Colorado Department of Public Safety

Colorado Future Vulnerability to Flood, Drought, Wildfire Assessment

Technical Proposal

Solicitation Number: RFAA 2019-0299

Due: Monday, June 17, 2019 at 2:00 PM MT

Submitted To:

Colorado Department of Public Safety
Procurement Office
Attention: Ms. Tammy Lichvar
700 Kipling Street
Denver, Colorado 80215

Submitted By:

Lynker Technologies, LLC
Graeme Aggett, Principal and
Chief Scientist
3002 Bluff Street, Suite 101
Boulder, Colorado 80301

Colorado VSS #
VS50000000005267

Boulder, Colorado **DC—Metro** **Pacific—Oahu**

REQUEST FOR PROPOSAL (RFP): RFAA 2019-0299
TITLE: Colorado Future Vulnerability to Flood, Drought and Wildfire Assessment
Date Due: Tuesday, June 17, 2019 2:00 PM MT

COLORADO DEPARTMENT OF PUBLIC SAFETY

SIGNATURE PAGE

ISSUING OFFICE: This Request for Proposal (RFP) is issued by the Colorado Department of Public Safety (CDPS), Executive Director's Office. The CDPS Procurement Office is the sole point of contact concerning this solicitation.

Issuing Office Address: Colorado Department of Public Safety
Procurement Office
700 Kipling Street
Denver, CO 80215

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COLORADO VSS # (Not FEIN or SSN) VS50000000005267 Date 6/17/2019

NAME OF COMPANY Lynker Technologies, LLC

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CITY Boulder STATE Colorado ZIP CODE 80301

PHONE 720-446-1701

EMAIL gaggett@lynkertech.com

Indicate if your company is registered and verified by the U.S. Department of Veteran Affairs as a Service-Disabled Veteran-Owned Small Business:

☐ YES (if yes, please submit validation with your bid response) ☒ NO

PRINT NAME OF COMPANY REPRESENTATIVE Graeme Aggett

TITLE Principal and Chief Scientist

SIGNATURE OF COMPANY REPRESENTATIVE ____________________
Handwritten **ORIGINAL** signature by an authorized officer or agent of the company.

SIGN AND RETURN THIS PAGE WITH PROPOSAL SUBMISSION

1. Transmittal Letter

June 17, 2019

Colorado Department of Public Safety
Procurement Office
Attention: Ms. Tammy Lichvar
700 Kipling Street
Denver, Colorado 80215

RE: Colorado Future Vulnerability to Flood, Drought and Wildfire Assessment
RFAA 2019-0299

Dear Ms. Lichvar,

Please accept Lynker Technologies, LLC's (Lynker) formal response to the Colorado Department of Public Safety's (the Department) Request for Proposal (RFP) for an Assessment of Colorado's Future Vulnerability to Flood, Drought, and Wildfire. We are excited to have the opportunity to offer our services to conduct this this very important project.

With this proposal submission, Lynker positively affirms our willingness to comply with all work requirements, general contracting requirements, and other terms and conditions as specified in the RFP. We also affirm our willingness to enter into a contract containing substantially similar terms published with *RFP Exhibit E—Sample State Contract*. Lynker has reviewed *RFP Exhibit E–Sample State Contract*, and we will not take any exceptions to any language in the document.

Dr. Graeme Aggett is the proposed project manager and will act as the point of contact for all matters pertaining to this contract. His contract information is provided below. Lynker's submitted *Technical Proposal* and *Price Proposal* are valid for 180 days.

Sincerely,

Dr. Graeme Aggett, Principal and Chief Scientist, Proposed Project Manager
Lynker Technologies, LLC | 720.446.1733 | gaggett@lynkertech.com

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Glossary of Key Terms

Exposure	The people, livelihoods, habitats, species, infrastructure, or economic, social, or cultural assets that could be adversely affected by a stressor (Sayers *et al.*, 2016).
Hazard (analysis)	An assessment of the probability and severity of flood, drought, and wildfire stressors.
Hazard (natural)	Historical or future flood, drought, and wildfire events that lead to adverse consequences for social, economic, and or natural systems.
Impacts	The consequences or effects of a hazard on the environment, economy, and human health.
Resiliency	The ability of social, economic and environmental systems to cope with flood, drought, and wildfire risks, limiting the significance of any associated harmful consequences should they occur, and having the capacity to adapt in a way that reduces future risks.
Risk	An assessment of where populations, infrastructure, and critical facilities are vulnerable to hazards, and to what extent injuries or damage may occur (FEMA, 2015).
Scenario	A baseline state or future projection of (a) climate conditions or (b) the human population occupancy and distribution on the environment.
Sectors	Categories of the environment and society that represent systems that may be impacted by natural hazards (e.g. infrastructure, economy, public health, agriculture, recreation & tourism, and environment).
Sensitivity	The propensity of a particular receptor/asset to experience harm as a result of a given hazard.
Vulnerability	The propensity or predisposition of a given receptor (or group of receptors) to be adversely affected by a hazard. Vulnerability encompasses a variety of concepts and elements including sensitivity to harm, exposure, and value (the value society places on the harm caused).

2. Executive Summary and Project Control

Executive Summary

The impacts of climate change are already being felt in communities across Colorado. Higher temperatures and drier conditions have led to larger wildfires, while population growth has expanded the wildfire-urban interface, meaning these events have much greater impact. Persistent droughts have impacted the agricultural economy, stressed urban water supplies and accelerated groundwater depletion. Economic losses from major storm events such as the Front Range 2013 floods continue to increase, the impacts often greatly exacerbated by the compound effects of wildfire. State policymakers are under pressure to make decisions on climate change that intersect with many other policy domains and have both immediate, short-term consequences and profound, long-term implications. Assessing climate change risks to inform adaptation planning is thus becoming critically important. Failure to effectively plan for and manage future climate change risks will result in significantly greater damage to infrastructure, businesses, the economy and society in general.

In response to a request from the Colorado Department of Public Safety (CDPS) Division of Homeland Security and Emergency Management (DHSEM) and the Colorado Water Conservation Board (CWCB), this proposal presents a formal structure for evaluating climate change risk as a critical component of state adaptation decision-making. The proposed work will develop an accessible, cost-effective and user-tested climate change risk assessment framework that will align with existing state plans for climate change, resiliency, multi-hazards, water, and water supply, so the state can better identify, quantify, prioritize and manage their climate change risks. Our work product will be delivered through an easy to use, visually engaging and enlightening ‘Climate Change Multi-hazard Risk Assessment Tool’.

Using a defensible approach to risk assessment based on understandable and consistent definitions, Lynker proposes a bottom-up approach to the modeling of risk that will focus on quantifying hazards at fine spatial scales and intersecting those analyses with information on populations, assets, and economic activity. We will catalogue and manage the outputs from our analysis at the county level, with options to then summarize, present and visualize these impacts at larger spatial scales including user-defined regions appropriate for this analysis.

We conceptualize our workflow for this project as a pyramid, where each successive layer builds on the foundation laid before it (*Figure 1. Project Framework*). Critical to the success of the project will be our efficiency **gathering, organizing and analyzing relevant data** to inform models. Lynker brings great efficiencies here because of roles we have on related state and other agency projects, however this component will still be a significant part of the project and the foundation for success. Next, we will **quantify baseline risks**. Methods will vary across the different natural hazards and will be tailored to the available data. As part of the baseline analysis we will **build conceptual models of risk** for each natural hazard in an iterative process that will begin with a qualitative description of multi-hazards, the assets exposed to those hazards in the baseline period, and how climate and socioeconomic changes might affect future risk. This will be supported by case-study prototypes for each natural hazard at a finer spatial resolution than that for the main, state-level study. These targeted studies will provide training data to quantify the monetary risk affiliated with major historical flood, drought and wildfire events, and assess the retrospective cost/benefit of mitigation activities. It will also provide information to validate our state-level hazard and economic models, and enable us to home-in on a framework for scenario planning and mitigation analysis. This step will also be a conceptual incubator for optimizing communication and working relationships with our state partners.

Next, we will **develop future scenarios**. The climate and socioeconomic factors that drive risks from flood, drought and wildfire are different for each natural hazard; thus, the scenarios used to quantify future risks will need to be tailored to each analysis. Once future climate scenarios are developed, we will incorporate these changes into our baseline models for each natural hazard to quantify future risk from flood, drought and wildfire. These future models will also be used to highlight the key drivers of vulnerability, and to begin evaluating adaptations that could be used to decrease future economic impacts. Once we have a solid understanding of future risks for multi-hazards, we will **identify future resilience actions**. Using the results of the future models, we will analyze options for improving resilience that could decrease overall costs relative to a no-adaptation scenario. Finally, we will develop and refine a visualization tool. This Climate Change Multi-hazard Risk Assessment Visualization Tool will evolve step-wise through the project with relevant components being developed and tested in agile fashion at each tier in the pyramid and with input from the state. This final product will allow users to turn specific hazards and impacts on and off and gain a high-level understanding of the state's current and future vulnerabilities. The Lynker Team is intimately familiar with Colorado's hazard and climate change mitigation plans and studies, having worked on many of these over the past 15 years. Our entire approach is aligned with the momentum created by these planning efforts, and especially aimed at mitigation goals contained within the 2018 State Hazard Mitigation Plan and Colorado Climate Change Adapation Plan.

In addition to summarizing our workflow, *Figure 1* also highlights where the primary levels of effort will be focused, and the schedule for the work. This framework offers several benefits to the state's climate change adaptation process. First, gathering data and characterizing baseline vulnerabilities early in the project will allow the state to identify climate change risks and integrate them with their mainstream risk management process. Second, it makes optimal use of the state's limited adaptation resources by taking a tiered approach, allowing DHSEM and CWCB to start from a lower knowledge base using minimal resources and, as required, move to more complex and resource-intensive risk assessment processes. Third, it introduces a time-dependent vulnerability rating which recognizes the characteristics of climate change risks—that they are long term and associated with a considerable degree of uncertainty. Finally, it considers business inter-dependencies that can exacerbate impacts but that might be overlooked in a purely sector-based impacts evaluation. Throughout this proposal we highlight the appropriate use context for each risk assessment tier, explore key technical differences among the tiers, describe how each tier informs the next (higher) tier, and describe performance testing. We propose developing multiple case study applications and training the state in the use of this tiered climate risk assessment approach in the context of broader adaptation planning.

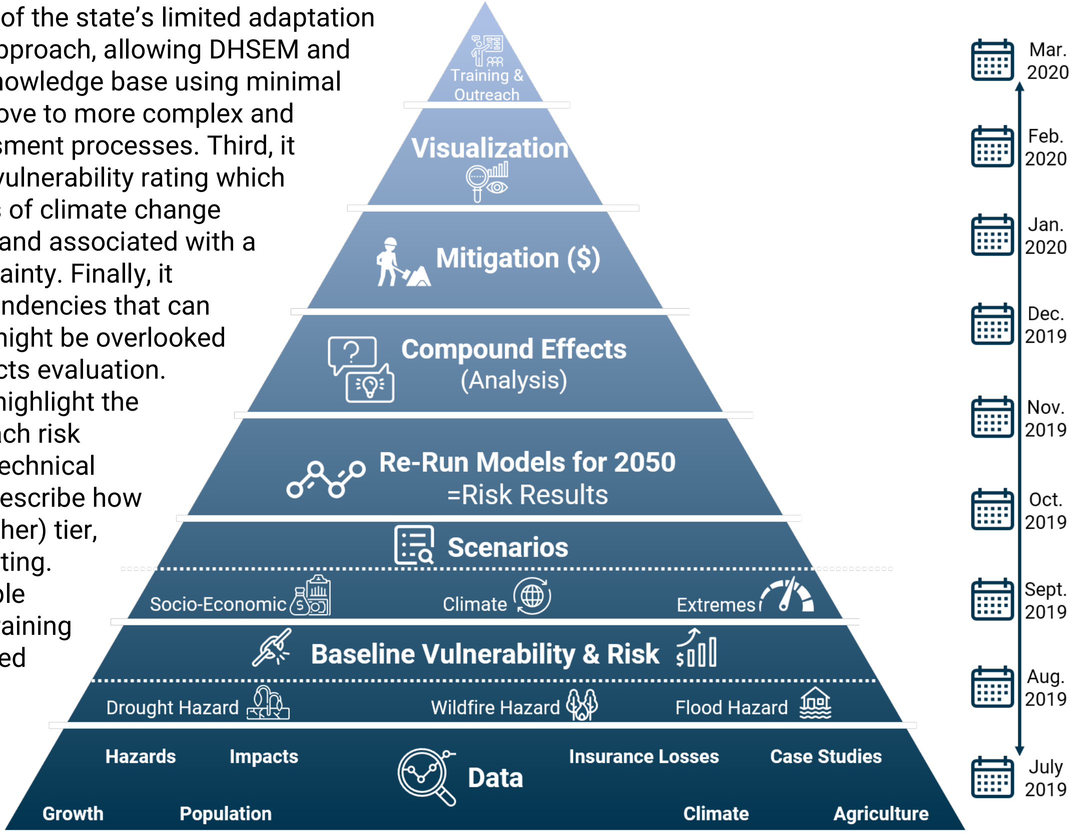


Figure 1. Project Framework

Project Priorities

Lynker's Boulder-based group works for local, state and federal agencies. We are a small team but have grown steadily since we kicked off in 2014. In the past year we have strategically hired several new team members to augment our existing hazard and risk analysis team and to support this area of our work that we are most passionate about. This steady growth continues. We have always made the state a high priority, and this project has absolute precedence, with the Lynker Colorado team all committed to support this effort at the highest level. This is exemplified by the group lead (Dr. Aggett), who, unlike leads in most large companies, has complete autonomy with which to ensure resources are focused as promised. The majority of Lynker's base-load is with our NOAA client at the National Water Center (NWC) where we are developing next-generation tools to enable better modeling and management of present day and future hydrologic hazards and risks CONUS-wide. Dr. Aggett is able to manage the NWC team so that it does not interfere with this state project at all. Rather, we can draw on some of our NWC staff if we need them. We have, however, built an entirely local team for this project that we aim to have handle all the necessary work, per our schedule. Most of the key personnel on the team – both within Lynker and across our partners – will be available to this project at the 50-85% level.

Our project manager will be available at the 50% level, and he will be supported at 85% by a senior assistant project manager. This management team (Aggett and Spies) has worked successfully for the state in this formation on recent projects. We will manage deliverables by sending a technical memo describing data, methods and results to the state at the end of each tier, and reviewing the technical content using the draft visualization tool as it develops. The Lynker Team is committed to doing this review every month in person with the state team in Denver or in Boulder, or via web meetings - whichever is most convenient for the state team. Our project manager will always be available to the state project manager.

Project Management and Control

Project Manager Graeme Aggett will work with the state team to develop a kickoff meeting agenda that includes a detailed project management plan (PMP) to keep the project on time and within budget. The PMP will clearly outline project deadlines, key performance indicators (KPIs), a clearly defined scope of work, organizational structure, communication plans, and committed staffing plans.

Lynker uses International Organization for Standardization (ISO)-Compliant Quality Management System (QMS) processes and benchmarks to enable us to verify quality across all subtasks and deliverables. We use our QMS to guide the development of contract- and project-level Quality Control and Surveillance plans (QCP/QASP), leveraging checklists, templates, surveillance metrics and best practices and other artifacts from our ISO and Capability Maturity Model Integration (CMMI) libraries. In addition, a key component of all of our work includes consistent, reliable, and open communication with our customers.

Lynker will deliver completed technical memos outlining our methodology and how to use the risk analysis and visualization tool, materials, minutes, and detailed notes from all participants in advisory group and stakeholder meetings, and monthly status reports for our monthly project team meetings. Finally, we will deliver a completed visualization tool, and a comprehensive final report, including scenarios, vulnerability and risk analysis results, and potential costs/benefits of resilience actions.

Additional information on our project management techniques and methodology is provided in *Section 4—Management Plan* on page 48.

3. Technical Approach (SOW Section C)

Lynker's approach to this project will be based on some fundamental principles. First, it will be **well-informed**. Lynker has conducted numerous climate change and multi-hazard risk analyses at state, local and national scales, so we are familiar with the range of data, technical and policy challenges and options for addressing them. Second, our approach to this project will be driven by **collaboration**. While we have deep team experience with multi-hazard and climate change risk assessment, we need and want input from our state partners and their stakeholders to develop analyses and tools that are most appropriate and useful for their collective needs. Third, the Lynker Team recognizes that the quality of our final analysis will fundamentally depend on the **quality of the data** we harvest, develop and organize to fuel this study. We are well positioned to conduct this part of the project efficiently, having contributed to the development of many of these datasets, and given our connections to state and other agencies that can connect us with the right data. Fourth, we are adept at filling data gaps with defensible approaches, having done this for many US and international projects. We understand that new data will continue to come online that can update and enhance the work being proposed here, so we will develop a **flexible framework** for the state that will enable these data to be plugged in to update our risk assessments. Finally, we are basing our entire study on **reasonable and proven risk assessment methods**. Quantifying and monetizing impacts from natural hazards and climate change requires judgements and assumptions. Lynker's approach will use the skills and experience of professional economists who have great experience in this field, and who have a focus on not overreaching to ensure that outputs are reasonable and defensible.

3.1. Background and Expertise

Lynker Technologies, LLC (Lynker) is a water science and engineering company delivering environmental science solutions to a dynamic and increasingly complex world. Engaging with the natural and manmade environment demands a sophisticated understanding of the various stressors and an ability to balance the needs of the environment, the economy, and society. Lynker provides this understanding through innovative decision support solutions that address the increasing demand for better information to address pressing environmental concerns.

Lynker's scientists and engineers are experts in natural hazard and risk assessment, economics, modeling, water resources engineering, and climate change impacts, and are highly skilled in solving complex terrestrial water management and climate-related challenges. We also develop innovative data visualization solutions that allow stakeholders at various scales (local, regional, global) to make informed decisions about how to best serve their communities.

Why Lynker?

- *Experts in Data Science, Data Visualization, and Climate Change analysis*
- *Entirely a Colorado-based team*
- *Decades of working on CWCB data development and handling, Colorado climate change analysis, decision support system development, and data visualization projects*
- *Decades of experience supporting economic valuations of climate change impacts*

Lynker staff have always put the state first. We know how to listen to CWCB managers and engage their stakeholders with the goal of developing useful information and tools that can help Colorado's decision makers with assessing and mitigating climate hazards more effectively, now, and in an uncertain future.

3.1.1. Project Team

Lynker's Boulder, CO-based scientific consulting division serves our local, regional, state and federal clients by helping to solve complex problems, including multi-hazard and risk analysis, physical process modeling, climate science, water supply planning, data analysis, data management and data visualization, and public engagement. For decades, we have assisted local agencies and municipalities with natural hazard and risk management challenges. We have led multiple projects (including the $1.4 million Emergency Watershed Protection) focused on helping Jamestown CO respond to and recover from the devastating 2013 Front Range flood. We have guided USDA-funded wildfire hazard and risk modeling efforts for Eastern Washington State. We have developed flood hazard and risk models for communities along the Nile in Ethiopia and Sudan, and FIRM and RISK maps for communities in CA and WA. We also helped develop the concept of Channel Migration Zone (CMZ) hazard modeling for the state of Washington and helped the Colorado Water Conservation Board (CWCB) adapt this approach for their Risk MAP program. Key Lynker staff have conceptualized and developed approaches to assess drought vulnerability at the state scale and have served on technical panels for the National Integrated Drought Information System (NIDIS).

***Lynker** is a leader in providing scientific modeling services, climate change impact analyses, and water resources science and engineering solutions for our state, local, and federal clients.*

Within the past two years, Lynker has invested in strategic hires with unique capabilities and expertise developing climate change vulnerability assessments at both local and national scales. These strategic hires have spent several years modeling and monetizing climate change impacts, and leading climate change vulnerability assessments for clients including the US Environmental Protection Agency (USEPA), the National Oceanic and Atmospheric Administration (NOAA), and the Department of Housing and Urban Development (HUD). More broadly, we work as consultants and as principal investigators for federal agencies including NOAA, National Aeronautics and Space Administration (NASA), United States Department of Agriculture (USDA), Environmental Protection Agency (EPA) and the United States Geological Survey (USGS). We are currently the small business lead serving NOAA and the National Weather Service (NWS) in development of a next generation flood forecast system. Lynker is also a longstanding Esri partner, enabling our team to explore and apply their latest content and tools. For example, in 2019, Lynker completed an innovative effort for CWCB to visualize data from the Colorado Drought Plan using Esri's suite of ArcGIS Online (AGOL) products. Lynker team members constantly communicated with CWCB to ensure the prototype applications were effective and the final application could be maintained by CWCB upon completion. Lynker has supported Esri with development and testing of their ArcHydro data model, and we recently led the installation of an ArcGIS Enterprise for the Office of Water Prediction.

As the lead for this project, Lynker brings an ideal blend of technical and project management experience, including a stable of agile and committed scientists, data managers, and technologists with a long-standing working relationship with the state. To supplement Lynker's skills and abilities we have partnered with select leading companies, individuals, and organizations to expand the insight and capabilities to meet the needs of this project. Our partners, who are also all Colorado-based, include:

***Abt Associates (Abt)** provide technical and professional services for impacts analysis including public health, housing, agriculture, and adaptation.*

Abt Associates (Abt) is a mission-driven, global leader in research and program implementation in the fields of environmental protection, public health, housing and community development, food security and agriculture, and governance. Abt's climate change impacts team, which will serve this project, comprises a Boulder-based group of economists, climate policy specialists, adaptation experts, and geographic information systems specialists, that has developed and employed innovative approaches to modeling climate change impacts for a range of local, state, federal and international clients.

Colorado State Forest Service (CSFS) is a state agency at the forefront of Colorado wildfire risk assessment, adaptation and mitigation. CSFS develops models, education materials and programs to assist homeowners, landowners and communities in taking action to reduce their wildfire risk. Through a variety of programs, CSFS encourages the creation of fire-adapted communities through the implementation of forest management to increase forest resiliency. For example, CSFS developed an initial Colorado Wildfire Risk Assessment (CO-WRA) in 2013 (since updated in 2017). This assessment was based on leveraging data and achievements of the West Wide Wildfire Risk Assessment (WWA) project, and tailoring these to reflect Colorado conditions, requirements and priorities.

***Colorado State Forest Service (CSFS)** are the experts in fire risk analyses, fire modeling, and fire data analysis having completed the Colorado Wildfire Rask Assessment (CO-WRA).*

Anchor Point Wildland Fire Solutions. Founded in Boulder, Colorado in 1999, Anchor Point develops and supports risk-based wildland fire mitigation solutions from community planning through forest plans. Their core focus is wildland fire risk assessment and protection of home, community and resource values. Anchor Point uses cutting-edge fire science and fire modeling techniques to yield the highest quality fire management solutions available today. The group is made up of active fire managers, subject-matter experts and advisors on wildland- urban interface issues throughout the United States and world-wide. Anchor Point served on the Technical Advisory Committee and Fuels Update Team for the Colorado Wildfire Risk Assessment Portal.

Molly Urbina, Urbina Strategies, LLC. Headed by Ms. Molly Urbina, Urbina Strategies provides expert land use and resilience consulting for private, public and non-profit sectors. Molly recently served as the Executive Director of the Colorado Resiliency and Recovery Office appointed by Governor John Hickenlooper in February of 2014. Some of her relevant experience also includes 4 years as the resiliency and recovery leader of the state to coordinate the diverse and complex portfolio of disaster recovery and resiliency efforts.

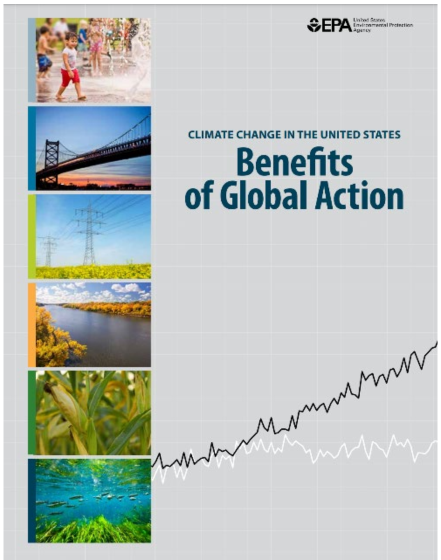


Figure 2. Climate Change Impacts and Risk Assessment

The Lynker Team has monetized climate change impacts for U.S. EPA for over a decade, including for flood, drought, and wildfire

David Mills, Peak to Peak Economics. Mr. Mills is an economist with more than 20 years of project experience for state and federal clients developing and applying methods to quantify and monetize changes in human health, welfare, and environmental conditions. His work has been widely published in the peer reviewed literature and incorporated into influential government reports including the U.S. Global Change Research Program's 2016 report *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* by the U.S. Global Change Research Program (USGCRP) (USGCRP, 2016)

Joseph J. Barsugli, Ph.D. Dr. Barsugli has over ten years' experience applying his training in climate theory and modeling to a wide range of real-world problems in water resources and ecosystem management in Colorado and the western Unites States. He also pursues research on physical climate science and the impacts of climate change through his appointment as a Research Scientist III at the Cooperative Institute for Research in the Environmental Sciences at the University of Colorado at Boulder, a joint institute between NOAA and CU. In addition to providing climate analyses for numerous climate adaptation projects, he has also written or co-authored papers on the evaluation and use of climate projections including "The Practitioner's Dilemma."

3.1.2. Statement of Qualifications

This section provides a brief overview of our team's qualifications as they apply to this solicitation. The technical approach described in *Section 3.2 General Approach* on page 15 provides more specific details about how we will apply this expertise to help CDPS build a useable, defensible analysis of Colorado's vulnerability to flood, drought and wildfire hazards.

The Lynker Team has exceptional subject matter expertise. The Lynker Team will provide the state with a balanced blend of hazard and risk modeling specialists, physical scientists, economists, highly efficient data handlers, and expert climate policy specialists. Our team is seasoned with decades of experience in the hazard, vulnerability, risk and climate fields, yet we are fresh in that we are all very curious and thus stay current with the state-of-the-art in this arena. Our team is extremely well connected across all of the relevant agencies within the State of Colorado, as well as across an international network of leaders in the fields of hazards, risk assessment, climate change and economics. Our scientists and engineers are leading experts in hydrology, drought, wildfire, and other climate impacts, and have published multiple papers on topics directly relevant to this project (see Appendix 5—References).

Our team's economists are particularly skilled at monetizing projected impacts attributed to a changing climate, having completed similar projects for U.S. EPA's Climate Science Impacts Branch in support of their Climate Change Impacts and Risk Assessment (CIRA) project over the past decade (EPA, 2015). Our team also has an exceptional understanding of climate change vulnerability and adaptation, and includes a lead author and assessment report member of the Intergovernmental Panel on Climate Change (IPCC).

The Lynker Team is entirely Colorado-based. While we have broad and deep experience that extends to national and international projects, our primary expertise and passion is in applying hazard, risk and climate change analyses in the state where we live and with which we are most familiar. Indeed, Lynker staff have served the State of Colorado for over 20 years. We played a key technical role in assessing hydrologic impacts of climate change for CWCB's Colorado River Water Availability Study (CRWAS) and conceptualized and led the state Colorado Drought Vulnerability Study, this work being the first of its kind to inform a state Drought Plan. Lynker staff conceptualized and developed a NOAA-funded Climate Change Drought Vulnerability Decision Support System in a project that included CWCB as a key stakeholder, and we have led the spatial systems component of Colorado's Decision Support Systems (CDSS), developed a Flood Decision Support System for CWCB, and have most recently developed a drought vulnerability visualization tool, also for CWCB. Our local presence will allow us to meet with the project team at any time over the course of this fast-paced project, allowing us to review information and discuss options in a structured yet flexible way.

The Lynker Team has deep experience in climate change vulnerability. In addition to our ongoing hazard, vulnerability and climate change work for the State of Colorado, the Lynker Team has an unparalleled record in supporting climate change vulnerability assessments at both local and national scales. In particular, key members of the Lynker Team (including Cameron Wobus, Dave Mills, Joel Smith, Russ Jones, and Heather Hosterman) played leading roles in U.S. EPA's CIRA project for more than a decade. CIRA focused on quantifying vulnerability to climate-modulated stressors, and on monetizing the damages from those stressors under a changing climate (EPA, 2015). While the CIRA effort emphasized results at a national scale, the analyses were supported by impact assessments executed at much finer geographic scales such as the city or county level, consistent with CDPS' goals under this solicitation. For the CIRA work, these staff specifically addressed the vulnerability from flood, drought, and wildfire, quantifying and monetizing impacts to help U.S. EPA meet their program objectives for examining the potential benefits of greenhouse gas mitigation.

The Lynker Team understands data visualization. Risk analyses tend to be highly mathematical, statistical, and probabilistically-oriented. Data on risks and hazards tend to be heterogeneous, complex, interdependent, and correlated in ways that are not immediately apparent. Lynker is adept at using existing and emerging visualization technologies for data exploration to help explain, analyze and communicate risks. We have decades of experience developing thoughtful data visualization methods and techniques, including our recently completed drought vulnerability visualization tool for CWCB. Because the risk analyst and the public in general may differ on what constitutes a risk, these techniques can help the risk assessor better understand underlying factors and generate better risk products (including maps), thus communicating a clearer message to the public. Risk data derived from the approach laid out in this proposal will portray multiple scenarios, and our visualization approach will facilitate greater interpretation and constructive interrogation of these by individual stakeholders.

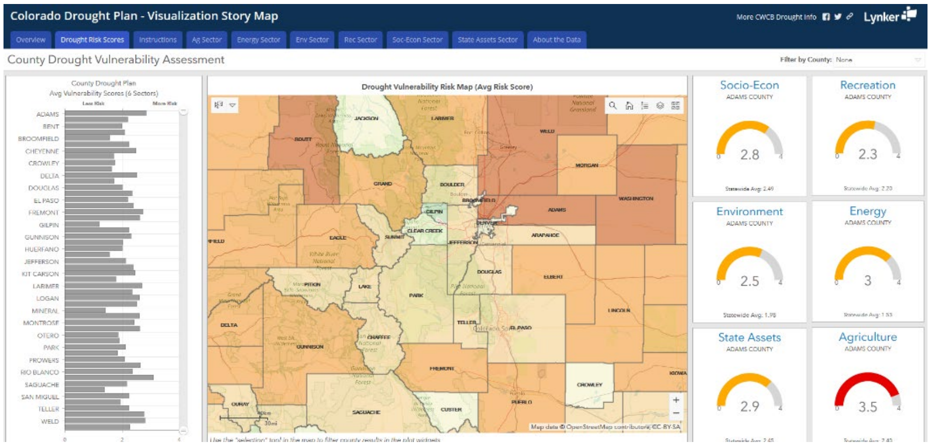


Figure 3. Data Visualization

The Lynker Team developed an innovative visualization tool to illustrate Colorado's drought vulnerability

3.1.3. Lynker's Experience with Climate Hazards

Our team has extensive experience analyzing flood, drought and wildfire hazards, both within the State of Colorado and across the United States and the world.

Flood

The Lynker Team has been working on flooding issues in Colorado since 2006 when Dr. Aggett led the development of the state's first prototype Flood DSS for the CWCB Flood Section, a project in which he and his staff became intimate with all the key flood hazard, risk and planning information for Colorado organized and displayed within that comprehensive system. He has also engaged with the state to extend national flood forecasting work he and his team have done supporting NOAA-National Weather Service.

Immediately following the 2013 Front Range floods, Dr. Aggett led the recovery efforts for the Town of Jamestown, working hand-in-hand with Mayor Tara Schoedinger to develop a Stream Corridor Master Plan for Jamestown, work that was then used to prioritize design opportunities for the town and generally guide recovery efforts to build resilience to future flood and debris events. Many design elements were implemented to mitigation the effects of future large flood events, such as retention basins for debris flows, improved bridge design, right-sized culvert design and installation, and property buy-backs to remove structures from the floodway. Aggett led seven flood recovery efforts in all, including a $2.4M Emergency Watershed Protection (EWP) project aimed at mitigating future risk to the town. Beyond the immediate flood recovery Lynker has also conducted two Front Range river restoration projects and developed two watershed protection plans, all aimed at enhancing system resiliency to climate change. In 2017 Lynker designed a FEMA-funded Flood ALERT system for Jamestown. This on-the-ground experience gives the Lynker Team terrific insights into the funding of adaptation projects, and what climate change considerations need to be taken into account in developing engineering designs and in planning.

In related work, Page Weil from Lynker has helped CWCB with an approach to develop *non-stationary* rainfall intensity-duration-frequency (IDF) curves. IDF curves are commonly used for the design of water resources and related infrastructure such as flood control, bank levees protecting roads, culverts and bridges, etc. However, climate change is expected to alter climatic extremes, a concept termed nonstationarity. Here we show that given nonstationarity, current IDF curves can substantially underestimate precipitation extremes and thus, they may not be suitable for infrastructure design in a changing climate and may lead to underestimation of extreme precipitation by as much as 60%, increasing the flood risk and failure risk in infrastructure systems. This has important cost implications when investing limited climate change mitigation dollars This approach can help improve decisions in this regard.

FEMA has recognized that channel migration zone (CMZ) hazards can, in many locations around the US, be a more costly hazard than overbank flooding. After the 2013 floods, in which debris flows saw channels switch location and direction as erosive debris flows ran through them, Colorado is now recognized as being one of those states. Working for the State of Washington, Dr. Aggett contributed with three co-authors to development of the first guidelines for CMZs, and was the first to implement these for Yakima County. In 2018 he helped adapt the methodology to Colorado conditions in a CWCB project aimed at enhancing the Colorado RiskMap program.

