and long-term environmental tracking (*3.2*). These technologies would enable the identification of vulnerable systems (pre-project) or the delineation of extreme events (*3.7*).

5. TRACK RECOMMENDATIONS

From the seven themes discussed in the workshop we identified four tracks that based on key outcomes and high impact deliverables are especially "convergence ready".

1. Cooperative communities as a catalyst for change: The objective of this track is to deliver novel, effective, unbiased data-driven decision support tools to help overcome current challenges, find socially, politically, economically, and culturally acceptable solutions, and catalyze communities to build (or implement policy for) sustainable water supply systems. The decision support tools would likely include (but not be limited to) informational support through workforce development or continuing education, access to real-time monitoring data, support through data / data analysis tools, and technology transfer platforms that make this information readily available to both the public and decision makers in a transparent way. Example deliverables could include (1) a clear, co-developed decision-making processes including suggested processes for conflict resolution, code of conduct, establish communication norms, and accountability mechanisms; (2) case studies conducted at a variety of scales and in a variety of social landscapes, where transparency with perceived success and failure are both used to provide valuable insights; or (3) a fully developed adaptive management strategy with implementation plans, a communication network of trained personnel that have successfully implemented community development strategies in the past and can provide transferable insights into process and comparisons to other ongoing or past projects.

2. Building a Community of Learners and Professionals of Practice: The objective of this track is to design community-based and user-inspired approaches and frameworks for workforce development that can address local/regional water resource challenges and related equity and policy issues. The foundation of these frameworks will be equitable partnerships between communities facing water access challenges and academics. Approaches should combine i) the building of competencies among academic contributors on engagement and culturally appropriate translation of their specialized knowledge and its application with ii) the intentional development pathways for historically under-represented communities that will be empowered to address local/regional water related issues. Examples include creation of on-ramps to career opportunities, civic engagement projects/volunteerism focused on water issues, and awareness of higher education opportunities.

3. Ensuring Water Supply for the Future: The objective of this track is to ensure and enhance future water supplies through accelerating implementation of aquifer recharge projects, increased safe water access in underserved communities, identification, and acceptance of new alternative water sources such as water reuse and atmospheric water capture, and the modification of existing regulatory frameworks to enable uptake. This track emphasizes local solutions developed through an interdisciplinary approach that includes physical scientists, engineers, social scientists, and end users. Solutions would be developed over a five-year period to stabilize groundwater levels, implement conservation and new water supplies for continued growth and ensure equitable access to affordable, clean and adequate water supply that is secure and sustainable for everyone. High impact deliverables could include the development of new rainwater- and humidity-harvesting technologies to increase available freshwater supply, as well as technologies to enhance aquifer recharge; an evaluation of societal attitudes and norms regarding water reuse and recycling; and the creation of develop feasible and sustainable best practices for using industry wastewater for clean groundwater recharge

4. Hydrologic disturbance frameworks for decision makers. The objective of this track is to develop a suite of tools that can be used by communities with varying levels of resources to manage for sustainable climate resilient watersheds. Tools include: technology transfer that provides equitable access to enduring data and climate projections tailored to meet specific needs identified by the community; cost-effective, easily deployable technologies for identifying changes in the timing, quality, and quantity of water resulting from hydrologic disturbance such as floods and droughts as well as impacts from wildfire; grass-roots team building frameworks founded in the science of communication and problem solving; affordable employment of nature based mitigation methods; and user-friendly, effective software for communicating risk, mitigation, and management strategies associated with hydrologic disturbance. This community centric approach will bring a diversity of stakeholders together and elevate their collective knowledge of the range of hydrologic disturbances, challenges surrounding compounded or accelerated disturbance regimes, and facilitate the sharing of practices.

6. EXAMPLE TEAMS AND PARTNERSHIPS

This workshop engaged participants from multiple disciplines and organizations with diverse expertise, including the academic, industry, non-profit, and government sectors. The goal was for participants to converge to identify innovative tools, methods, and solutions to ensure clean and available water for communities in the future, with an eye towards high-impact results and outcomes achievable in three to five years. We have identified examples of cross-cutting teams and partnerships to address challenges identified in the recommended tracks.

1. Cooperative communities as a catalyst for change: Environmental Scientists, Social Scientists, Data Scientist, Regulators, Policy Makers, Water Operations Specialists, Education Specialists (e.g., K-12 Educators and Administrators).

2. Building a Community of Learners and Professionals of Practice: K-12 educators, K-12 Administrators, Community Non-profit Organizations, current Professionals of Practice, Community College Administrators, Undergraduate and Graduate Educators, Pedagogy Researchers, NSF INCLUDES Network, Psychologists and Social Scientists

3. Ensuring Water Supply for the Future: Environmental Scientists, Social Scientists, Data Scientist, Regulators, Policy Makers, Water Operations Specialists, Engineers (Civil, Electrical, Electronic), Water and Wastewater System Operators, and Water End Users

4. Hydrologic disturbance frameworks for decision makers: Environmental Scientists, Social Scientists, Data Scientist, Policy Makers, Software Developers, Virtual Reality Game Developers, Municipal Utilities, Natural Resource Harvesting/Production Companies

