Incorporating Climate Uncertainty into Water Allocations in Kansas

Submitted by

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A.1. Executive Summary

20 April 2021

University of Kansas Center for Research, Inc., Lawrence, Douglas, Kansas

Category B Application

The aim of this project is to include climate uncertainty into the water supply allocation procedure in the State of Kansas. Water supply allocations in the state of Kansas are determined by the Kansas Water Office (KWO) by using a water balance model that incorporates six river basins, 21 reservoirs (16 are federal reservoirs), 51 inflows and 163 sources of consumptive use. The model uses water balance across the system based on defining the water demands and climatic inputs, which includes streamflow and evaporation loss from reservoirs. The current practice at KWO is to use 1950's climate, which was an extreme drought period in the state of Kansas, for determining water allocations. While the 1950's drought was an extreme event for Kansas, it relies on stationarity, the idea that natural systems fluctuate within an envelope of unchanging variability. Yet due to extensive anthropogenic change of Earth's climate, there have been changes to the water cycle that impacts the hydrologic cycle and makes a single drought event an inadequate representation of climate uncertainty. This lack of robustly accounting for climate uncertainty limits the ability of the state to conduct long-term water supply planning and anticipating the range of future resource conditions for much of its projected population growth area. This project will overcome this weakness by developing a procedure for incorporating climate uncertainty into the water allocation process in the state of Kansas. This procedure includes four key components: 1) quantify climate uncertainty using historical climate and climate projections from state of the art climate models, 2) use a hydrologic modeling framework to estimate the uncertainty in streamflow and evaporation due to climate uncertainty, 3) modify the existing KWO water allocation model to use an ensemble of streamflow and evaporation inputs, and 4) quantify the uncertainty in future water allocations due to climate based on a Bayesian probabilistic framework. Each of these components plays and important role for ensuring sustainable and resilient water allocations in Kansas and thus enabling reliable water supply into the future.

Two Year Project Starting September 1, 2021 and Ending August 31, 2023

The proposed work is not located on a Federal facility.

A.2. Technical Project Description and Milestones

A.2.1 Project Motivation and Overview

It has been over 15 years since Milly et al. stated that stationarity, the foundation for most water resource designs and decision making, is dead (2005). Stationarity is the idea that natural systems fluctuate within an envelope of unchanging variability, yet due to extensive anthropogenic change of Earth's climate, there have been changes to the variables used for engineering design and decision making, such as precipitation, streamflow, and evapotranspiration (Huntington 2006; Kam et al. 2014, 2018; Sanderson et al. 2019). The inability to properly address non-stationarity in routine water resource design threatens societies ability to withstand climate extremes which have devastating impacts on ecosystems and many aspects of society including recreational, food supply, energy and water use, and result in significant financial losses (Wilhite 2000). The devastating impacts of extremes have the potential to amplify as a result of increasing population and the threat of human induced climate change. Under these conditions, continuing with a stationarity approach to engineering-design threatens the long-term sustainability of both the natural environment and human populations. More sustainable and resilient engineering design for both human society and the environment can be achieved by addressing non-stationarity through the widespread availability of data, computational resources, and data-science techniques that can provide a wealth of information and insights about the climate uncertainty in the design process. Yet, the vast amount of data and techniques remain unused due to the difficulty of designing amid interactions between natural ecosystems and human society, the complexity of the data sets and methods, and the uncertainty involved. While the complete transformation to more sustainable water resource design practices will be long and require the integration of multiple efforts, the proposed work will help incorporate climate uncertainty into water allocation in the state of Kansas.