For more than seven years, Dr. Cameron Wobus has also been leading national-scale studies to quantify and monetize flood damages in a changing climate (Wobus *et al.*, 2014, 2017, 2019; Mills *et al.*, 2018). Through this work, Lynker has unique insights into the types of data that can be used to inform analyses of baseline and future flood risk. We have also created a framework for quantifying time-varying flood damages that uses future flood probabilities informed by leading projections of climate-adjusted hydrology. We will adapt this framework for this project, allowing us to hit the ground running to deliver an efficient, data-driven analysis tailored to the State of Colorado.

Drought

Lynker staff have been working on drought in Colorado for decades. Dr. Graeme Aggett has served on a National Integrated Drought Information System (NIDIS) panel for Remote Sensing of Drought while working as principal investigator (PI) on a three-year NASA-funded drought study monitoring soil moisture and ET in the South Platte. Our senior scientist, Ben Harding, led the development of climate change methods in the Colorado River Water Supply Assessment (CRWAS) project, which sought to quantify the changes in water supply considering climate change. The CRWAS project was updated by Lynker in 2015 (CRWAS-II), to consider climate change impacts in the context of water supply and water demand, allowing our team to identify areas with decreasing streamflow and increasing evaporation. CRWAS-II was completed for the entire state of Colorado by river basin, allowing CWCB (and any users of the data), to analyze changes in water supply and demand by watershed. The analysis from CRWAS-II provides the backbone of the climate change scenarios in Colorado's Water Plan.

Lynker staff (Aggett, Harding) contributed to the 2012 Joint Front Range Climate Vulnerability Study, which showed that by 2050, spring snowmelt runoff could begin up to two weeks earlier than today, while one of Denver's most significant sources of water, the South Platte River, could see a decline in streamflow by up to 30 to 35 percent. Residential development for millions of additional people will require a lot of water, yet water is already oversubscribed, and 83 percent of our water is currently used for agriculture. As the climate warms, more water will evaporate and sublimate from mountain snowpacks before it ever reaches reservoirs, and agricultural demand will rise. This means there will be less water go to around as an ever-rising population conflicts with a decreasing water supply.

Lynker staff conceptualized and led the Drought Vulnerability study for the state in 2013. This project developed detailed spreadsheets assessing vulnerabilities across the state by sector (agriculture, municipal & industrial, etc.) and was used to inform Colorado's Drought Mitigation and Response Plan, providing a framework for determining vulnerable assets impacted by drought in Colorado. This experience will allow us to efficiently collect and organize asset data for the vulnerability analysis of this project. Most recently, Lynker developed the drought vulnerability visualization tool for CWCB, which provides a real-time analysis of drought vulnerability by county in Colorado. This tool was built as a part of Lynker's work on the 2018 update of the Drought Mitigation and Response Plan. Additionally, Lynker completed an update to the Climate Change analysis (Annex C) of the Drought Plan, determining how drought conditions may change in the future (2050). Our team analyzed annual minimum flows, 2-year low flows, 5-year low flows, and 10-year low flows for the historical flow record and compared it with climate-adjusted flow for 2050, using CRWAS-II and CRWAS-I datasets.

Wildfire

The Lynker Team includes wildfire experts from the Colorado State Forest Service, who bring the knowledge and experience of the Colorado Wildfire Risk Assessment (CO-WRA) to Lynker's risk analysis and resilience framework. CO-WRAP is the primary tool for the CSFS to display wildfire risk information, and to provide a consistent, comparable set of scientific results to be used as a foundation for wildfire mitigation and prevention planning in Colorado. This latest version of CO-WRAP will enable Lynker to rerun the model with climate instead of meteorological forcings, and to adapt the risk model to enable us to integrate growth projections into our loss modeling.

Anchor Point brings the Lynker Team a unique combination of technical expertise and firefighting experience. The principals and staff of Anchor Point have an extensive history in wildland and wildland-urban interface (WUI) management which has been utilized to participate in and provide development assistance with the National Wildfire Hazard and Risk Assessment Methodology. They have also served on a FEMA Development Team - "Home Builder's Guide to Construction in Wildfire Zones" Technical Fact Series P -737 (FEMA, 2008). They also developed the International Code Council (ICC) Wildland-Urban Interface Code, the Nation's first building code for construction in the WUI, and contributed to the development team for the National Fire Protection Association (NFPA) FireWise program.

Anchor Point is extremely well connected with the state and county level wildfire practitioners we will need to access for hazard, vulnerability and mitigation data. Anchor Point Principal Rod Moraga oversees fire behavior analysis for hazard and risk assessments, prescribed burns and community wildfire protection plans. He served as a Fire Behavior Analyst for Rocky Mountain Incident Management Teams for 10 years and is currently the Chairperson of the Colorado Prescribed Fire Council and Management Academy. Chris White has specialized in Wildland-Urban Interface Fire Management for over 30 years. He started his fire career in 1987 working with both the US and Colorado State Forest Service, taking on the responsibility of pre-planning for approximately 1,100 subdivisions for wildland fire hazards and developing mitigation plans to reduce wildfire impacts. Mr. White became Colorado's first county-level Wildland Fire Coordinator in Summit County and he has been a member of the Western Governors Association (WGA) Federal Wildfire Policy Review Committee.

Since 2011, the Lynker Team has developed and managed research teams to quantify and monetize the potential impacts of climate change on the acreage burned by wildfires throughout the western United States. Led by Dave Mills, this work involved integrating the work of ecologists, geographers, wildfire managers, and economists, while developing and evaluating data from federal sources (e.g., reported wildfire acreage burned and associated response costs), peer-reviewed literature, and government reports. The results of these studies have been incorporated into multiple federal reports and have also been published in the peer-reviewed literature (e.g. Mills *et al.*, 2015, 2018).

3.2. General Approach

The Colorado Department of Public Safety (CDPS), Division of Homeland Security & Emergency Management (DHSEM) in coordination and cooperation with the Colorado Department of Natural Resources, Colorado Water Conservation Board (CWCB) requires a quantitative analysis of Colorado's current and future vulnerability to flood, drought, and wildfire hazards that can be used to make more informed decisions on mitigation and adaptation strategies.

Lynker understands that State policy makers are under pressure to make decisions on climate change which intersect with many other policy domains and that have both immediate, short-term consequences and more profound, long-term implications. This project will bring together multiple perspectives on state-scale hazard, vulnerability, growth, and climate change risk assessment to tackle the challenges of risk-based analyses and expert assessment as well as the management of uncertainty over different time scales.

Conventional approaches to risk assessment are challenged by the significant temporal and spatial dynamics of climate change; through the interaction of multiple risk factors (compound effects) and by the amplification of risks through societal preferences and values. Climate change creates cascading risks in physical systems, ecosystems, economy and society, often inter-related and creating the circumstances for irreversible and undesirable crossing of thresholds at multiple scales. Socio-economic change related to growth often increases the vulnerability of the assets at risk. Assessing climate and socio-economic risks for multiple hazards across domains and sectors, and in a manner meaningful to decision-makers, is therefore a major scientific, policy, and planning challenge. Fortunately, the State of Colorado has, over the past several years, made considerable progress in this direction by developing plans, projects, models and data that can contribute to the development of the proposed climate change risk assessment. Lynker staff have contributed directly and significantly to many of these efforts and will thus be able use these resources efficiently in order to directly tackle the main challenge of this project.

3.2.1. Risk Analysis Framework

Lynker understands that stakeholders often use different definitions of **hazard**, **vulnerability** and **risk**, which can lead to methodological confusion and difficulties in communicating assessment results to decision makers. A clear definition of these key terms is essential, both for understanding our general project approach and for consistency with previous work in the State of Colorado. In this section we provide an overview of our definitions and conceptualization of these terms, as well as an overview of how we will build our general analytical frameworks for flood, drought and wildfire impacts.

In the RFP and in this proposal, the term **hazard** refers generally to flood, drought or wildfire. In the risk analysis field, each of these hazards can also be quantified by its probability and its intensity (*Figure 4. Hazard, Vulnerability, and Risk*). *Probability* is the likelihood of an event occurring (e.g., a "100-year" flood has a1% chance of occurring in any given year). *Intensity* is the severity or magnitude of the event (e.g., drought intensity may be determined by the magnitude of streamflow reduction or soil moisture deficit).

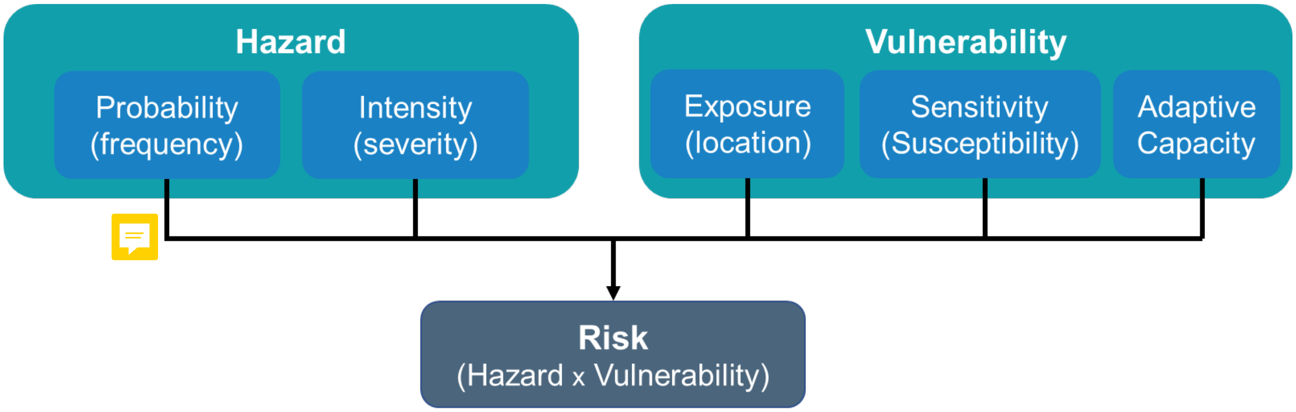


Figure 4. Hazard, Vulnerability, and Risk

Relationships between hazard, vulnerability and risk as used in this proposal.

Consistent with the USGCRP, we use the term **vulnerability** to describe the tendency for people or assets to be adversely affected by climate-related impacts. Vulnerability can be described by the elements of exposure, sensitivity and adaptive capacity. In the context of this proposal and project, *exposure* reflects the contact between assets or people and specific hazards (e.g., homes within a flood zone or adjacent to a forest that might burn). *Sensitivity* refers to the degree to which those assets or people could be affected (e.g., a house with asphalt shingles and cedar siding is more sensitive to fire than a brick home with a metal roof). *Adaptive capacity* is the ability to adjust or respond to hazards. One of the key goals of this project is to help the state identify and prioritize those adaptations.

Finally, **risk** is defined as the probability of occurrence of an unwanted event multiplied by the consequence of the event. Risk is thus a function of hazard and vulnerability (*Figure 4. Hazard, Vulnerability, and Risk*). Throughout this project, quantifying current and future risk (hazard x vulnerability) will be the ultimate objective, as this metric encompasses both the physical hazards and the impacts of those hazards. Risk will be the metric that forms the foundation of monetary damages from flood, drought, and wildfire events, where each hazard interacts with assets across Colorado's regions and counties. This common metric of dollars will be used in the simple visualization tool we will develop to compare within and across those hazards.

3.2.2. General Project Approach

We envision a bottom-up approach to the modeling of risk that will focus on quantifying hazards at fine spatial scales and intersecting those analyses with information on populations, assets, and economic activity. We will catalogue and manage the outputs from our analysis at the county level, with options to then summarize and visualize these impacts at larger spatial scales including user-defined regions appropriate for this analysis (i.e., groups of counties, see *Section 3.5.3*), or for the state as a whole. The general approach below envisions a highly collaborative and iterative approach between the Lynker Team and the state to ensure that the highest priority objectives are realized and that any tradeoffs associated with critical decisions are fully understood and considered (e.g., the ability to speak to impacts at finer scales than those supported by the precision of the hazard models). Our generalized project approach is described below, along with references to other sections of the proposal with additional details.

1. **Build conceptual models of risk for each natural hazard.** Our experience has shown that the strength of climate impact analyses is a direct reflection of the initial choices made with respect to the types of data to be collected and the general analytical approach. In our experience, this is an iterative process that will begin with a qualitative description of flood, drought, and wildfire natural hazards, the assets exposed to those hazards in the baseline period, and how climate and socioeconomic changes might affect future risk. While we provide details of our proposed technical approach for each hazard within this proposal, each conceptual model will first be vetted with the state project team and refined as needed to ensure

that baseline risks can be defensibly described. Conceptual models will be modularly linked to the overarching framework of risk quantification.

2. **Gather relevant data to inform models.** This is the most critical step, since any model of vulnerability will only be as good as the data that feeds it. Relevant information will include physical data to quantify the hazards (e.g., historical streamflow records, vegetation type and cover data, topographic data, etc.); geographic information to enumerate asset exposure (property information, transportation infrastructure, water and wastewater treatment locations, power plant locations, etc.); economic data to quantify asset value and cost of damages (e.g. property values, local sales and tax revenue, rebuilding costs, recreational use revenue, etc.); baseline climate information (temperature, precipitation, streamflow); and quantified impacts from historical flood, drought and wildfire. We summarize the data collection task in ***Section 3.3*** of this proposal.
3. **Quantify baseline risks.** The methods used to quantify risks in the baseline will vary across the different natural hazards and will be tailored to the available data in each case. For flood, drought, and wildfire, we will develop an analytical approach that is simple, defensible, reproducible, and firmly rooted in available data. We will inform this baseline analysis with a set of case studies of historical flood, drought and wildfire events in Colorado. ***Section 3.4*** describes our proposed approach to analyzing risk for each stressor.
4. **Develop future scenarios.** The climate and socioeconomic factors that drive risks from flood, drought and wildfire are different for each natural hazard; thus, the scenarios used to quantify future risks will need to be tailored to each analysis. Our team has worked with a full range of climate model outputs, including raw global climate model data; downscaled products; land surface hydrology outputs from the Variable Infiltration Capacity (VIC) model; downscaled and routed streamflow data; and outputs from a range of dynamic vegetation/wildfire models. Similarly, we are well versed in using future socioeconomic scenarios to drive changes in overall risk. Wherever possible, we will utilize climate and socioeconomic scenarios already developed for Colorado's Water Plan. A more complete description of our scenario development is included in ***Section 3.5***.
5. **Quantify future risk.** Once future climate scenarios are developed, we will incorporate these changes into our baseline models for each natural hazard to quantify future risk from flood, drought and wildfire. These future models will also be used to highlight the key drivers of vulnerability, and to begin evaluating adaptations that could be used to decrease future economic impacts. We will work collaboratively with our state partners when evaluating risk to determine which aspects are best to monetize and which may be best supported by qualitative descriptions leading to defensible estimates of risk. A summary of our approach to evaluating adaptation is provided in ***Section 3.6***.
6. **Identify future resilience actions.** Using the results of the future models, we will analyze options for improving resilience that could decrease overall costs relative to a no adaptation scenario. This will include an analysis of changing asset vulnerability with time as well as an understanding of how the hazard itself may change. Our resilience analysis will also be informed by the case studies, wherein we will gather relevant data on resilience actions undertaken following historical events in the state. A summary of our approach is provided in ***Section 3.6***.
7. **Build visualization tool.** We will use outputs from the baseline and future risk analysis to develop a data visualization tool, that will allow users to turn specific hazards and impacts on and off and gain a high-level understanding of the state's current and future vulnerabilities. A summary of our approach to the visualization tool is provided in ***Section 3.7***.

3.2.3. Alignment with the Colorado State Hazard Mitigation Plan (SOW Section C.2)

The Lynker Team is intimately familiar with Colorado's hazard mitigation plans, having worked on many of these over the past 8 years. Colorado's most recent State Hazard Mitigation Plan (SHMP) was a wide-scoped document that examined many hazards that occur within Colorado and identified priorities of working to mitigate the impacts of these hazards. The mitigation objectives (A-G) outlined within the Colorado State Hazard Mitigation Plan are (Colorado DPS, 2018):

We understand that the motivation of this work stems from the objectives set forth in the SHMP combined with the rising costs of natural hazards. A vulnerability and risk analysis that considers climate change will help Colorado mitigate future hazards.

A. Support and empower local and regional mitigation strategies through statewide guiding principles, programs, and resources

B. Promote activities that are climate neutral and supportive of appropriate renewable and alternative energy

C. Strengthen hazard risk communication tools and procedures

D. Strengthen continuity of operations at the federal, state, regional, tribal, and local levels of government to ensure the delivery of essential services

E. Strengthen cross-sector connections across the state government

F. Identify specific areas at risk to natural hazards and zones of vulnerability

G. Expand public awareness, education, and information programs relating to hazards and mitigation methods and techniques

Our project approach will seek to incorporate these goals as *guiding principles* throughout the life of the project. We also understand the special importance of flood, drought, and wildfire hazards throughout the State, since a poll of the State Hazard Mitigation Team identified flood, drought, and wildfire as the three most important hazards to focus future mitigation efforts.

The Colorado Hazard Mitigation Plan (HMP), updated in 2018, does a thorough job in aligning with the Colorado Flood Hazard Mitigation Plan, (FHMP) the Colorado Drought Mitigation and Response Plan (DMRP), Hazard Identification Risk Assessment Plan, (HIRA) and vice versa. There are numerous other Colorado specific plans that support the goals and objectives of the HMP and that will be useful in identifying and capturing data in support of the project for developing scenarios, analyzing vulnerabilities and analyzing resiliency.

A list of adopted, updated plans, and policies that advance hazard mitigation practices in the state of Colorado with a summary of their alignment to the Lynker Team's approach has been included in *Appendix 3—Alignment with Colorado Hazard Mitigation Plans and Updates* on page 67.

3.3. Data Collection (SOW Section C.1)

To help the State of Colorado understand and quantify its current and future risks from flood, drought and wildfire, we must first build a comprehensive database of the physical, socioeconomic and climatic conditions that drive each of those risks in both the current and future time periods. The data we collect in this first task will lay the foundation for each of the models and analyses that follow; thus it is critical that we cast as broad a net as possible in this data collection task, that we maintain strict data management protocols throughout the project, and that we understand and acknowledge the shortcomings and uncertainties associated with each dataset we collect.

Figure 5. Relevant Data, below provides an overview of the types of data the Lynker team plans to compile for our analyses. Additional details on these data elements are presented, by hazard, in the following subsections. Throughout our data collection efforts we plan to use our connections across each of the participating state agencies to review data options to ensure we strike an appropriate balance between using the most comprehensive and up-to-date information available versus using data from alternative, well-established survey or census efforts that could facilitate future updates to our projections.

	Physical Data	Socioeconomic Data	Climate/Environmental Data
Flood	▪ Roads, bridges ▪ Critical infrastructure (water treatment plants, hospitals) ▪ Private assets (homes, businesses)	▪ Socioeconomic projections (population, economy) ▪ 2050 land use ▪ Pricing data (structures, homes)	▪ CMIP5 downscaled flow data ▪ USGS flow data ▪ Gridded meteorological datasets (PRISM, NLDAS)
Drought	▪ State assets (parks, public waters) ▪ Critical infrastructure (dams, ditches, water utility intakes) ▪ Distribution of cropland (crop type, irrigated and non-irrigated, CDSS) ▪ Lands supporting livestock through grazing and herd locations by type of animal	▪ Socioeconomic projections (population, economy) ▪ 2050 land use ▪ Pricing data (land, cattle) ▪ Tax and fee revenue (income tax, permit revenue, land board leases)	▪ CRWAS-II climate change data (flow, precipitation, temperature) ▪ VIC modeled hydrologic data (soil moisture, evaporation) ▪ CDSS irrigated acres ▪ Gridded meteorological datasets (PRISM, NLDAS) ▪ USGS flow data
Wildfire	▪ Critical infrastructure (water treatment plants, hospitals) ▪ Private assets (homes, businesses)	▪ Socioeconomic projections (population, economy) ▪ 2050 land use ▪ Pricing data (structures, homes) ▪ Tax revenue ▪ Human health (loss of life, air quality)	▪ CMIP5 downscaled data (temperature, precipitation, wind) ▪ Gridded meteorological datasets (PRISM, NLDAS) ▪ Colorado State Forest Service tree index ▪ Wildlife datasets

Figure 5. Relevant Data

Figure 6 illustrates data of high initial interest to Lynker's Team for addressing the risk from flood, drought, and wildfire.

The data columns in the table above are structured to outline the data inputs needed to quantify each of the primary components within the risk analysis framework, where physical data corresponds to exposure, socioeconomic data corresponds to sensitivity/value, and climate/environmental data corresponds to measurements of hazard.

3.3.1. Physical Data

The physical datasets we compile for our analysis will inform both the hazard and vulnerability components of the risk equation. These physical data include current information on both the natural and the built environment that will inform risk estimates for 2018, as well as projections of these data that could inform associated risks in 2050. While the physical data requirements will vary across the three natural hazards, there will be many areas of overlap, as summarized below.

For flooding, required physical data will include stream gaging data describing historical runoff conditions; mapped regulatory floodplains and flood extents from historical events; and digital topographic data to help determine relative measures of flood risk outside of mapped flood zones. It will also include aspects of the built environment, including flood protection and flow regulation infrastructure (e.g., levees, dams, and canals); public infrastructure that could be vulnerable to current and future flooding (e.g., roads, bridges, and water treatment plants); and private assets including homes, businesses and irrigated lands.

For drought, we will incorporate land cover data from CDSS; and historical drought index data from the US Drought Monitor. In addition, we will compile information on agricultural and livestock operations in the state to understand the scope of the activity exposed to current and future drought conditions. Because drought does not typically directly damage or destroy infrastructure, data on the built environment will not be a high priority for this stressor but will be available because of its importance for flooding and wildfires.

For wildfire where, similar to flooding, damage and destruction of resources exposed to the hazard is possible, we will compile data on aspects of the built environment including homes and businesses, and public infrastructure such as power lines and water conveyances. For consistency and efficiency, we can use a similar database to inform both the flood and wildfire assessments. Additional physical data developed specifically for wildfires will include geographic information that provide a relative ranking of burn probability (e.g., in the Colorado Wildfire Risk Assessment Portal (CO-WRAP) available at https://co-pub.coloradoforestatlas.org/#/) and existing boundaries used to define wildfire-urban interface (WUI) regions around the state.

3.3.2. Socioeconomic Data

The socioeconomic datasets we compile will primarily inform the vulnerability component of the risk equation, for both 2018 and 2050. The Lynker team will work closely with our state partners to identify preferred data sources for this information to ensure quality is balanced with the ability to replicate and easily update the analyses with new data in the future. The baseline socioeconomic data we will compile will generally consist of the following:

- The value of identified public and private infrastructure including buildings, utilities, roads and bridges, and private residences
- A monetized summary of the economy by economic sector, including the total value of taxable sales, income, and employment
- Demographic information including at least the age distribution in the population and ideally information with respect to sex and race

Existing data for most infrastructure, both public and private, has geo-referenced detail that allows the assets to be specifically located (e.g., the physical address for houses and utilities). The Lynker Team owns a national-scale parcel database describing the spatial footprint of homes throughout the United States, as well as assessed value of each of those properties. We will work with relevant state agencies to augment this database with information on the value of other assets such as roads and bridges (e.g., from CDOT), agricultural assets (e.g., from CDA), and water utilities (e.g., from CDPHE); and we will use this information to develop monetized estimates for these resources after working with the state partners to select an appropriate value indicator (e.g., value of improvements to a taxable parcel, replacement value for assets such as roads or utilities). This level of spatial detail will support aggregation to any additional regions of interest for a hazard (e.g., county, floodplain, WUI).

We will then work with our state partners to develop an appropriate approach for allocating residential populations and, if desired, economic activity within a region. The Lynker team will identify preferred data sources for this information to ensure quality is balanced with the ability to replicate and easily update the analyses with new data in the future. For example, we will collectively assess whether existing public information on individual revenue from the Colorado Department of Revenue (see https://www.colorado.gov/pacific/revenue/statistics-income, *Table 17 Income and Tax Data by County*) and sales tax across 31 economic sectors (see https://www.colorado.gov/pacific/revenue/retail-sales-report, *Monthly County by Industry Reports*) is best suited for this analysis. An example of a specific question we would have for our partners is whether the sales tax information from the referenced reports is best suited for highlighting economic activity in the tourism and recreation sector of the Colorado economy, or if there is better information that could be paired with these reports to highlight this sector while avoiding potential double counting. This is a question we anticipate state partners including Colorado Counties, Inc. and the Colorado Municipal League may have experience addressing and where we believe we could work with the project partners to better understand and access the full suite of information potentially available from sources such as the Department of Revenue.

For demographic data, it may be possible to use Census population data to allocate populations by reporting units such as Census Blocks that could then be used to create greater detail with respect to the population distribution. This data could then be used, potentially, to improve our analysis of vulnerability based on age, income, or other relevant socioeconomic factors. For example, age, sex and race-based shares of the population in an area could be developed using Census data and then applied to the State's population projections to maintain consistency while providing additional desired detail for specific populations of interest.

We recognize that health impacts including injury and loss of life are specifically described in the SOW as an area of interest. We have specific experience in modeling health impacts of flood and wildfire, having recently published on the topic (e.g., Mills et al., 2018). To help illustrate the potential health impacts, the Lynker team will incorporate case studies (e.g., the Front Range floods of 2013, wildfires affecting Colorado Springs in 2012 - Black Forest- and 2013 -Waldo Canyon ; 2012-2013 drought) and information from recent summaries of the potential health effects of these hazards from the literature (e.g., USGCRP, 2016) while highlighting important caveats with respect to using impacts from observed events to project future impacts (i.e., one hopes future warnings and advice from public agencies may be more closely followed).

3.3.3. Climate Data

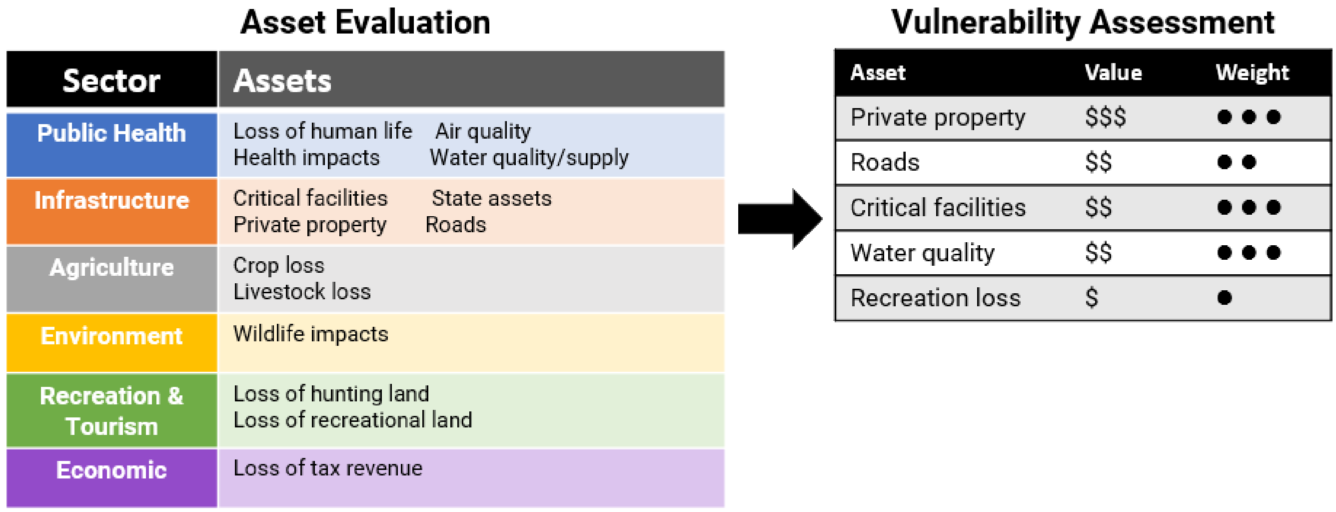
Each of the risk models must be driven by climate datasets that can simulate both baseline and future conditions. The specific climate forcings will vary across the three natural hazards; thus, the baseline and future data needs will also vary. For example, riverine flood risk in the baseline is driven by peak streamflow data, which we will compile from USGS or other stream gage archives. Drought and wildfire is driven by a combination of temperature and precipitation anomalies, which we will obtain from historical, gridded meteorological forcings such as PRISM and the North American Land Data Assimilation System (NLDAS); observations from the NOAA Precipitation archive; and historical drought index data from the Western Regional Climate Center (WRCC) and National Drought Mitigation Center (NDMC).

For each of the three natural hazards, we will also need to develop future climate scenarios to quantify how those hazards will change in the future. As described in **Section 3.5**, these future scenarios will be tailored to flood, drought, and wildfire, and we will extract these data from scenarios developed for Colorado's Water Plan or from relevant Coupled Model Intercomparison Project Phase 5 (CMIP5) archives, as appropriate.

3.4. Risk Analysis (SOW Section C.4)

Note that for the purposes of maintaining a consistent definition of risk and vulnerability throughout our proposal, we have renamed this section to "Risk Analysis" (task C.4 – "Vulnerability Analysis" in the SOW).

For each of the three natural hazards, we will develop a data-driven modeling approach to quantify the economic impact of the hazard in the baseline period (2018) and a future period represented by the mid-century (2050). This will begin with a conceptual model of each hazard, which will help us determine what data needs to be collected to quantify hazard, vulnerability and risk in the baseline and future periods. This data collection and conceptual model development will also allow us to prioritize the drivers of risk for each natural hazard. For flood, drought, and wildfire we will first compile a list of all assets that may be at risk. We will group these assets into larger sectors, which may be helpful for more broadly characterizing risk later in the project. The assets evaluation will be combined with a high-level cost analysis to develop a semi-quantitative ranking of vulnerability (see *Figure 6. Asset Evaluation*). As shown in *Figure 6*, for example, the primary risks from flooding might be related to losses of private property, critical facilities, and bridges, with lesser impacts from crop losses, lost wages or tourism dollars. By scoping out the relative importance of these assets for each hazard early in the project, we can ensure that each of our physical models addresses the most significant vulnerabilities and risks for Colorado.



Asset Evaluation

Sector	Assets
Public Health	Loss of human life Air quality Health impacts Water quality/supply
Infrastructure	Critical facilities State assets Private property Roads
Agriculture	Crop loss Livestock loss
Environment	Wildlife impacts
Recreation & Tourism	Loss of hunting land Loss of recreational land
Economic	Loss of tax revenue

Vulnerability Assessment

Asset	Value	Weight
Private property	$$$	●●●
Roads	$$	●●
Critical facilities	$$	●●●
Water quality	$$	●●●
Recreation loss	$	●

Figure 6. Asset Evaluation

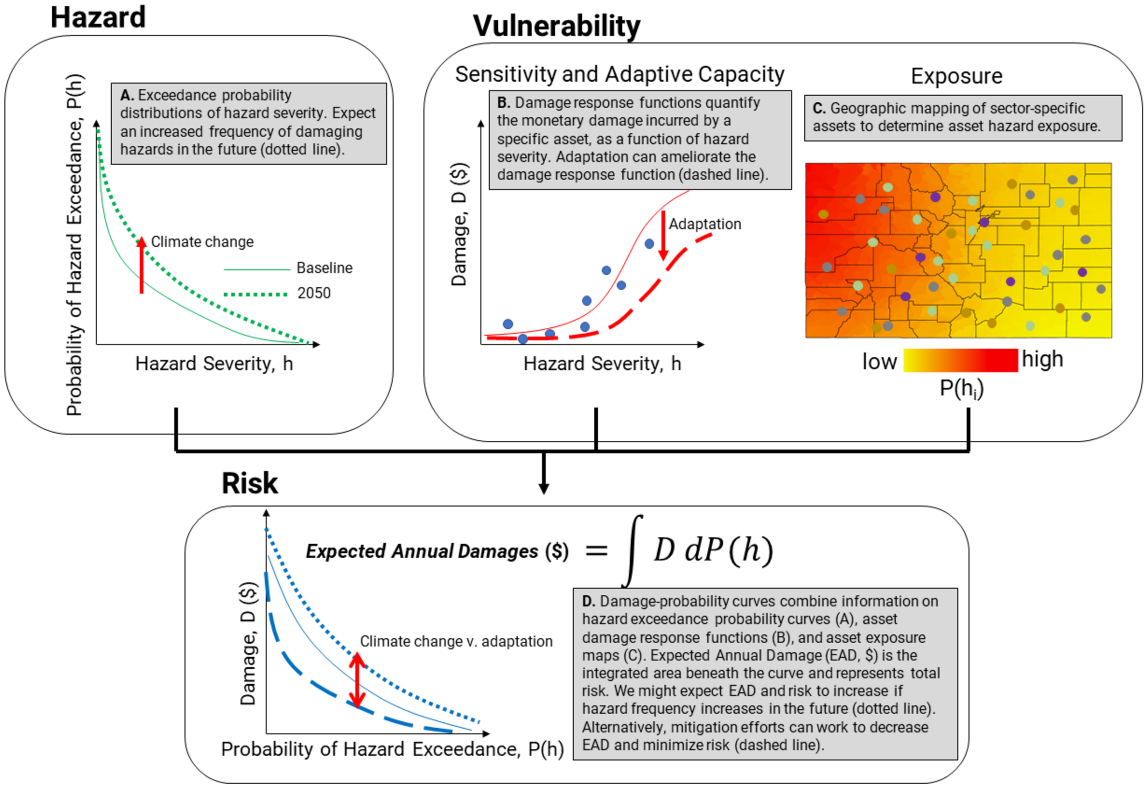
Conceptual model showing how we will use asset evaluation to prioritize risk drivers for each hazard.