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8. APPENDICES

8.1 PARTICIPANTS

Name	**Institution/Organization**	**Faculty/Department**	**Position/Title**
Abba Ahmed	Aurora Water	Water Resources	Water Resources Project Manager
Alan Raflo	Virginia Water Resources Research Center	Not applicable	Research Associate/Editor
Allison Rhea	Colorado Forest Restoration Institute	Forest and Rangeland Science	Research Associate
Benjamin Ruddell	Northern Arizona University	School of Informatics Computing and Cyber Systems	Professor
Beverley Wemple	University of Vermont	Geography & Geosciences	Professor
Brian Beckage	University of Vermont	Plant Biology	Professor
Catherine Gibson	The Nature Conservancy	New York	Water Resource Scientist
Chris Graham	San Francisco Public Utilities Commission	Hetch Hetchy Water and Power	Water Operations and Maintenance Manager
Deidre Wheaton	Jackson State University	Professional Interdisciplinary Studies (College of Education)	Associate Professor of Interdisciplinary Studies
Douglas Toomey	University of Oregon	Earth Sciences	Director, Oregon Hazards Lab; Associate Dean for Research, Provost's Environmental Initiative
Elizabeth	University of Colorado	CIRES	Water Resources

Payton			Specialist
Emily Elliott	University of Pittsburgh	Geology & Environmental Science	Professor
Erich Hester	Virginia Tech and AAAS Science and Technology Policy Fellow at U.S. Dept of Energy	Civil and Environmental Engineering (VT) and Water Power Technologies Office (US DOE)	Associate Professor (VT) and AAAS Fellow (US DOE WPTO)
Erin Seybold	Kansas Geological Survey/Univ. of Kansas	Geohydrology	Assistant Scientist (Hydrogeochemistry)
Erinanne Saffell	Arizona State University	School of Geographical Sciences and Urban Planning	AZ State Climatologist
Ethan Knight	Western Water Assessment	CIRES, CU Boulder	Associate Scientist
George McMahon	Arcadis	Water	Vice President, National Expert
George Schuler	The Nature Conservancy	New York	Director, New York Water
Helen Fillmore	UC Davis	Tahoe Environmental Research Center	Chemist/Research Associate
Jamie McEvoy	Montana State University	Earth Sciences-Geography	Associate Professor of Geography
Jason Polk	Center for Human GeoEnvironmental Studies	Western Kentucky University Earth, Environmental & Atmospheric Sciences	Professor and Director
Jessie Olson	Left Hand Watershed Center	N/A	Executive Director
Jessie Pearl	The Nature Conservancy	Arizona	Freshwater Scientist
John Cohn	BETA Technologies / IBM Corp / UVM CEMS	UCM CS	Distinguished visiting scholar
John Warinner	Watersolving, LLC	All	Owner
Jory Lerback	University of California, Los Angeles	Earth, Planetary and Space Sciences	Postdoctoral Fellow
Kevin Bladon	Oregon State University	Forest Engineering, Resources, and Management	Associate Professor and Associate Department Head
Laura Lautz	National Science	Earth Sciences	Program Director

	Foundation		
Mary Hingst	University of Delaware	Water Science and Policy	Environmental Fellow/PhD Candidate
McKenzie Skiles	University of Utah	Geography	Assistant Professor
Nicholas Parker	Army Futures Command	Dept. of the Army	Senior Intel Specialist - Futures
Patrick Kormos	National Weather Service - NOAA - DOC	Colorado Basin River Forecast Center	Senior Hydrologist
Phil Saksa	Blue Forest Conservation	Science & Research	Chief Scientist
Praveen Kumar	University of Illinois, Urbana-Champaign	Prairie Research Institute	Executive Director of Prairie Research Institute
Rita Teutonico	National Science Foundation	GEO/OCE	Program Director
Sai Veena Sunkara	University of California Davis	Civil and Environmental Engineering	Postdoctoral scholar
Salli Dymond	Northern Arizona University	School of Forestry	Associate Professor
Sarah Brennan	NASA		
Sarah Whateley	The Nature Conservancy	NY Division	Water Resource Scientist
Scott Ensign	Stroud Water Research Center	Research	Assistant Director
Sean Fleming	US Department of Agriculture	NRCS National Water and Climate Center	Technical Lead, Applied R&D
Shawn Jackson	Arkansas Department of Agriculture Natural Resources Division	Floodplain Management	State Climatologist/State NFIP Coordinator
Steve Kwast			
Steve Malers	Open Water Foundation and TriLynx Systems	Do it all	CEO, CTO
Steven Patten	City of Milton-Freewater, OR	Public Works	Public Works Eng Tech
Tao Wen	Syracuse University	Earth and Environmental Sciences	Assistant Professor
Thomas Parris	ISciences, LLC	N/A	President
Tom Michalek	RESPEC	Water and Natural Resources	Senior Hydrogeologist
William Shuster	Wayne State U., Professor,	Civil and	Chair, Professor

	Dept. Chair, Civil-Environmental Engrg.	Environmental Engrg.	