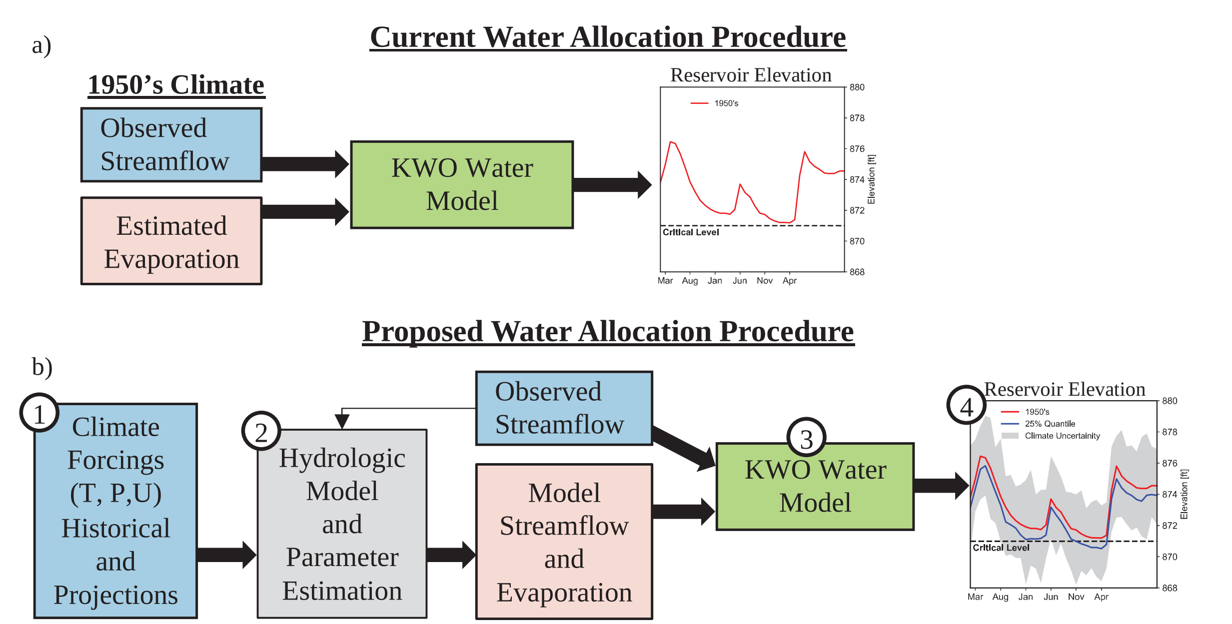

Figure 1 - *Overview of the current procedure for allocating water in Kansas as well as the proposed procedure which consists of 4-key areas that are discussed in detail below.*

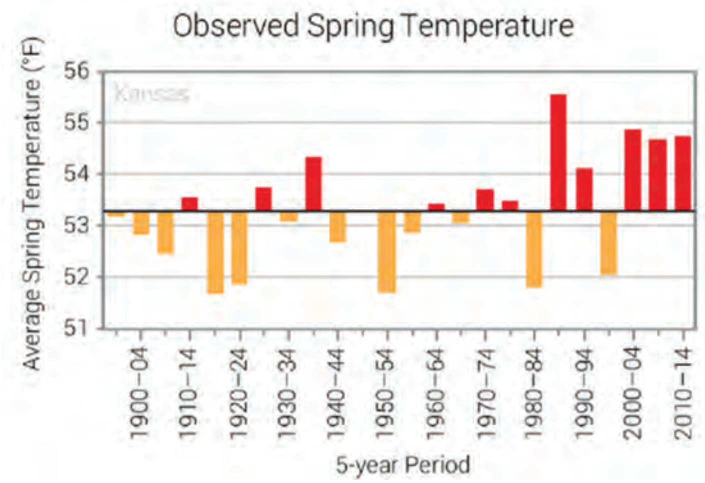

Figure 2 – *Warming trends in Kansas have been particularly noticeable in the spring in recent decades. (from Frankson et al., 2017).*

The water allocations in the state of Kansas are determined by the Kansas Water Office (KWO). To aid in the water allocation process, KWO uses a water balance model that incorporates six river basins, 21 reservoirs, 51 inflows and 163 sources of consumptive use. The model uses water balance across the system based on defining the water demands and climatic inputs for the model, which includes streamflow and evaporation loss from reservoirs. The current practice at KWO is to use the model based on streamflow and evaporation estimated during the 1950's drought (**Figure 1a**). While the 1950's drought was an extreme event for Kansas, it does not adequately represent the most severe past or future drought potential.

Specifically, changing climate will likely alter drought duration, intensity, and reservoir evaporation, all of which will impact water storage and allocation. An example of a change in climate in Kansas is given in **Figure 2**, which shows an increase in average Spring time

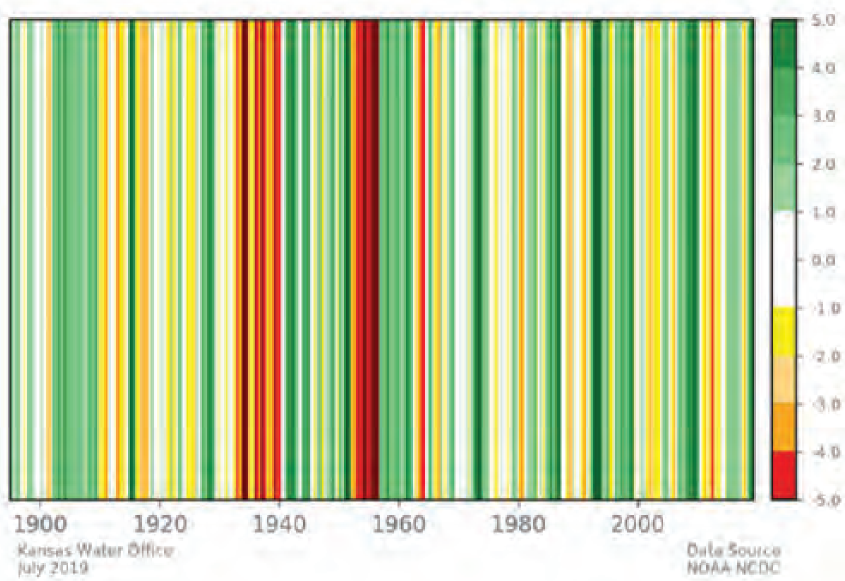

Figure 3 – *Historical Kansas Palmer Drought Severity Index (PDSI) values. PDSI utilizes precipitation, temperature, and available water content data to estimate relative dryness. Classifications typically range from extremely wet (PDSI > 4.0) to extreme drought (PDSI < -4.0). Historical PDSI data illustrates the year-to-year variability of water resources in Kansas, as well as the severity of extreme events like the 1930's and 1950's droughts.*