We will then tailor our risk analyses so that we can defensibly model each hazard in the baseline and future period, and so that we can identify the key drivers of risk for each natural hazard. Although the differing physical drivers of risk will require a different modeling framework for each hazard, the conceptual approach for flood, drought, and wildfire will be similar, as shown in *Figure 7. Risk Quantification*. Specifically, for each hazard we will use available data to populate a model relating hazard probability to severity; we will compile information to understand the relationship between damage and hazard severity and the geographic distribution of assets exposed; and we will then combine the vulnerability and hazard models to quantify risk.

As part of this effort, the Lynker Team's economists will work closely with the state partners to review and, if necessary, refine approaches for monetizing damages for consistency with how similar impacts are treated by the state in other contexts. As previously described, much of this will involve choices about the datasets to be used. Related methodological issues will likely include topics such as the treatment of impacts in different time periods to provide a common frame of reference for comparison (i.e., discounting to express losses in terms of present value); and possible substitution effects that could dilute impacts at a sufficiently large spatial scale (i.e., tourism dollars shifting to the southwestern part of the state following a forest fire in the central mountains).

Upon project initiation and as a part of the project risk analysis, we plan to conduct several spatially/temporally targeted case studies to validate our proposed risk assessment framework. Targeted studies will quantify the monetary risk affiliated with major historical flood, drought and wildfire events, and assess the retrospective cost/benefit of mitigation activities. This will provide an opportunity to 1) validate hazard models, 2) validate economic models, and 3) focus in on an appropriate framework for scenario planning and mitigation analysis. Additionally, this exercise will be a conceptual incubator for optimizing communication and working relationships with our state partners. Starting with small steps will allow our team to learn from early mistakes and identify an efficient pathway to project success at the state-wide level.

The remainder of this section describes the specific analytical approach that we will apply to each natural hazard.



A. Exceedance probability distributions of hazard severity. Expect an increased frequency of damaging hazards in the future (dotted line).

B. Damage response functions quantify the monetary damage incurred by a specific asset, as a function of hazard severity. Adaptation can ameliorate the damage response function (dashed line).

C. Geographic mapping of sector-specific assets to determine asset hazard exposure.

$$\textbf{\textit{Expected Annual Damages (\$)}} = \int D\, dP(h)$$

D. Damage-probability curves combine information on hazard exceedance probability curves (A), asset damage response functions (B), and asset exposure maps (C). Expected Annual Damage (EAD, $) is the integrated area beneath the curve and represents total risk. We might expect EAD and risk to increase if hazard frequency increases in the future (dotted line). Alternatively, mitigation efforts can work to decrease EAD and minimize risk (dashed line).

Figure 7. Risk Quantification

Conceptual Model of Risk Quantification

3.4.1. Flood

Flood risk is a function of hydrologic conditions including land cover, soil moisture, and precipitation anomalies, as well as the location of assets relative to known and unknown hazard zones. In Colorado, flooding can be a result of prolonged, extreme precipitation events like the 2013 floods; short duration, extreme precipitation like the Big Thompson floods in 1976; or rapid melt of mountain snowpack from warm temperatures or rain on snow events. In all cases, the quantification of flood risk requires an understanding of the probability of those events in the present and the future, as well as the distribution of assets that might be vulnerable to impacts.

Our approach to modeling flood risk in the baseline and future will build from the methodology we have developed to support national-scale analyses of climate change impacts on flood damages. The basis of this methodology has been peer reviewed and published by our team multiple times (e.g. Wobus *et al.*, 2017, 2019; Mills *et al.*, 2018), and was used to support the economic analyses for USEPA's CIRA project (EPA, 2015), the most recent National Climate Assessment (USGCRP, 2018), and supporting publications (Martinich and Crimmins, 2019). The core of this method is also very flexible, and can be easily modified to develop Colorado-specific estimates of flood risks in both baseline and future time horizons. In this section we describe our proposed approach, focusing on the datasets and methods we propose to use to characterize hazard, vulnerability, and risk.

3.4.1.1. Flood Hazard

Flood hazard fundamentally results from streams, rivers, or extreme rainfall events that inundate areas that are typically dry. Available data on flood hazard is closely tied to mapped floodplains (corresponding to the extent of a flood with a specific recurrence interval, such as the "100-year" or 1% exceedance probability event). Many of the rivers in Colorado have mapped floodplains corresponding to 100-year and 500-year flood extents. For other areas, we may need to infer flood extents from other hydrologic models, such as the National Water Model. In either case, each mapped or inferred flood extent will provide an estimate of flood severity, with a corresponding estimate of the probability of occurrence of that event.

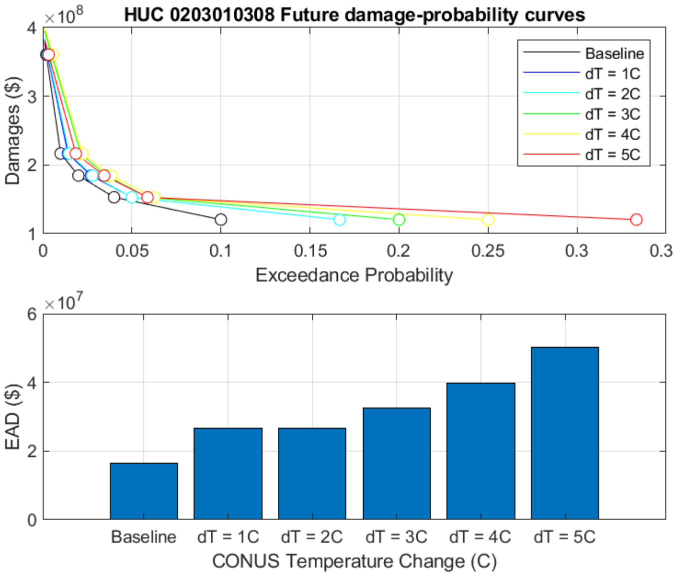


Figure 8. Example Flood Model Outputs

Expected annual damage (risk) is the area under the damage-probability curve and shifts with changing climate or socioeconomic scenarios. From Wobus et al. (2019).

From these mapped and inferred floodplains, baseline flood hazard can be quantified as a probability distribution of flood events, each with an associated severity characterized by flood depth or flood extent. Future flood hazard can be considered in terms of either the changing severity or the changing probability of these specified events. From our prior work, we have found that modeling changes in the exceedance probability of specified flood events is a more straightforward approach to estimating changes in flood hazard than calculating changes in the magnitude of those events. As in our previous work, we will use changes in exceedance probabilities to characterize changes in flood hazard. To extract these changes, we will utilize downscaled hydrology data that was developed by a consortium of Federal agencies to simulate changes in streamflow across a range of CMIP scenarios (Reclamation, 2014). This archive has the benefit of being peer reviewed; the precipitation projections have already been routed through a hydrologic model; and we already have these data formatted in a way that will allow us to quickly and efficiently develop multiple climate change scenarios for the 2050 time horizon. **Section 3.5** provides a more detailed discussion of how we will develop these scenarios to look at future flood hazard.

3.4.1.2. Flood Vulnerability

Colorado's vulnerability to flooding is a function of the total value of homes, roads, bridges and public infrastructure that could be impacted by flood hazards, and the degree to which those assets are susceptible to damage. Our flood vulnerability analysis will therefore rely on geospatial data describing homes, infrastructure, and other assets exposed to flooding or erosion risk; the economic valuation and secondary impacts to those assets at a parcel level; mapped floodplains and associated return intervals from FEMA; mapped and inferred fluvial hazard zones; inferred flood extents from the National Water Model; and the elevations within floodplains from digital topography.

One of the key challenges to this approach will be obtaining all of the necessary data to inform a quantification of fluvial hazard vulnerability at a state-wide scale. Parts of the state will invariably have more comprehensive data than others describing floodplain extent, fluvial hazard zones, and historical events. This will make it challenging to develop a spatially comprehensive quantification of vulnerability. In our national-scale work, we have addressed this issue using a case-study approach, in which we utilize areas with the most comprehensive data to calculate scaling factors that can fill in for missing data. Our experience working through these issues with other clients, as well as our team's close relationships with key members of the Project team for this effort, will ensure that we can meet these challenges head on and develop workable solutions.

3.4.1.3. Flood Risk

To characterize flood risk, we will overlay the vulnerability and hazard data to calculate 1) the total value of assets within each of the mapped and inferred flood hazard zones, 2) the annual chance of flooding or erosion within each of those flood hazard zones, and 3) the monetary loss incurred at each parcel based on published depth-damage functions or potential losses from erosion (USACE, 2000). The expected annual damages (risk) in the baseline can then be calculated for each mapped floodplain as the area under the damage-exceedance probability curve, such as the black line in *Figure 8. Example Flood Model Outputs*. Statewide, the total expected annual damages from flooding will then be the sum of expected annual damages from each individual floodplain.

We have successfully implemented the risk framework described above on a national scale, to estimate monetary damages to homes and buildings from flooding. For the State of Colorado, we will have substantially more granular data that we will use to refine this general methodology. For example, while national-scale work was implemented at a census block scale, we now have a parcel-level database for the State of Colorado that provides high-resolution detail on the location, type, and value of each property within each flood hazard zone. In addition, we have begun to compile information on water utilities, roads and bridges, and other assets within flood hazard zones that we can utilize to expand the scope of risk for this detailed state analysis. Finally, while our national-scale analysis was limited to mapped flood hazard zones, we expect to be able to augment the flood hazard footprint in Colorado using information available from other hydrologic models, such as the National Water Model.

The ability and desire to incorporate additional risks from flooding, particularly longer term risks from extended loss of public services and infrastructure, will be assessed with the state partners. For example, the ability to assess potential impacts to agriculture from delays or inability to plant crops will be evaluated with impacts such as the potential relocation of populations and businesses to different reporting regions (e.g., counties) following particularly severe flooding.

3.4.1.4. Flood Case Study

For flooding, we will build our case study around the 2013 floods in Boulder and surrounding communities. The Boulder flood was unique in that heavy rainfall over this long-duration event was focused on the lower elevation foothills just to the west of town, and rainfall rates decreased rapidly in the higher elevations further the west. Because of this rainfall distribution, many of the damages came from the small creeks draining the foothills, as opposed to the larger watersheds with catchment areas reaching to higher elevations. The damages caused by these smaller streams are the types impacts that might not be easily captured in our more generalized, state-wide model of flood risk, so a case study focused on this event will help us calibrate our hazard models to account for these more nuanced risk factors. This calibration might include applying scaling factors to account for finer-resolution hazards than our state-wide models can capture, or developing site-specific estimates of how compounding effects can influence coarser-scale estimates of risk.

3.4.2. Drought

Because of our semi-arid climate, drought is a natural climatic phenomenon in Colorado. Since 1893, Colorado has experienced seven multi-year droughts, and there is a 32% chance that some degree of drought can occur in any given year (Colorado DPS, 2018). While previous droughts have improved the adaptive capacities of major economic sectors to mitigate impacts and reduce vulnerabilities, future climate conditions project an increased frequency of prolonged dry atmospheric conditions likely to increase the intensity and duration of drought events. Thus, water managers and political decision makers require a clear understanding of current and future drought hazard, in order to properly guide mitigation efforts and plan appropriately for future development to limit risks.

3.4.2.1. Drought Hazard

Drought hazards are defined differently to various stakeholders, as demonstrated by the numerous definitions of drought outlined below. While this project will primarily be focused on the broader meteorological and hydrologic drought definitions, it is important to acknowledge and distinguish agricultural and socioeconomic droughts given their significant impacts within the context of drought in Colorado.

- **Meteorological** drought is characterized by periods of below average precipitation.

- **Hydrologic** drought is characterized by deficiencies in surface water (“blue-water drought”) encompassing variables like streamflow, reservoir storage, and snowpack; and groundwater supplies (“green-water drought”) which includes vegetation and soil moisture content.
- **Agricultural** drought refers to inadequate water supply to meet the needs of agricultural operations. For example, insufficient soil moisture or irrigation water to supply crop growth, or insufficient surface water to hydrate livestock.
- **Socioeconomic** drought occurs when sustained arid conditions adversely affect human quality of life, and/or regional economic vitality. Socioeconomic drought typically arises as a secondary consequence of hydrologic, meteorological, and/or agricultural drought.

Additionally, drought hazards vary by location, intensity and frequency:

- **Location** – drought conditions can manifest heterogeneously across the state, leading to regionally specific hazards and associated vulnerabilities. Also, drought conditions in one region can have secondary impacts on other regions not explicitly exposed to drought conditions (e.g. limited alpine snowpack reduces summer water supplies to the plains).
- **Intensity** –The intensity of precipitation deficits (meteorological), surface water anomalies (hydrologic), crop and livestock water shortages (agricultural), or socioeconomic impacts can vary for a given drought duration.
- **Duration** – Drought conditions can persist for short durations, such as monthly or seasonal periods of anomalously dry conditions, or for longer durations, such as periods of several years.
- **Frequency** – Drought conditions are naturally reoccurring phenomena in Colorado that can be probabilistically characterized in terms of historical exceedance probabilities.

Consistent with the broad range of definitions, drought hazard can be quantified by a number of different indices that synthesize meteorological and hydrological data into a numeric quantification of drought severity, accounting for both drought intensity and duration. Different indices speak to different types of drought hazard. For example, Surface Water Supply Index (SWSI) or April 1 Snow Water Equivalent (SWE) are often used to characterize hydrologic drought in Colorado. On the other hand, the Palmer Drought Severity Index (PDSI) and Crop Moisture Index (CMI) are often used to assess the severity of agricultural drought.

The Lynker Team will incorporate spatially distributed historical meteorological data, hydrological model simulations, and paleoclimate proxy data to infer the frequency, intensity and duration of historical droughts throughout the state. Specifically, we will use these data to assess drought severity through the lens of several well-established drought indices. Model-derived drought indices will be trained and validated against available archives of monthly drought index maps made available from the United States Drought Monitor**.** We recognize that there are many drought indices available to quantify drought severity, and no one index is best. Discussions with our state partners will help constrain our focus to those indices most applicable to the different sectors and stakeholders.

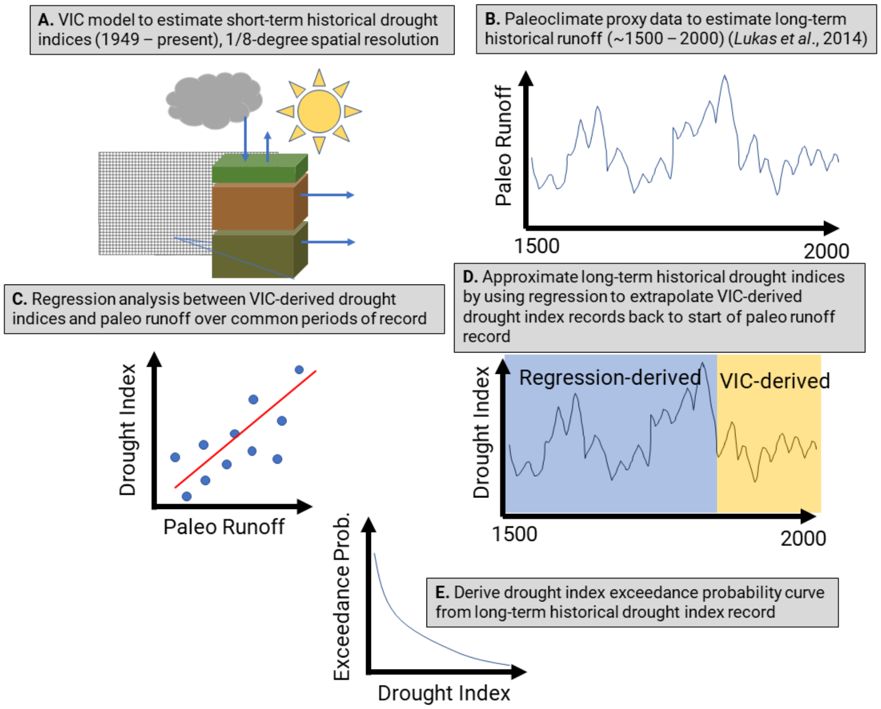


Figure 9. Baseline Drought Hazard Workflow

Leveraging short-term model-derived data and long-term paleoclimate data to generate robust drought index exceedance probability curves

Our approach will utilize spatially distributed meteorological data and Variable Infiltration Capacity (VIC) hydrologic model (Liang *et al.*, 1994) simulations as key data sources from which any drought index value may be calculated (*Figure 9. Baseline Drought Hazard Workflow*, A). Historical meteorological data (air temperature, precipitation, humidity, and wind speed) are available at 1/8-degree resolution across the state from 1949 to present (Maurer *et al.*, 2002). These data have been used by our team to force VIC hydrological simulations, which yield estimates of soil moisture, evapotranspiration, potential evapotranspiration, and full natural flows at 1/8-degree spatial resolution from 1949 to present.

There are several benefits associated with using a physically based hydrological modeling approach for quantifying drought hazard. First, quantifying drought hazard often requires more than just meteorological information, such as additional knowledge of hydrologic states and fluxes (e.g. soil moisture and streamflow). A physically based model, such as VIC, is a widely accepted tool to assess the hydrologic pathways through which meteorological events are transformed and manifested as drought. Second, model predictions at a 1/8-degree grid cell spatial resolution can be aggregated up to larger spatial domains of interest, such as discrete political domains (e.g. counties), river reaches, river basins or agricultural parcels. Third, Lynker scientists have already constructed and calibrated the VIC model for the state of Colorado, and model results are readily available for rapid analysis. Finally, a physically based hydrological model provides a tool for predicting the future drought hazards by changing model forcings (i.e. meteorology) and parameters (e.g. land cover) according to specific scenarios of future climate and socioeconomic conditions.

The relatively short record of meteorological data and VIC model forcings (1949 – present) is liable to bias our probabilistic understanding of drought by excluding extreme events apparent in longer-term paleoclimate records (Lukas *et al.*, 2014). To address this shortcoming, we will rely on paleoclimate proxy data sets, specifically tree ring reconstructed runoff records (Lukas *et al.*, 2014) (*Figure 9. Baseline Drought Hazard Workflow*, B), to build drought index time series further back in time. This will be done by correlating drought indices with tree ring derived streamflow over a common period of record (*Figure 9. Baseline Drought Hazard Workflow*, C). Regressions will be used to extrapolate back in time and approximate long-term historical drought index values (*Figure 9. Baseline Drought Hazard Workflow*, D).

Once long-term historical, spatially distributed, drought index estimates are constructed, we will derive exceedance probability curves that illustrate the probability that a drought of a certain severity will occur in any given year (*Figure 9. Baseline Drought Hazard Workflow*, E).

3.4.2.2. Drought Vulnerability

Drought is a unique natural hazard because the duration of drought conditions plays a key role in the magnitude and degree of impacts. The key challenge in quantifying drought vulnerability is linking measurements or estimates of drought severity and duration (i.e. drought indices) to the associated negative impacts (i.e. monetary damages) across multiple sectors. *Figure 7. Risk Quantification* on page 23 enumerates obvious drought-related negative impacts on six major sectors that warrant economic assessment for this study. Within the drought risk management field, the common approach to assessing vulnerability involves developing a timeseries of statistical hazard events to be combined with available records of direct or indirect damages associated with a drought event. The resulting damage response function attempts to translate a range of drought hazards to an estimate of harm for specific sectors (Sayers *et al.*, 2016).

Damage response functions will be targeted for each individual sector, but our initial analysis will look to identify the most prominent subsectors with quantifiable impacts with the understanding that drought vulnerability is not evenly distributed across all sectors. As a starting point, we will first look to incorporate all the drought impact data currently used for the county-level drought vulnerability analysis within the Colorado Drought Mitigation and Response Plan (CWCB, 2013).

Once the damage response relationships are generated from the historical and/or synthetic datasets and reviewed and accepted with our State partners, the final piece to assessing the drought vulnerability will be to develop an inventory of assets that are susceptible to damages (e.g. acres of dryland agriculture). This inventory will be largely based on the inventory presented in the Colorado Drought Mitigation and Response Plan but updated as needed per conversations with our state partners.

3.4.2.3. Drought Risk

To quantify drought risk, we will combine the probabilistic quantification of drought hazard (drought exceedance probability curves) with exposure inventories and damage response functions to derive damage probability relationships. These relationships will be used as a starting point to quantify the expected annual damages incurred by each sector from drought hazard. At the same time, the Lynker Team's economists will work with state partners, notably the Department of Agriculture, to develop relevant guidelines for summarizing risk given the particularities of the agriculture and livestock sectors. For example, we anticipate evaluating past droughts to understand if and how localized drought impacts may be offset by shifts in activity across regions in the state and the presence and use of crop insurance and other commodity price support programs. We also anticipate the length and severity of a drought may affect the structure of these industries, particularly for extended droughts, and we want to coordinate with the state to ensure these risks are captured appropriately.

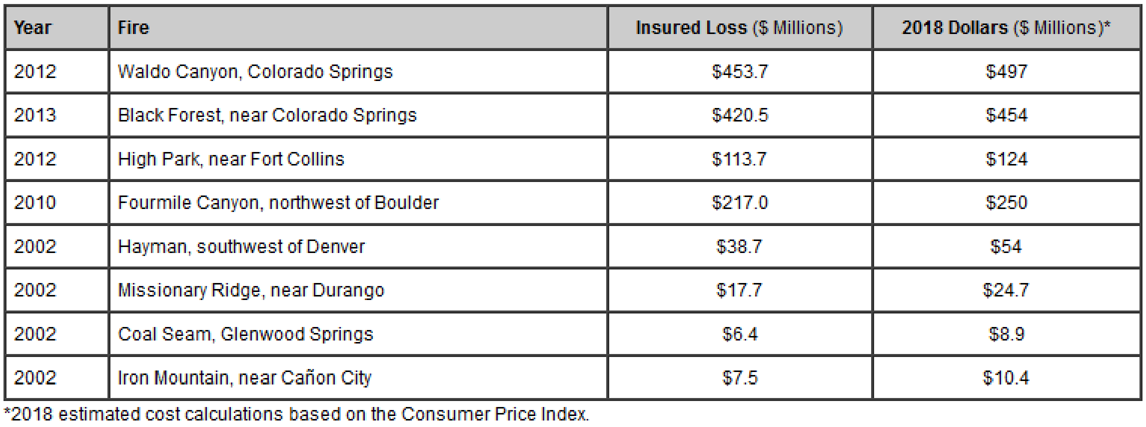
3.4.2.4. Drought Case Study

As a case study, we will consider how the 2011 – 2013 drought impacted the agricultural sector in the Arkansas River Basin. According to Gunter *et al.*, 2012, the Arkansas Basin suffered a loss of 1,300 jobs and ~$105 million in economic activity in the wake of the 2011 – 2013 drought. The well documented impacts of this event provide a benchmark for validating our workflow. Specifically, we will be able to validate the capacity of the VIC model to recreate observed drought conditions and validate economic models of agricultural sector impacts.

3.4.3. Wildfire

Wildfire is a growing threat in the Colorado Rocky Mountains and foothills, where population is booming and encroaching on the Wildland–Urban Interface (WUI), a zone of transition between wildland (unoccupied land) and human development. Communities in the WUI are at risk of catastrophic wildfire, while their presence disrupts the natural fire ecology. Colorado State University (CSU) researchers estimate that by the year 2030, the size of Colorado's WUI will have increased to 720,000 homes (from an estimated 313,000 in 2010), greatly increasing the vulnerability. Based on projections, the areas at greatest risk of wildfires is correlated with continuing population growth over the next 25 years, highlighting how the overall risk from wildfire is likely to increase from population growth.

The overall estimated cost of the 2002 Colorado wildfire season was $98 million (in 2018 dollars), but wildfire losses from that season were eclipsed by losses in 2010, 2012, and 2013 (*Figure 10*). The 2012 Wildfire Season took a particularly devastating toll on Colorado residents, burning more than 600 homes and personal property. Damage estimates now total $622 million (2018 dollars) from insurance claims that include smoke damage, additional living expenses, damaged and destroyed homes, as well as personal belongings and vehicles.



Year	**Fire**	**Insured Loss** ($ Millions)	**2018 Dollars** ($ Millions)*
2012	Waldo Canyon, Colorado Springs	$453.7	$497
2013	Black Forest, near Colorado Springs	$420.5	$454
2012	High Park, near Fort Collins	$113.7	$124
2010	Fourmile Canyon, northwest of Boulder	$217.0	$250
2002	Hayman, southwest of Denver	$38.7	$54
2002	Missionary Ridge, near Durango	$17.7	$24.7
2002	Coal Seam, Glenwood Springs	$6.4	$8.9
2002	Iron Mountain, near Cañon City	$7.5	$10.4

*2018 estimated cost calculations based on the Consumer Price Index.

Figure 10. Colorado Wildfire Insured Losses

(Source: Rocky Mountain Insurance Information Association).

Better understanding of wildfire behavior and ecology behavior within and around the WUI highlights not just the need for informed policy and emergency response planning, but also the need to understand what impacts climate change has had and will have on wildfire. Large wildfires in the United States burn more than twice the area they did in 1970, and the average wildfire season is 78 days longer. Changes in climate, especially earlier snowmelt due to warming in the spring and summer, have led to hot, dry conditions that boost this increase in fire activity over much of the U.S. West, where projections show that an average annual 1 degree Celsius temperature increase would increase the median burned area per year as much as 600 percent in some types of forests.

Figure 11. Waldo Canyon Fire, 2012

The Lynker Team will begin our approach to understanding wildfire risk with a characterization of the datasets needed for baseline analysis of wildfire, development of the calculation of the hazard and finally an identification of the vulnerabilities. The hazard and vulnerability analyses will be used to calculate risk and identify costs, where risk is the product of hazard and vulnerability.

3.4.3.1. Hazard

Wildfire risk depends on a number of factors, including temperature, precipitation, soil moisture, and the presence of vegetation (fuel). All these factors have strong direct or indirect ties to climate variability and climate change. Higher spring and summer temperatures and earlier spring snowmelt typically cause soils to be drier for longer, increasing the likelihood of drought and a longer wildfire season. These hot, dry conditions also increase the likelihood that wildfires will be more intense and long-burning once they are started by lightning strikes or human error. The costs of wildfires, in terms of risks to human life and health, property damage, and state and federal dollars, are devastating, and they are only likely to increase unless we better address the risks of wildfires and reduce our activities that lead to further climate change.

Lynker has engaged with Colorado State Forest Service (CSFS) for this project, and with their consultants Technosylva who we will sub-contract for this project through CSFS. CSFS, with support from Technosylva, have developed a Wildfire Risk Assessment (CO-WRA) for Colorado. This leveraged data and achievements of the West Wide Wildfire Risk Assessment (WWA) project to tailor to Colorado conditions, requirements and priorities.

CSFS have developed the Colorado Wildfire Risk Assessment Portal (CO-WRAP), which uses the best available data, science, and technology available to describe wildfire risk in the state. This portal was updated in 2017 with new and better calibrated surface fuels data, and subsequent updated risk assessments from model re-runs. For this project we have defined hazard as probability times intensity, which aligns with the methods used for the CO-WRA, thus we propose to use flame length as the measure of intensity (severity) which also aligns with the CO-WRA modeling framework. Generally speaking, the higher the flame length, the more intense the wildfire. The probability of the hazard will rely on the annual burn probability, which was also calculated as a part of the CO-WRA, using stochastic simulation of over 2 million fires throughout Colorado. This stochastic simulation was combined with a spatial dataset of all historical fire ignitions in Colorado from 1992-2017 to determine a final burn probability for the state. These methods allow us to build on the wildfire modeling that has already been completed for Colorado for use in the development of our baseline scenario.

3.4.3.2. Vulnerability

Our approach to quantifying wildfire vulnerability will use the core datasets available from the CO-WRA to characterize the baseline vulnerability or current conditions. These datasets include current parcel data for Colorado with special emphasis on the wildland urban interface (WUI), National Land Cover Dataset (NLCD) land use supplemented as needed and including the Colorado State Forest Service (CSFS) tree type dataset. These datasets will also include economic data to attach value to assets (as shown in *Figure 7. Risk Quantification* on page 23), such as structures (e.g., private property), critical facilities (e.g., water treatment plants, transmission lines), air quality degradation and water quality degradation. Each asset will be transferred to a spreadsheet relating a specific dataset/source data to each asset and a weighting of the assets. The weightings will be determined in coordination with our state partners and any project steering committee.

While many of the input datasets reflect a snapshot of current conditions (for example the CO-WRA uses 2016 LANDSCAN population estimates which is particularly useful for rural populations), the baseline climate datasets used in the CO-WRA reflect a 30-year average so as not to bias the data from medium-term (e.g., 10-year) wet or dry climate sequences. The CO-WRA used four assets to determine vulnerability, of which they weighted wildland urban interface and drinking water importance as the two most important factors. Although we may use some of the same indexes (e.g., the wildland urban interface or human population exposure) we will likely consider others not included in the CO-WRA. Our final asset databases, coupled with value, will be used to determine the most vulnerable assets and help to prioritize relative importance in coordination with our state partners.

The Lynker Team will work to update the datasets used in the baseline scenario to reflect the projected changes in conditions in 2050. This will include projected changes in climate, population, buildings, and economic conditions (e.g., levels of activity and prices). These updates will be completed using state demographic projections as discussed in **Section 3.5**. This is especially important to understanding future changes to land use and development in the wildland urban interface. We may also consider changes in plant type in 2050, however, this type of information is highly uncertain, and may harm rather than help by increasing error (e.g., Mills et al., 2015). Finally, we will update our economic datasets to include price adjustments needed to reflect the best estimates for 2050. As with the baseline scenario, many of the asset estimates (population, land use, future pricing) will reflect best estimates for 2050, while the climate data will reflect a window centered around 2050.

3.4.3.3. Risk

Risk will be calculated as the product of hazard and vulnerability (*Section 3.2.1 Risk Analysis Framework* on page 15) to align with our methods for drought and flood. The vulnerability datasets and weightings will be combined with the probability and severity of the event using response functions, to relate assets to expected annual damages. For instance, damage to a home will be modified according to the intensity (flame length), where the property value is taken from our parcel database.

The Lynker Team will also consider the compound effects of wildfire with flood and drought. Beyond the risk associated with property damage, wildfires cost states and the federal government millions in fire-suppression management. The US Forest Service's yearly fire-suppression costs have exceeded $1 billion for 13 of the 18 years between 2000 and 2017. In 2015, these costs exceeded $2 billion, and in 2017 they totaled almost $3 billion. The risk to property owners is particularly acute in areas at the WUI, where environmental and health costs of wildfires are also considerable. Not only do wildfires threaten lives directly, but they have the potential to increase local air pollution, exacerbating lung diseases and causing breathing difficulties even in healthy individuals. Additionally, a counterintuitive aspect of mountain forest wildfires is their ability to increase flash flood risk. The loss of vegetation from wildfires and the inability of burned soil to absorb moisture can cause flash floods and debris flow when heavy rain follows fires. This phenomenon was experienced along the front range in 2013 where an extreme flood event was greatly exacerbated by mud and debris flows, substantially increasing the damages. Finally, wildfire events are often coincident with periods of drought (e.g., 2012 in Colorado) compounding the economic pressure communities can face, dealing with multiple natural hazards simultaneously.

3.4.3.4. Wildfire Case Study

As 2012 began in Colorado, about 50 percent of the state was already designated in drought based on the US. Drought Monitor. Temperatures soared in June to levels not seen since the extreme drought and heatwaves of notable historic drought years – 1954 and 1934. Temperatures climbed well over 100 F on many days. Denver and Colorado Springs both set daily and all-time records, and the all-time state record high temperature of 114 F was matched at Las Animas, in southeastern Colorado. Reference evapotranspiration rates measured by the agricultural weather network, CoAgMet, were the highest ever observed in the network's 20-year history. Forests were very dry by June. The table was set for two of Colorado's most destructive wildfires, the High Park fire in northern Colorado and the Waldo Canyon fire near Colorado Springs, both which ignited in June. The devastating Colorado wildfire season of 2012 was the most publicized impact from the drought of 2012 and was responsible for an estimated 450 million dollars in insured losses and 5 fatalities. This does not include the costs of fighting the fires. The cost for fighting the High Park fire alone was around $40 million. In total, there were twelve major wildfires reported.

The proximity of these fires to large population centers and the large number of homes burned or threatened set these fires apart from typical Colorado wildfires. On June 26th alone 350 homes were lost to the Waldo Canyon fire making it the most destructive fire in Colorado's history. That title had been given to the High Park fire just a few weeks earlier for burning 259 homes For our case study, we will work with CSFS and Anchor Point to select one or both of these fires, recognizing they have well documented impacts and will provide a benchmark for validating our workflow. Specifically, we will be able to validate the capacity of the CO-WRA model to recreate observed conditions and validate economic models of losses to housing and life, and also related health impacts (smoke inhalation-related health data is becoming available in time for this study). Both of these fires were largely a function of drought and have subsequently influenced flood hazards, and will thus enable us to consider compound effects as well as the details of how climate change and growth may change key dynamics of similar events by 2050 (e.g. fuel types and availability; encroachment on the WUI; etc.).

3.5. Scenarios (SOW Section C.3)

Once the baseline risks for flood, drought, and wildfire have been modeled for the entire state, we will calculate future changes in risk by using appropriate climate and socioeconomic scenarios to perturb these baseline conditions. We will use climate change projections to modify the probability and/or intensity of each stressor (e.g., changes in hazard) and we will use demographic and land use changes to modify changes in exposure and/or sensitivity to those stressors (e.g., changes in vulnerability). This section describes our approach to developing future climate and socioeconomic scenarios for this component of our analysis. Figure 12 expresses the climate and socioeconomic scenarios in a 3-dimensional space, portraying uncertainty in the third dimension, which increases with time as we move from current conditions to future conditions (2050).