8.2 ADDITIONAL KEY WATER RESOURCE FACTS:

- A 1 in 10 year precipitation event is expected to be 1.5 times more likely under a 1.5 degree increase in global surface temperature, and a 1 in 10 year drought is expected to be 2 times more likely (IPCC, 2021). These changes have already had profound impacts on river water quantity (Hammond et al., 2021; Zipper et al., 2021) and by extension and quality and water security.
- Warming shifts precipitation from snow to rain; shrinking snowpack induces early snowmelt and prolonged summer droughts (Aulenbach and Peters, 2018; Godsey et al., 2014; Jenicek et al., 2018; Milly and Dunne, 2020; Rhoades et al., 2018). The shift from snow to rainfall in a warmer climate is predicted to result in less streamflow (Berghuijs et al., 2014).
- The use of nitrogen (N) and phosphorus (P) fertilizers to increase agricultural productivity is predicted to increase 3-fold by 2050 unless more efficient fertilizer use can be implemented (Tilman et al., 2001).
- Higher concentrations and loads of solutes and sediments increase water treatment costs. Poor water quality increases the need for sediment removal, filtration, and additional processes such as removal of disinfection byproducts, therefore raising the overall capital cost of construction of water-treatment plants (WTPs) and subsequent operations and maintenance (O&M) (McDonald et al., 2016).
  - Elevated sediments and nutrients have been estimated to increase water treatment costs for 29% of cities globally, with operation and maintenance costs increasing on average by 53 ± 5% and replacement capital costs increasing by 44 ± 14% (McDonald et al., 2016).
- The changing climate, whether coming in the form of gradual increasing temperature or dramatic climate extremes, have profound impacts on water quality (Milner et al., 2017; Whitehead et al., 2009).
- Concentrations of sediments, salts, and nutrients have been escalating worldwide in the past decades.
  - DOC and water browning have increased in Europe, North America, and Asia, which has been attributed to changing climate or recovery from acid rain (Clark et al., 2010; Laudon et al., 2012; Monteith et al., 2007).
  - Out of 232 monitoring sites in the US, concentrations of sodium, calcium, magnesium and potassium increased significantly at 29-39% of sites from the late 20th to early 21st century (Kaushal et al. 2018).
  - 90% of the mainland US experienced an increase in pH since the mid-20th century.

8.2 AGENDA

Date	Time	Duration	Activity Title	Activity Description
Tues, Oct 25, 2022, 12pm - 2pm, ET. Microlab	**12:00 PM**	START		
	12:00 PM	:05	Coming into the room	Settling people in - there are always a couple of latecomers
	12:05 PM	:15	**Official Start**	Welcome - Pam (5) NSF welcome - Aurali (10) - Workshop Objectives - This session objective
	12:20 PM	:10	**Facilitator introduction** - Introduction the the process - introduction to KiStorm	open the challenge page on kistorm and demo how to do postits - show where all the survey responses are - and the rational for the theme labels - then ask audience to be making postits of challenges that come to mind during presentations today challenge wall will have been opened at registration time
	12:30 PM	:5	**Organizers Reflection of survey responses**	Pam et al to present their rationale on thier analysis
	12:35 PM	:10	**practitioners / stakeholder video**	
	12:45 PM	:20	**Breakout discussions** - randomly mixed groups to discuss thoughts on previous presentations	participants - can you identify any challenges that you can write up onto the challenge wall?
	1:05 PM	:20	**BREAK**	
	1:25 PM	:5	Set up for next activity - Tim	

	1:30 PM	:20	**We are all experts** - If any one of us were presenting on the challenges facing "Water for a changing planet", what would we be pointing out as important challenges? - capture challenges on kistorm challenge wall - perhaps use survey responses here as the focal point for discussion (added advantage that participants read all the material)	in mixed breakout groups (groups of 3 or 4) - briefly introduce yourselves - share / discuss your views on the big challenges from your own perspectives
	1:50 PM	:05	**Plenary discussion**	A reflection on the points that have come out of discussions so far - what are we seeing / feeling? Whats Missing? What haven't we talked about yet?
	1:55 PM	:5	**Preparing ourselves for the forthcoming workshop**	- keep thinking / talking with colleagues / adding to challenge wall - prepare yourself to think about FUTURE challenges - times - commitment - importance / excitement for workshop - thank yous, and see you next week
	2:00 PM	END	target end 2pm	
Mon, Oct 31, 2022, 12pm -	**12:00 PM**	START	Stakeholders and Disciplines prioritise the challenges	
	12:00 PM	:10	**Welcome back** - Pam -- reitterate NSF criteria	- reminder of overall objective , divergent-convergent and third third - Objective for today - Exploring the opportunity for novel research. Looking for themes from our previous session
	12:10 PM	:10	**Facilitator Welcome** - to the process and review of what everyone created in the previous microlab -- adding more --voting most important - set up for next activity	- KiStorm has the challenges from previous session - Remind how to use Kistorm

4pm, ET - Virtual Session 1	12:20 PM	:23	**review of microlab challenges** - whats missing? prepare for more items - We will be starting a new wall of challenges - you can draw upon your first thoughts from the microlab, but we are hoping that you will dive in a little deeper and specific today note - you might want to STAR those postit notes that are of most interest to you for later discussion	
	12:43 PM	:35	**Real world issues Breakout discussions** Why is this different to the microlab challenges? **(Including the reflection on microlab challenge wall....)** **what is your local community worried about right now?** discussing our thoughts on what **end-users / stakeholders / beneficiaries** will be worrying about right now What are the interesting questions scientists should ask? What are the cool questions? ***Societal / translational impact where is the convergence that is ripe for acceleration actionable? fuzzy 3 years?*** - We are trying to understand the landscape of all the possible issues / challenges within this topic - Listen carefully to what colleagues have to say - Make sure your opinion is heard / recorded - We arent trying to solve anything at this stage - we are	Random Groups - briefly introduce yourselves - discuss your expert views / opinions / perspectives on the challenges of "water for changing planet" - capture challenges and type them onto challenge wall Kistorm wall groups will be organized - 4-5 groups **REMIND FOLKS THAT ORGANIZING TEAM WILL BE ACTING AS PARTICIPANTS IN THIS SESSION**

			trying to articulate all the possible problems - We arent prioritising challenges at this stage (we will do that later)	
	1:18 PM	:27	report outs from previous	
	1:45 PM	:15	**BREAK**	
	2:00 PM	:04	**Future challenges** Reflecting on current capabilities and the gap we need to close in order to get to where we want to be. What are the hurdles/challenges in our way?	a short presentation to stimulate conversation for participants - or tim to set up "Possible prompts for breakout sessions: **1. The best time to plant a tree is 20 years ago, the second best is right now"". What do you wish we had put in practice 20 years ago? What do we need to put in practice now so that we do not have regrets in 20 years?**