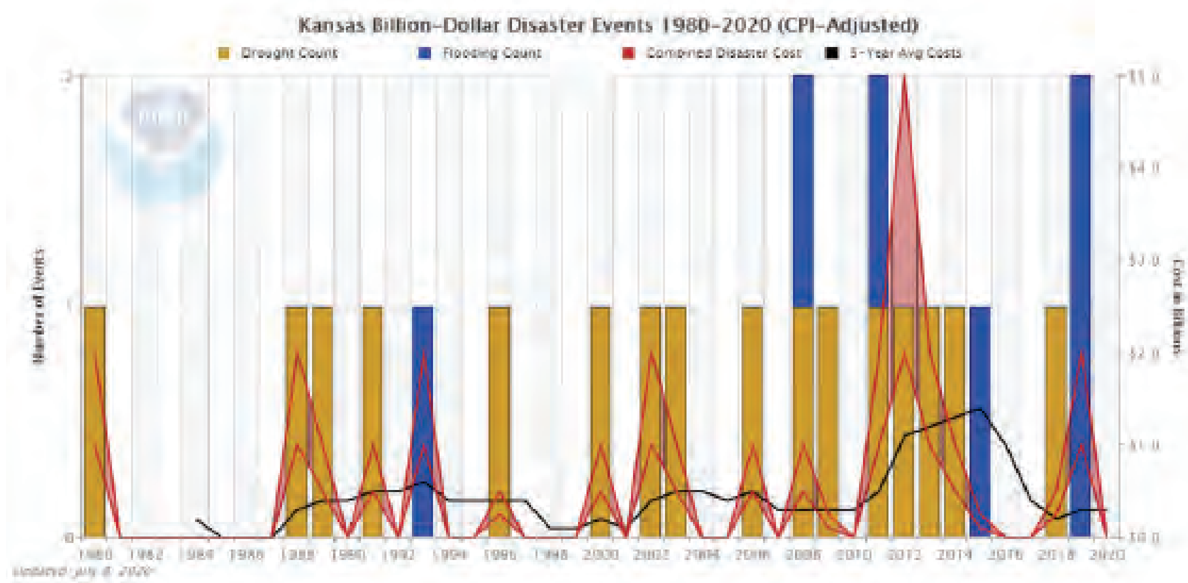

Figure 4 – *Listing of drought and flood events with damage impacts over a billion dollars as recorded by NOAA. Frequent recurrence of drought events will stress reservoir refill capabilities and reservoir storage supplies available to maintain streamflow. Increases in temperature and evaporation will require water resource planning modifications to prevent future shortage.*

temperature (Frankson et al., 2017). This increase in Spring temperature will impact the evaporation and thus reduce water storage in reservoirs. Increases in temperature and evaporation will require water resource planning modifications to prevent future shortages in water resources. Historical drought data illustrates the year-to-year variability of water resources in Kansas, as well as the severity of extreme events like the 1930's and 1950's droughts (**Figure 3**). The lack of sufficient water storage will greatly impact the Kansas economy, particularly during drought events. **Figure 4** shows the economic impact of climate related disasters (droughts and floods) in the state of Kansas from 1980-2020. Frequent recurrence of drought events will stress reservoir refill capabilities and reservoir storage supplies available to maintain streamflow. In addition, the number of days with temperatures above 100°F are project to increase in the late 21st century (**Figure 5**). The aim of this project is to work with KWO to include climate uncertainty into the water allocation procedure in Kansas (**Figure 1b**). This new methodology for water allocation includes four key components: 1) quantify climate uncertainty using historical climate and climate projections from state of the art climate models, 2) use a hydrologic modeling framework to estimate the uncertainty in streamflow and evaporation due to climate uncertainty, 3) modify the existing KWO water allocation model to use an ensemble of streamflow and evaporation inputs, and 4) quantify the uncertainty in future water allocations based on a Bayesian probabilistic framework. Each of these components is discussed below in detail and plays an important role for incorporating climate uncertainty into the water allocation practice and will ensure sustainable and resilient water resources in Kansas.

A.2.2 Climate Uncertainty

Climate extremes have devastating impacts on many aspects of society including recreational, food supply, energy and water use, and ultimately result in significant financial losses. These devastating impacts of extremes have the potential to amplify as a result of increasing population and the threat of human induced climate change. Specifically, global precipitation patterns will likely change in a warming climate as a result of an intensification of the hydrologic cycle. Further, a change in atmospheric circulation patterns will lead to poleward displacement of storms that can produce subtropical dry zones (Marvel and Bonfils 2013). The anthropogenic impact on multivariate extremes could further strain water resources thereby impeding society's sustainability into the future. Specifically for Kansas, climate change has the potential to alter seasonal temperature and precipitation which will have cascading impacts on water storage, agriculture, economic stability and natural ecosystems (Brikowski 2008; Araya et al. 2017; Forzieri et al. 2017). In the wake of climate extremes, there is still hope of developing a resilient society that is capable of adapting to change and more efficiently utilize water resources through quantifying and predicting the potential changes to the climate system. Yet, due to the chaotic nature of the atmosphere, individual storms that cause extremes that strain water resources cannot be predicted. However, as computational resources and our understanding of the climate have improved, the use of physically based climate models to make predictions of possible climate scenarios has become widely available. While these climate simulations likely do not represent the actual future climate, they provide realizations of possible climate variables, such as precipitation and temperature, that can be used to define the climate uncertainty in water resources decision making and planning.