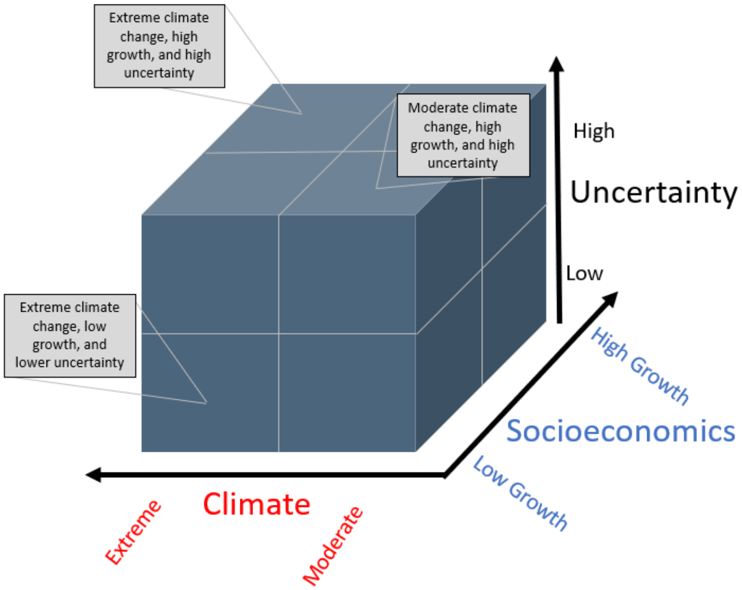


Figure 12. Climate, Socioeconomics, and Uncertainty

3.5.1. Climate Scenarios

We will develop future climate change scenarios that are either extracted from, or consistent with, the scenarios in Colorado's Water Plan ("hot and dry" and "between 20th century observed and hot and dry"), where "hot and dry" represents the 75th percentile (more severe conditions) and "between 20th century observed and hot and dry" represents the 50th percentile (median conditions from climate model projections). However, because the physical drivers of flood, drought and wildfire hazards are different, the physical models we will use to quantify current and future risks from each of these hazards must also vary. Thus, while some of our impact models can be driven directly by the scenarios developed for Colorado's Water Plan, others will use its methods of climate scenario selection (as developed from CRWAS-II; (Harding, 2015). Namely, selecting model projections that represent 50th percentile (median future conditions) and 75th percentile (more severe future conditions) according to the necessary model inputs (temperature, precipitation, flow, evaporation, etc.). Below, we provide a brief description of our proposed climate scenarios for each of the three climate hazards.

3.5.1.1. Flood

Riverine flooding in Colorado can be associated with large precipitation events that may result in short duration flash flood type events, or longer duration floods such as those that Colorado experienced in September 2013. Although extreme precipitation (i.e., <1% annual exceedance probability) ultimately drives these events, other hydrologic factors including antecedent soil moisture, snowpack, and the spatial scale of storms contribute to overall flood hazard and the incidence of flooding events. Thus, simply extracting projected changes in precipitation and temperature from climate model outputs would not provide an accurate means of projecting future changes in flood hazard (e.g. Sharma, Wasko and Lettenmaier, 2018). Instead, a hydrologic model is required.

Because developing a new hydrologic model of the state of Colorado is beyond the scope of this study, we propose to develop future scenarios for flooding using the CMIP5 downscaled hydrology projections already developed by a consortium of Federal and university partners including NCAR, USBR, and USACE (Reclamation, 2014). These routed flow data have outputs from 29 climate models and two emissions scenarios (RCP 4.5 and RCP 8.5) representing a total of 58 future hydrologic scenarios, all of which we already have in hand. Using these routed hydrology projections, we will use a scenario selection methodology that is consistent with the scenarios for CRWAS-II and therefore Colorado's Water Plan. Specifically, we will sort the model outputs according to a relevant metric of future hydrologic extremes (e.g., 90th/95th percentile annual maximum flow) and develop empirical percentiles calculated from the sorted flow data to select an ensemble of model projections representative of median (i.e., 50th percentile) and more severe (i.e., 75th percentile) future conditions. While the specific metrics used to select the 50th and 75th percentile model ensemble will be different from what is in the Colorado Water Plan, this methodology will maintain agreement with the State's methods (Harding, 2015). A baseline period centered on 2018 will be used to calculate historical values for the annual maximum flow event and a future period centered on 2050 will be used to represent 2050 conditions.

3.5.1.2. Drought

Climate scenarios used to assess future drought risk should adequately represent a plausible range of water supply stresses projected for the 2050 time horizon. The second phase of the Colorado River Water Availability Study (CRWAS-II) (Harding, 2015), developed seven aggregated climate change scenarios, two of which were used in Colorado's Water Plan: "Between 20th Century Observed and Hot and Dry" and "hot and dry". These scenarios were developed in terms of the balance/imbalance between water supply (runoff) and demand (CIR) by running CMIP3 and CMIP5 climate forcing scenarios through a hydrological model. Because these scenarios are defined hydrologically, with a specific focus on supply/demand, they are ideally suited for assessing future vulnerability to drought hazard. We will use these two scenarios from Colorado's Water Plan for the drought study. The baseline period for these scenarios is centered on 1985, while the future period is centered on 2050.

3.5.1.3. Wildfire

Increasing air temperature is well documented to play a role in increasing wildfire trends; however, decreases in summer precipitation (or wetting rain days) have been found to be an even more important factor in determining burned area in western US forests (Holden *et al.*, 2018). The wildfire climate change scenarios selected should reflect the importance of temperature and precipitation for future conditions in Colorado while aligning with the intent of Colorado's Water Plan. The two Water Plan scenarios were developed in a normalized space, plotting runoff versus CIR (evaporation), where "hot and dry" represents 75th percentile CIR and 25th percentile flow (more severe) and "between 20th century observed and hot and dry" represents 50th percentile CIR and 50th percentile flow (median conditions). We propose to use the same plotting positions as the Water Plan to select wildfire conditions according to summer temperature (May-September) and summer precipitation (May-September). Thus, "hot and dry" will represent 75th percentile temperature and 25th percentile precipitation (more severe) and "between 20th century observed and hot and dry" will represent 50th percentile temperature and 50th percentile precipitation (median conditions). Like the scenarios developed for the Water Plan, these scenarios will include an ensemble of model projections from CMIP3 and CMIP5. We will use historical data to represent baseline conditions, while future conditions will be centered around 2050.

While we believe the development of the scenarios is the most thoughtful alignment of Colorado's Water Plan and the individual analyses that are necessary for flood, drought, and wildfire, we also welcome further discussion with our state partners. Should a consensus form which utilizes other projections from CRWAS-II or other methods for the development natural hazards, we welcome a discussion that meets the needs of all parties.

3.5.2. Socioeconomic Scenarios

Population

The Colorado Water Plan incorporates five alternative future population scenarios for the 2050 time frame, and the ongoing Statewide Water Supply Initiative (SWSI) study has updated the latest projections to incorporate the latest 2018-2050 projections from the State Demographic Office. For this project we will look to implement the "Business as Usual Scenario" as a baseline growth projection. The "Business as Usual Scenario" represents the "official" population projection for the state and is used for a variety of governmental planning purposes. To capture the full range of future projections, we will also consider the "Weak Economy Scenario" and/or the "Hot Growth Scenario" (see *Figure 13*). The "Weak Economy" projection represents a population growth less than the "Business as Usual Scenario" while the "Hot Growth" projection represents growth substantially greater than the "Business as Usual Scenario". These county-level population projections will form the basis of our spatially distributed inventory of hazard susceptible infrastructure.

Consistent with the RFP's guidance to address both a "hot and dry" and "in-between hot and dry and 20th century observed" climate scenario we will work with the state project partners to pair these climate scenarios with an appropriate socioeconomic scenario, or combination of scenarios, from the list above to provide a starting point for developing the socio-economic data for the 2050 alternatives.

At this point, we understand the existing future scenarios identified above at least define the total future populations, at the county level. The Lynker team will use this information as a starting point with our state partners to further explore and understand the economic assumptions associated with the scenarios so that we can then appropriately adjust baseline data to represent these future conditions. For example, we will need to ensure that we understand how specific assumptions for these scenarios were made with respect to:

- The overall size of the economy in terms of reported income from individuals and businesses
- Distribution of economic activity (e.g., taxable sales) across the final sectors identified for the 2018 baseline
- Changes in price levels overall and within key sectors, for example change in average home prices and commodity prices, where the results for a sector may vary significantly from an economy-wide state average

With an understanding of the information already available with these scenarios, the Lynker team will then work with our state partners to identify reasonable and appropriate methods to adjust baseline data in areas where specific projections of economic conditions are not available in order to update the 2018 data to reflect conditions consistent with the selected scenarios in 2050. For example, we may consider the appropriateness of extending recent trends in changes in the average home prices in counties to project an average value in 2050. Similarly, we will consider options for distributing any changes in projected 2050 populations within a county, or specific area of interest such as a floodplain or a WUI, while considering related factors such as trends in insurance and existing growth or development restrictions in county growth plans.

A specific example of an area where we envision the need and desire for considerable interaction with the Project Team is with respect to the distribution, level, type, and value of anticipated future agricultural and livestock activity in the state. In particular, our team anticipates working closely with the Department of Agriculture to ensure their expertise is fully accounted for in developing the relevant future information for these sectors recognizing how current pressures with respect to population growth and demand for water rights are already affecting agricultural and livestock operations in the state.

In cases where projections rely on specific assumptions to update baseline data, we will ensure these are fully documented to both highlight areas where new data could be considered over time to replace assumptions and to understand the uncertainty in projected hazards.

3.5.3. Representative Regions

Our analysis will begin with a focus on quantifying hazards at the county level across Colorado, leveraging the large datasets that are maintained by many counties and the frequent summarizing of data collected by the state at the county level, particularly with respect to summaries of economic activity. We are aware, however, that there will be many data gaps which may challenge the ability to complete county-level statewide analysis. Therefore, we expect to group our county analyses together in a logical framework that will assist in both extrapolation of results from county-to-county as well as providing a high-level summary snapshot of results across the state. This will provide benefit both to users of the data visualization tool as well as policymakers across Colorado.

We developed 9 representative regions as shown in *Figure 14. Representative Regions in Colorado* to help capture trends in our risk analysis across the counties. We wanted to capture, as best as possible, climatic regions, projected change in future climate, socioeconomic regions, as well as impacts that may be important for flood, drought, and wildfire. Thus, we informed our region selection by examining a variety of classification schemes for Colorado based on work completed for *Climate Change in Colorado* (Lukas *et al.*, 2014), the Colorado State Hazard Mitigation Plan (Colorado DPS, 2018), EPA Level III Ecoregions, the Colorado Drought Vulnerability Study – Climate Change Analysis (Annex C), and NOAA's Climate Divisions. Upon award, we will work with members of the Project Team to refine these regions as needed to ensure that our final product meets the needs of all relevant stakeholders.

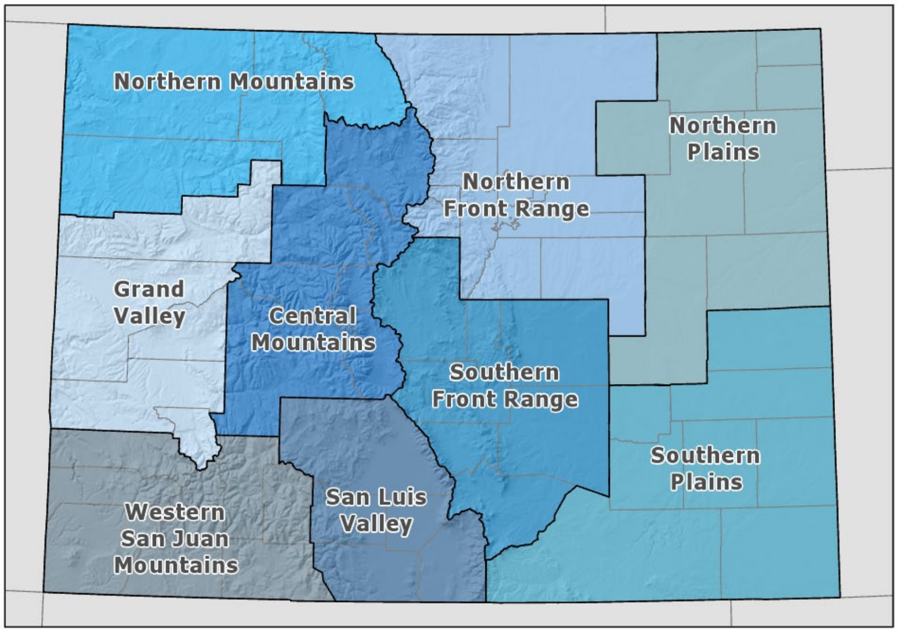


Figure 13. Representative Regions in Colorado

3.6. Resilience Analysis (SOW Section C.5)

Resilience is generally defined as the ability to recover from a difficulty. **Adaptive capacity** typically refers to actions taken to avoid or mitigate the effects of vulnerability to a natural hazard. Adaptive capacity is a way to reduce the vulnerability of a community.

For this project, the goal of our resilience analysis is to extend the work completed for the risk analysis (identification of vulnerabilities, quantification of expected annual damages) to develop actionable strategies for communities, counties and state level governments to decrease the overall costs due to flood, drought and wildfire in the future relative to 2018.

This phase of the project will be focused on evaluating multiple comparisons of vulnerability scenarios to determine the following:

> *Resiliency is the ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges – including disasters and climate change – and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations.*
>
> Definition of resiliency adopted by Colorado Resiliency Working Group (CRWG)
> Source: Colorado Resiliency Framework

How risk may change with management or incentives to reduce vulnerability

Our approach to calculating risk uses hazard x vulnerability, where the vulnerability is determined from exposure (location) and the sensitivity (susceptibility) to the hazard. As we develop the datasets for future (2050) population growth and buildout, we will be updating databases of spatial information (GIS), vulnerable assets, increased or decreased exposure of the assets, and costs associated with 2050 conditions. We will use this information to isolate the increases in risk and associated cost from increases in vulnerability alone, rather than vulnerability plus increased hazard (i.e., increase in hazard severity or recurrence due to climate change). Conversely, this will allow us to monetize the changes in risk due to incentives or policies (e.g., restrictions on development in floodplains or the WUI) that could be used to reduce vulnerability.

Recovery costs based on risk changes over time (2018 to 2050)

The risk analysis will provide monetary damages and recovery costs expected for flood, drought, and wildfire, and will be informed by case studies with specific costs from historical events. Our hazard-specific models will allow us to quantify how risk changes over time, from current conditions to 2050, and can be extended to understand how recovery costs would increase through time assuming no adaptations are undertaken. This "no adaptation" future scenario will allow us to isolate the climate drivers of increased risk, and will provide an upper end to future costs from each hazard. This can feed into a cost-benefit analysis for adapting to the hazard (e.g., improved forest management practices or larger bridge spans), and will help to highlight the most beneficial areas to focus future resilience funding.

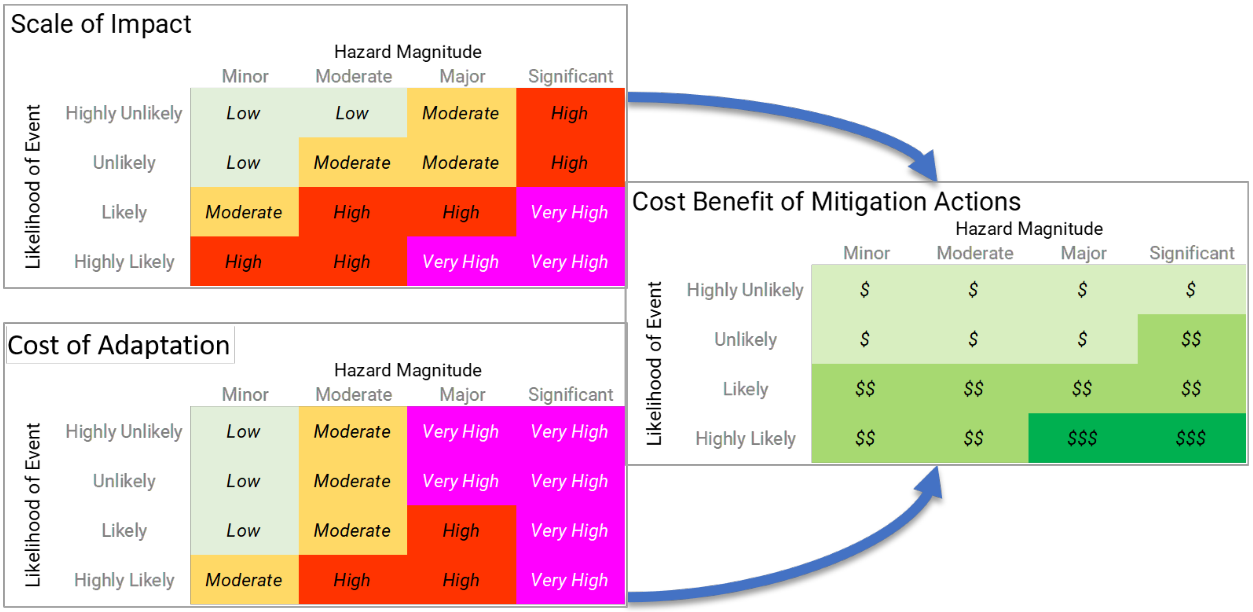
Methods of improving resilience to provide a cost-savings against future climate change

We will use the experience we have gained from our risk analysis, especially the improved understanding of how vulnerability changes under our climate change and buildout scenarios to isolate the drivers that have the biggest impact on risk, and therefore, the solutions that can be used to reduce exposure and improve resilience. We expect to develop a suite of ideas for improving resilience that may be applicable to each of the vulnerable sectors (Infrastructure, Agriculture, Recreation & Tourism, Public Health, Economy, and Environment).

We plan to provide case studies of hazards from different representative regions in Colorado. We anticipate that these case studies of local scenarios will be the ideal setting to showcase resilient planning solutions to combat climate change. The case study may show a flood, drought, or wildfire scenario in the context of a historical event, then show how that event may look in 2050, and finishing with an analysis of mitigating for climate change (improving resilience) versus doing nothing.

3.6.1. Resilience Conceptual Overview

Using the output from the risk assessment, our approach to the resiliency analysis will focus on identifying the resiliency strategies that provide the greatest benefit with regards to the level of impact and likelihood of a hazard event. The matrix in *Figure 15. Example Risk Assessment Model Output* illustrates an example of the output that can be generated from the risk assessment. A corresponding impact matrix with estimated costs of resiliency (*Figure 16. Resiliency Strategies*) would then be developed to evaluate where cost-benefit savings may have the greatest positive impact.



Scale of Impact

Likelihood of Event	Hazard Magnitude			
	Minor	Moderate	Major	Significant
Highly Unlikely	Low	Low	Moderate	High
Unlikely	Low	Moderate	Moderate	High
Likely	Moderate	High	High	Very High
Highly Likely	High	High	Very High	Very High

Cost of Adaptation

Likelihood of Event	Hazard Magnitude			
	Minor	Moderate	Major	Significant
Highly Unlikely	Low	Moderate	Very High	Very High
Unlikely	Low	Moderate	Very High	Very High
Likely	Low	Moderate	High	Very High
Highly Likely	Moderate	High	High	Very High

Cost Benefit of Mitigation Actions

Likelihood of Event	Hazard Magnitude			
	Minor	Moderate	Major	Significant
Highly Unlikely	$	$	$	$
Unlikely	$	$	$	$$
Likely	$$	$$	$$	$$
Highly Likely	$$	$$	$$$	$$$

Figure 14. Example Risk Assessment Model Output

3.6.2. Flood

One of the key outcomes of our flooding analysis will be an identification of "hot spots" of flood vulnerability in Colorado, as well as the key drivers of vulnerability to flooding and other fluvial hazards. Based on these data, we can begin to evaluate options for improving resilience that could decrease overall future costs relative to a "no adaptation" baseline. For flood vulnerabilities, these options could include investments in flood protection infrastructure such as dams and levees; retrofitting bridges or other assets to withstand larger flows; or implementing floodplain buyout programs to remove homes from fluvial hazard zones. Informed by the results of our vulnerability analysis, we will develop a range of potential adaptations, as well as associated costs and benefits of those adaptations.

3.6.3. Drought

Our risk analysis aims to identify which regions and sectors may benefit from drought resiliency efforts. The risk analysis will form the basis of examining sector specific strategies for estimating the cost-benefit measures associated with drought vulnerable locations. The Drought Vulnerability Assessment within the Colorado Drought Mitigation and Response Plan identifies a multitude of adaptive capacities and resiliency characteristics for each of the seven sectors evaluated, and we will attempt to examine the potential benefits of the most impactful mitigation strategies. Examples of drought resiliency and adaptive management that may be included in the drought resiliency analysis includes:

- Low water-use crop transitions and reducing cropped land footprints

- Enhanced agricultural engagement in water markets
- Water re-use and recycling
- Inter-basin transfers
- Additional reservoir capacity
- Improve leakage control in water delivery systems
- Update building codes to promote water-efficient homes and businesses
- Alternative transfer methods (ATMs)

Flood Flood Hazard Mitigation Plan (CWCB, 2010)	1. Reduce flood impacts to Colorado's economy, people, state assets, and environment 2. Promote awareness and education of flood hazards and watershed protection 3. Coordinate and provide planning, technical assistance, and financial resources for state, local, and watershed planning efforts 4. Continue to update and develop floodplain maps for risk assessment, planning, and awareness applications 5. Promote and encourage the adoption of model codes and higher standards that emphasize hazard mitigation
Drought Colorado Drought Mitigation and Response Plan (CWCB, 2010)	1. Improve water availability monitoring and drought impact analysis 2. Increase public awareness and education 3. Work collaboratively with water rights holders to voluntarily augment water supply through mechanisms to transfer to areas of shortage during droughts 4. Coordinate and provide technical assistance for state, local, and watershed planning efforts 5. Reduce water demand/encourage conservation 6. Reduce drought impacts to Colorado's economy, people, state assets, and environment 7. Continue to develop intergovernmental and interagency stakeholder coordination 8. Evaluate potential impacts from climate change
Wildfire Colorado Wildfire Mitigation Plan draft (DHSEM, 2010)	1. Strengthen local capacity in wildland fire preparedness, suppression, and mitigation 2. Enhance state leadership and coordination in interagency wildland fire response 3. Improve statewide public awareness regarding the role of fire in Colorado landscapes and tools for wildland fire prevention

Figure 15. Resiliency Strategies

Figure 16 summarizes the mitigation goals and actions from Colorado's hazard mitigation plans for flood, drought and wildfire

3.6.4. Wildfire

Our risk analysis of wildfire throughout Colorado will allow us to identify those counties and regions that are most vulnerable or most exposed to this hazard. By comparing current vulnerability to the estimate 2050 vulnerability we will identify the most as-risk areas, where the cost of implementing mitigation efforts may be the most beneficial. Similarly, we can use our risk analysis to determine those areas where the hazard itself has increased, that is where the probability and severity of occurrence has increased. This may identify additional options for wildfire mitigation or confirm those based on population and buildout scenarios. Wildfire mitigation options are varied, including methods available to small private landowners as well as larger options for state and county governments. Some examples of wildfire mitigation from the CSFS and the Colorado Wildfire Mitigation Plan include:

- Fuel mitigation and pine beetle mitigation
- Support and fund wildfire preparedness plans and training for local personnel
- Administer funds for fuels mitigation cost-sharing program

- Become a FireWise USA community
- Encourage fire adapted communities through education/outreach CSFS Forest Action Plan (decrease fire suppression costs & improve safety)
- Home protection from wildfire (defensible space, structural ignitability, fuel knowledge) and support efforts for informed decision-making
- Wildland-urban interface (WUI) training for local fire personnel
- Clarify roles and responsibilities for sheriffs and fire protection districts
- State leadership in providing coordinated messages for homeowners, landowners
- Support Community Wildfire Protection Plans (CWPP)

3.6.5. Resilience Analysis Case Studies

For each hazard, we will also leverage information from our case studies to provide detailed, hazard-specific analysis of how resilience actions can improve future outcomes.

For flooding, we will leverage our case study of the 2013 Boulder flood to better understand the costs and the potential benefits of community-level flood adaptation and mitigation efforts. For example, actual community-scale investments in resilience measures like improved floodplain management, wider bridge spans, and property buyouts each have real costs and expected benefits associated with them, which can provide a guide for other communities across the state. Our case study approach will provide us with ground truth as we scale up these estimates of resilience costs and benefits to a state-wide scale.

For drought, we will consider how the 2011 – 2013 drought impacted the agricultural sector in the Arkansas River Basin. The Arkansas Basin suffered a loss of 1,300 jobs and ~$105 million in economic activity in the wake of the 2011 – 2013 drought (Gunter *et al.*, 2012). Our case study will allow us to consider how a suite of climate and socioeconomic scenarios may have exacerbated the event, and explore the cost/benefit of drought mitigation strategies, such as encouraging farmers to transition to drought resilient and less water intensive crops.

For wildfire we will consider how the large, destructive events during the 2012 fire season impacted property and human life across the Front Range. The High Park and Waldo Canyon fires occurred within several weeks of one another during Summer 2012, affecting the greater adjacent Fort Collins and Colorado Springs communities, respectively. The case study will allow us to consider how these large and costly fires may present themselves under future climate change conditions as well as future socioeconomic scenarios. Finally, we will consider how mitigation measures may help to reduce risk and provide cost savings from these destructive wildfire events.

3.7. Data Visualization (SOW Section 3.6)

The Lynker team proposes to design and develop an interactive web application with data-driven features aimed at summarizing and illustrating the results and findings of the risk analysis. The content will be presented in a clear and concise layout with the goal of providing stakeholders across the state with a comprehensive understanding of local and regional future climate hazards along with an intuitive view of potential mitigation impacts. Throughout the risk analysis and scenario evaluation project phases, the Lynker team will focus on producing data products that are easily visualized and provide clear messaging of the project results and key findings.

3.7.1. Approach

Our proposed approach to developing the Climate Vulnerability Assessment Tool (CVAT) application will primarily rely on the Esri ArcGIS Online (AGOL) suite of tools to develop and host intuitive and feature rich visualization applications. AGOL applications are used extensively for water resource studies (including within CWCB) for seamlessly visualizing geospatial data through dashboards and story map applications. Lynker's team of data scientists have experience working with cutting-edge GIS and data analytics applications and specialize in applying ERSI's suite of online and desktop tools. Lynker also employs a team of web application developers that can deliver modern, web-based mapping solutions scaled to each client's needs. The final application will fully meet the project's goal of providing a consistent statewide framework for evaluating Colorado's risk profile to drought, wildfire, and flood under current and future scenarios. Our approach to designing and implementing the data analysis tools for this project will focus heavily on the goal of providing an intuitive and robust resource for users to explore the current and future risk of flood, drought, and wildfire statewide and the actions and cost associated with mitigating or not mitigating those risks.

The Lynker team will implement aspects of the agile development methodology for this visualization application. This incremental agile approach includes the following project stages:

- Planning and design
- Develop prototype visualization applications
- Testing and documentation
- Gather and assess feedback

This development approach allows for ample opportunities for the Project Team participants to review the progress and provide feedback and guidance throughout the project duration. Defining the most effective layouts and visualization components will be developed through an iterative process, allowing project staff to prototype and revise the framework throughout the project duration.

The Lynker team has extensive experience implementing data visualization applications through the AGOL platform. Our team of data scientist routinely implement AGOL tools for project applications that are directly relatable to this project. The primary advantage of using the AGOL environment is the accessibility of the predeveloped applications, widgets, and templates. With the easily customizable AGOL applications, our team of data scientists can spend more time focused on visualizing the underlying data narratives and less time writing custom mapping and plotting code.

The Lynker team will work collaboratively with the Project Team participants from the initial design phase through production to ensure the proposed AGOL framework provides intuitive and feature-rich tools for examining future hazard conditions under different scenarios.

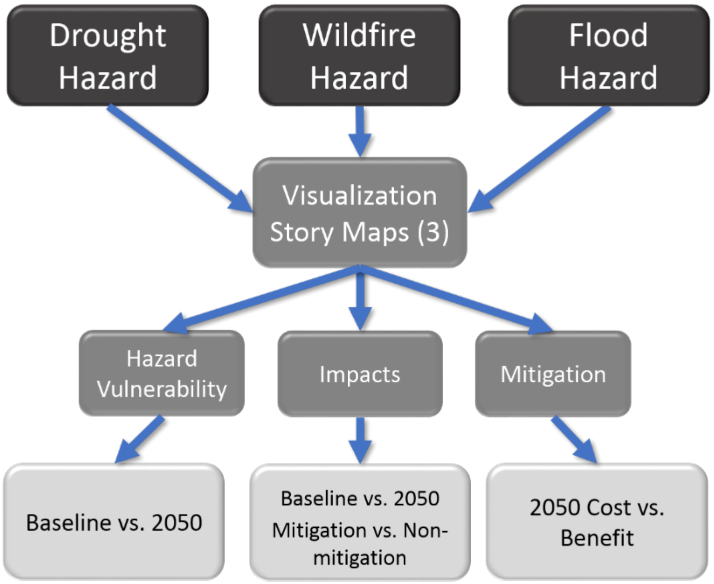
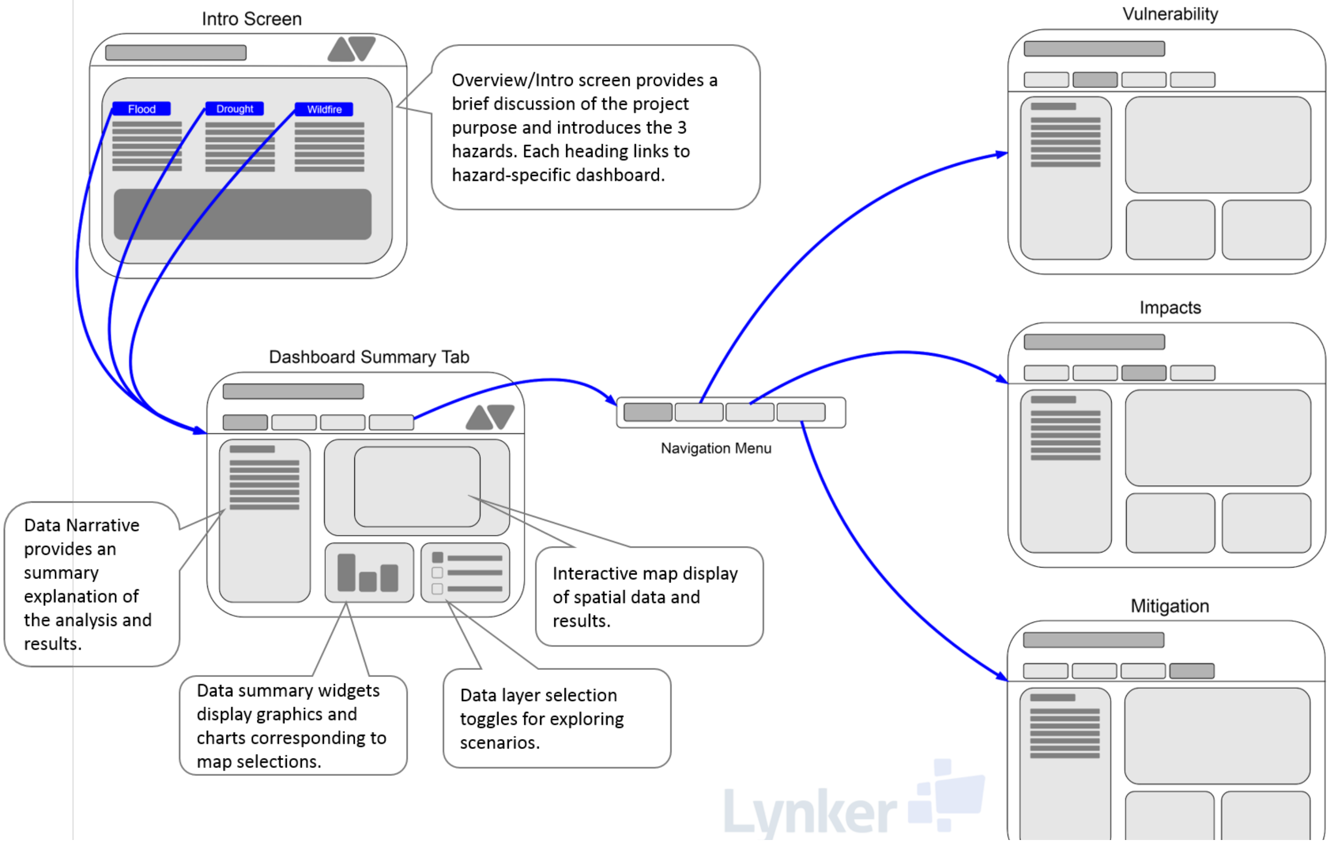


Figure 16. Data Visualization Workflow

The workflow here outlines the draft layout of the proposed visualization tool. Each of the three hazards will be individually illustrated through a common story map application. The hazard specific story maps will incorporate a consistent layout to ensure users can compare supporting data and results from each of the three hazard analyses. The story map navigation will focus on grouping the displays for vulnerability, impacts, and mitigation results. This layout aims to give users a simple yet data-rich visualization portal to evaluate future vulnerabilities and the modeled impacts from the three hazards, while also highlighting how and where potential savings from strategic resilience may benefit our communities. Dynamic cartography displays and user controlled toggles will be incorporated throughout the application. The spatial data will be configured to display



Overview/Intro screen provides a brief discussion of the project purpose and introduces the 3 hazards. Each heading links to hazard-specific dashboard.

Data Narrative provides an summary explanation of the analysis and results.