			2. If it were 2075, what advice would you provide past water practitioners, researchers, and the public and private sectors? "
2:04 PM	:30	**Breakout discussions** ***The best time to plant a tree is 20 years ago, the second best is right now"". What do you wish we had put in practice 20 years ago? What do we need to put in practice now so that we do not have regrets in 20 years?*** - What might be all the challenges we face in the future?	In newly mixed groups - briefly introduce yourselves - discuss barriers to reaching our desired future **- as a group, agree 5 key challenges and put them on kistorm**
2:34 PM	:16	**Plenary highlights from previous discussion**	
2:50 PM	:30	**Vote - most important items And Break**	10 dots per person, don't refresh your page 1. Multidisciplinarity 2. Society Changing 3. Diverse partnerships 4. Acceleration
3:20 PM	:10	**review of voting outcome**	
3:30 PM	:25	**Review of challenge wall - THEME suggestions** Are themes emerging? - write up those suggested themes on postits	In breakout groups - with a bit of gentle music?
3:55 PM		~~**Whats missing?**~~ ~~plenary discussion~~	
3:55 PM	:05	Preparing for our next ession	Give them homework - review post its from Challenge Wall Microlab - and copy and paste any that you think should be included

				in Session 1 challenge wall to be brought forward to the theming.
	4:00 PM	END	target 4:00 end	organizers to choose preferred themes
Weds, Nov 02, 2022, 12pm - 4pm, ET - Virtual Session 2	**12:00 PM**	START	Interdisciplinary discussions about new approaches	
	12:00 PM	:15	**Welcome back & plan for the day**	MAJOR THEMES list of themes and sub-themes and how community input helped to define them. OVERVIEW AND FINDINGS Within each theme/sub theme: Major challenges or barriers facing the theme/sub-theme Big ideas for solutions/needs Goals and impacts if this sub-theme was successful High-impact deliverables in a three-year time-frame identified Why this is Convergent Ready Possible Barriers to implementation identified
	12:15 PM	:15	**Reviewing the themes** **Holly to overview the headings** - All challenges have been put into theme groups (as per your recommendations) - do not feel constrained by these themes and the items within (they are simply constructed in an attempt to make it easier for you to navigate) - You may be interested in talking about a number of these themes, but we have to start somewhere, so which theme would you like to sign up to to spend the next hour digging deeper into (have a second choice up your sleeve in case we need to move people to balance out group numbers) - you are working on a theme in service to this community - no	this is an individual task - no discussion 1. Building a Community of Learners and Professionals of Practice 2. Cost-effective, real-time monitoring technologies from headwater to tap 3. Cooperative Communities as Catalyst for Change 4. Ecosystem services for safer communities 5. Big Data for Big Problems 6. Save for the Future 7. Hydrologic disturbance frameworks for decision makers

			one owns anything	
	12:30 PM	:10	**Sign up to your chosen theme** - and explanation of process; - introduce working documents and task	Introduce the google doc template
	12:40 PM	:55	**Refine the themes** - Participants go into breakout rooms to work on thier theme / document	
	1:35 PM	:15	**Break - continue work if need be**	
	1:50 PM	:55	**Continue work on documents Give folks option to move to another room**	
	2:45 PM	:40	**Report back from working groups (and Builds & Concerns)** - During which everyone has chance to leave constructive feedback via facilitated 'builds & concerns' activity	7 groups @ 4mins each
	3:25 PM	:10	**BREAK**	
	3:35 PM	:20	**Incorporating feedback** groups go back to their documents and incorporate the feedback (B&C)	

	3:55 PM	:05	**Wrap-up** - discussion of what we're doing on Friday (continuing the previous half hour) **- welcome to visit any documents to add comments**	
	4:00 PM	END	target 4:00 end	
Fri, Nov 04, 2022, 12pm - 4pm, ET - Virt	**12:00 PM**	START		
	12:00 PM	:20	Welcome back - revisit / present the RFP - Pam with slides	
	12:20 PM	:20	**Re-familiarize yourselves with ALL the google docs and leave any additional comments that you might want to leave.**	
	12:40 PM	:5	**set up next activity** **- show new prompts** sign up page **Go to the group that you first started in??**	Drop outcomes prompt in Working Documents

ual Ses sio n 3	12:45 PM	:60	**BREAKOUT 1 - OUTCOMES** **outcomes** - specificity - measurable - timebound - application	**Use the existing document and Wednesdays feedback to distill/synthesize one single outcome that is 2-3 sentences long. (You will share this with the workshop at the end of the breakout). Multiple ideas can be combined to create one outcome. Work toward consensus across group members. Consider starting with the big idea, drawing from "key challenges", "research questions" as the starting point. Keep in mind the convergence accelerator goals below. Make sure to identify:** **Who will change? i.e., the target subject.** **What will change? i.e., the desired change expressed as an action verb.** **What fields of knowledge will be brought together, i.e., the convergence** **By how much? i.e., the expected results.** **By when? i.e., the time frame.** **Convergence accelerator goals:** **National societal impact** **Relies on multidisciplinary teams and partnerships** **Accelerates the delivery of science to practitioners to derive solutions.** **Broaden participation of underrepresented group**
	1:45 PM	:40	**REPORT BACKS** **report back on outcomes?** **with a round robin discussion?** *can anyone spot cross cutting themes? write in chat* *do themes need merging?*	**With builds & concerns - make visible during activity** **Do we see cross cutting thems?** **Do we see themes that ought to be merged?**
	2:25 PM	:28	**Break**	