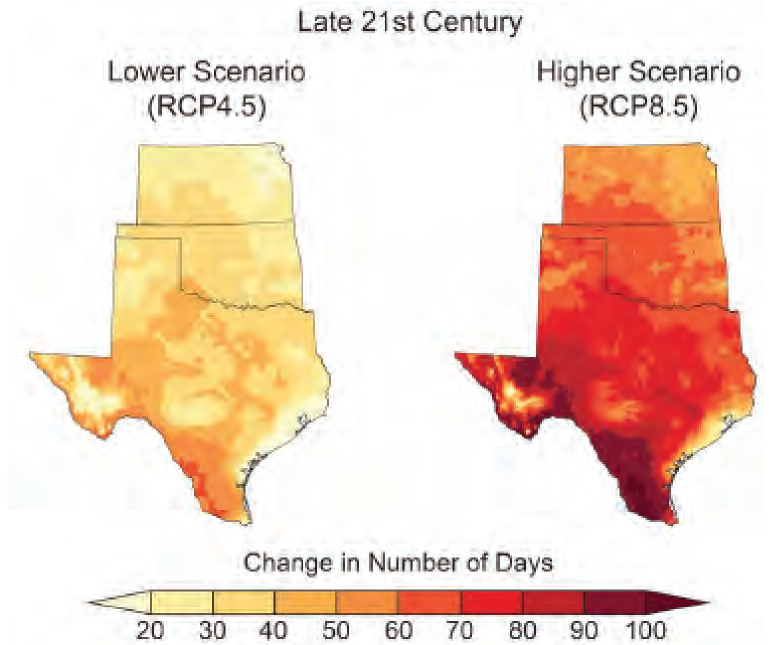

Figure 5 – *Projected increase in number of days above 100° throughout the Southern Great Plains. (from Kloesel et al., 2018)*

For this work, the climate variables will be derived from the Coupled Model Intercomparison Project phase 5 (CMIP5), which includes state of the art climate models that capture key feedbacks between the land, ocean and atmosphere (Taylor et al. 2012). The estimates include multiple models and several emissions scenarios under Representative Concentration Pathways (RCP's) 2.6, 4.5, 6.0 and 8.5. The 1° x 1° (approximately 100 km) spatial resolution of the CMIP5 climate models is too coarse to represent the local hydrologic cycle. To overcome this scale issue, statistically downscaled climate data will be used from the CMIP5 Climate and Hydrology Projections datasets (Bureau of Reclamation 2013). An example of downscaled temperature projections for the state of Kansas are given in **Figure 6**. Specifically, we will use the LOCA-CMIP5, which has been downscaled to $1/16^{th}$ degree (approximately 6 km) based on the data from Livneh et al. (2015, 2013). This includes data from observations, historical climate models and future projections under RCP 4.5 and 8.5 from 31 different climate models. The downscaled daily temperature and precipitation fields will be used to produce consistent estimates of wind through conditional resampling based on the observed data. The conditional resampling will select realizations from the observational history of wind that are consistent with the downscaled values from the CMIP5 climate models for both historical and future simulations. This approach will generate daily values of wind from the observational dataset that are consistent with the CMIP5 estimates of temperature and precipitation. This approach is consistent with the downscaling methodologies of many hydrologic forecast systems (Yuan et al. 2015, 2013). Initially we will focus on generating climate scenarios from the CMIP5, but we will also explore incorporating the latest climate projections from CMIP6 (Eyring et al. 2016). The CMIP6 climate projections will be statistically downscale to a daily gridded product using the same methods used for the CMIP5 projections. Incorporating the CMIIP6 projections has two major advantages. First, it will create a framework for incorporating future climate projections into the systems to ensure the KWO system stays up to date and consistent with future climate projections. Second, it allows for a comparison of the relative difference between CMIP5 and CMIIP6 projections over Kansas and a means of quantifying the potential uncertainty associated with climate projections.

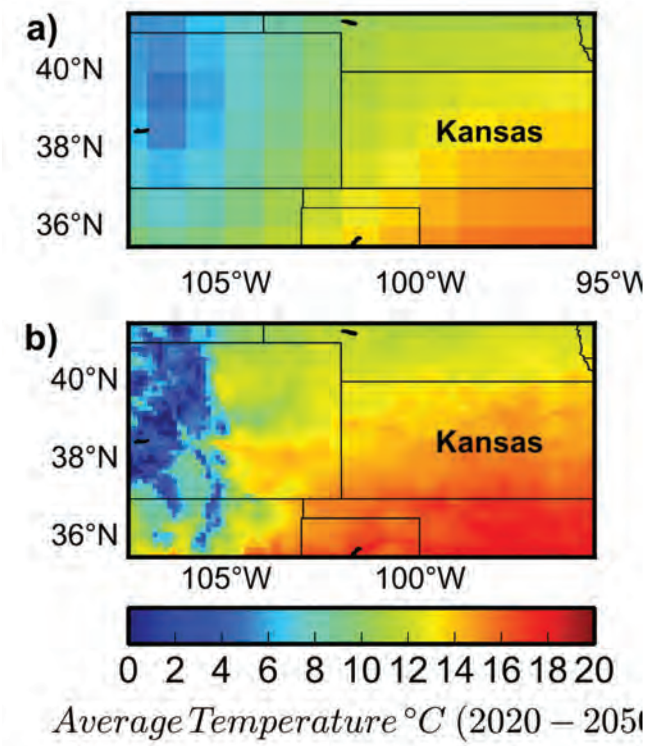

Figure 6 - *Example of temperature projection over Kansas for 2020-2050 from the RCP2.6 emission scenario from the gfdl-cm3 model for a) the 1 x 1climate model resolution and b) the downscaled 0.125 x 0.125 resolution.*