Interactive map display of spatial data and results.

Data summary widgets display graphics and charts corresponding to map selections.

Data layer selection toggles for exploring scenarios.

Figure 17. Data Visualization Strategies

both county level and the representative regions to give users access to both local and regional outputs. Note that this framework design is an initial draft based on previous project experience. Our project team will fully engage the Project Team during the application design phase through the development process to ensure the final product meets expectations.

To help streamline the development to production process, we recommend CWCB provide a user account with publishing capabilities on the CWCB AGOL organizational account for the duration of the project. This approach would allow the Lynker team to access the state's organization account where all of the application content will be hosted. Based on past experience working with CWCB, we assume the CWCB AGOL Organization account will have licensing access to the "Essential Apps Bundle" which includes access to the Map Viewer, Operations Dashboard, Web AppBuilder, and Story Maps applications.

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Partner
Network
Silver

Why use AGOL?

- Cost effective – CWCB already has an AGOL Organization account
- Data and applications hosted on the AGOL cloud (minimal CWCB maintenance required)
- Flexibility for integrating new SWSI content within existing CWCB tools (e.g. CDSS)
- Seamless transition from development to production
- Fully supported framework that will facilitate future updates and edits
- Ready-to-use data analysis widgets for interactive plots, charts, and indicators
- Functionality for embedding external content (images, charts, documents, web content, etc.)

Our team will work with the Project Team to ensure the framework developed for this project is scalable and accessible for future enhancements or updates. The AGOL infrastructure is the ideal tool for ensuring that future updates and enhancements to the applications do not require a comprehensive understanding of software code used to develop the initial applications. All AGOL applications can be created and edited using intuitive tools and controls through the AGOL web portal – no manual coding required.

Based on the information provided in the project Statement of Work and our experience designing successful applications, we created a draft wireframe (*Figure 19*) to summarize the key features and general layout of our proposed visualization application. This preliminary wireframe will be reviewed/refined during the initial kickoff and reevaluated during early project meetings. **Our project team is committed to working closely with the Project Team to ensure the proposed layout achieves the project goals while working within the capabilities of the AGOL framework.**

Lynker Visualization Tool Examples

- *CWCB Drought Plan Visualization Tool: https://arcg.is/0iuSXm*
- *CRWAS Temperature Offset Tool: https://arcg.is/1nyzSO*
- *Jamestown Automated Flood Warning System Project Design: https://arcg.is/0yS0KO*

Using the framework developed and refined in the planning and design phase, the Lynker team will produce a series of AGOL mapping and data analysis applications to create a robust visualization portal (example view in *Figure 18*). The visualization product will be composed of the following content features:

- Feature Layers – hosted shapefiles (point, line, and polygon layers) with processed/summarized data features contained in the attribute tables
- Web Maps – online map applications with layer formatting data pop-ups configured to display the relevant attribute data

- Dashboards & Web Mapping Apps – interactive layout with widgets that display statistics from the data contained in the embedded web maps
- Externally embedded content – documents, images, websites, and customized plots (created/hosted outside AGOL)
- Story Map Application – interactive narrative layout with applications embedded as tabs/pages within a concise story map layout

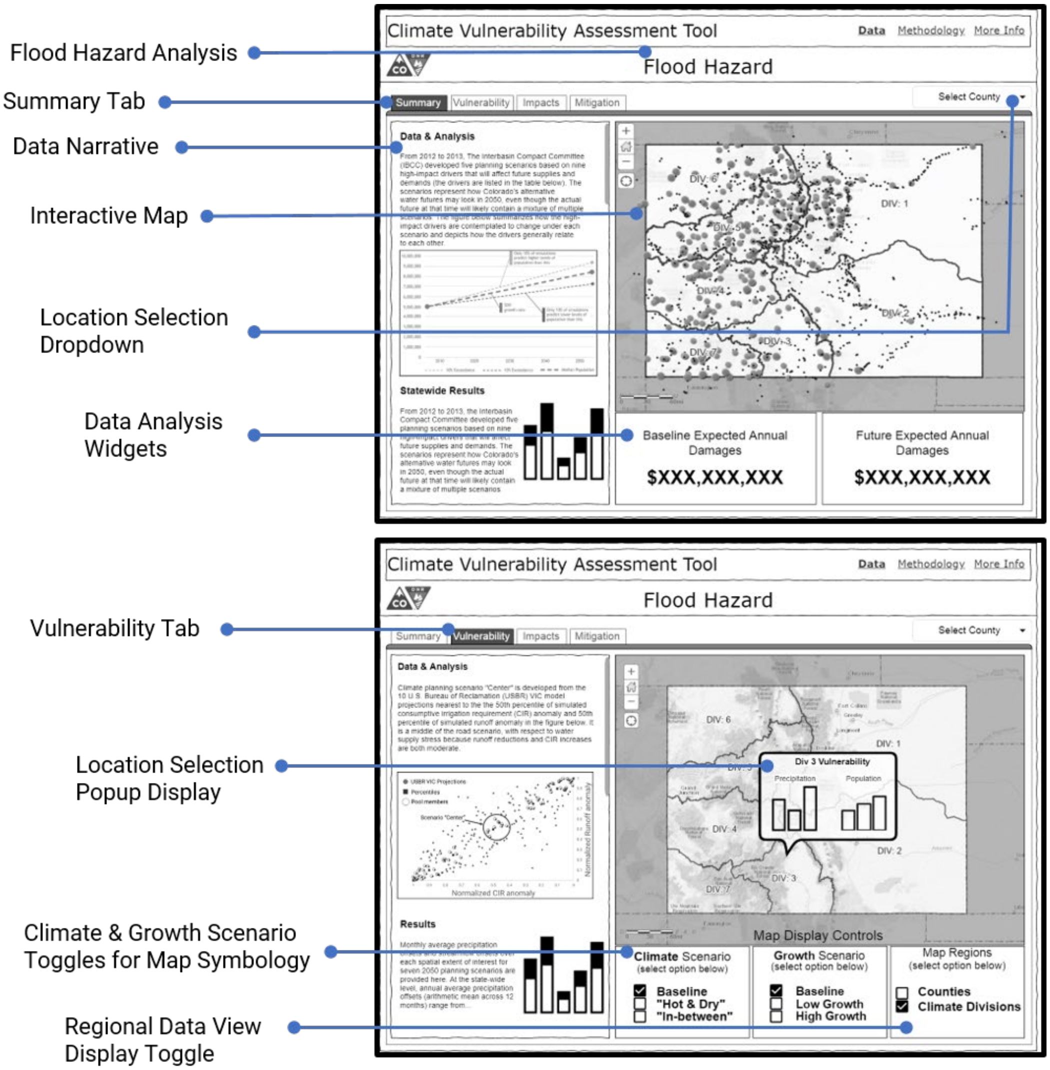


Figure 18. Data Visualization Wireframe Examples

3.8. Outreach (SOW Section C.7)

Lynker recognizes that coordinated outreach and engagement could be an important part of this project, since the Project Team and Project participants are spread across more than 15 state and Federal agencies. These outreach and engagement activities could be as simple as coordinated meetings to ensure we gather the most relevant data from each participating agency, or as detailed as webinars to test different concepts for our visualization tool after initial analyses are complete. Recognizing that the actual stakeholder engagement component of this project may not come into focus after award, this section provides examples of our team's qualifications in stakeholder outreach and engagement to demonstrate that we can meet the needs of the State.

Lynker places great emphasis on outreach, education and extension of our work and tools to the users that need them and can make best use of them. We have led climate change hazard and risk outreach meetings internationally and for domestic federal, state and local agencies. Lynker staff (Graeme Aggett) led a hydro-economic climate risk assessment project for the World Economic Forum in Tanzania and delivered the outreach at state and local levels, and to three multinational companies. Senior Planner Megan O'Grady has led multiple stakeholder engagement studies related to climate resilience, on behalf of clients including the US Department of Housing and Urban Development, NOAA, and the New York State Energy and Research Development Authority (NYSERDA). For each of these projects, she used these stakeholder engagement sessions to streamline baseline data collection and to evaluate the utility of different decision support tools. Senior Scientist Cameron Wobus led multiple community sessions on climate risks in Mozambique for USAID, and co-led flood risk outreach sessions for NYSERDA with Ms. O'Grady. Joel Smith from Abt has, as a function of his position on the National Academy of Sciences Panel on Adapting to the Impacts of Climate Change, led outreach, guidance and training on climate change risk assessment for multiple international organizations, the U.S. government, states, municipalities and the nonprofit and private sectors.

In Colorado we have led many outreach efforts including key roles on the Colorado state Climate Change Technical Advisory Group (CCTAG) (Harding and Barsugli). The Lynker team have also led multiple projects developing technologies and concepts to support multi-hazards and climate change risk outreach, including a drought vulnerability visualization tool, a serious drought game, a NOAA-funded Climate Change Drought Decision Support System for Colorado, and CWCB-funded Flood Decision Support System.

Lynker staff led six FEMA and NRCS-funded flood recovery projects in the aftermath of the September 2013 floods. After working long days in Jamestown spread over many months, Dr. Aggett and his team delivered weekly outreach reports to the entire community each Thursday night. Helping the community understand how the impacts of flooding had been exacerbated by wildfire-related debris flows enabled us to develop community support for science-informed river restoration design, resilience planning, and adaptation options that were focused on the hazardous processes the town had actually endured and are likely to experience more frequently under a changing climate.

Most recently Lynker has worked with Coalition for the Poudre River Watershed (CPRW) and stakeholders from the Greeley and Windsor area, conducting public meetings related to the Lower Poudre River master plan we developed for CPRW (see *Figure 20. Public Outreach*). Our team has the proven ability to effectively facilitate all types of meetings; from large community outreach meetings, to advisory committees comprised of diverse stakeholders, technical interagency working group meetings, and focused task force meetings. Lynker's expertise is in collaborative decision-making dynamics, which involves designing processes that identify and involve key stakeholders, identify issues that need to be addressed, provide structure to meetings, and develop strategies to achieve desired results and consensus-based agreements. Additionally, the Lynker team has experience in the capacity building of technical concepts and resources that would help train citizen scientists to be well-informed and efficient in the new 'Climate Change Multi-hazard Risk Assessment Tool' and project case studies.

Figure 19. Public Outreach

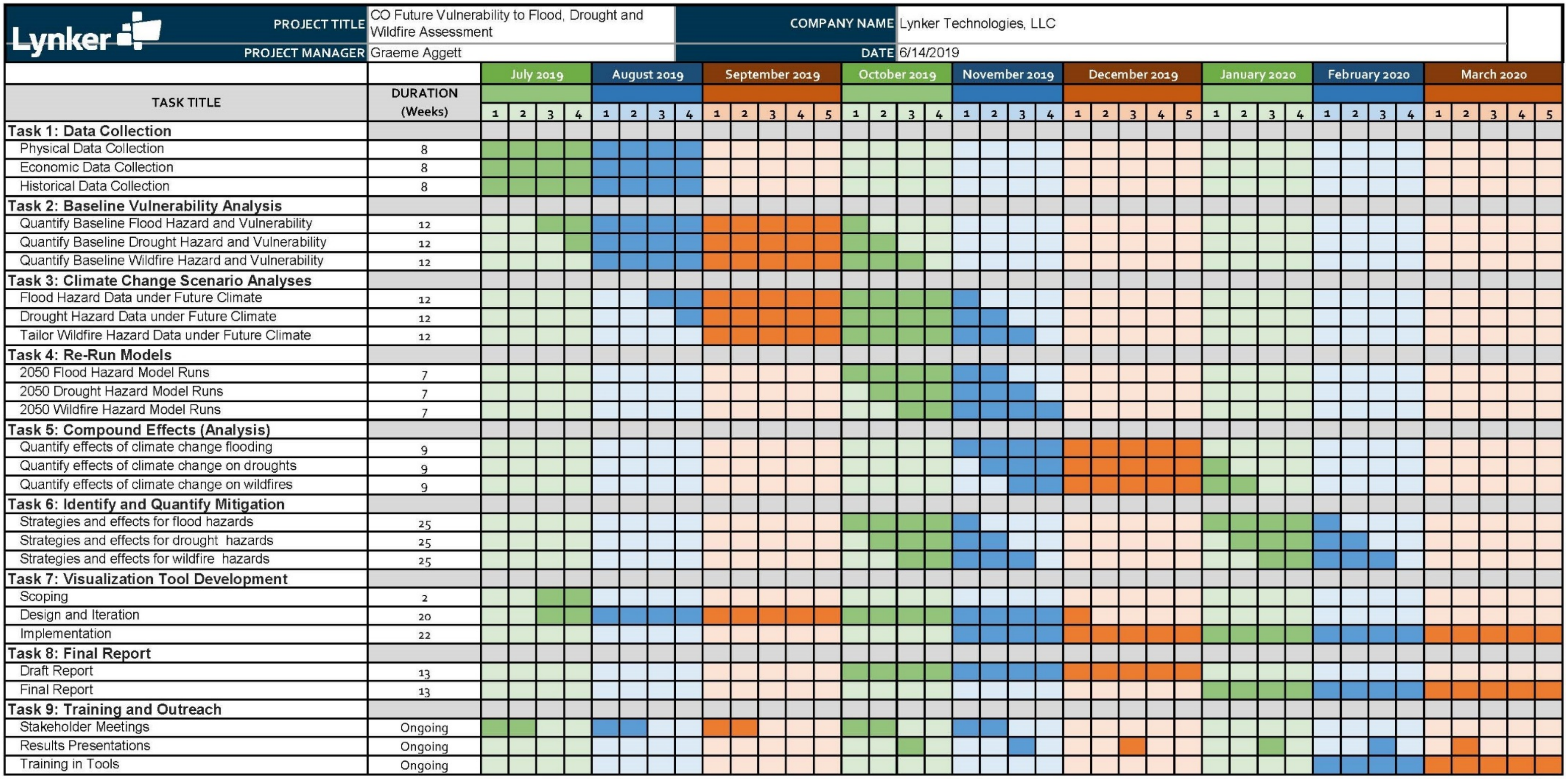
Lynker working closely with the CPRW during a public meeting for the Lower Poudre River Master Plan

Lynker also worked closely with the Lefthand Watershed Oversight Group (LWOG) in 2018 to develop a conceptual model and citizen science program for adaptive management and resilient river restoration. A large part of the project was interacting with project stakeholders, which included members of municipalities, counties, and watershed groups, to develop the Monitoring and Assessment Framework, a comprehensive guide describing monitoring parameters that are frequently used for rivers assessments.

For this project our strong leadership team will ensure timely delivery of monthly status reports, as well as record keeping and delivery of project meeting minutes, for distribution to the State, its partners and any relevant steering committee. Lynker has the experience to lead stakeholder meetings and guide them in a meaningful way, such that goals and objectives guide meeting discussions, leading to consensus and results. We will work closely with the state to ensure we bring the appropriate messages, materials and people to deliver outreach for this project. We imagine the 'Climate Change Multi-hazard Risk Assessment Tool' will be a part of this outreach, and will be the ideal venue with which to test and get feedback on the utility of the tool prior to final delivery.

3.9. Project Spreadsheet/Schedule

Immediately below, please find Lynker's spreadsheet detailing all levels of activity over the project timeline to meet all deadlines listed in the *Statement of Work* for project deliverables. This spreadsheet has also been included as an electronic attachment to the *Technical Proposal*.



PROJECT TITLE: CO Future Vulnerability to Flood, Drought and Wildfire Assessment
COMPANY NAME: Lynker Technologies, LLC
PROJECT MANAGER: Graeme Aggett
DATE: 6/14/2019

TASK TITLE	DURATION (Weeks)	July 2019				August 2019				September 2019					October 2019				November 2019				December 2019					January 2020				February 2020				March 2020				
		1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5
Task 1: Data Collection																																								
Physical Data Collection	8	■	■	■	■	■	■	■	■																															
Economic Data Collection	8	■	■	■	■	■	■	■	■																															
Historical Data Collection	8	■	■	■	■	■	■	■	■																															
Task 2: Baseline Vulnerability Analysis																																								
Quantify Baseline Flood Hazard and Vulnerability	12			■	■	■	■	■	■	■	■	■	■	■	■																									
Quantify Baseline Drought Hazard and Vulnerability	12				■	■	■	■	■	■	■	■	■	■	■	■																								
Quantify Baseline Wildfire Hazard and Vulnerability	12					■	■	■	■	■	■	■	■	■	■	■	■																							
Task 3: Climate Change Scenario Analyses																																								
Flood Hazard Data under Future Climate	12							■	■	■	■	■	■	■	■	■	■	■	■																					
Drought Hazard Data under Future Climate	12								■	■	■	■	■	■	■	■	■	■	■	■																				
Tailor Wildfire Hazard Data under Future Climate	12									■	■	■	■	■	■	■	■	■	■	■	■																			
Task 4: Re-Run Models																																								
2050 Flood Hazard Model Runs	7														■	■	■	■	■	■																				
2050 Drought Hazard Model Runs	7															■	■	■	■	■	■																			
2050 Wildfire Hazard Model Runs	7																■	■	■	■	■	■																		
Task 5: Compound Effects (Analysis)																																								
Quantify effects of climate change flooding	9																		■	■	■	■	■	■	■	■	■													
Quantify effects of climate change on droughts	9																			■	■	■	■	■	■	■	■	■												
Quantify effects of climate change on wildfires	9																				■	■	■	■	■	■	■	■	■											
Task 6: Identify and Quantify Mitigation																																								
Strategies and effects for flood hazards	25														■	■	■	■	■									■	■	■	■	■								
Strategies and effects for drought hazards	25															■	■	■	■	■									■	■	■	■	■							
Strategies and effects for wildfire hazards	25																■	■	■	■	■									■	■	■	■	■						
Task 7: Visualization Tool Development																																								
Scoping	2			■	■																																			
Design and Iteration	20			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
Implementation	22																		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 8: Final Report																																								
Draft Report	13														■	■	■	■	■	■	■	■	■	■	■	■	■													
Final Report	13																											■	■	■	■	■	■	■	■	■	■	■	■	■
Task 9: Training and Outreach																																								
Stakeholder Meetings	Ongoing	■	■			■	■			■	■				■	■			■	■																				
Results Presentations	Ongoing																■				■				■					■				■				■			
Training in Tools	Ongoing																															■	■	■	■	■	■	■	■	■

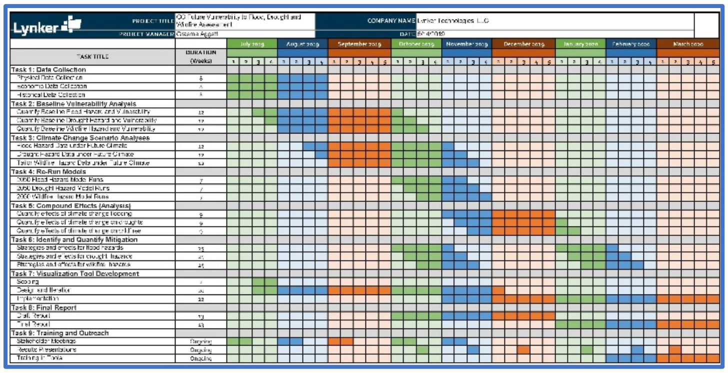
Figure 20. Project Spreadsheet

4. Management Plan

Lynker believes that every project should begin with a successful project management strategy, documented in a project plan that includes a detailed project schedule to keep the project on time and on budget. Our team understands that communication and client input throughout the course of the project are essential to a successful project completion. Lynker has a proven track record of applying effective and efficient communication strategies to ensure our client and all project personnel are informed and actively involved throughout the entire course of the project.

4.1. Administration and Management

Upon award, the Lynker project manager will develop and share a web-based Gantt chart to continually track project progress at the project personnel and subtask level. Our project Gantt charts provide a valuable tool to supplement bi-weekly status reports/calls while also providing a comprehensive tracking system to efficiently monitor the project timeline to an on-schedule completion.



4.1.1. Systems for Project Planning, Monitoring and Reporting

As the prime offeror, Lynker presumes all management and fiduciary responsibility for the team throughout the project's life cycle. Lynker's proposed Management Team has enterprise project experience in planning, tracking, and managing projects of comparable size to our proposed solution. Lynker achieves high quality, measurable results through our adept application of industry-recognized frameworks and methodologies such as PMI's PMBoK, ISO, LSS, CMMI, and ITIL. We focus on selecting those processes and best practices that suit our customers' mission priorities, technical requirements, enterprise architectures, and organizational culture.

Our success-driven approach to Project Management Plans, shown below, empowers our Program Manager, Assistant PM, and team members to act decisively in meeting the state's needs, while giving our team a reliable support structure and reach back to additional Lynker Team resources including our subs.

Table 1. Lynker's Mature, Proven Project Management Approach

Process	Approach
Initiate	▪ Collaborating with our partners for pricing, resumes, and capabilities
Plan	▪ Identify resource requirements for eachSOW activity, and map skills, capabilities, and subject matter expertise to them. ▪ Develop and maintain a centralized Program Management Plan (PMP), to include a contract-level Work Breakdown Structure and master schedule. Develop implementation plans to govern, guide, and track projects specifying schedule/resource usage baselines according to the specific requirements. ▪ Additionally, this PMP will include project-specific activities, timelines, critical paths, resource assignments, cost and schedule baselines, deliverables, quality metrics, risks, etc.

Execute and Report	▪ Continually communicate with the state and key stakeholders. The Lynker PM is the primary point of contact (PoC) to the customer and is responsible for overall contract delivery. ▪ Our PM, and team members identify issues and develop strategies to control risks. We review task issues and risk lists at least weekly and summarize them in progress reporting to the customer point of contact and our PM. Lynker's PM summarizes contract-wide risks and issues in our monthly reporting to the Town. ▪ Our PM and captures cost and work progress and compares against performance baselines ▪ Our PM sends the state PoC regular (at least monthly) technical memos including status reports
Monitor, Control, and Track Compliance	▪ Our PM, with assistance from our team, monitors overall performance to identify risks early and take effective corrective action to address quality, cost, or schedule issues. ▪ Track day-to-day team performance against approved task-level QCP and performance standards, working with team members to maximize effective resource usage, staff assignments, and budget status. ▪ Our PM monitors overall contract compliance to all state and other applicable standards, mandates and policies ▪ Our PM verifies overall team performance against the approved QCP, or as stated within the Lynker PMP, and takes corrective action as needed to effectively resolve issues ▪ Lynker's quality organization independently verifies that all project work adheres to and meets quality assurance requirements
Close	▪ Provide final deliverables and contract closeout reports with recommendations for improvement and an assessment of best practices

Additional features of our approach to managing the project include:

Project Management Plans (PMP) - Our PM is the customer's PoC at the Contract level. The contract PMP, will guide overall efforts and provides the Master Schedule and WBS, which provides a template for consistent contract tracking and reporting. Our PM will deliver the PMP to the state team PoC within 5 days of Contract Award, and update it as work progresses, providing cost, schedule, resource, and quality metrics against their respective baselines in our monthly contract-level status and financial reports. At the project level, our team will review all draft documentation with the state's PoC at task kickoff, revise to incorporate government feedback, and implement them to guide the project's performance. Upon approval, our PM will baseline and track progress against approved cost, schedule, and scope/WBS, reporting metrics in their weekly and monthly status reports.

Cost and Schedule Management - Lynker uses MS Nav and Quickbooks, along with DCAA-compliant cost accounting practices for invoicing and ensuring accurate and compliant financial management, to ensure the accuracy, integrity, timeliness, and transparency of financial data. We also use tools such as MS Project to track progress against our WBS and schedule, cost, and resource assignment baselines. Our methodology enables us to track progress across tasks consistently; identify new resource or skillset needs and/or opportunities for cross-team collaboration and utilization; and proactively address dependencies, constraints, inefficiencies, and risks rapidly, effectively, and as a holistic team.

Lynker additionally maintains an extremely strong financial position – we have annual revenues exceeding $5 M, a backlog of contract work worth in excess of $8 M, and ample cash reserves that can support the inclusion of this contract, without the need to seek additional capital. We have no debt, a million-dollar line of credit should they ever become necessary, and a customer portfolio that includes more than 90% of revenue from federal contracts, all of which contribute to our low-risk financial profile.

ISO-Compliant Quality Management System (QMS) – We leverage ISO processes and benchmarks to enable us to verify quality across all tasks and deliverables. We use our QMS to guide the development of contract- and project-level Quality Control and Surveillance plans (QCP/QASP), leveraging checklists, templates, surveillance metrics and best practices, and other artifacts from our ISO and CMMI libraries. Our QCPs/QASPs will drive our performance monitoring and control activities, ensuring our team focuses on establishing effective and consistent processes that minimize service variation, continually improve time-to-service, and measure and verify quality delivery to the 100% satisfaction of the customer.

Subcontractor Management – We have existing and long-term relationships with Abt, Anchor Point, and our individual subs, and will leverage our previous history of successful collaboration to ensure we provide the best personnel to the state irrespective of company affiliation. Our approach also ensures we can respond effectively to changes in the state's priorities.

Customer Satisfaction – We conduct customer satisfaction surveys to formally assess satisfaction with our performance

4.2. Quality Control

Lynker uses a proven Design Quality Assurance approach for all of its State and Federal projects. The Lynker team can demonstrate significant (more than adequate) capacity to perform project tasks in the required time and the flexibility to add resources when required. We have highly experienced project managers that excel in client communication, project tracking, and issue resolution.

At Lynker, delivery of inherently high-quality services is the responsibility of all team members. The project manager maintains the primary responsibility for verifying compliance with contract quality expectations while our technical team members are responsible for high quality delivery of support and services within their respective subtasks. Our Project Manager attends all key meetings with the client and conducts check-ins with the project manager to ensure the project is on-time and on-budget. The PIC is also available at any time to discuss the project with the client.

Lynker's quality assurance approach is comprehensive, clear, realistic, and effective. As an ISO 9001 certified company, our standard approach includes:

- Establishing standard, repeatable processes to prevent defects at all project lifecycle stages, from design through operations and maintenance including:
- Quantifying the cost of complexity, especially with respect to eliminating the root causes of non-valued activities
- Promoting continuous improvement of the quality of products and services.

In addition, Lynker's quality assurance processes include proactive risk management. From pre-award to successful completion of each subtask, we continually identify, analyze, monitor, and control issues that may impact schedule, cost, or quality. We maintain a comprehensive risk register which describes each risk, date discovered, probability and severity, triggers, related issues, and our team's collective recommendations for mitigating and preventing their occurrence. Our collaborative approach includes reviewing current and emerging issues, identifying root causes, and developing mitigation strategies as key activities at our weekly meetings. Along with the routine project update meetings, Lynker maintains an open dialogue with project personnel to promote clarity and ensure a complete understanding of the project status.

4.3. Organization and Key Personnel

Lynker's organizational structure along with a visual representation of the project workflow is provided in the below graphic:

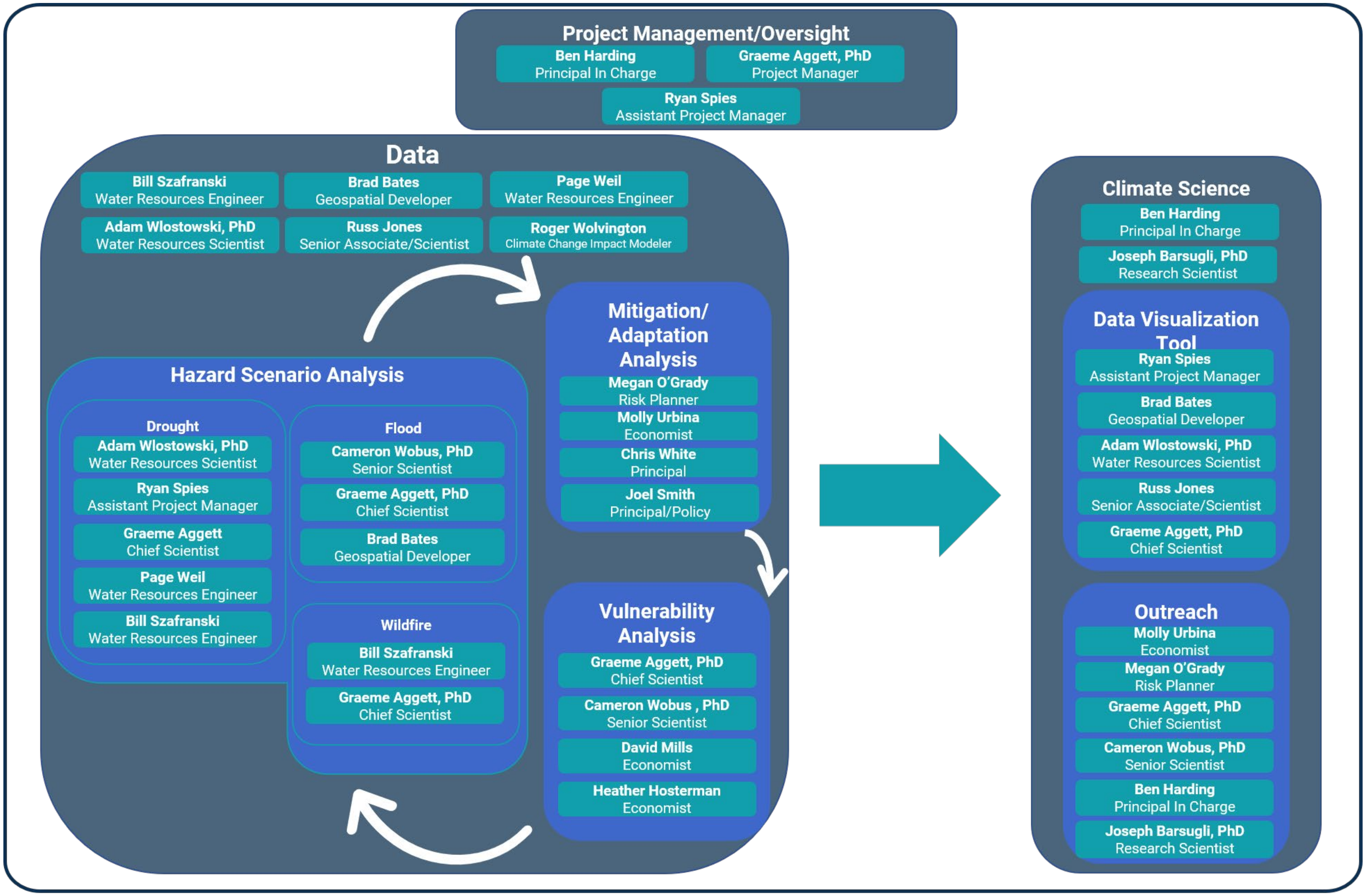


Figure 21. Lynker Organizational Structure

4.3.1. Lynker Key Personnel

Lynker is focused on using the best available climate science, applying cutting edge modeling techniques, and developing risk assessment technologies and methods that can be used to anticipate eventualities, strengthen infrastructure, protect people and places, and incorporate the ability to recover. Our team's diverse experience gives us a broad picture of how the various components of this project intersect and support each other, and will enable us to address the climate extremes and adaptation needs of this project holistically. Key Lynker project personnel include:

Table 2. Lynker Personnel

Dr. Graeme Aggett, Project Manager, Chief Scientist	
Background and Relevant Experience	Dr. Graeme Aggett is a Principal and Chief Scientist at Lynker Technologies and leads the Boulder-based Water Resources Division in conceptualizing, developing, implementing, and directing projects involving hydrologic analysis of watersheds and systems, and development of water resource management decision support systems. Dr. Aggett is broadly trained in surface water hydrology and hydraulics, hydrologic forecasting, fluvial geomorphology and sediment transport, geospatial analysis and remote sensing, and hazard and risk analysis, including assessments of climate change on hydrologic systems. He has conducted Flood Hazard and Risk Assessments for the World Bank and a Water Futures Risk Assessment for the World Economic Forum, and developed the first multi-hazard earthquake risk assessment for the New Zealand Earthquake Commission. Graeme has been based in Colorado for 14 years and has supported the state (CWCB and DNR) consistently during that period on multiple hazard, risk, climate change, decision support system development and data visualization projects. He has also led eight projects resulting from the 2013 Colorado floods, all aimed at mitigating flood hazard and enhancing resiliency. He leads Lynker's NOAA-National Weather service flood forecasting and hazard assessment team. Prior to moving to Colorado Graeme led a watershed hazards modeling team in Washington State. Dr. Aggett has over twenty years of experience applying these methods to problems at the people-earth surface interface, and continues to maintain an active research and publishing program in this field. He has served as Principal Investigator on NASA, NOAA and USDA-funded research projects. He is an active reviewer for the international journals Natural Hazards, Geomorphology, Earth Surface Processes and Landforms, International Journal of River Basin Management, Transactions in GIS and Water Resources Research.
Project Functions and Responsibilities	Project Manager and Chief Scientist
Project Availability	50%
Assigned Project Tasks	Dr. Aggett will provide overall project management and guidance for the state to get the best out of our talented Lynker team,as well as assist in hazard scenario analyses, vulnerability analysis, aid in the development of the data visualization tool and assist with outreach and education on an as needed basis.
Ben Harding, Principal in Charge	
Background and Relevant Experience	Mr. Harding has more than four decades of diverse experience in water resources engineering. His practice began with research into the development of advanced waste treatment processes, including treatment of municipal wastewater for potable reuse and treatment of wastewaters produced when retorting oil shale. For more than thirty years his practice has focused on the design, development, and use of hydrologic and river/reservoir system models, decision support systems, hydraulic models, water-quality models, GIS, and databases. Mr. Harding has been a leader in moving research innovations into practice, including the use of network flow algorithms to simulate water resources systems, the use of paleo hydrology, the development of quantitative estimates of projected future hydrology and water demands based on climate model output, and the application of non-parametric stochastic methods and Monte Carlo

	techniques to quantify risk in water resources planning. Mr. Harding has served as an expert witness in one original-jurisdiction interstate water dispute and eight large toxic-tort litigations. Mr. Harding has been the project manager and technical lead a number of projects relating to climate change and climate extremes including three projects that involved the development of climate-impacted intensity duration frequency curves for municipal areas in Canada. In addition, he was the project manager and technical lead for an evaluation of the impact of climate change on water availability in the Colorado River Basin, with a detailed analysis of water availability within the State of Colorado, and he was the project manager and technical lead for a study of the impacts of climate change over the entire state of Oklahoma. Mr. Harding is a registered Professional Engineer in Colorado, New Mexico and Oklahoma.
Project Functions and Responsibilities	Principal in Charge and Water Resources Engineer
Project Availability	15%
Assigned Project Tasks	Mr. Harding will act as the project Principal in Charge and will provide assistance with the climate science and outreach portions of the project. Mr. Harding will contribute his knowledge and expertise to other areas of the project on an as needed basis.
Ryan Spies, Assistant Project Manager	
Background and Relevant Experience	Mr. Spies is a hydrologic scientist with experience in hydrometeorological data analysis, statistical hydrology assessments, environmental geospatial data analysis, and surface water modeling applications using climate projection modeling inputs. Having worked for both the public and private sectors, Mr. Spies has conducted hydrologic and hydraulic modeling studies throughout the United States including river forecast model development and calibration for the National Weather Service. Additional project experience includes remote sensing applications, model parameterization optimization, flood inundation mapping, hydrologic-hydraulic model coupling, and developing web-based data visualization tools. His professional interests include hydrologic forecasting, flood mitigation planning, riverine data analysis, Python-based data visualization and analysis, and sustainable water resources planning.
Project Functions and Responsibilities	Assistant Project Manager and Water Resources Scientist
Project Availability	85%
Assigned Project Tasks	Mr. Spies will aid Dr. Aggett in providing overall project oversight as well as contributing to gathering relevant data and the development of the data visualization tool. Mr. Spies will also contribute his knowledge and expertise to other areas of the project on an as needed basis.
Dr. Cameron Wobus, Senior Scientist	
Background and Relevant Experience	Dr. Cameron Wobus is a broadly trained Earth scientist with specific expertise in hydrology, geomorphology, and numerical modeling. His recent research has focused on climate change impacts on hydrology, landscapes and human systems. For example, Dr. Wobus has developed national-scale models of changes in flood risk and asset damages due to intensification of the hydrologic cycle in the United States; and he has analyzed long-term meteorological records to characterize historical and potential future extremes in precipitation and temperature to support water utility planning. He has also developed future scenarios of extreme precipitation and extreme temperature to support future planning for state transportation departments, including the Michigan DOT, New Jersey DOT, Massachusetts DOT, and Caltrans. Between 2010 and 2015, Dr. Wobus served as an expert supporting the State of Louisiana in its NRDA claims for the Deepwater Horizon oil spill, leading a team of academic experts to provide data-driven solutions to support inter-agency discussions and settlement negotiations. Prior to his career in consulting, Dr. Wobus was a research scientist at the University of Colorado, where he led a field-based, multi-investigator study of climate change and coastal erosion on the North Slope of Alaska. Dr. Wobus regularly presents his work at national and international meetings. His

	more than 30 peer-reviewed publications have appeared in journals including Nature, Geophysical Research Letters, Global Environmental Change, Climatic Change, Earth's Future, Geology, Natural Hazards and Earth System Sciences, and the Journal of Geophysical Research.
Project Functions and Responsibilities	Senior Scientist
Project Availability	50%
Assigned Project Tasks	Dr. Wobus will assist with various hazard scenario analyses, vulnerability analyses, and will assist with any climate science components of this project. When necessary, Dr. Wobus will also assist with outreach and education. Dr. Wobus will also contribute his knowledge and expertise to other areas of the project on an as needed basis.
Brad Bates, Geospatial Developer	
Background and Relevant Experience	Mr. Bates is a Geospatial Developer with expertise in data analysis, full-stack web map development, satellite remote sensing, and water resources. He is an expert in the geoprocessing and visualization of massive weather model output data in real-time web mapping environments. He has supported the NOAA National Water Center's Geo-Intelligence Division within the Office of Water Prediction for the past 2 years. His primary role at the National Water Center is to develop a real-time inundation mapping capability using the National Water Model. During his master's work, he partook in several applied research and academic projects, including satellite remote sensing of historical floods using optical and radar systems, estimation of threats to recreational fisheries in Central America, historical alluvial and aeolian sediment transport, and fluvial geomorphology. Brad regularly presents his National Water Model visualization work at national meetings.
Project Functions and Responsibilities	Geospatial Developer
Project Availability	75%
Assigned Project Tasks	Mr. Bates will assist with gathering relevant data and various hazard scenario analyses. In addition, he will also contribute to the development of the data visualization tool. Mr. Bates will also contribute his knowledge and expertise to other areas of the project on an as needed basis.
Dr. Adam Wlostowski, Water Resources Scientist	
Background and Relevant Experience	Adam Wlostowski is a water resources scientist specializing in watershed hydrology and solute fate and transport. Dr. Wlostowski has eight years of experience in academic research and is a recent addition to the Lynker team. His work has been published in leading environmental journals, including Water Resources Research, Limnology and Oceanography, Geophysical Research Letters, Geomorphology, and Journal of Geophysical Research. His skill set includes hydrological and hydraulic modeling, environmental solute transport modeling, environmental data collection, and Geographical Information Systems (GIS). Key water resources work has involved synthesizing long-term hydrological data sets to quantify basin-scale water budgets, quantifying reactive solute transport dynamics in rivers with the One-dimensional Transport with Inflow and Storage (OTIS) model, and installing/maintaining hydrological sensors networks to measure stream discharge, water quality, soil moisture, and soil temperature.
Project Functions and Responsibilities	Water Resources Scientist
Project Availability	85%
Assigned Project Tasks	Dr. Wlostowski will assist with gathering relevant data and various hazard scenario analyses. In addition, he will also contribute to the development of the data visualization tool. Dr. Wlostowski will also contribute his knowledge and expertise to other areas of the project on an as needed basis.

<table>
<tr><th colspan="2">Page Weil, PE, Water Resources Engineer</th></tr>
<tr><td>Background and Relevant Experience</td><td>Page Weil has consulted in the private and non-profit sectors for ten years. He has done projects for local, state, federal and international clients for water resources planning and climate change impact analysis. Clients have used Mr. Weil's models to plan water rights operations, evaluate environmental flow requirements, set reservoir targets and assess infrastructure feasibility and risk. Mr. Weil has broad experience in applying peer reviewed datasets to model both long term trends and extreme events under a changing climate. He has conducted dozens of climate change impact analyses and resiliency projects for the State of Colorado and other regions of the US. He has helped clients understand the changing water needs of their municipal, agricultural and industrial facilities. He has also helped them project their flood risk under a warmer and wetter future climate.
In the water resources realm, he has worked with numerous entities to help them understand their risk and ideal systems operations to maintain firm water supplies through increasing demands, drying hydrology and the development of new infrastructure. Mr. Weil has worked with the CWCB CDSS suite of tools and models to represent water resources operations in and around Colorado. Mr. Weil has experience in numerous water resources models including, StateMod, CDSS, ExcelCRAM, RiverWare, as well as several custom-built toolkits in various database programs.</td></tr>
<tr><td>Project Functions and Responsibilities</td><td>Water Resources Engineer</td></tr>
<tr><td>Project Availability</td><td>45%</td></tr>
<tr><td>Assigned Project Tasks</td><td>Mr. Weil will assist with gathering relevant data and various hazard scenario analyses. In addition, Mr. Weil will contribute his knowledge and expertise to other areas of the project on an as needed basis.</td></tr>
<tr><th colspan="2">Bill Szafranski, Water Resources Scientist</th></tr>
<tr><td>Background and Relevant Experience</td><td>Mr. Szafranski is a water resources scientist at Lynker with responsibilities spanning surface water hydrology, watershed modeling, climate change analysis, watershed planning, statistical hydrology, and project management. He brings 11 years of scientific and engineering expertise to Lynker's water resources practice. Mr. Szafranski is experienced using watershed models such as the Variable Infiltration Capacity (VIC) model for climate change analyses and large-scale hydrologic investigations and the Hydrologic Simulation Program-FORTRAN (HSPF) model for watershed-water quality investigations. He has worked on many climate change projects including the Colorado River Water Availability Study (CRWAS) Phase II and impact studies for the City of Boulder and City of Aurora. He helped lead the development of the Lower Poudre River Master Plan, which included leading public engagement meetings focusing on river resilience.
He excels at statistical analysis using the software and programming language R, where his master's degree focused on the development of a nonparametric stochastic streamflow model to simulate daily flows. He has developed and calibrated watershed models for smaller stakeholder agencies as well as larger agencies such as the National Weather Service (NWS). He also has expertise using ESRI's GIS applications including ArcGIS Pro and building captivating Story Maps to share project work quickly and easily with the public.</td></tr>
<tr><td>Project Functions and Responsibilities</td><td>Water Resources Scientist</td></tr>
<tr><td>Project Availability</td><td>70%</td></tr>
<tr><td>Assigned Project Tasks</td><td>Mr. Szafranski will assist with gathering relevant data and various hazard scenario analyses. In addition, Mr. Szafranski will contribute his knowledge and expertise to other areas of the project on an as needed basis.</td></tr>
</table>

Roger Wolvington, Climate Change Impact Modeler	
Background and Relevant Experience	Mr. Wolvington is a software developer with over 25 years of experience programming applications for water resources modeling and environmental database development. His work has involved the statistical analysis of Global Climate Model (GCM) simulation impacts on precipitation and temperature and using the Variable Infiltration Capacity model (VIC) to calculate climate change impacts to CIR, base flows and runoff for river basins and individual grid cells in Colorado, Oklahoma and parts of Canada. Mr. Wolvington has designed and developed additional analysis software programs to evaluate the physical and administrative impacts of climate change on river basin systems.
Project Functions and Responsibilities	Climate Change Impact Modeler
Project Availability	55%
Assigned Project Tasks	Mr. Wolvington will assist with gathering relevant data and various hazard scenario analyses. In addition, Mr. Wolvington will contribute his knowledge and expertise to other areas of the project on an as needed basis.
Megan O'Grady, Risk Planner	
Background and Relevant Experience	Megan O'Grady has over 15 years of experience working on policy issues, over 12 of which have been focused explicitly on supporting local climate change adaptation. She supports decision makers with climate-related risk assessments by working at the nexus of technical climate information and policy. She works with clients at the local, state, and national scale to incorporate climate risk planning into their existing planning streams. In particular, she guides and manages projects that provide technically-sound climate change information to clients by presenting information in tangible and innovative formats. At Abt Associates, Ms. O'Grady's clients included the U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Housing and Urban Development (HUD), the New York State Energy and Research Development Authority (NYSERDA), the Water Utility Climate Alliance (WUCA), and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). Prior to joining Abt Associates, Ms. O'Grady was the Project Manager for the inaugural New York City Panel on Climate Change (NPCC) under Mayor Michael Bloomberg. This work was codified in New York City and continues to be updated every five years. She also managed a New York State-wide assessment of climate vulnerability that looked at the impacts of three themes (climate risks, vulnerability and adaptation, and equity and economics) in eight sectors (water resources, coastal zones, ecosystems, agriculture, energy, transportation, telecommunications, and public health) known as ClimAID. She has authored over 13 climate change publications and presented her work domestically and internationally. She has a Bachelor of Arts in Environmental Studies from Saint Olaf College and Master of Public Administration in Environmental Policy from Columbia University's School of International and Public Affairs (SIPA).
Project Functions and Responsibilities	Risk Planner
Project Availability	90%
Assigned Project Tasks	Ms. O'Grady will assist with various mitigation and adaptation analyses as well as outreach efforts. In addition, Ms. O'Grady will contribute her knowledge and expertise to other areas of the project on an as needed basis.

4.3.2. Additional Supporting Lynker Personnel

Although not specifically identified as Key Personnel within the project Organizational Chart, we may also include the following Lynker personnel on an as needed basis to contribute towards project deliverables.

Table 3. Supporting Lynker Personnel

Sophia Sigstedt, Professional Hydrogeologist (PH-GW)	
Background and Relevant Experience	Sophia Sigstedt is a certified professional hydrogeologist by the American Institute of Hydrology. She has a M.S. in Hydrology and a B.S. in Environmental Science and Biology and more than ten years of experience. Her experience includes hydrogeochemical evolution and water quality analysis, geochemical modeling, applications of stable isotopes to groundwater and water resource studies, radiocarbon dating of groundwater, numerical groundwater modeling, basin-scale water resource management, and conjunctive use management. She has diverse experience in hydrology, water rights, water resources engineering, and water resources planning and management. She has been integral in several basin-scale water management studies involving development of hydrologic data, forecast of future water demands, and creation of planning models to investigate effects of changes in water management. Her work includes litigation support in a variety of water rights proceedings including historical consumptive use analysis, evaluation of surface/groundwater interactions, groundwater modeling, conjunctive administration of surface water and groundwater rights, stream depletion analysis, development of protective terms and conditions, settlement negotiations, and expert witness testimony.
Project Functions and Responsibilities	Professional Hydrogeologist (PH-GW)
Project Availability and Assigned Project Tasks	Ms. Sigstedt will contribute her knowledge and expertise to the project on an as needed basis.

Resumes for all individuals listed in the above tables are included in *Appendix 1—Resumes* on page 65.

4.4. Subcontractor Key Personnel

As described in *Section Background and Expertise* on page 9, the Lynker Team is made up of experts not only from Lynker but also from other leaders in climate change and assessment including Abt Associates, AnchorPoint Wildfire Solutions, Urbina Strategies, as well as a number of independent consultants. A summary of subcontractor personnel is provided in the table below. In addition, complete resumes for all individuals listed in *Table 4. Subcontractor Personnel* can be found in *Appendix 1—Resumes* on page 65.

Table 4. Subcontractor Personnel

Abt Associates—Joel Smith, Principal/Scientist	
Background and Relevant Experience	Mr. Smith has 33 years of experience with environmental, policy, and regulatory issues, particularly as they relate to global climate change. He is an expert on global climate change impacts and adaptation. He was deputy director of the U.S. Environmental Protection Agency's (EPA's) Climate Change Division (CCD). He was coeditor of EPA's Report to Congress, The Potential Effects of Global Climate Change on the United States, published in 1989; and As Climate Changes: International Impacts and Implications, published by Cambridge University Press in 1995, on international impacts of climate change. He has published 7 edited books and more than 50 journal articles on climate change. Mr. Smith was a member of the U.S. National Climate Assessment coordinating committee for the report published in 2014; a coordinating lead author for the North America chapter of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2014; a lead author for the Synthesis chapter on climate change impacts for the Fourth Assessment Report, published in 2007; and a coordinating lead author for the same chapter in the Third Assessment Report, published in 2001. In 2007, the IPCC was awarded the Nobel Prize for Peace. He has supported municipal, state, and federal governments as well as non-profits, other national governments, and international organizations in understanding, assessing and adapting to vulnerabilities to climate change. He has made numerous presentations and conducted training on climate change for international and domestic audiences, including the United Nations Framework Convention on Climate Change (UNFCCC) and the American Society for Civil Engineers.
Project Functions and Responsibilities	Principal and Policy Analyst
Project Availability	35%
Assigned Project Tasks	Mr. Smith will provide oversight of all Abt Associates team members as well as assist with policy related tasks throughout the project. In addition, Mr. Smith will contribute his knowledge and expertise to other areas of the project on an as needed basis.
Abt Associates—Russ Jones, Senior Associate/Scientist	
Background and Relevant Experience	Mr. Jones is a specialist in geographic information systems (GIS), remote sensing (RS), and cartography. He has more than 25 years of experience as a GIS/RS consultant, including more than 21 years related to climate change, providing extensive mapping, analysis, and modeling support in the areas of natural resource damage assessments, ecology, sociology, economics, and climate change. In the field of climate change, he has worked on a variety of projects examining impacts and adaptation responses, including several studies modeling impacts to the environment from global climate change, sea level rise and storm surge, and human responses to sea level rise. Mr. Jones has conducted numerous studies for transportation planning agencies in NY, NJ, CA, MA, MI, and TN assessing the vulnerability of infrastructure to flooding caused by extreme precipitation and temperature events as well as changes in fire dynamics. This work utilizes spatially explicit projections of extreme precipitation and temperature using Global Climate Models from the latest Intergovernmental Panel on Climate Change's Fifth Assessment Report (CMIP5) under alternative emission scenarios. Mr. Jones has also worked on studies modeling the vulnerability of watersheds to climate change across the United States, including examining the sensitivity of water supply to climate

	change for watersheds in Boulder and Aspen, Colorado, and the impacts to winter recreation for a number of ski areas. Mr. Jones is providing ongoing support to the U.S. Environmental Protection Agency's (EPA's) Climate Change Division examining the impact of alternative climate change emissions scenarios on freshwater fisheries habitat, water supply/demand, transportation bridge infrastructure, carbon sequestration associated with vegetation change, and changes in fire dynamics across the United States.
Project Functions and Responsibilities	Senior Associate and Scientist
Project Availability	30%
Assigned Project Tasks	Mr. Jones will assist with gathering relevant data needed for this project. In addition, he will also contribute to the development of the data visualization tool. Mr. Jones will also contribute his knowledge and expertise to other areas of the project on an as needed basis.
Abt Associates—Heather Hosterman, Economist	
Background and Relevant Experience	Ms. Hosterman has over ten years of experience in economic and policy analysis, with a focus on climate change impacts and adaptation. She has experience quantifying current and future impacts of climate change and extreme events, taking into consideration changes in population, and assessing the costs and benefits of potential climate adaptation actions. Her work includes evaluation of economic losses and health impacts from extreme events and climate change scenarios to key sectors at national and local levels; multi-criteria and benefit-cost analyses of natural resource management alternatives, including climate resilience actions; climate change vulnerability assessment and adaptation planning; and development of an accessible toolkit that allows users assess their vulnerability to climate risks. At Abt Associates, Ms. Hosterman's clients are primarily federal, state, and tribal government agencies. Prior to joining Abt Associates, Ms. Hosterman was a researcher at an academic and environmental institute. Ms. Hosterman has authored or contributed to over twenty journal articles, book chapters, and technical reports, and presented her work at domestic and international conferences. Her work is referenced in the U.S. Global Change Research Program's Fourth National Climate Assessment, Volume II.
Project Functions and Responsibilities	Supporting Economist
Project Availability	40%
Assigned Project Tasks	Ms. Hosterman will assist with various vulnerability analyses throughout this project. In addition, Ms. Hosterman will contribute her knowledge and expertise to other areas of the project on an as needed basis.
Urbina Strategies—Molly Urbina, Economist	
Background and Relevant Experience	Molly Urbina provides expert land use and resilience planning consulting to private, public and nonprofit sectors utilizing years of experience in shaping an adaptable, vibrant and resilient future for present and future generations. Ms. Urbina recently served as the Executive Director of the Colorado Resiliency and Recovery Office appointed by Governor John Hickenlooper in February of 2014. Some of her relevant experience also includes 4 years as the resiliency and recovery leader of the state to coordinate the diverse and complex portfolio of disaster recovery and resiliency efforts
Project Functions and Responsibilities	Planner
Project Availability	50%

Assigned Project Tasks	Ms. Urbina will assist with the various mitigation and adaptation analyses required for this project. In addition, she will also assist with outreach and education efforts. Ms. Urbina will also contribute her knowledge and expertise to other areas of the project on an as needed basis.
Anchor Point—Chris White, Principal	
Background and Relevant Experience	Mr. White is the Chief Operating Officer of Anchor Point Group LLC. This team of professional fire consultants specializes in hazard and risk assessments, the development of Community Wildfire Protection Plans, National Wildlife Coordinating Group (NWCG) training, and operational pre-attack planning. Mr. White has specialized in Wildland-Urban Interface Fire Management for over 20 years. He started his fire career in 1987 working with both the US and Colorado State Forest Service. After taking on the responsibility of pre-planning for approximately 1,100 subdivisions for wildland fire hazards and developing mitigation plans to reduce wildfire impacts, Mr. White became Colorado's first county-level Wildland Fire Coordinator in Summit County. Mr. White has been a member of the Western Governors Association (WGA) Federal Fire Policy Review Committee, WGA Prescribed Fire Policy Committee, NWCG Hazard and Risk Assessment Methodology Committee, and National Fire Protection Association (NFPA) Wildland Fire Committee. He also represented the International Association of Fire Chiefs (IAFC) on a new national initiative to integrate structural firefighters into the wildland fire management arena. Mr. White offers additional technical expertise as a Structure Protection Specialist to Type 1 and 2 National Incident Management Teams. As a certified Structure Protection Specialist, he is responsible for integrating fire-behavior modeling and structure protection tactics to develop structure protection plans for large fire events throughout the US.
Project Functions and Responsibilities	Principal
Project Availability	50%
Assigned Project Tasks	Mr. White will assist with the mitigation and adaptation analyses that are required for this project. In addition, Mr. White will contribute her knowledge and expertise to other areas of the project on an as needed basis.
Dave Mills, Economist	
Background and Relevant Experience	For more than 20 years, David Mills has drawn on his economics training and experience completing impacts assessments to assemble and manage project teams to identify, develop, and integrate information from multiple disciplines to answer questions focused on direct and indirect health, welfare, and ecosystem impacts of proposed actions. The methods and applications used have developed and produced quantified and monetized impact results used to inform and educate the public and government agencies, and have been widely published in peer-reviewed literature and government reports.
Project Functions and Responsibilities	Economist
Project Availability	50%
Assigned Project Tasks	Mr. Mills will contribute to the various vulnerability analyses called for in this project. In addition, Mr. Mills will also contribute his knowledge and expertise to other areas of the project on an as needed basis.
Joseph Barsugli, PhD	
Background and Relevant Experience	Dr. Barsugli has over ten years' experience applying his training in climate theory and modeling to a wide range of real-world problems in water resources and ecosystem management in

	Colorado and the western Unites States. He also pursues research on physical climate science and the impacts of climate change through his appointment as a Research Scientist III at the Cooperative Institute for Research in the Environmental Sciences at the University of Colorado at Boulder, a joint institute between between NOAA and CU. In addition to providing climate analyses for numerous climate adaptation projects, he has also written or co-authored papers on the evaluation and use of climate projections including "The Practitioner's Dilemma."
Project Functions and Responsibilities	Climate Research Scientist
Project Availability	5%
Assigned Project Tasks	Dr. Barsulgi, will climate science related tasks throughout the project. In addition, Dr. Barsugli, will contribute his knowledge and expertise to other areas of the project on an as needed basis.

4.4.1. Additional Supporting Subcontractor Personnel

Although not specifically identified as Key Personnel within the project Organizational Chart, we may also include the following subcontractor personnel on an as needed basis to contribute towards project deliverables.

Abt Associates—Lorine Giangola, PhD, Economist	
Background and Relevant Experience	Dr. Giangola specializes in natural resources conservation and management, analysis of environmental decision-making under climate change, and climate change adaptation in socioecological systems, with a focus on agroecosystems. She has expertise in landscape and conservation science, problem-oriented and context-sensitive approaches to policy analysis, quantitative and qualitative policy research methods, and interdisciplinary economic valuation methods. Her work has included assessments of climate vulnerability for multiple sectors at multiple scales, analysis of soil and water quality impacts of land management alternatives under climate change, management of agricultural resources for environmental quality, analysis of climate change adaptation actions at national and local levels, development of regional and national climate vulnerability reduction alternatives, cost-benefit analysis and cost-effectiveness analysis of natural resources management alternatives, development of financing strategies for adaptation projects, and conservation and management of protected lands. Dr. Giangola has worked closely with local, state, and national government agencies, non-governmental organizations (NGOs), industry leaders, academic researchers, landowners, and members of local communities to address complex environmental and natural resource problems, in the U.S. and internationally. Dr. Giangola has worked on agriculture and climate change issues in multiple regions of the U.S., including Colorado. Her doctoral dissertation focused on the U.S. agricultural system, where she worked closely with farmers and agriculture sector stakeholders to conduct economic analysis of the costs of achieving water quality targets through broader implementation of soil and water conservation practices. Dr. Giangola's consulting work has focused on identification, development, and finance of priority natural resources management actions to advance climate change adaptation and increase resilience to climate impacts.
Project Functions and Responsibilities	Economist
Assigned Project Tasks	Dr. Giangola will contribute her knowledge and expertise to the project on an as needed basis.
Anchor Point—Rod Moraga, Project Manager	
Background and Relevant Experience	Mr. Moraga has been with Anchor Point Group LLC since 1998 and is currently the CEO of the firm. He leads the ecosystem management and wildfire planning divisions, as well as development and implementation of comprehensive ecosystem management plans. His focus is on combining advanced fire behavior modeling and sound silvicultural practices to enhance

	ecosystem health, while mitigating the Wildland-Urban Interface fire threat. He also oversees the fire behavior analysis for hazard and risk assessments, prescribed burns and community wildfire protection plans. Mr. Moraga has been involved at all levels of forest management - from inventory and prescription development to implementation of thinning and restoration. As a principal author of the forest ecosystem management plan for the City of Boulder, he developed a process that used sound silvicultural practices that achieved both forest health improvement and fire mitigation measures. His experience and strong background in fire operations, fire ecology, forestry and Wildland-Urban Interface ensures that recommendations are viable and practical to the end user. Mr. Moraga further offers technical expertise in fire behavior modeling. As a certified Fire Behavior Analyst, he is charged with predicting fire behavior and spread during large fire events throughout the United States. This requires a keen understanding of fuels, weather and topography and their cumulative interactions. These predictions are used by the incident management team to support their operational and tactical decision.
Project Functions and Responsibilities	Project Manager
Assigned Project Tasks	Mr. Moraga will contribute his knowledge and expertise to the project on an as needed basis.

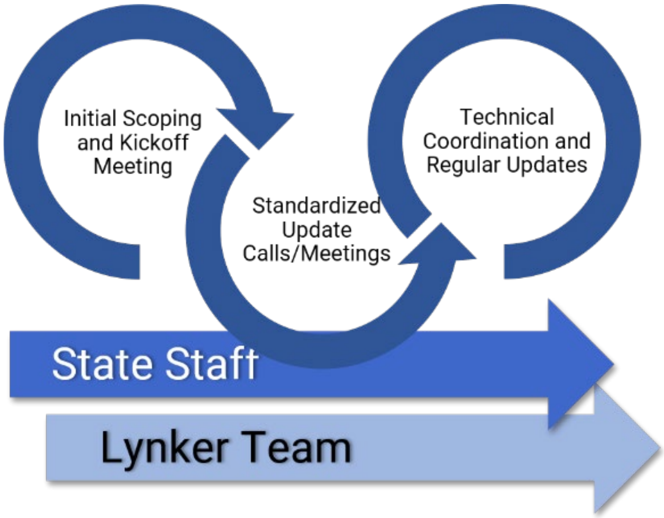
5. Location of Key Personnel

As depicted in *Figure 23*, the Lynker Team is entirely Colorado based. Across our entire team, our primary expertise and passion is in applying hazard, risk and climate change analyses in the state where we live and with which we are most familiar.

Figure 22. Lynker's Local Presence and Team

Throughout the duration of this project, State staff will have uninhibited access to the project team. Upon award and project kick-off, Lynker will work with the State to establish a communication plan that includes regular project updates (on a pre-agreed upon basis) as well as open lines of communication to allow for technical coordination and other updates on an as needed basis.

In addition to a formal communication plan, Lynker always maintains near constant informal communications with State staff to increase efficiencies, foster a collaborative project approach, and ultimately facilitate the completion of project deliverables.



6. Appendices

Immediately following this page, please find the following appendices:

- Appendix 1—Resumes
- Appendix 2—Subcontractor Resumes
- Appendix 3—Alignment with Colorado Hazard Mitigation Plans and Updates
- Appendix 4—Letter of Support
- Appendix 5—References
- Appendix 6—RFP Signature Page
- Appendix 7—RFP Exhibit C, Colorado W9 Form
- Appendix 8—RFP Exhibit E, Sample Contract

Appendix 1—Resumes

Immediately following this page, please find resumes for the following Lynker Personnel:

- Graeme Aggett, PhD
- Brad Bates
- Ben Harding
- Megan O'Grady
- Sophia Sigstedt
- Ryan Spies
- Bill Szafranski
- Page Weil
- Adam Wlostowski, PhD
- Cameron Wobus, PhD
- Roger Wolvington

Graeme Aggett, PhD

Principal and Water Resources Practice Lead

Education

Ph.D. Geomorphic Hazards, University of Southern California, 2004

M.S. Hydrology/Natural Hazards, University of Auckland, 1995

B.S. Hydrology/Geomorphology GIScience, University of Auckland, 1993

Memberships/Affiliations

American Geophysical Union

European Geophysical Union

International Association of Hydrologic Sciences

New Zealand Hydrological Society

American Water Resources Association

American Society for Photogrammetry and Remote Sensing

Association of State Floodplain Managers

Employment History

Principal and Chief Scientist, Lynker Technologies, 2014-present

Global Water Practice Lead, Amec, 2009-2014

Hydrology/Spatial Information Team Lead, Riverside Technology, 2005-2009

Assistant Professor & Director of the Center for Spatial Information, Central Washington University, 2000-2005

Sole-Proprietor, Geozentec, 2003 to 2005

Research Team Lead, Research School of Earth Sciences, Wellington, NZ, 1994-1997

Team Leader, Royal Marine Commando, UK Special Forces, 1980-1987

Summary

Dr. Aggett is Chief Scientist at Lynker Technologies and leads the Water Resources Division in conceptualizing, developing, implementing, and directing projects involving hazard and risk assessment, and hydrologic analysis of watersheds and systems. Dr. Aggett has expertise in surface water hydrology and hydraulics, hydrologic forecasting, fluvial geomorphology and sediment transport, geospatial analysis and remote sensing, and hydrologic impacts of climate change. He also has expertise in Earthquake Hazard and Risk modeling. Dr. Aggett has over twenty years of experience applying these methods to problems at the people-earth surface interface, and continues to maintain an active research and publishing program in this field.

Dr. Aggett currently leads Lynker's prime contract supporting the NOAA-National Weather Service Office of Water Prediction (OWP) Hydrologic Forecasting project, including the Geospatial Intelligence Division of OWP. He has been a Principal Investigator on federal research projects for NASA, NOAA and USDA. Dr. Aggett is an editor for international journals: *Natural Hazards*, *Journal of Hydrology*, *Geormorphology*, the *International Journal of River Basin Management*, *Water Resources Research*, and *Transactions in GIS*.

Core Skills

- Hazard and Risk Assessment
- Hydrologic forecasting
- Fluvial and hillslope Geomorphology and Geomorphic Hazards
- Modeling impacts of climate change
- Developing and implementing GIS-based water resource management DSS and data visualization
- Modeling watershed and floodplain processes at multiple scales
- Assessing drought hazard and vulnerability
- Modeling spatial patterns of urban growth and hydrologic impacts

Selected Project Experience

- World Economic Forum: 2013 Water Resources Group.
  - Project Lead assessing Tanzania's vulnerability to climate change impacts on water availability for growth. Included adaptation strategy recommendations involving multi-national private sector funding (CocaCola, SAB-Miller and Nestle).
- Drought Vulnerability Assessment (2013)
  - *Colorado Water Conservation Board - developed and led a drought vulnerability assessment for the state of Colorado. Assessed drought vulnerability across multiple sectors*
- Flood Hazard and Risk Assessment (2010)
  - World Bank - Nile River in Ethiopia and Sudan. Developed database, risk assessment methodology, and analysis for Nile River.
- Climate Change Drought Decision Support System (2009)
  - NOAA - South Platte River, Colorado; Principal Investigator. Small Business Innovation Research project (SBIR) to provides widespread and low-cost access to tools that can be used to generate scenarios of future streamflow and maps of water availability vulnerabilities.
- Earthquake Risk Assessment Wellington, New Zealand
  - NZ Earthquake Commission (EQC)/Southern California Earthquake Commission (SCEC). Developed multi-hazard (ground shaking; fault rupture; tsunami; earthquake induced landslide; liquefaction) risk assessment for City of Wellington, used by EQC and private insurers to develop maximum probable losses and casualty estimates.

Brad Bates

Geospatial Developer

Education

MS, Geography

BS, Geography

The University of Alabama

Employment History

Lynker Technologies, LLC, Geospatial Developer, 2017-Present

The University of Alabama, Lead Developer of the United States Flood Inundation Map Repository, 2016

NOAA/CUAHSI, National Flood Interoperability Experiment Resident Fellow, 2015

The City of Tuscaloosa, AL, GIS Intern, 2015

Summary

Mr. Bates is a Geospatial Developer with expertise in data analysis, full-stack web map development, satellite remote sensing, and water resources. He is an expert in the geoprocessing and visualization of massive weather model output data in real-time web mapping environments. He has supported the NOAA National Water Center's Geo-Intelligence Division within the Office of Water Prediction for the past 2 years. His primary role at the National Water Center is to develop a real-time inundation mapping capability using the National Water Model. During his master's work, he partook in several applied research and academic projects, including satellite remote sensing of historical floods using optical and radar systems, estimation of threats to recreational fisheries in Central America, historical alluvial and aeolian sediment transport, and fluvial geomorphology. Brad regularly presents his National Water Model visualization work at national meetings.