	2:53 PM	:32	**BREAKOUT 2 - DELIVERABLES** **Back into breakout groups to work on session 3 prompts (round 2)** **Deliverables** **happy if people want to switch things up a bit.**	**Focus on Deliverables** **Deliverables are the specific, tangible things produced that enable the outcomes to be achieved. Consider drawing especially from key aspects from "societal and scientific/technical outcomes" as a starting point. Please provide at least six deliverables that you would expect with your given outcome.** **What would the deliverables be at the end of 1 year? And, why are these the first deliverables?** **What would the deliverables be at the end of 3 years?** **What would the product continue to deliver on at 5-10 years?**
	3:25 PM	:15	**closing thoughts on postit notes - what was your most important takeaway?**	What have you walked away with? What is the most fruitful takeaway you've heard here? Has this workshop inspired you to change anything about your science?
	3:40 PM	:05	**Closing**	Share the Feedback Survey Page with participants
	3:45 PM			Ask organizers for a meeting to debrief

8.3 CHALLENGES/BARRIERS

The challenges and barriers identified by the participants grouped into themes.

Theme	Challenges/Barriers
1. Building a Community of Learners and Professionals of Practice	How do we ensure equity in water-related decisions, recognizing that many underserved communities / underrepresented groups may lack the resources and power necessary to engage in participatory processes.
1. Building a Community of Learners and Professionals of Practice	How do we usher in solutions that do not continue to discriminate against structurally disadvantaged populations and communities?

1. Building a Community of Learners and Professionals of Practice	How do we best engage with communities and assess their needs so we can (co)produce the best usable science possible for the communities to best make decisions?
1. Building a Community of Learners and Professionals of Practice	How do we present pathways for transforming water use, infrastructure, and regulation that sufficient numbers of people find attractive and want to implement as opposed to being threatening and anxiety provoking? Change is hard. Change to something as fundamental as water is even harder. How do we make change in such a way that we maintain future flexibility to face unknown surprises?
1. Building a Community of Learners and Professionals of Practice	How do we build trust and embed with communities to engage in a science-based dialogue to produce community-relevant data that points at solutions? Bill S. Detroit MI
1. Building a Community of Learners and Professionals of Practice	What are the ways we can build water science around community needs? How are the ways that we can learn what those community needs are?
1. Building a Community of Learners and Professionals of Practice	Information campaign around water to build back public relationship with water
1. Building a Community of Learners and Professionals of Practice	How do we empower “underserved communities” to turn them into an effective political force that can challenge the “well served communities” to better achieve environmental and social justice?
1. Building a Community of Learners and Professionals of Practice	How do we effectively communicate water policy and technical solutions to de-politicize public reaction?
1. Building a Community of Learners and Professionals of Practice	How do we share local success stories and best practices in an accessible and sustainable way, including data and potential partnership and stakeholder contacts?
1. Building a Community of Learners and Professionals of Practice	How do we identify what is "critical," deserving of society's limited attention and resources? Is the earth's critical zone a useful metaphor or maybe model for trying to see the issues that cross over the parts of the human environment, as the earth critical zone crosses over the atmosphere, hydrosphere, biosphere, and lithosphere? This would include expanding the definition of the critical zone to include human/social elements.
1. Building a Community of Learners and Professionals of Practice	How do we translate academic research to something water system operators can use? Operators are often low on time, expertise and technical savvy.
1. Building a Community of Learners and Professionals of Practice	What are the ways we can continue to advance "water" knowledge when regulatory mechanisms lag behind 20+ years (Safe Water Drinking Act, TMDLs). That is, how can we protect ecosystems and human health despite inadequate and antiquated regulations?

1. Building a Community of Learners and Professionals of Practice	How can we leverage co-production of knowledge to have success stories at a regional scale? To what degree will stakeholder engagement and knowledge transfer from large interdisciplinary science projects take to ensure sustainability it efforts?
1. Building a Community of Learners and Professionals of Practice	Mining is essential for green revolution--need to be mindful of future impacts. Oversight is currently low--need community-driven regulation. Social justice considerations--need to overcome anti-regulation attitudes. Especially true for impacts that aren't visible, eg groundwater impacts. Critical to protect gw.
1. Building a Community of Learners and Professionals of Practice	How do we balance an open data approach with concerns about privacy, anonymizing data, protecting critical resources), etc.?
1. Building a Community of Learners and Professionals of Practice	how can we support long-term humble relationships that generate culturally relevant (and thus more lasting/effective/equitable) and agile solutions to rapidly changing problems?
1. Building a Community of Learners and Professionals of Practice	I really like how the investigators in the PacIOOS et al. projects asked the community where THEY felt the sensors would provide the most relevant data to THEM. Indigenous knowledge must be taken seriously by investigators. I see community engagement as often overlooked, overridden, and undervalued. We as scientists must be flexible in our experimental designs, even if it means more time and expense. The scientific process may need to be viewed in a new way.
1. Building a Community of Learners and Professionals of Practice	Can we incentivize solution-based research/initiatives at the regional scale by defining and requiring partnerships for funding access?
1. Building a Community of Learners and Professionals of Practice	How can we circumvent complex politics of nested institutions to get help to communities in need after an extreme event?
1. Building a Community of Learners and Professionals of Practice	How does one include underserved communities that are hard to reach, and how does can we find solutions to problems that of such communities that transcend water? - Group 4 in first breakout on Oct 31
1. Building a Community of Learners and Professionals of Practice	How do we find exemplars of what to do and what not to do to create resilient futures?
1. Building a Community of Learners and Professionals of Practice	How do we bridge research with practice and policy?
1. Building a Community of Learners and Professionals of	Individual people often lack the information needed to have agency over their water - what information do people need, and how do we get it to them in a way that they trust?