A.2.3 Hydrologic Modeling

The daily values of temperature, precipitation, and wind derived from climate simulations will be used to drive a land surface model. A land surface model tracks key land surface processes, such as infiltration, base flow, runoff, soil moisture and evaporation and provides gridded output of soil moisture, evaporation and runoff and can be used to quantify changes in streamflow and evaporation due to climate uncertainty (Demaria et al. 2015, 2016). This work will initially use the Variable Infiltration Capacity model (Liang et al. 1994) land surface model. The model will be run in water balance mode using the NASA Land Information System modeling framework (Kumar et al. 2006; Peters-Lidard et al. 2007). The Land Information System (LIS) provides a computationally robust framework for running land surface models, and will be implemented on high performance computing resources available to the PI Roundy's research group at the University of Kansas. Utilizing the Land Information System framework will also facilitate the integration of other land surface models, such as the Noah-MP model as the project allows. The gridded outputs from the land surface model will be used in conjunction with a hydrologic routing model that mimics the movement of water through the natural stream channels, based on

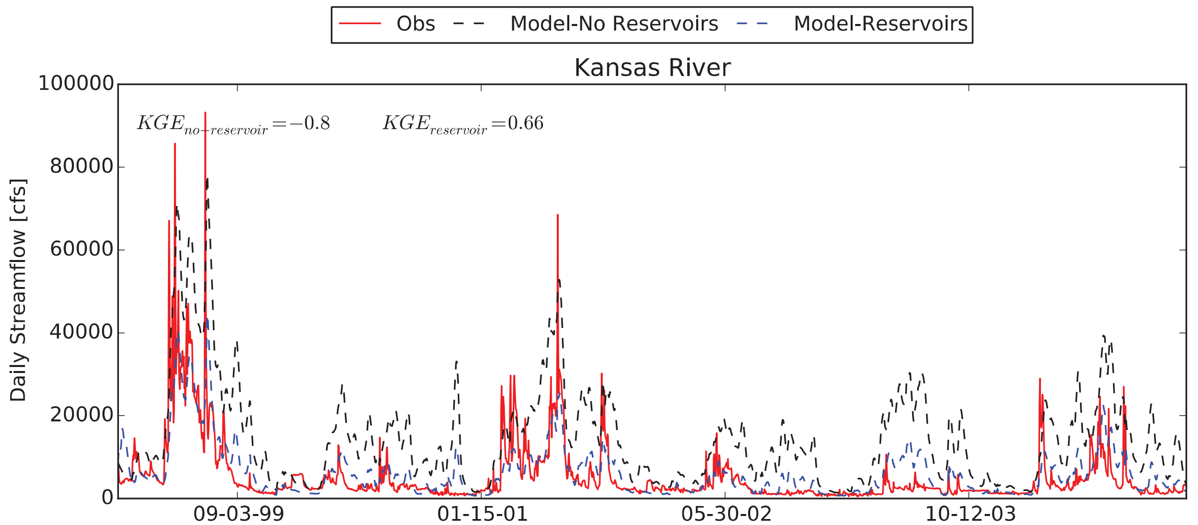

Figure 7 - *An example of streamflow from the water model with and without reservoir operations for the Kansas River. Including reservoir operations increases the KGE from -0.8 to 0.66 (A KGE of 1 is a perfect prediction), compared to USGS observed streamflow.*

topography and other stream channel characteristics. The routing model will utilize the 30 arc sec (approximately 1km) Hydrosheds topography dataset (Lehner et al. 2008) and a PI Roundy developed algorithm based on a slope-adjusted velocity parameterization based on the work of (Gong et al. 2009). Although this routing algorithm only solves continuity and not momentum, it provides a computationally efficient method that has been utilized in several hydrologic monitoring and forecasting applications (Sheffield et al. 2013; Yuan et al. 2015). This routing method also includes a simple reservoir model that accounts for the reservoir volume, evaporation and withdrawals. An example of using the routing model in conjunction with the VIC land surface model with no calibration is shown in **Figure 7** for the Kansas River near Kansas City. The improved prediction (KGE of -0.8 to 0.66, where 1 is a perfect prediction) of streamflow for the Kansas River is achieved by accounting for the 10 reservoirs upstream from the gauge near Kansas City. Both the VIC model and the routing model will be calibrated using the Shuffle Complex Evolution (SCE) optimization algorithm (Duan et al. 1992). The routing model parameter estimation will focus on the streamflow velocity parameter and the VIC parameter estimation will focus on spatially varying baseflow and infiltration parameters based on USGS streamflow gage derived gridded outputs following the technique developed by Troy et al. (2008). The calibrated model will then be validated for a separate time period focused on the low flows for the streamflow inputs needed for the KWO water allocation model. Calibrating the model setup for these inputs will ensure representative results from the hydrologic model and ensure a meaningful representation of climate uncertainty.