Core Skills

- Full stack geospatial development in the Esri environment
- Python
- Hydrology
- Process automation
- Data visualization

Selected Project Experience

Project: Technical support, Real-Time National Water Model Visualization (2017-Present)

NOAA, Tuscaloosa, AL, 2017-Present

Supporting the development of architecture, Python libraries, system design, web map and web application design, and maintenance of a real-time visualization system of the NOAA National Water Model. Includes the research and development of novel cartographic and geoprocessing techniques to post-process and visualize over 2.7 million stream locations across the continental United States. Visualization services are designed for and used by U.S. river forecast centers to enhance hydrologic prediction.

Project: Technical support, Improve Terrain and Bathymetry datasets for enhanced inundation mapping (2017-Present)

NOAA, Tuscaloosa, AL, 2017-Present

Supporting the improvement of a national relative elevation grid for the purpose of improving inundation mapping capabilities. Work closely with industry partners to identify areas of improvement in the hydrologic conditioning of digital elevation models. Use a combination of in-situ high water measurements and interpolated depths to evaluate the accuracy of relative elevation grids created from a variety of techniques.

Benjamin Harding, PE

Water Resources Engineer

Education

B.S., Civil Engineering, University of Colorado, Boulder, CO, 1971

Memberships/Affiliations

American Society of Civil Engineers

American Geophysical Union

Employment History

Water Resources Engineer, Lynker Technologies, 2014-present

Principal, AMEC, 2007-2014

Principal, Hydropshere Resource Consultants, 1985-2007

Summary

Mr. Harding has more than four decades of diverse experience in water resources engineering. His practice began with research into the development of advanced waste treatment processes, including treatment of municipal wastewater for potable reuse and treatment of wastewaters produced when retorting oil shale. For more than thirty years his practice has focused on the design, development, and use of hydrologic and river/reservoir system models, decision support systems, hydraulic models, water-quality models, GIS, and databases. Mr. Harding has been a leader in moving research innovations into practice, including the use of network flow algorithms to simulate water resources systems, the use of paleo hydrology, the development of quantitative estimates of projected future hydrology and water demands based on climate model output, and the application of non-parametric stochastic methods and Monte Carlo techniques to quantify risk in water resources planning. Mr. Harding has served as an expert witness in one original-jurisdiction interstate water dispute and eight large toxic-tort litigations.

Mr. Harding has been the project manager and technical lead a number of projects relating to climate change and climate extremes including three projects that involved the development of climate-impacted intensity duration frequency curves for municipal areas in Canada. In addition, he was the project manager and technical lead for an evaluation of the impact of climate change on water availability in the Colorado River Basin, with a detailed analysis of water availability within the State of Colorado, and he was the project manager and technical lead for a study of the impacts of climate change over the entire state of Oklahoma.

Mr. Harding is a registered Professional Engineer in Colorado, New Mexico and Oklahoma.

Core Skills

- Water Resources Planning
- Water Resources Systems Analysis
- Decision Support Systems Development
- Climate Change Impact Assessment
- Groundwater Contamination

Selected Project Experience

- Oklahoma Climate Impacts on Water Supply
    - *Oklahoma Water Resources Board*
- Yampa River Master Plan Modeling
    - *Upper Yampa Water Conservancy District*
- Colorado River Water Availability Study Phases I and II
    - *Colorado Water Conservation Board*
- Climate Change Hydrology
    - United States Bureau of Reclamation
- Climate Impacts on Extreme Events
    - *Various Clients, Canada*
- Verdigris River Water Resources Modeling and Climate Impact Assessment
    - *Oklahoma Water Resources Board*

Megan O'Grady

Risk Planner

Education

MPA, Columbia University, School of International and Public Affairs, Environmental Policy, 2008

BA, Saint Olaf College, Environmental Studies, 2001

Memberships/Affiliations

American Society of Adaptation Professionals

Employment History

Lynker Technologies, Risk Planner, July 2019–present

Abt Associates (formerly Stratus Consulting), Senior Analyst, 2013–June 2019

NASA Goddard Institute for Space Studies; Climate Systems Research, Columbia University, Project Manager, 2007–2010

United Nations Children's Fund (UNICEF), Section Manager, 2004–2006; Education programme assistant, 2002–2004; Human resources assistant 2001–2002

Summary

Megan O'Grady has over 15 years of experience working on policy issues, over 12 of which have been focused explicitly on supporting local climate change adaptation. She supports decision makers with climate-related risk assessments by working at the nexus of technical climate information and policy. She works with clients at the local, state, and national scale to incorporate climate risk planning into their existing planning streams. In particular, she guides and manages projects that provide technically-sound climate change information to clients by presenting information in tangible and innovative formats. At Abt Associates, Ms. O'Grady's clients included the U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Housing and Urban Development (HUD), the New York State Energy and Research Development Authority (NYSERDA), the Water Utility Climate Alliance (WUCA), and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL).

Prior to joining Abt Associates, Ms. O'Grady was the Project Manager for the inaugural New York City Panel on Climate Change (NPCC) under Mayor Michael Bloomberg. This work was codified in New York City and continues to be updated every five years. She also managed a New York State-wide assessment of climate vulnerability that looked at the impacts of three themes (climate risks, vulnerability and adaptation, and equity and economics) in eight sectors (water resources, coastal zones, ecosystems, agriculture, energy, transportation, telecommunications, and public health) known as ClimAID.

She has authored over 13 climate change publications and presented her work domestically and internationally. She has a Bachelor of Arts in Environmental Studies from Saint Olaf College and Master of Public Administration in Environmental Policy from Columbia University's School of International and Public Affairs (SIPA).

Core Skills

- Assessing climate change impacts and community vulnerabilities
- Increasing the accessibility of information on climate change impacts, vulnerability, and resilience
- Incorporating climate change science into policy
- Improving decision support through needs assessments, community engagement, thoughtful communication approaches, and innovative tool design
- Skilled project management

Sophia C. Sigstedt

Professional Hydrogeologist (PH-GW)

Lynker

Education

M.S., Hydrology, New Mexico Institute of Mining and Technology, 2010

B.S., Environmental Science with Biology, New Mexico Institute of Mining and Technology, 2008

Years of Experience

10

Employment History

Lynker Technologies, LLC, Hydrogeologist, 2015-Present

AMEC Environment & Infrastructure, Hydrogeologist, 2010-2015

NM Institute of Mining and Technology, Research Assistant, 2008-2010

NM Institute of Mining and Technology, Teaching Assistant, 2009

Laboratory of Biochemical and Biomedical Research, Research Assistant, 2007-2008

Summary

Sophia Sigstedt is a certified professional hydrogeologist by the American Institute of Hydrology. She has a M.S. in Hydrology and a B.S. in Environmental Science and Biology and more than ten years of experience. Her experience includes hydrogeochemical evolution and water quality analysis, geochemical modeling, applications of stable isotopes to groundwater and water resource studies, radiocarbon dating of groundwater, numerical groundwater modeling, basin-scale water resource management, and conjunctive use management.

She has diverse experience in hydrology, water rights, water resources engineering, and water resources planning and management. She has been integral in several basin-scale water management studies involving development of hydrologic data, forecast of future water demands, and creation of planning models to investigate effects of changes in water management. Her work includes litigation support in a variety of water rights proceedings including historical consumptive use analysis, evaluation of surface/groundwater interactions, groundwater modeling, conjunctive administration of surface water and groundwater rights, stream depletion analysis, development of protective terms and conditions, settlement negotiations, and expert witness testimony.

Core Skills

- Hydrogeologic and hydrogeochemical analysis performed using Modflow2K, Modflow-Surfact
- Modflow-USG, MODPATH, PEST, IDSCU-AWAS, SAC-SMA, Lag/K, Snow-17, StateCU, RefET, Hydrus, Leapfrog, Netpath, Phreeqc, SaltNorm, Aquachem, ArcGIS, and RockWare.

Selected Project Experience

- Snake River Conjunctive Administration of Water Rights
    - *Idaho Ground Water Appropriators, ID, 2012-2019*
- South Platte River & Boulder Creek Conjunctive Administration of Water Rights
    - *City of Boulder, CO, 2010-2019*
- Laramie County Control Area Hydrogeologic Model
    - *Wyoming State Engineer's Office, WY, 2013-2014*
- Determination of Appropriable Water for Salt Basin Groundwater
    - *New Mexico State Engineer's Office Interstate Stream Commission (ISC), NM, 2007-2010*
- Navajo Nation Zuni Basin Water Rights Adjudication
    - *Navajo Nation, NM, 2011-2012*
- Middle Rio Grande Conservancy District (MRGCD) Ad Valorem Tax Assessment
    - *Bureau of Indian Affairs (BIA), NM, 2011*
- National Weather Service Hydrologic Modeling and Support
    - *National Oceanic Atmospheric Administration (NOAA), Federal, 2014-2017*

Ryan Spies, CFM

Water Resources Scientist

Education

M.S., Geology, Iowa State University, 2013

B.S., Meteorology, Iowa State University, 2011

Memberships/Affiliations

American Meteorological Society

Association of State Floodplain Managers

Employment History

Lynker Technologies, LLC, Hydrologic Scientist, 2015-Present

AMEC Foster Wheeler, Hydrologist/Meteorologist, 2014-2015

US Geological Survey, Hydrologist, 2013-2014

Iowa State University, Research Assistant, 2011-2013

Summary

Mr. Spies is a hydrologic scientist with experience in hydrometeorological data analysis, statistical hydrology assessments, environmental geospatial data analysis, and surface water modeling applications using climate projection modeling inputs. Having worked for both the public and private sectors, Mr. Spies has conducted hydrologic and hydraulic modeling studies throughout the United States including river forecast model development and calibration for the National Weather Service. Additional project experience includes remote sensing applications, model parameterization optimization, flood inundation mapping, hydrologic-hydraulic model coupling, and developing web-based data visualization tools. His professional interests include hydrologic forecasting, flood mitigation planning, riverine data analysis, Python-based data visualization and analysis, and sustainable water resources planning.

Core Skills

- Geospatial data analysis and tool development
- Data analysis and applications using land surface, meteorological, and hydrological products including: *Coupled Model Intercomparison Project (CMIP3 & CMIP5), Parameter-Elevation Regressions on Independent Slopes Model (PRISM), National Land Cover Database (NLCD), Gridded Soil Survey Geographic Database (gSSURGO), HYDRO1K Digital Elevation Model, NOHRSC Snow Data Products, National Hydrography Dataset (NHD Plus), USGS StreamStats*
- Automated data processing and visualization programming in multiple programming languages including: *Python, R, Fortran, XML, Jupyter Notebooks, MS Excel spreadsheet*

Selected Project Experience

- Colorado Water Conservation Board Drought Plan Update
    - *Colorado Water Conservation Board, Denver, CO, 2017-2019*
    - Project story map: https://arcg.is/0iuSXm
- Evaluation of Potential Impacts of Tailing Storage Facility Dam Failure on Salmon Habitat in Southwestern Alaska
    - *The Nature Conservancy, Juneau, AK, 2018-2019*
- Hydrologic Modeling and Support for Streamflow and Reservoir Model Development
    - *Natl. Weather Service Office of Hydrologic Dev., 2015-2017*
- Automated Flood Warning System Development
    - *Town of Jamestown, Jamestown, CO, 2017-2018*
    - Project story map: https://arcg.is/1yPnnK
- Comparison of NEXRAD Multisensor Precipitation Estimates to Ground-Based Precipitation Gage Observations
    - *US Geol. Survey, IL Water Science Cntr, Urbana, IL, 2013-2014*
- Estimating the Rain-Snow Discrimination Temperature Parameter, DuPage County, Illinois
    - *US Geological Survey, Illinois Water Science Center, Urbana, IL, 2013-2014*

Bill Szafranski, MS, CFM

Water Resources Scientist

Education

2015, M.S., Civil Engineering – Hydrology and Water Resources, University of Colorado, Boulder, CO

2006, B.S., Hydrologic Sciences, University of California, Santa Barbara, CA

Memberships/Affiliations

Certified Floodplain Manager (CFM), 2019

American Water Resources Association Professional Member

Employment History

Lynker Technologies, LLC, Water Resources Scientist, 2015-Present

AMEC Foster Wheeler, Water Resources Scientist, 2012-2015

AMEC Environment & Infrastructure, Water Resources Scientist, 2008-2012

Kinnetic Laboratories, Inc., Environmental Scientist, 2007-2008

Summary

Mr. Szafranski is a water resources scientist at Lynker with responsibilities spanning surface water hydrology, watershed modeling, climate change analysis, watershed planning, statistical hydrology, and project management. He brings 11 years of scientific and engineering expertise to Lynker's water resources practice. Mr. Szafranski is experienced using watershed models such as the Variable Infiltration Capacity (VIC) model for climate change analyses and large-scale hydrologic investigations and the Hydrologic Simulation Program-FORTRAN (HSPF) model for watershed-water quality investigations. He has worked on many climate change projects including the Colorado River Water Availability Study (CRWAS) Phase II and impact studies for the City of Boulder and City of Aurora.

He helped lead the development of the Lower Poudre River Master Plan, which included leading public engagement meetings focusing on river resilience.

He excels at statistical analysis using the software and programming language R, where his master's degree focused on the development of a nonparametric stochastic streamflow model to simulate daily flows. He has developed and calibrated watershed models for smaller stakeholder agencies as well as larger agencies such as the National Weather Service (NWS). He also has expertise using ESRI's GIS applications including ArcGIS Pro and building captivating Story Maps to share project work quickly and easily with the public.

Core Skills

- Watershed modeling (VIC, HSPF)
- Municipal water supply planning
- Climate change analysis
- Data analysis (R language and environment for statistical computing)
- Spatial analysis (ArcMap, ArcPro, ESRI story maps)

Selected Project Experience

- Colorado Drought Mitigation and Response Plan Update
    - *Colorado Department of Natural Resources (DNR), Denver, CO, 2018*
- Climate Change Water Supply Assessment Update
    - *City of Boulder, Colorado, Water Utility Division, Boulder, CO, 2018-present*
- Project: Lower Poudre River Flood Recovery and Resilience Master Plan
    - *Coalition for the Poudre River (CPRW), Larimer and Weld Counties, CO 2016-2017*
- Climate Change Impact Analysis
    - *Confidential Client, California, 2016-2017*
- *Stochastic Hydrology Modeling for Municipal Drought Resilience*
    - *United Utilities, Carlisle, United Kingdom, 2016*
- Stream Stewardship Through Citizen Science
    - Lefthand Watershed Oversight Group (LWOG), Boulder County, CO, 2018
- Chatfield Watershed Model
    - Chatfield Watershed Authority (CWA), Jefferson and Douglas Counties, CO, 2015-2016
- Colorado River Water Availability Study (CRWAS) Phase II
    - Colorado Water Conservation Board, Denver, CO, 2014

Page Weil, PE

Water Resources Engineer

Education

M.S. Civil Engineering, University of Colorado, 2015

B.S. Civil/Environmental Engineering, University of Colorado, 2005

Memberships/Affiliations

Licensed Professional Engineer, Colorado (PE), 2014

Certified Floodplain Manager (CFM), 2014

Licensed GIS Professional (GISP), 2015

American Water Resource Association

American Geophysical Union

Returned Peace Corps Volunteer Association

Employment History

Lynker Technologies, LLC, Water Resources Engineer, 2014-Present

AMEC Environment and Infrastructure, Water Resources Engineer, 2009-2014

US Peace Corps, Philippines, Water Sanitation Technician, 2006-2009

Summary

Page Weil has consulted in the private and non-profit sectors for ten years. He has done projects for local, state, federal and international clients for water resources planning and climate change impact analysis. Clients have used Mr. Weil's models to plan water rights operations, evaluate environmental flow requirements, set reservoir targets and assess infrastructure feasibility and risk. Mr. Weil has broad experience in applying peer reviewed datasets to model both long term trends and extreme events under a changing climate. He has conducted dozens of climate change impact analyses and resiliency projects for the State of Colorado and other regions of the US. He has helped clients understand the changing water needs of their municipal, agricultural and industrial facilities. He has also helped them project their flood risk under a warmer and wetter future climate.

In the water resources realm, he has worked with numerous entities to help them understand their risk and ideal systems operations to maintain firm water supplies through increasing demands, drying hydrology and the development of new infrastructure. Mr. Weil has worked with the CWCB CDSS suite of tools and models to represent water resources operations in and around Colorado. Mr. Weil has experience in numerous water resources models including, StateMod, CDSS, ExcelCRAM, RiverWare, as well as several custom-built toolkits in various database programs.

Core Skills

- Municipal Water Supply Planning
- Extreme Events Forecasting
- Climate Change Impacts

Selected Project Experience

- Projecting Extreme Event Intensities under Climate Change for Floodplain Risk
    - *CWCB, Colorado, 2017-2019*
- Regional Water Resources Planning Model Development and Calibration
    - *Eagle River Water and Sanitation District, Vail, CO, 2017-Ongoing*
- Review of Changing Extreme Events Due to Climate Change
    - *Denver Water, Denver, CO, 2018-Ongoing*
- Colorado Water Availability Study Phase-II (CRWAS-II) Support
    - *CWCB, Colorado, 2009-2019, Ongoing*
- Assessment of Water Resources Vulnerability Under Climate Change
    - *Confidential Client, USA, 2018*
- Projecting Extreme Event Intensities under Climate Change for Floodplain Risk
    - *CWCB, Colorado, 2017-2019*
- Statistical Modeling to Study Climate Change Impacts on Municipal Stormwater Intensities
    - *Environment Canada, 2012-2015*

Adam Wlostowski PhD

Water Resources Scientist

Education

PhD University of Colorado Boulder

MS Pennsylvania State University

BS Pennsylvania State University

Memberships/Affiliations

American Geophysical Union

Employment History

Lynker Technologies, LLC, Water Resources Scientist, 2019 - Present

Institute of Arctic and Alpine Research, Postdoctoral Research Associate, 2017 - 2019

Summary

Adam Wlostowski is a water resources scientist specializing in watershed hydrology and solute fate and transport. Dr. Wlostowski has eight years of experience in academic research and is a recent addition to the Lynker team. His work has been published in leading environmental journals, including Water Resources Research, Limnology and Oceanography, Geophysical Research Letters, Geomorphology, and Journal of Geophysical Research. His skill set includes hydrological and hydraulic modeling, environmental solute transport modeling, environmental data collection, and Geographical Information Systems (GIS). Key water resources work has involved synthesizing long-term hydrological data sets to quantify basin-scale water budgets, quantifying reactive solute transport dynamics in rivers with the One-dimensional Transport with Inflow and Storage (OTIS) model, and installing/maintaining hydrological sensors networks to measure stream discharge, water quality, soil moisture, and soil temperature.

Core Skills

- Solute Transport and Water Quality Modeling
- Watershed Hydrological Modeling
- Hydrological Data Analysis
- Design and Maintenance of Hydrologic Sensor Networks

Selected Project Experience

- Modeling the Influence of Climate Change on Nutrient Spiraling in Arctic River Networks
  - *National Science Foundation, North Slope, Alaska, 2010-2013*
- Water Balance Analysis of the National Science Foundation's Critical Zone Observatories
  - *National Science Foundation, Multiple sites across the United States, 2017-2019*
- "Active Layer" Thermodynamics in a Warmer World
  - *National Science Foundation, McMurdo Dry Valleys, Antarctica, 2014-2017*

Cameron Wobus, PhD

Senior Scientist

Lynker

Education

PhD, Massachusetts Institute of Technology, Earth Sciences (Geomorphology)

MS, Dartmouth College, Earth Sciences (Hydrogeology)

BA, Bowdoin College, Economics and Geology, *summa cum laude*

Memberships/Affiliations

American Geophysical Union

Employment History

Lynker LLC, Senior Scientist (May 2018-Present)

Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Research Affiliate (2009–present)

Abt Associates, Principal Associate (2017-2018); Senior Associate (2016–2017)

Stratus Consulting, Managing Scientist (2012–2016); Senior Scientist (2008–2011)

Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Research Scientist (2005–2009)

Massachusetts Institute of Technology, Research Assistant and Teaching Assistant (2000–2005)

Camp Dresser and McKee, Inc., Environmental Scientist/Hydrogeologist (1997–2000)

Summary

Dr. Wobus is a broadly trained Earth scientist with specific expertise in hydrology, geomorphology, and numerical modeling. For nearly a decade, Dr. Wobus has supported state, federal and international clients with analysis of climate change impacts on hydrology, landscapes and human systems. He has developed national-scale models of flood risk and asset damages due to intensification of the hydrologic cycle in the United States; and he has analyzed long-term meteorological records to characterize historical and potential future extremes in precipitation and temperature to support water utility and transportation planning for clients including the USEPA, Michigan DOT, California DOT (Caltrans) and USAID. Prior to his career in consulting, Dr. Wobus was a research scientist at the University of Colorado, where he led a field-based, multi-investigator study of climate change and coastal erosion on the North Slope of Alaska. Dr. Wobus regularly presents his work at national and international meetings. His more than 30 peer-reviewed publications have appeared in journals including *Nature, Geophysical Research Letters, Global Environmental Change, Climatic Change, Earth's Future, Geology, Natural Hazards and Earth System Sciences,* and the *Journal of Geophysical Research*.

Core Skills

- Climate change impacts, vulnerability and adaptation
- Environmental data analysis
- Fluvial and coastal geomorphology
- Riverine hydrology and hydraulics

Selected Project Experience

- Modeling the impacts of climate change on inland flood damages
    - *US Environmental Protection Agency (EPA), Climate Change Division, Washington DC, 2013-present.*
- Developing risk metrics for extreme climate events
    - *US Environmental Protection Agency (USEPA), Climate Change Division, Washington DC, 2017-2018.*
- Modeling effects of climate change on extreme events in the US
    - *US Environmental Protection Agency, Office of Water, Washington DC, 2013-2017.*
- Models to Inform Climate Change Impacts on Transportation
    - *Michigan DOT, Lansing, MI, 2013-2014.*
- Estimating the Impacts of Climate Change and Copper Mining on Salmon Habitat in Southwestern Alaska
    - *The Nature Conservancy, Arlington, VA, 2009-2015*

Roger R. Wolvington

Climate Change Impact Modeler

Education

1986, B.S., Electrical Engineering, University of Colorado, Boulder, CO

Employment History

Lynker Technologies, LLC, Climate Change Impact Modeler, 2015-Present

AMEC, Senior Applications Developer, 2007-2015

Software Developer, Hydrosphere Resource Consultants, 1988-2007

Summary

Mr. Wolvington is a software developer with over 25 years of experience programming applications for water resources modeling and environmental database development. His work has involved the statistical analysis of Global Climate Model (GCM) simulation impacts on precipitation and temperature and using the Variable Infiltration Capacity model (VIC) to calculate climate change impacts to CIR, base flows and runoff for river basins and individual grid cells in Colorado, Oklahoma and parts of Canada. Mr. Wolvington has designed and developed additional analysis software programs to evaluate the physical and administrative impacts of climate change on river basin systems.

Core Skills

- Python Programming
- Database Design
- Software Development
- Quantitative/Qualitative Analysis—Modeling

Selected Project Experience

- Washington State Agricultural Impact Study
  - *Private Client, Denver, CO, 2019*
- California Climate Change Impacts to River Basin Runoff
  - *Private Client, Southern California, 2018*
- Colorado River Water Availability
  - *Colorado Water Conservation Board, Denver, CO, 2009-2014*
- Oklahoma Climate Change Assessment
  - *Oklahoma Water Resources Board, Oklahoma City, OK, 2010*
- Colorado River Basin Climate Change Modeling
  - *United States Bureau of Reclamation, Washington, DC, 2009*
- Oklahoma River Basin Models
  - *Oklahoma Water Resources Board, Oklahoma City, OK, 2008-2014*

Appendix 2—Subcontractor Resumes

Immediately following this page, please find resumes for the following Lynker Subcontractor Personnel:

- Joel Smith, Abt Associates
- Loraine Giangola, Abt Associates
- Heather Hosterman, Abt Associates
- Russ Jones, Abt Associates
- Molly Urbina, Urbina Strategies
- Dave Mills, Peak to Peak Economics
- Chris White, Anchor Point Wildland Fire Solutions
- Rod Moraga, Anchor Point Wildland Fire Solutions
- Joseph Barsugli, PhD, Consultant

Joel Smith

Principal Associate/Scientist

Education

MPP, University of Michigan, Ann Arbor, Public Policy, 1982

BA, Williams College, Williamstown (MA), Political Science (concentration in International Relations), 1979

Memberships/Affiliations

American Association for the Advancement of Science

American Society of Adaptation Professionals

Employment History

Abt Associates (formerly Stratus Consulting), Principal Associate/Scientist, 2016–present; Principal 1998–2016

Hagler Bailly, Principal/Manager, 1992-1998

U.S. Environmental Protection Agency, Deputy Director, Climate Change Division; Special Assistant to the Assistant Administrator for Policy, Planning and Evaluation; Analyst Office of Policy Analysis, 1984-1992

Office of the Secretary of Defense, Presidential Management Intern, 1982-1984

Summary

Mr. Smith has 33 years of experience with environmental, policy, and regulatory issues, particularly as they relate to global climate change. He is an expert on global climate change impacts and adaptation. He was deputy director of the U.S. Environmental Protection Agency's (EPA's) Climate Change Division (CCD). He was coeditor of EPA's Report to Congress, The Potential Effects of Global Climate Change on the United States, published in 1989; and As Climate Changes: International Impacts and Implications, published by Cambridge University Press in 1995, on international impacts of climate change. He has published 7 edited books and more than 50 journal articles on climate change. Mr. Smith was a member of the U.S. National Climate Assessment coordinating committee for the report published in 2014; a coordinating lead author for the North America chapter of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2014; a lead author for the Synthesis chapter on climate change impacts for the Fourth Assessment Report, published in 2007; and a coordinating lead author for the same chapter in the Third Assessment Report, published in 2001. In 2007, the IPCC was awarded the Nobel Prize for Peace. He has supported municipal, state, and federal governments as well as non-profits, other national governments, and international organizations in understanding, assessing and adapting to vulnerabilities to climate change. He has made numerous presentations and conducted training on climate change for international and domestic audiences, including the United Nations Framework Convention on Climate Change (UNFCCC) and the American Society for Civil Engineers.

Mr. Smith has worked with municipal and state governments on climate change vulnerability adaptation including the City of Boulder, Boulder County, Denver Water, Aspen, Flagstaff, Seattle, California and Florida. He has also conducted training for water managers on understanding climate change science and adaptation principles. The training has been provided in Colorado, California, the Pacific Northwest, and most recently, in Florida. Mr. Smith has also conducted international training on vulnerability assessment and adaptation planning.

Core Skills

- Develop Climate Change Scenarios
- Climate Change Vulnerability Assessment
- Climate Change Adaptation
- Policy and decision analysis
- Economic analysis

Lorine Giangola

Associate

Education

PhD, University of Colorado Boulder, Natural Resources Management and Policy, 2012

MS, University of Colorado Boulder, Environmental Policy Analysis, 2008

BA, University of Virginia, Environmental Sciences (biology and Spanish minor), 2002

Memberships/Affiliations

Soil and Water Conservation Society

Employment History

Abt Associates (formerly Stratus Consulting), Associate, 2018-present; Senior Analyst, 2015-2018

University of Colorado Boulder, Postdoctoral faculty, STEM Coordinator, 2012-2014

Summary

Dr. Giangola specializes in natural resources conservation and management, analysis of environmental decision-making under climate change, and climate change adaptation in socioecological systems, with a focus on agroecosystems. She has expertise in landscape and conservation science, problem-oriented and context-sensitive approaches to policy analysis, quantitative and qualitative policy research methods, and interdisciplinary economic valuation methods. Her work has included assessments of climate vulnerability for multiple sectors at multiple scales, analysis of soil and water quality impacts of land management alternatives under climate change, management of agricultural resources for environmental quality, analysis of climate change adaptation actions at national and local levels, development of regional and national climate vulnerability reduction alternatives, cost-benefit analysis and cost-effectiveness analysis of natural resources management alternatives, development of financing strategies for adaptation projects, and conservation and management of protected lands. Dr. Giangola has worked closely with local, state, and national government agencies, non-governmental organizations (NGOs), industry leaders, academic researchers, landowners, and members of local communities to address complex environmental and natural resource problems, in the U.S. and internationally.

Dr. Giangola has worked on agriculture and climate change issues in multiple regions of the U.S., including Colorado. Her doctoral dissertation focused on the U.S. agricultural system, where she worked closely with farmers and agriculture sector stakeholders to conduct economic analysis of the costs of achieving water quality targets through broader implementation of soil and water conservation practices. Dr. Giangola's consulting work has focused on identification, development, and finance of priority natural resources management actions to advance climate change adaptation and increase resilience to climate impacts.

Core Skills

- Natural resources management and policy analysis, with a focus on agroecosystems
- Climate vulnerability assessment and development of adaptation and resilience plans
- Economic and financial analysis of resilience options
- Climate science communication

Heather Hosterman

Associate

Education

MEM, Duke University, Nicholas School of the Environment, 2008

BA, University of California, Santa Cruz, Politics, Environmental Studies and Politics, 2003

Employment History

Abt Associates, Inc. (formerly Stratus Consulting), Associate, 2018–Present; Senior Analyst, 2016–2018; Senior Economist, 2014–2016; Senior Associate, 2011–2014

Duke University, Duke Carbon Offsets Initiative, Research Analyst, 2010–2011; Research Associate, 2009–2010

Duke University, Nicholas Institute for Environmental Policy Solutions, Research and Policy Associate (Fellowship), 2008–2010

Nicholas School of the Environment, Duke University, Graduate Teaching Assistant, 2007

Summary

Ms. Hosterman has over ten years of experience in economic and policy analysis, with a focus on climate change impacts and adaptation. She has experience quantifying current and future impacts of climate change and extreme events, taking into consideration changes in population, and assessing the costs and benefits of potential climate adaptation actions. Her work includes evaluation of economic losses and health impacts from extreme events and climate change scenarios to key sectors at national and local levels; multi-criteria and benefit-cost analyses of natural resource management alternatives, including climate resilience actions; climate change vulnerability assessment and adaptation planning; and development of an accessible toolkit that allows users assess their vulnerability to climate risks. At Abt Associates, Ms. Hosterman's clients are primarily federal, state, and tribal government agencies. Prior to joining Abt Associates, Ms. Hosterman was a researcher at an academic and environmental institute.

Ms. Hosterman has authored or contributed to over twenty journal articles, book chapters, and technical reports, and presented her work at domestic and international conferences. Her work is referenced in the U.S. Global Change Research Program's Fourth National Climate Assessment, Volume II.

Core Skills

- Climate change vulnerability assessments and resilience planning
- Quantitative assessment of climate change and extreme event impacts
- Economic analysis of resilience options.

Russell W. Jones

Senior Associate/Scientist

Education

MA, University of California, Davis, Geography, 1993

BA, University of Colorado, Boulder, Geography, 1989

BA, Regis University, Philosophy (geology minor), 1987, Summa Cum Laude

Employment History

Abt Associates (formerly Stratus Consulting), Senior Associate/Scientist, 2016–present; Managing Analyst, 2006–2016; Senior Analyst, 2003–2005; Senior Associate, 1998–2003

Hagler Bailly, Associate, 1998

Alsea Geospatial, Inc., GIS Analyst, 1996–1998

Environmental Systems Research Institute, Technical Specialist, 1995–1996

Post-Graduate Researcher, Sierra Nevada Ecosystem Project, University of California, Davis (1993–1995)

Cartographer, Freelance Cartography, Sacramento, CA (1995)

Instructor, University of California, Davis (1994)

Summary

Mr. Jones is a specialist in geographic information systems (GIS), remote sensing (RS), and cartography. He has more than 25 years of experience as a GIS/RS consultant, including more than 21 years related to climate change, providing extensive mapping, analysis, and modeling support in the areas of natural resource damage assessments, ecology, sociology, economics, and climate change. In the field of climate change, he has worked on a variety of projects examining impacts and adaptation responses, including several studies modeling impacts to the environment from global climate change, sea level rise and storm surge, and human responses to sea level rise. Mr. Jones has conducted numerous studies for transportation planning agencies in NY, NJ, CA, MA, MI, and TN assessing the vulnerability of infrastructure to flooding caused by extreme precipitation and temperature events as well as changes in fire dynamics. This work utilizes spatially explicit projections of extreme precipitation and temperature using Global Climate Models from the latest Intergovernmental Panel on Climate Change's Fifth Assessment Report (CMIP5) under alternative emission scenarios.

Mr. Jones has also worked on studies modeling the vulnerability of watersheds to climate change across the United States, including examining the sensitivity of water supply to climate change for watersheds in Boulder and Aspen, Colorado, and the impacts to winter recreation for a number of ski areas. Mr. Jones is providing ongoing support to the U.S. Environmental Protection Agency's (EPA's) Climate Change Division examining the impact of alternative climate change emissions scenarios on freshwater fisheries habitat, water supply/demand, transportation bridge infrastructure, carbon sequestration associated with vegetation change, and changes in fire dynamics across the United States.

He has published more than 20 peer-reviewed journals and 4 books on climate change and a number of reports for EPA and the U.S. Congress.