1. Building a Community of Learners and Professionals of Practice	How do we culture a futurism mindset for education, management, and regulation to ensure groundwater resources are sustainable for the coming decades, centuries, etc.? (e.g., a "Water Future fund" to address problems that are known and yet to come, not just those here now).
1. Building a Community of Learners and Professionals of Practice	What are the ways we can reform graduate and undergraduate education so that our next generation water leaders come out with the skillsets they need: Community engagement, science communication, teambuilding skills, interdisciplinary aspects of how water impacts human lives (equity, quality, quantity, affordability).
1. Building a Community of Learners and Professionals of Practice	How do we ensure positive impact, momentum and sustainability of projects at a local level within regional scale (share data? coordinating entity? encourage local multi-disciplinary teams?, prioritizing funding for regional scale?) - Steve Malers
1. Building a Community of Learners and Professionals of Practice	What are the ways we can leapfrog convergence across disciplines by learning and communication skills from other convergence groups? Barriers across academic disciplines are real. Is a mediator needed for these efforts...always?
1. Building a Community of Learners and Professionals of Practice	We need to train future leaders with skills for cross-disciplinary teamwork, but how do we leap-frog the timescale to implement those skills today?
1. Building a Community of Learners and Professionals of Practice	Global challenges: How can we learn from/share solutions across nations? Eg how to address salt water intrusion--an issue for island nations, communities, eg Long Island
1. Building a Community of Learners and Professionals of Practice	How might we use time intentionally to build relationships and trust to co-create solutions to water issues with impacted communities?
2. Cost-effective, real-time monitoring technologies from headwater to tap	How do we up(down)scale solutions regionally, nationally, globally, etc. to fit the problems identified in such a way that they are adaptable, achievable, and sustainable by those in need?
2. Cost-effective, real-time monitoring technologies from headwater to tap	How does NSF better support projects that involve long-term monitoring rather than one-off projects that may not result in a sustainable solution or shared data? "Observatories" do not seem to equate to long-term monitoring?
2. Cost-effective, real-time monitoring technologies from headwater to tap	How might we acquire data needed for real-time monitoring of water quantity and quality in an affordable way?
2. Cost-effective, real-time monitoring technologies from headwater to tap	How might we increase our monitoring infrastructure to improve our ability to identify "hot spots" or "hot moments" of poor water quality? For example, we quickly developed the process to monitor wastewater from specific dorms to track Covid-19 infections - how might this be applied to other "contaminants of concern"?

2. Cost-effective, real-time monitoring technologies from headwater to tap	How might we work with develop a flexible hydrologic tool that can be adapted by communities to address local/regional issues. For example, could we develop a tool that allows folks to know which watersheds will face lower "low flows" as climate continues to change so they can decide how to manage their resources?
2. Cost-effective, real-time monitoring technologies from headwater to tap	How do we incorporate adaptation measures to various sources of uncertainty involved in decision making in many aspects?
2. Cost-effective, real-time monitoring technologies from headwater to tap	How might we increase communities agency about water use by delivering water quality assessment in real time to peoples homes after a flood ?
2. Cost-effective, real-time monitoring technologies from headwater to tap	Is there some nifty “gadget” that could be invented/designed and built that a single householder could have installed on their house’s water supply lines that would change water chemistry such that lead (Pb) leaching from pipes & pipe joints would be greatly limited?
2. Cost-effective, real-time monitoring technologies from headwater to tap	Crazy idea: Can pumped water electricity storage also be used to store water for use in time of drought?
2. Cost-effective, real-time monitoring technologies from headwater to tap	Need to invest in technological solutions for addressing these issues.
3. Cooperative Communities as Catalyst for Change	Rethinking reseach-to-operations (R2O): how do we get the signals right - so that (a) researchers solve problems in a way that's useful to practitioners & stakeholders, while (b) also ensuring that practitioners & stakeholders have the capacity to effectively leverage new research outcomes and products?
3. Cooperative Communities as Catalyst for Change	How do we deal with short timeframe expectations of people (politicians, society, election cycles) when dealing with long timeframe water problems that need persistent attention, funding, patience, etc.? - Steve Malers
3. Cooperative Communities as Catalyst for Change	How do historic uses that have been encoded into law or regulation create structural constraints that limit potential solutions to present day issues and challenges? How do we re-think/re-imagine and then re-write those laws or regulations in ways that respect both historic users for whom law and regulation granted stability for their water supply and those that have historically been left out as well as new arrivals due to population growth and migration?
3. Cooperative Communities as Catalyst for Change	How might we imagine/reimagine the water rights system that underlies our water management practices/behaviors? Prior approp and riparian rights may have worked in the 20th century but how do they apply to a changing world.
3. Cooperative Communities as Catalyst for Change	How can we develop a system that would allow transferability of best practices/tools to other geographic areas?