To provide a more robust evaluation of the land surface model predictions, we will also explore the use of the National Water Model (NWM) for generating the needed inputs to the KWO model. The NWM framework provides simulations of the hydrologic systems at 'hyper-resolutions'(Senatore et al. 2015; Yucel et al. 2015) and is based on the WRF-Hydro framework. NWM provides modularized coupling components that connect many processes, including surface runoff, channel flow, lake/reservoir flow, sub-surface flow, and land-atmosphere exchanges in a computationally robust framework. The PI's research group has extensive experience running both the LIS and WRF-Hydro modeling framework. Running both modeling frameworks will be advantageous as it helps ensure a successful outcome to the proposed work and will provide a means of assessing the uncertainty in land surface model predictions.

A.2.4 Interface with the KWO Water Model

The main aspect of the new framework is to seamlessly incorporate climate uncertainty into the KWO water allocation procedure. This will be done by using streamflow and evaporation from the hydrologic modeling based on historical and future climate as inputs into the KWO water allocation model (**Figure 8**). The inputs include streamflow at 51 locations and reservoir evaporation for 21 reservoirs. The needed data will be extracted from the hydrologic model data and converted into the required input format for the KWO water allocation model. The KWO model will be modified to allow for the automated setup and running of many input data sets to create an ensemble of historical and future scenarios used to quantify the uncertainty associated with climatic variability. As time and resources permit, the interaction between water allocation management procedures and climate will also be explored through an ensemble approach of adjusting water management practices and regulations within the water balance model (**Figure 9**). This will allow for improved determination of future water storage requirements needed to sustain environmental flows and maintain sufficient water quality within five river basins.

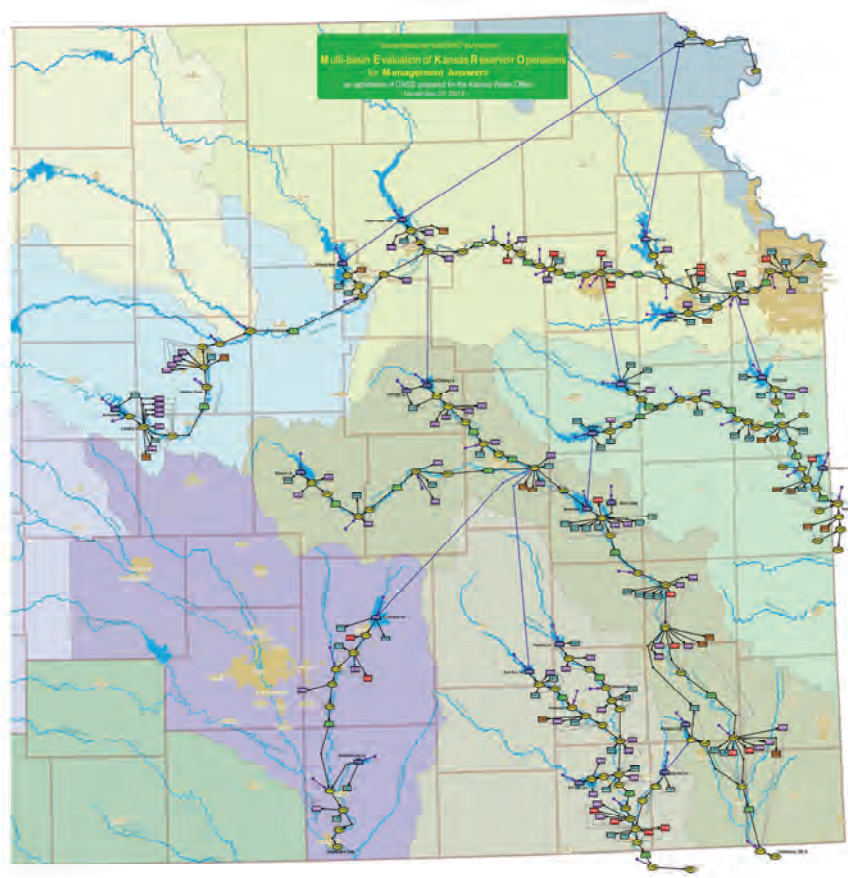

***Figure 8** - A schematic of the KWO model used to allocate water in the state of Kansas. The interface will allow model output from the hydrologic models to be used as input into the KWO model.*

Modifications to the KWO OASIS water allocation model will be conducted through a collaborative process between Hazen and Sawyer and the KWO. Hazen and Sawyer will be contracted to make programming modifications to the model framework to incorporate positional analysis mode capabilities, which will allow for efficient running of many data sets concurrently from the hydrological modeling through the water allocation model. This will drastically reduce the amount of staff time required to run the many variations of the climatic data through the water allocation model. To more efficiently receive results on how environmental flow targets are maintained, water supply shortages, and system reservoir balancing should be conducted to meet all operational constraints and supply agreements. KWO will ensure the water allocation model is remaining consistent in its following of operational constraints and conduct modifications to modeling runs to produce the most consistent analysis to comply with Kansas statutes and regulations.

Modifications will also incorporate the development of data dashboards that can be used for improved data dissemination and communication with decision makers, stakeholders, and government partners. In the past the KWO has conducted Drought Planning simulation workshops with stakeholders, the incorporation of these data dashboards and this project's climate data will further the capabilities to work with municipalities and regional groups to educate them on their potential water resource risk exposure and improve their water resource planning capabilities. The connection of the KWO water allocation model to real-time data streams will also greatly improve the capabilities and efficiencies for it to be used as a drought management and operational tool to meet all local, state, federal, and environmental water user needs.