Core Skills

- GIS
- RS analysis (including satellite imagery and aerial photo interpretation)
- Cartographic design
- Spatial modeling
- Climate change analysis

Molly Urbina

President and CEO

Education

Colorado State University Denver, CO (Project Management Certificate Fall – 1998)

Metro State University Denver, CO (1985 – 1995)

Colorado State University Denver, CO (1983 – 1985)

Memberships/Affiliations

Habitat for Humanity of Metro Denver Committee

Ecodistricts Board of Directors

Denver County Court Judicial Nominating Commission

Employment History

State of Colorado, Executive Director of Governor's Resiliency and Recovery Office (appointed by Governor Hickenlooper), 2014-2017

City and County of Denver, Deputy Director of Community Planning and Development (appointed by Mayor's Hickenlooper, Vidal and Hancock), 2005-2014

Oakwood Homes, LLC, Director of Government Affairs, 2004-2005

CRL Associates, Inc, Director of Development Services, CO 1997-2004

Summary

Molly Urbina provides expert land use and resilience planning consulting to private, public and nonprofit sectors utilizing years of experience in shaping an adaptable, vibrant and resilient future for present and future generations. Ms. Urbina recently served as the Executive Director of the Colorado Resiliency and Recovery Office appointed by Governor John Hickenlooper in February of 2014. Some of her relevant experience also includes 4 years as the resiliency and recovery leader of the state to coordinate the diverse and complex portfolio of disaster recovery and resiliency efforts.

Core Skills

- Community Development
- Strategic Planning
- Program and Project Management
- Leadership and Problem solving
- Government Liaison

Project Specific Experience

- *Executive Director of Governor's Resiliency and Recovery Office*
    - Served in a leadership capacity as the Resiliency and Recovery Officer for the State
    - Led coordination the diverse and complex portfolio of disaster recovery from the 2013 Floods with a sense of urgency
    - Managed the collaboration and coordination of overarching recovery and resiliency activities with numerous multi-disciplinary federal, state, local, nonprofit and private sector partners to advocate for and leverage resources and develop long-term strategies and support and empower Colorado communities
    - Led the development and implementation of a first of its kind Colorado Resiliency Framework, Colorado's roadmap to building stronger, safer, more resilient in the face of climate change, natural disasters and other major challenges with a holistic approach
    - Launched a first of its kind web-based Resiliency Resource Center providing guidance and best practices to empower resilience action in communities
    - Set priorities, communicated transparently and delivered measurable results to recover from the 2013 Flood and other disasters while also shaping an adaptable and vibrant future for Colorado
- *City and County of Denver*
    - Managed all aspects of a complex and busy City and County Department including Planning and Community Development, Permitting and Inspections with approximately 200 employees and $17M budget
    - Led the organization and implemented strategic priorities • Instrumental in Zoning Code rewrite, implementation and re-mapping of the City

David Mills

Economist

Education

M.A., Economics, University of Colorado

B.A., Economics, Colby College

Employment History

Independent Consultant, 2019-Present

Abt Associates: Senior Associate, 2016–2019

Stratus Consulting: Managing Analyst, 2010–2016; Senior Analyst, 2006–2010; Senior Associate, 2003–2005; Associate, 1998–2002

Hagler Bailly: Associate, 1996–1998

Colorado Department of Healthcare Policy and Financing: Health Policy Analyst, 1995–1996

Summary

For more than 20 years, David Mills has drawn on his economics training and experience completing impacts assessments to assemble and manage project teams to identify, develop, and integrate information from multiple disciplines to answer questions focused on direct and indirect health, welfare, and ecosystem impacts of proposed actions. The methods and applications used have developed and produced quantified and monetized impact results used to inform and educate the public and government agencies, and have been widely published in peer-reviewed literature and government reports.

Core Skills

- Leading the integration of data sources and methods from different disciplines to provide quantitative and qualitative answers to previously unanswered questions
- Applying economic theory and methods to express results in analytical frameworks (e.g., benefit-cost, break-even, lifetime cost) that can be readily understood and used in public and private sector decision-making
- Processing data using quantitative analytical programs, including SAS, Microsoft Excel, and Access
- Communicating results and methods in publications, conferences, and public meetings.

Project Specific Experience

- Climate Change Impacts and Risk Analysis Research (CIRA) Project (2016–2019), Project Manager
    - U.S. Environmental Protection Agency (EPA)
- Impacts of Climate Change on Human Health in the United States (2014–2016), Project Manager
    - U.S. Environmental Protection Agency
- Impact of Climate Change on Ecosystem Services (2011–2016), Project Manager
    - U.S. Environmental Protection Agency
- Impact of Climate Change on Vectorborne and Waterborne Diseases (2011–2016), Project Manager
    - U.S. Environmental Protection Agency
- Human Health and Welfare Impacts of Extreme Heat Events (2002–2016), Project Manager
    - U.S. Environmental Protection Agency
- Benefits Assessment of Alternative Air Pollution Controls (1998–2013), Technical Analyst/Project Manager
    - U.S. Environmental Protection Agency, Clean Air Markets Division

Chris White

Principal in Charge

Education

BS, Environmental Resource Management, Penn State University

Memberships/Affiliations

International Code Committee; Certified Instructor – WUI Code; Berthoud Fire Protection District

Nationally Certified Structure Protection Specialist; Nationally Certified Firing/Burn Boss

Employment History

Wildland Coordinator Berthoud Fire Protection District – Berthoud, CO (2006–Present)

Boulder County Senior Fire Management Specialist – Boulder, CO (1996–2002)

Summit County Fire Code Officer – Breckenridge, CO (1993–1996)

Summary

Mr. White is the Chief Operating Officer of Anchor Point Group LLC. This team of professional fire consultants specializes in hazard and risk assessments, the development of Community Wildfire Protection Plans, National Wildlife Coordinating Group (NWCG) training, and operational pre-attack planning.

Mr. White has specialized in Wildland-Urban Interface Fire Management for over 20 years. He started his fire career in 1987 working with both the US and Colorado State Forest Service. After taking on the responsibility of pre-planning for approximately 1,100 subdivisions for wildland fire hazards and developing mitigation plans to reduce wildfire impacts, Mr. White became Colorado's first county-level Wildland Fire Coordinator in Summit County.

Mr. White has been a member of the Western Governors Association (WGA) Federal Fire Policy Review Committee, WGA Prescribed Fire Policy Committee, NWCG Hazard and Risk Assessment Methodology Committee, and National Fire Protection Association (NFPA) Wildland Fire Committee. He also represented the International Association of Fire Chiefs (IAFC) on a new national initiative to integrate structural firefighters into the wildland fire management arena.

Mr. White offers additional technical expertise as a Structure Protection Specialist to Type 1 and 2 National Incident Management Teams. As a certified Structure Protection Specialist, he is responsible for integrating fire-behavior modeling and structure protection tactics to develop structure protection plans for large fire events throughout the US.

Core Skills

- Community and ecosystem vulnerability assessments:
    - Definition of critical areas for mitigation and management
    - Community and stakeholder meetings
    - Forest management, project layout, and design
    - Application of remote sensing for vulnerability assessments
- Fire management:
    - Wildfire and incident management training
    - Community protection planning
    - Watershed analysis and planning
    - Public information
    - Air resource management.

Project Specific Experience

- Comprehensive Fire Management Planning
    - Bastrop County, Texas, 2014-2017
- Community Wildfire Protection Plan and Annual Work Plan
    - San Miguel County, Colorado, 2013-2014
- Comprehensive Fire and Fuels Management Planning
    - San Marcos, California, 2012-2013

Rod Moraga

CEO/Project Manager

ANCHORPOINT
WILDLAND FIRE SOLUTIONS

Education

BS, Natural Resource Management (Forestry), Cook College of Agriculture, Rutgers University

Memberships/Affiliations

Nationally Certified Fire- Behavior Analyst

Long-Term Fire Analyst, Division Group Supervisor, Firing/Burn Boss, and Prescribed Fire Manager

Society of American Foresters

Employment History

City of Boulder Prescribed Fire Manager – Boulder, CO 1998–2002

City of Boulder Open Space Forest and Fire Ecologist – Boulder, CO 1996–1998

Summary

Mr. Moraga has been with Anchor Point Group LLC since 1998 and is currently the CEO of the firm. He leads the ecosystem management and wildfire planning divisions, as well as development and implementation of comprehensive ecosystem management plans. His focus is on combining advanced fire behavior modeling and sound silvicultural practices to enhance ecosystem health, while mitigating the Wildland-Urban Interface fire threat. He also oversees the fire behavior analysis for hazard and risk assessments, prescribed burns and community wildfire protection plans.

Mr. Moraga has been involved at all levels of forest management - from inventory and prescription development to implementation of thinning and restoration. As a principal author of the forest ecosystem management plan for the City of Boulder, he developed a process that used sound silvicultural practices that achieved both forest health improvement and fire mitigation measures. His experience and strong background in fire operations, fire ecology, forestry and Wildland-Urban Interface ensures that recommendations are viable and practical to the end user.

Mr. Moraga further offers technical expertise in fire behavior modeling. As a certified Fire Behavior Analyst, he is charged with predicting fire behavior and spread during large fire events throughout the United States. This requires a keen understanding of fuels, weather and topography and their cumulative interactions. These predictions are used by the incident management team to support their operational and tactical decision.

Core Skills

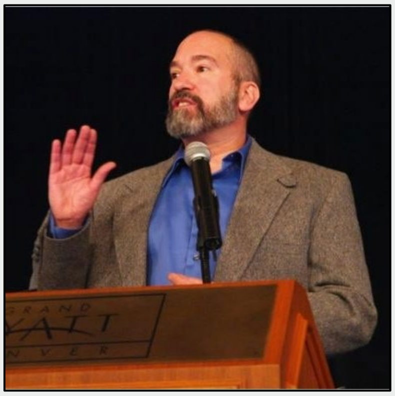
- Fire-behavior analysis and management:
    - Hazard risk assessments
    - Fuels and fire modeling
    - Prediction and interpretation
    - Wildland Fire Decision Support System Analysis
    - Operational briefings
    - Division group supervisor/technical specialist on non-fire incidents
    - Ecosystems and forest management.
- Prescribed fire management and protection planning:
    - Coordination of prescribed fire program
    - Wildfire and incident management training
    - Community protection planning
    - Forest management planning and implementation

Project Specific Experience

- Eagle River Fire Protection District Community Wildfire Protection Plan
    - Eagle County, Colorado, 2015-2016
- Lexington Hills Community Wildfire Protection Plan
    - Lexington Hills, California, 2013-2014
- Vail Resorts Ecosystem Management Plan
    - Beaver Creek, Colorado, 2013-2015

Joe Barsugli, PhD

Research Scientist



Education

Harvard University, Physics, B.A. magna cum laude, 1982

University of Washington, Atmospheric Sciences, Ph.D., 1995

Appointments

6/2010- present. Research Scientist III, CIRES, University of Colorado, Boulder, CO. Currently affiliated with the CIRES Western Water Assessment and NOAA Earth Systems Research Laboratory, Physical Sciences Division.

3/1998- 5/2011. Research Scientist II, CIRES, University of Colorado, Boulder, CO

5/1997-2/1998. Research Scientist I, CIRES, University of Colorado, Boulder, CO

5/1995-5/1997. Research Associate, CIRES, University of Colorado, Boulder, CO

Summary

Dr. Joe Barsugli is a research scientist affiliated with CIRES -- the Cooperative Institute for Research in Environmental Sciences, at the University of Colorado at Boulder, and at the Western Water Assessment, a joint effort between NOAA and CU. He also works closely with the University Consortium of the USGS North Central Climate Science Center. Trained in climate theory and modeling, he works at the "technical interface" connecting climate science with the practitioners and technical staff who are informing planning for water and land management in the Colorado region, and connecting researchers to the problems faced by managers.

Core Skills

- Climate Change
- Climate Modeling
- Attribution and Predictability Assessments

Selected Relevant Publications

Hobbins, M.T., I. Rangwala, J.J. Barsugli, C.F. Dewes, 2018: Extremes in evaporative demand and their implications for drought and drought monitoring in the 21st Century. Extreme Hydrology and Climate Variability: Monitoring, Modeling, Adaptation and Mitigation, edited by Melesse A.M., W. Abtew, G. Senay , Elsevier (in press)

Sofaer, H. R., J. J. Barsugli, C. S. Jarnevich, J. T. Abatzoglou, M. K. Talbert, B. W. Miller and J. T. Morisette, 2017: Designing ecological climate change impact assessments to reflect key climatic drivers. Glob. Change Biol., 23 (7) 2537-2553, doi: 10.1111/gcb.13653

Guentchev, G. S., R. B. Rood, C. M. Ammann, J. J. Barsugli, K. Ebi, V. Berrocal, M. S. ONeill, C. J. Gronlund, J. L. Vigh, B. Koziol and L. Cinquini, 2016: Evaluating the Appropriateness of Downscaled Climate Information for Projecting Risks of Salmonella. Int. J. Environ. Res. Public Health, 13 (3), doi: 10.3390/ijerph13030267

Rangwala, I., C. F. Dewes, and J. J. Barsugli, 2016: High Resolution Climate Modeling for Regional Adaptation. EOS Trans. AGU, 97, doi: 10.1029/2016EO048615

Livneh, B. , J. S. Deems, B. Buma, J. J. Barsugli, D. Schneider, N. P. Molotch, K. Wolter and C. A. Wessman, 2015: Catchment response to bark beetle outbreak and dust-on-snow in the Colorado Rocky Mountains. J. Hydrol., 523 196-210, doi: 10.1016/j.jhydrol.2015.01.039

Barsugli, J. J., et al., 2013: The Practitioner's Dilemma: How to Assess the Credibility of Downscaled Climate Projections. Eos Trans. AGU, 94 (46) 424-425

Deems, J. S., T. H. Painter, J. J. Barsugli, J. Belknap, B. Udall, 2013: Combined impacts of current and future dust deposition and regional warming on Colorado Basin snow dynamics and hydrology. Hydrol. Earth Syst. Sci., 17 (11) 4401-4413.

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Appendix 3—Alignment with Colorado Hazard Mitigation Plans and Updates

Relevant Climate and Hazard Mitigation, Plans, Practices, and Policies for the State of Colorado	
2018-2023 Colorado Hazard Mitigation Plan (SHMP) (Adopted November 2018)	
Key aspects relating to HMP Mitigation Objectives (A-G)	Goals, objectives defined to help guide the resulting litigation actions that will accomplish the goals. (defines HMP Mitigation Objectives A-G)
Data Sources Identified or Needed	
Key Recommendations in Plan	
Goals: ▪ Minimize the loss of life and personal injuries from all-hazard events ▪ Reduce losses and damages to state, tribal and local governments as well as special districts and private assets and support similar local efforts ▪ Reduce federal, state, tribal, local and private costs of disaster response and recovery ▪ Support mitigation initiatives and policies that promote disaster resiliency, nature-based solutions, cultural resources and historic preservation and climate adaptation strategies ▪ Minimize interruption of essential services and activities ▪ Incorporate equity considerations into all mitigation strategies ▪ Support improved coordination of risk mitigation between and among the public, private and non-profit sectors ▪ Create awareness and demand for mitigation as a standard practice **Objectives:** ▪ A) Supports and empowers local and regional strategies thru mitigation strategies through statewide guiding principles, programs and resources. ▪ B) Promote activities that are climate neutral and supportive of appropriate renewable and alternative energy. ▪ C) Strengthen Hazard Risk communication tools and procedures. ▪ D) Strengthen continuity of operations at state, regional tribal and local levels. ▪ E) Strengthen cross-sector connections across State Government. ▪ F) Identify specific areas at risk to natural hazards/zones of vulnerability. ▪ G) Expand public awareness, education and information programs relating to hazards and mitigation methods and techniques. ▪ Minimize the loss of life and personal injuries from all-hazard events	
Engagement Approach (not limited to listed)	State agency partners and natural hazard Subject Matter Experts across the state (SHMT), higher education, History Colorado and FEMA Drought Mitigation and Response Planning Committee (DMRPC)

	Individual SME interviews, Other Technical Assistant Partnerships CRWG posted on DHSEM website for public view and comment
Lynker Team Approach to Satisfaction of State Goals	Systemwide approach looking at interdependencies, overlaps or gaps in data for a comprehensive risk assessment for Flood, Drought and Wildfire with a snapshot of current conditions and 2050 impacts of climate change and population growth. "Rather than trying to predict the future by looking at the past scenario planning allows us to identify and account for key uncertainties." CWP
How Project Results Will Quantify Losses Avoided	
Colorado Flood Mitigation Plan (FHMP annex plan aligned with SHMP) Updated in 2018 as part of SHMP	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Reduce flood impacts to Colorado's economy, people, state assets and environment. ▪ Promote awareness and education of flood hazards and watershed protection. ▪ Coordinate and provide planning, technical assistance (TA), and financial resources for state, local and watershed planning efforts. ▪ Continue to update and develop floodplain maps for risk assessment, planning and awareness applications. ▪ Promote and encourage the adoption of model codes and higher standards that emphasizes hazard mitigation.
Data Sources Identified or Needed	
Key Recommendations in Plan	
▪ Reduce flood impacts to Colorado's economy, people, state assets and environment. ▪ Promote awareness and education of flood hazards and watershed protection. ▪ Coordinate and provide planning, technical assistance (TA), and financial resources for state, local and watershed planning efforts. ▪ Continue to update and develop floodplain maps for risk assessment, planning and awareness applications. ▪ Promote and encourage the adoption of model codes and higher standards that emphasizes hazard mitigation	
Engagement Approach (not limited to listed)	SHMP, Flood TAP AND DMRP during update
Lynker Team Approach to Satisfaction of State Goals	Systemwide approach looking at interdependencies, overlaps or gaps in data for a comprehensive risk assessment for Flood, Drought and Wildfire with a snapshot of current conditions and 2050 impacts of climate change and population growth. "Rather than trying to predict the future by looking at the past scenario planning allows us to identify and account for key uncertainties." CWP
How Project Results Will Quantify Losses Avoided	

<table>
<tr><th colspan="2">Colorado Drought Mitigation Plan (DMRP annex plan aligned with SHMP)
Updated in 2018 as part of SHMP</th></tr>
<tr><td>Key aspects relating to HMP Mitigation Objectives (A-G)</td><td>▪ Work Collaboratively with Local partners
▪ Increase public awareness
▪ Improve water availability monitoring and drought impact assessment
▪ Coordinate and provide technical assistance for state, local and watershed planning efforts.</td></tr>
<tr><td colspan="2">Key Recommendations in Plan</td></tr>
<tr><td colspan="2">▪ Improve Water Availability Monitoring and Drought Impact Assessment.
▪ Increase public awareness and education.
▪ Work collaboratively with water rights holders to voluntarily augment water supply through mechanisms to transfer to areas of shortage during droughts.
▪ Coordinate and provide TA for state, local and watershed planning efforts.
▪ Reduce water demand/encourage conservation.
▪ Reduce drought impacts to CO's economy, people, state assets and environment.
▪ Continue to develop inter-government and inter agency coordination and
▪ Evaluate potential impacts from climate change</td></tr>
<tr><td>Engagement Approach (not limited to listed)</td><td>SHMP, Flood TAP AND DMRP during update</td></tr>
<tr><td>Lynker Team Approach to Satisfaction of State Goals</td><td>Systemwide approach looking at interdependencies, overlaps or gaps in data for a comprehensive risk assessment for Flood, Drought and Wildfire with a snapshot of current conditions and 2050 impacts of climate change and population growth. "Rather than trying to predict the future by looking at the past scenario planning allows us to identify and account for key uncertainties." CWP</td></tr>
<tr><td colspan="2">How Project Results Will Quantify Losses Avoided</td></tr>
<tr><th colspan="2">Hazard Identification, Risk Assessment Plan (HIRA - Integrated into SHMP)
(Updated in 2018)</th></tr>
<tr><td>Key aspects relating to HMP Mitigation Objectives (A-G)</td><td>▪ Identifies natural, technological, and human-caused hazards and to evaluate the risk they pose to the State of Colorado, the health and safety of its citizens, property, and economy.
▪ A vulnerability and risk assessment is a decision support tool for determining the need for and prioritization of mitigation measures to protect assets, processes, and people. Shared responsibility between State and local communities.</td></tr>
<tr><td>Engagement Approach (not limited to listed)</td><td>SHMP, Flood TAP AND DMRP during update</td></tr>
</table>

Colorado Wildfire Risk Assessment Portal (CO-WRAP) Colorado State Fire Service (Process) (Updated in 2018)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Technological, and human-caused hazards and to evaluate the risk they pose to the State of
Data Sources Identified or Needed	
Key Recommendations in Plan	
▪ N/A The use of forest management actions and programs to protect our communities. ▪ Proactive forest management work to mitigate hazard potential. By constantly working to reduce future risks from wildfire, insects and other concerns. ▪ Proactively enhance public health and safety.	
Engagement Approach (not limited to listed)	Inter-agency coordination, U.S. Forest Service
Colorado Resiliency Framework (CRF) (Adopted 5/1/2015)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Colorado, the health and safety of its citizens, property, and economy. A vulnerability and risk
Data Sources Identified or Needed	
Key Recommendations in Plan	
▪ Include resiliency aspects in local codes and regulations ▪ Build capacity locally	
Engagement Approach (not limited to listed)	Statewide focus groups, community outreach at the regional level, Cross Sector state agencies (CRWG)
Lynker Team Approach to Satisfaction of State Goals	Scenario building, Vulnerability analysis, resilience analysis, collecting data, collaborative and inclusive engagement are key policy recommendations
Colorado Water Plan and Colorado Water Plan in Action Report (Nov 2017) (Adopted Nov. 2016)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Assessment as a decision support tool for determining the need for and prioritization of mitigation
Key Recommendations in Plan	
▪ Conduct adaptive management as necessary.	

▪ Coordinate statewide watershed-coalition and partnership plans, projects, monitoring, and adaptive management strategies. ▪ Watershed management plans may include potential impacts to the environment, public water supplies, and agricultural production from abandoned mines, and a strategy for addressing these impacts. CDPHE and DRMS are potential partners in developing a prioritized list of mines which could impact streams.	
Engagement Approach (not limited to listed)	Basin roundtables, Inter-Basin Compact Committee, PEPO Working Group of the IBCC, Water Investment Committee, State agency collaboration, Members of Colorado General Assembly Water Resources Review Committee (SB14-115) and Public comments from individuals, organizations and agencies
Colorado Climate Plan - Roadmap to 100% Renewable Energy By 2040 and Bold Climate Action (Updated in 2019)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Measures to protect assets, processes, and people.
Key Recommendations in Plan	
▪ Proactive plan to prevent hazards. ▪ Recommendations to reduce statewide greenhouse gas emissions. ▪ Equitable distribution of benefits, cost of compliance, opportunities to incentivize clean energy in transitioning communities and the potential to enhance the resilience of Colorado's communities and natural resources to climate impacts.	
Planning for Hazards: Land Use Solutions for Colorado (PFH) DOLA (Adopted in 2016)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ How to assess and integrate hazard mitigation in land use plans and policies, strengthen incentives, protecting sensitive areas, improving site development standards, improving buildings an infrastructure, enhancing administration and procedures.
Key Recommendations in Plan	
▪ Model code language ▪ Development agreements ▪ Transfer of development rights ▪ Cluster subdivision and stormwater ordinances ▪ Website components to educate and communicate successes that can be used as case studies for other scenarios	
Engagement Approach (not limited to listed)	Communities across Colorado, Higher education,
Rural Technical Assistance Program (RTAP) - Formerly called Colorado Blueprint (Adopted in June 2017)	

Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Technical Assistance to enhance rural economic development strategies across the state
Engagement Approach (not limited to listed)	Established program updated in 2017 with reach out to communities across Colorado and education of program/process for funding.
Rural Economic Resiliency in Colorado (OEDIT) Adopted in November 2016	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Roadmap to resiliency. To understand the factors affecting economic resiliency within communities. Detailed tangible and intangible assets and attributes that contribute to comparative advantages.
▪ Resiliency, transportation access, housing availability and supply, natural amenities, tangible and intangible assets, quality of life and smart growth	
Engagement Approach (not limited to listed)	Cross agency and interagency coordination, Focus Groups/interviews across 47 non metro counties, higher education
Colorado Hazard Mapping Program (CHAMP) - SB15-245 (CWCB) (Enabled hazard mapping pilot and funding through the state legislature in 2015)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Provide mitigation and a land use framework in areas likely to be affected by future flooding, erosion and debris flow events
▪ Identified Flood, Fluvial/Erosion and Debris Flow hazard mapping for portions of Colorado, created a CO Risk MAP Portal so counties or municipalities can use for more informed land use decisions	
Engagement Approach (not limited to listed)	Cross Agency coordination, CHAMP public meetings to engage locals and other technical experts
CDOT Risk and Resilience Program HB18-1394 (Enabled resilience principles through the state legislature)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Defines resilience, enabled 1-70 Risk and Resilience Pilot Study and the CDOT Resilience Policy Directive. ▪ (A-G)
I-70 Risk and Resiliency Pilot Final Report (Adopted in November 2017)	
Key aspects relating to HMP Mitigation Objectives (A-G)	▪ Demonstrated benefits of examining a highway transportation network and relationship to physical hazards assessing risk and for making investment decisions. ▪ (B, C, D, E, F, G)
Key Recommendations in Plan	

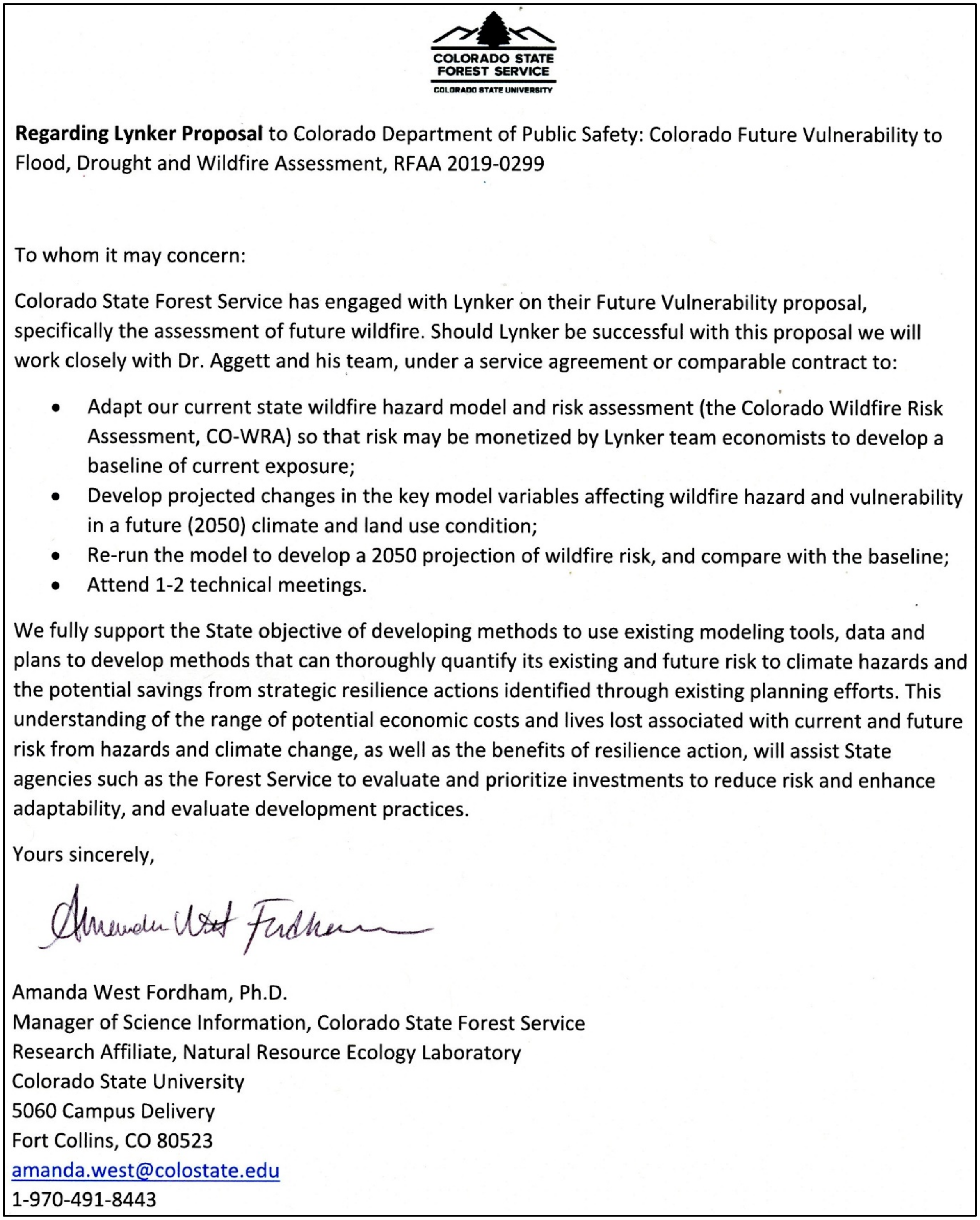
Identified rockfall, flooding risk… to expand risk management from the asset level into an organizational framework, evaluate projects with risk in mind, establish better process to evaluate for risk and incorporate principles into long range planning	
Engagement Approach (not limited to listed)	Agency-wide buy in with Executive Oversight committee, Transportation Commission, Data Advisory Committee, CDOT technical working group (briefings, meetings, workshops, external presentations and website/social media comm
CDOT Resilience Policy- Building Resilience into Transportation Infrastructure and Operations (Adopted in November 2017)	
Key aspects relating to HMP Mitigation Objectives (A-G)	Implement Resilience principles to CO Transportation practices and proactively manage risk to minimize disruptions an adapt to changing conditions (B, C, D, E, F, G)
Engagement Approach (not limited to listed)	Incorporate Resiliency principles and Risk mitigation,

In addition to the above referenced documents, we may also draw on other resources such as:

- Update to Building Code Tool Profile and New Model Code Language and Commentary (MSU), Sept 2018
- El Paso County Economic Development Assessment Team Report (U.S. Department of Economic Development Administration-Resilience in Economic Development Planning), October 2014
- Multi-Hazard Mitigation Plan City of Boulder, October 2014
- Colorado Wildfire Action Plan Enhancement-Climate Change Vulnerability Assessment (CSU), December 2014
- Farming: Adaptive Capacity and Climate Resilience (Sustainable Agriculture Research and Education and USDA)
- Local Government Guide to Recovery, April 2017
- Local Comprehensive Plans, area plans, drainage or watershed masterplans all have relevance into a systemwide approach to data collection and identifying alignment and gaps.

Appendix 4—Letter of Support

Immediately below, please find a letter of support from the Colorado State Forest Service at Colorado State University.



COLORADO STATE
FOREST SERVICE
COLORADO STATE UNIVERSITY

Regarding Lynker Proposal to Colorado Department of Public Safety: Colorado Future Vulnerability to Flood, Drought and Wildfire Assessment, RFAA 2019-0299

To whom it may concern:

Colorado State Forest Service has engaged with Lynker on their Future Vulnerability proposal, specifically the assessment of future wildfire. Should Lynker be successful with this proposal we will work closely with Dr. Aggett and his team, under a service agreement or comparable contract to:

- Adapt our current state wildfire hazard model and risk assessment (the Colorado Wildfire Risk Assessment, CO-WRA) so that risk may be monetized by Lynker team economists to develop a baseline of current exposure;
- Develop projected changes in the key model variables affecting wildfire hazard and vulnerability in a future (2050) climate and land use condition;
- Re-run the model to develop a 2050 projection of wildfire risk, and compare with the baseline;
- Attend 1-2 technical meetings.

We fully support the State objective of developing methods to use existing modeling tools, data and plans to develop methods that can thoroughly quantify its existing and future risk to climate hazards and the potential savings from strategic resilience actions identified through existing planning efforts. This understanding of the range of potential economic costs and lives lost associated with current and future risk from hazards and climate change, as well as the benefits of resilience action, will assist State agencies such as the Forest Service to evaluate and prioritize investments to reduce risk and enhance adaptability, and evaluate development practices.

Yours sincerely,

Amanda West Fordham

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Appendix 5—References

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Appendix 6—RFP Signature Page

Immediately following this page, please find a copy of Lynker's completed *RFP Signature Page*.

REQUEST FOR PROPOSAL (RFP): RFAA 2019-0299
TITLE: Colorado Future Vulnerability to Flood, Drought and Wildfire Assessment
Date Due: Tuesday, June 17, 2019 2:00 PM MT

COLORADO DEPARTMENT OF PUBLIC SAFETY

SIGNATURE PAGE

ISSUING OFFICE: This Request for Proposal (RFP) is issued by the Colorado Department of Public Safety (CDPS), Executive Director's Office. The CDPS Procurement Office is the sole point of contact concerning this solicitation.

Issuing Office Address: Colorado Department of Public Safety
Procurement Office
700 Kipling Street
Denver, CO 80215

SEALED PROPOSALS ACCEPTED AT THE ISSUING OFFICE ONLY. FAXED OR EMAILED PROPOSALS WILL NOT BE ACCEPTED. NO LATE PROPOSALS WILL BE ACCEPTED.

COLORADO VSS # (Not FEIN or SSN) VS50000000005267 Date 6/17/2019

NAME OF COMPANY Lynker Technologies, LLC

ADDRESS 3002 Bluff Street, Suite 101

CITY Boulder STATE Colorado ZIP CODE 80301

PHONE 720-446-1701

EMAIL gaggett@lynkertech.com

Indicate if your company is registered and verified by the U.S. Department of Veteran Affairs as a Service-Disabled Veteran-Owned Small Business:

☐ YES (if yes, please submit validation with your bid response) ☒ NO

PRINT NAME OF COMPANY REPRESENTATIVE Graeme Aggett

TITLE Principal and Chief Scientist

SIGNATURE OF COMPANY REPRESENTATIVE ______________________
Handwritten **ORIGINAL** signature by an authorized officer or agent of the company.

SIGN AND RETURN THIS PAGE WITH PROPOSAL SUBMISSION

Appendix 7—RFP Exhibit C, Colorado W9 Form

Immediately following this page, please find Lynker's completed *RFP Exhibit C, Colorado W9 Form*.

Appendix 8—RFP Exhibit E, Sample State Contract

Lynker has reviewed *RFP Exhibit E—Sample State Contract*, and we will not take any exceptions to any language in the document.