3. Cooperative Communities as Catalyst for Change	What might be all the ways we can identify common building blocks of information to best serve the full suite of interests to support water resource management decisions. Then, what are the ways to add to those “blocks” to best serve the local community.
3. Cooperative Communities as Catalyst for Change	How do we mitigate potential issues of conflict in the face of increasingly scarce water resources?
3. Cooperative Communities as Catalyst for Change	How might NSF foster a community that focuses on data-driven and policy-relevant work? What steps get us there? How do we recognize that different groups have different problems and require different solutions? How can we connect people and develop community around problem-based research rather than discipline-based research? How do we identify responsible parties (e.g. for developing data, for addressing policy, for coordinating with stakeholders, for scaling work, etc.)? What can we learn from adaptive management frameworks?
3. Cooperative Communities as Catalyst for Change	Concern that we spend a lot of time thinking and planning and knowing that we need to do something, and not acting on them quickly enough.,In the east, they know all the pipe infrastructure needs to be replaced., In coastal areas - we know saltwater intrusion is happening with sea level rise., In forests - extreme fire is having significant impacts on many systems
3. Cooperative Communities as Catalyst for Change	What might are all the ways that we can learn from other successful convergence teams? What are best practices in team building, defining process, deliverables, and soliciting community needs when coming from different disciplinary perspectives?
3. Cooperative Communities as Catalyst for Change	How can we make water policy a non-partisan concern?
3. Cooperative Communities as Catalyst for Change	How do we manage scaled issues from national to local, and back? National solutions often don't solve local problems.
3. Cooperative Communities as Catalyst for Change	How do we measure success of addressing social inequities?
3. Cooperative Communities as Catalyst for Change	How do we define inequitable access to resources in a world of limited resources?
3. Cooperative Communities as Catalyst for Change	How to overcome the financial challenges, especially for smaller communities? How to understand the trade-offs and engaging the community in where to invest? Is funding movable from one account to another--allowing multi-benefit projects? Sub-optimal projects result from siloed funding.
3. Cooperative Communities as Catalyst for Change	What types of solutions/interventions can be used in urban systems with aging infrastructure where the challenges are immense? What are the ways we can replace and upscale underground infrastructure without the

	extreme expense and difficulty of digging up cities and neighborhood ? What are the ways that residents can be protected from lead exposure IN their homes in cities where lead lines are being replaced up to the residence?
3. Cooperative Communities as Catalyst for Change	Need to understand the underlying economics of environmental risks and solutions, so paying for expensive solutions is justified.
3. Cooperative Communities as Catalyst for Change	How to identify or surface the needs or challenges of stakeholders at a watershed scale that are linked with water security (quality and quantity).
3. Cooperative Communities as Catalyst for Change	How to align incentives for the private sector to adopt BMPs but also identify the financial inefficiencies in some current practices (e.g., stream restoration not achieving biological uplift).
3. Cooperative Communities as Catalyst for Change	How to address issues when institutions and and legal systems (eg water rights) put up barriers to adaptation?
3. Cooperative Communities as Catalyst for Change	How do we raise voices equally in this space to address water resources concerns, so that no one suffers in silence?
3. Cooperative Communities as Catalyst for Change	How to incentivize lower GW uses? Will affect resilience. Hurdles to regulate/incentivize private landowners. How to get long-term thinking? Does higher-level regulation need to happen?
3. Cooperative Communities as Catalyst for Change	How to manage the challenge of climate change impacts (e.g. episodic drought) and the demands placed on groundwater by the expansion of irrigation to protect agriculture in a place like New York.
3. Cooperative Communities as Catalyst for Change	How might we create better land-use planning regulations to provide water quality, ecosystem resiliency, water supply and other benefits
3. Cooperative Communities as Catalyst for Change	How do we put solutions into the hands of local water users?
3. Cooperative Communities as Catalyst for Change	How do we continue to support an expanding and more productive population without using more resources unsustainably?
3. Cooperative Communities as Catalyst for Change	How do we create the proper balance between uniformity and diversity of water regulation and policy?
3. Cooperative Communities as Catalyst for Change	How to address inequities in rural communities? lack of expertise

3. Cooperative Communities as Catalyst for Change	How to get everyone to the table and everyone is heard and everyone is satisfied? Can be done. See Verde River example.
3. Cooperative Communities as Catalyst for Change	If cities are the best bet for climate players and enacting climate mitigation/adaptation - where does this leave rural communities?
3. Cooperative Communities as Catalyst for Change	groundwater is very individualistic-- well owners and policy/government don't talk. how can we learn from healthcare where we have small/local trust and data sharing, but also anonymity and data aggregation where individuals are not blamed for problems. how we can learn from "harm reduction" orgs?
3. Cooperative Communities as Catalyst for Change	How do we better incorporate social science and disadvantaged communities with technologists & scientists that are not experts in that space?
3. Cooperative Communities as Catalyst for Change	Is there a risk of shorter-term policies undermining political imperative for longer-term changes? Can certain short-term imperatives – e.g., responding to acute water problems – undermine longer-term goals, and how do you communicate this, let alone address it in govt/industry?
4. Ecosystem services for safer communities	How do we think about nature based solutions for water quality/quantity as part of "infrastructure" in terms of investment, construction, and management.
4. Ecosystem services for safer communities	How do we ensure solutions are environmentally sustainable in the long-term, and not just short-term fixes?
4. Ecosystem services for safer communities	How do we determine sustainable rate of use of water resources (rivers, lakes, aquifers, etc.) that can be naturally replenished, in the face of external pressures like climate change and population growth?
4. Ecosystem services for safer communities	How do we change land use planning/management today (e.g. wetland restoration or protection) to systematically project groundwater resources over the next 20 years?
4. Ecosystem services for safer communities	Need to connect the different aspects of natural and built infrastructure for more cohesive approach of addressing complex issues.
4. Ecosystem services for safer communities	Is geoengineering inevitable and what are the impacts?
5. Big Data for Big Problems	How might we incentivize the ag sector to collect and report their water use more accurately? How might this data be better operationalized in interstate water compacts?
5. Big Data for Big Problems	How might we leverage current technology (3D, A/R and V/R, machine learning, etc.) to make data more accessible/valuable to decision makers and stakeholders impacted by water resource decisions and challenges. This is about engagement of water stakeholders as well as their efforts to