Figure 9 *– Water supply allocations within the Kansas River Basin model that are reliant on releases of contracted reservoir during periods of low natural flow. The distribution of recent water use depicted through the alluvial corridor, highlighting the extensive irrigation development that shows increases in water use during extended drought periods. (Rockel, 2020)*

A.2.5 Probabilistic Evaluation

The uncertainty due to climate makes it difficult for municipalities, engineers, and planning agencies to prepare for and mitigate the impacts of extreme events on water resources. Decision making and design under climate uncertainty is particularly challenging, since climate impacts unfold over long periods of time and make it difficult to evaluate and validate any approach for incorporating climate uncertainty into the decision making and design process. The lack of a systematic way to develop and evaluate design and decision making under climate uncertainty results in inaction that limits resiliency to future extreme events. To help with decision making process for water allocation in Kansas under climate uncertainty a Bayesian statistical framework will be used. Bayesian statistics relies on Bayes Theorem given in one of its standard forms below.

$$P(E_j|D) = \frac{P(D|E_j) \cdot P(E_j)}{\sum_k P(D|E_k) \cdot P(E_k)}$$

The fundamental element of Bayesian statistics are probability distributions which will be defined using climate ensembles from KWO water allocation model. Bayes Theorem describes how probability distributions change as new data (*D*) becomes available. While there are many ways Bayesian statistics could be used to inform decision making under climate uncertainty, this work will develop approaches tailored to the needs of KWO and its local partners in collaboration with stake holders. For example, we will work with an ongoing watershed level study being conducted by the United States Corps of Engineers (USACE) on the Kansas River, a recently started Sustainable Rivers Project with The Nature Conservancy on the Kansas River, and several forty year water supply contracts being analyzed to meet the needs of 66% of the estimated Kansas total population in order to generate specific probabilistic metrics that meet the end user's needs.

A.2.6 Milestones

We intend to carry out the proposed research over a 2-year period (09/01/2021-8/31/2023) and expect the results of this work to persist well beyond the project time frame. Below is a preliminary

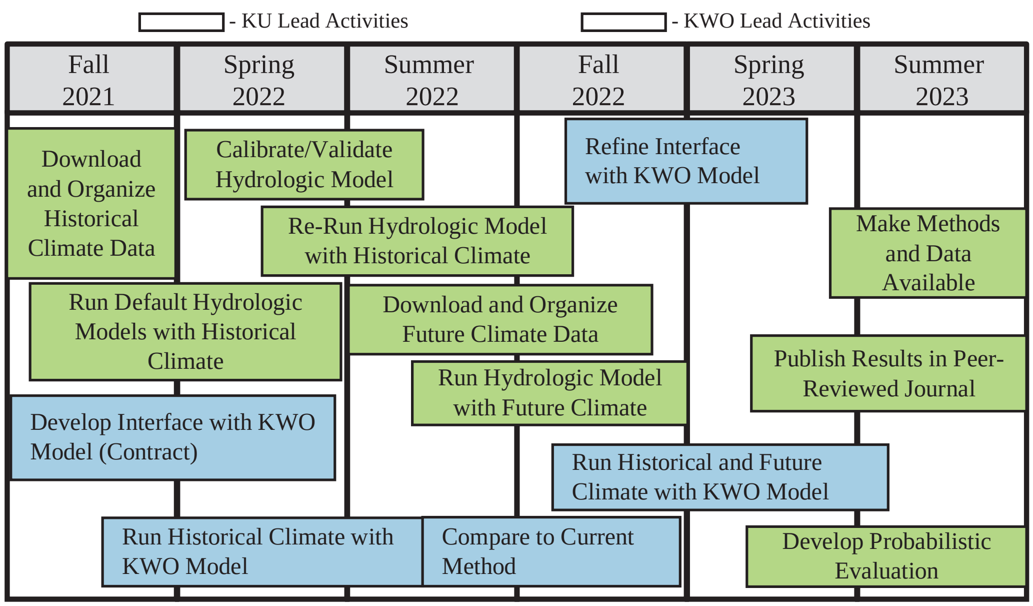

Figure 10 - *Schematic of activities and milestones for the proposed project that will ensure completion of the objectives to help ensure a more sustainable and climate resilient framework for water allocation in the State of Kansas.*

table of activities and milestones. The proposed activities and milestones will be primarily carried out by a graduate student in Civil, Environmental and Architectural Engineering with support from the project manager and Richard Rockel. An overview of the activities and tasks are shown in **Figure 10**. Activities that will be led by project manager at KU are shown in green and activities that will be led by Richard Rockel at KWO are shown in blue. This joint effort between KU an KWO utilizes the strengths of both institutions, as the project manager has extensive experience with utilizing climate data and developing, calibrating and running land surface and hydrologic models, while Richard Rockel has extensive experience with running the KWO water allocation model. To ensure coordination, collaboration and efficiency, there will be quarterly project meetings that alternate between KWO and KU to facilitate the successful completion of the proposed activities for a more sustainable and climate resilient framework for water allocation in the State of Kansas.