	make better governance decisions (and a way to distribute the most useful data and harvest their knowledge or observations in a way that it can be combined with data to provide richer insights useful for managing water more effectively. .
5. Big Data for Big Problems	How do we identify solutions within a framework of sustainability, resilience, and equity?
5. Big Data for Big Problems	How do we develop the space and support for solutions/tools/capabilities that were developed through soft-funded research to be supported and sustained long term?
5. Big Data for Big Problems	How might we develop a groundwater assessment tool that allows us to understand water resource availability to adapt to a changing planet?
5. Big Data for Big Problems	1) A need for an open data policy, technology solutions, & implementation strategies 2) Leverage digital twins (immersive & interactive environments to make data more accessible) 3) Data infrastructure needs its own dedicated funding 4) Security & privacy considerations and how to balance with open data 5). Better community & integration across stakeholders- virtual engagement and tools for breaking down silos
5. Big Data for Big Problems	As a filter for any particular issue, can we ask "what do we already know, how can we apply/use what we know, what do we need to know? - Alan R.
5. Big Data for Big Problems	How do we capitalize on emerging technologies (new sensors, scenario analysis, immersive data experiences)? - Steve Malers
5. Big Data for Big Problems	How do we meaningfully measure the usefulness of new knowledge, data, and products to stakeholders? Simply saying that a new data product was downloaded x times has limited value.
5. Big Data for Big Problems	How do we encourage open data as infrastructure, as a sufficient temporal and spatial baseline of data today that supports monitoring and addressing issues in the future?
6. Save for the Future	How do we pivot from reliance on large-scale surface water reservoirs to alternative projects to provide water supply resiliency.
6. Save for the Future	Infrastructure challenges: How to update infrastructure-given low resources $$$ New regulations/demands Infrastructure is inadequate even for existing climate How to meet next 50 years of demands Wastewater treatment is not up to standards Transportation overlaps with water, how to use nature-based solutions? Especially challenging for smaller communities

6. Save for the Future	How do we determine sustainable rate of use of water resources (rivers, lakes, aquifers, etc.) that can be naturally replenished, in the face of external pressures like climate change and population growth?
6. Save for the Future	How do we effectively coordinate federal, state, and local resources so there is a concentrated effort to address an issue?
6. Save for the Future	How do we give groundwater equitable stake in the future allocation of resources and regulations similar to surface water?
6. Save for the Future	How can we capitalize on water from flood events to solve water shortage issues?
6. Save for the Future	How might industry-produced water (typically very saline or other poor water quality) be treated or recycled into a more sustainable resource?
6. Save for the Future	How do we incentivize reductions in groundwater withdrawal in places without oversight and legislations on groundwater resources.
6. Save for the Future	Can we properly manage and actively recharge groundwater resources in locations as is, or do we need to assess land use and look at reducing our need for water through land use change?
7. Hydrologic disturbance frameworks for decision makers	How might scientists and community stakeholders most effectively engage in resiliency planning in the face of changing climate, acknowledging that planning efforts often take place at local to regional scales?
7. Hydrologic disturbance frameworks for decision makers	How to we plan and engineer for "surprise." If we over react to anticipated futures, we lose public support. If we under-react to anticipated futures we lose public support. Yet, it is virtually guaranteed we will either over or under react (most likely under).
7. Hydrologic disturbance frameworks for decision makers	How can we better capture/represent extreme events in our existing models (especially when we are limited by data in the observational record that captures these extremes)?
7. Hydrologic disturbance frameworks for decision makers	How can we overcome the disconnect between timescales over which stakeholder/agency models are being run (daily) and academic studies happen over (years)?
7. Hydrologic disturbance frameworks for decision makers	How might we build "models" (or do something other than build models) that account for the complexities and uniqueness of each watershed (in terms of ecological, hydrological, social, institutional, etc. characteristics) and the interconnectedness of water with so many other issues (groundwater-surface water; water-energy-food)
7. Hydrologic disturbance frameworks for decision makers	How do we standardize national screening and regulations for emerging contaminants in groundwater systems?

7. Hydrologic disturbance frameworks for decision makers	Water, fire, economics are unifying issues across the political space.
7. Hydrologic disturbance frameworks for decision makers	How can we share knowledge/expertise as land uses/land use practices change as a result of climate change. For example, one state starts relying on irrigation more than it had historically, what lessons can it leverage from other places that went through that shift already.
7. Hydrologic disturbance frameworks for decision makers	What is the difference between drought, short-term, long-term, and aridification? Consistent messaging is important.
7. Hydrologic disturbance frameworks for decision makers	How do we deal with increasing urbanization effects on drought risk (water supply) & flood risk?
8. Miscellaneous	How can we find creative ways to fund monitoring? this is essential for baseline understanding of natural systems
8. Miscellaneous	how can we create funding opportunities/data collection opportunities to capture response to extreme events (that are more nimble than multi-year NSF style grants)? RAPID is great, but more them?
8. Miscellaneous	How might we integrate the speed of this process (3-5 years) with the urgency of water quality challenges and impacted communities?
8. Miscellaneous	How do we reconcile needs across common themes e.g., water quantity in the western U.S. vs. water quality in the eastern U.S.?
8. Miscellaneous	How to streamline projects, accommodate competing interests? Anti-regulation attitudes. Struggles with under-staffing and inability to use more information even if it becomes available.
8. Miscellaneous	How do we implement health and privacy practices surrounding the stigma of water quality in rural and plain communities using groundwater wells and springs, or more modern communities facing economic consequences?
8. Miscellaneous	Who are the players that can affect change? Is it the cities?