A.3. Project Location

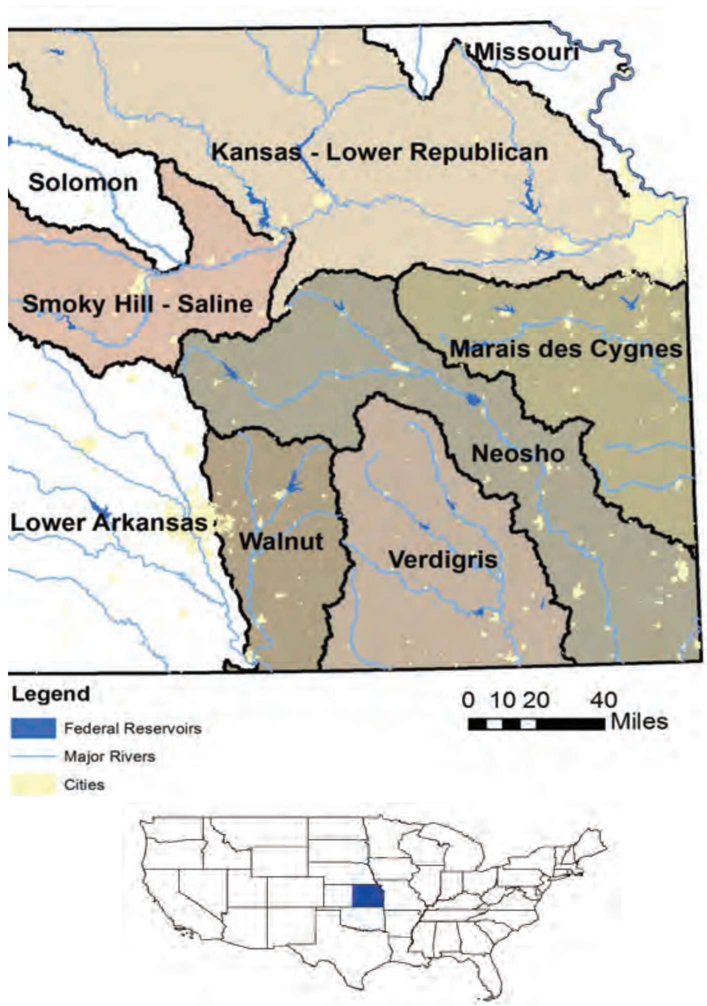

Figure 11 - *A map of the project area, which includes 6 basins and 21 federal reservoirs.*

KWO's model is comprised of six watersheds in central and eastern Kansas: Lower Smoky Hill River Basin, Kansas River Basin, Marais des Cygnes River Basin, Neosho River Basin, Verdigris

River Basin, and Walnut River Basin. Since the model at its core is a reservoir operations model, the upstream points of the basins are the large federal reservoirs. In this project, the same six basin model domain will be used, with simulated climatic data replacing historic data. A map of the project area is included below in **Figure 11**. Water supply within the project location is dominated by surface water use, the majority of which is supplied through operation of the Federal reservoirs through KWO owned water rights and administered river operational agreements. In formulating these river operational agreements, it is necessary to balance the water quantity and quality needs of all water user groups: municipal, environmental, industrial, recreational, and irrigation are all potentially impacted.

A.4. Data Management Practices

The data produced from this work consisting of the process and analysis scripts as well as the data itself, will be made freely available through the Computational Hydrology webpage (http://hydrology.faculty.ku.edu/index.html). This archiving will be done by the Program Manager, who has experience with archiving data and making it available online. This data will be made available in the last year of the project. As the climate data constitute a large amount of data, it will be stored in an organized file structure that will be well documented and composed of individual files available through ftp. The individual files will be in the netcdf-4 format following the guidelines that provide general solutions to anticipated needs of data providers, applications developers, and data services (http://www.unidata.ucar.edu/software/netcdf/papers/nc4_conventions.html). The source code for this framework will also be made available through the GitHub repository for those interested in porting these functions into a different analysis environment. Furthermore, all research data including model runs, development versions of the modules and processing scripts will be archived and made available through the research data server for a period of 10 years from the project start date. The results and finding of this work will also be published in refereed journals and presented at regional conferences such as the Governor's Water Conference and the ASCE meetings.

A.5. Evaluation Criteria

A.5.1 Project Benefits to Water Supply Reliability

1 - Water Management Issues Addressed by Project

This project will address water supply uncertainties for the state. Water users in six river systems simulated in the KWO model depend on KWO determined water supply storage based on the 1950s drought of record. This current method of determining storage need not only assumes a static climate but also only prepares users for a drought of a single set duration and magnitude. The coupling with climate model projections enables a greater understanding of future needs for storage by evaluating potential future climate scenarios and probabilistic effects. The reliability of reservoir storage during drought addressed by this project is a very severe issue for the future as the nature of the current projections could potentially leave water users unprepared for droughts of higher severity or longer duration. Potentially leaving 66% of the projected future population, much of the state's industry, growing number of irrigated acres, and environmental needs with insufficient water supplies reserved in storage for future drought events.

Furthermore, reservoir water supplies are allocated for many uses, all of which will be impacted by future climatic variability. Four of the river basins have reservoir allocations that are dedicated to maintaining minimum flow targets to provide sufficient water quality to instream biologic uses, dilute naturally occurring discharges of chlorides and sulfates, and meet river access requirements. This portion of Kansas has a cyclical short-term climate pattern, with dramatic shifts in precipitation patterns, with floods one year followed at times by several years of drought.

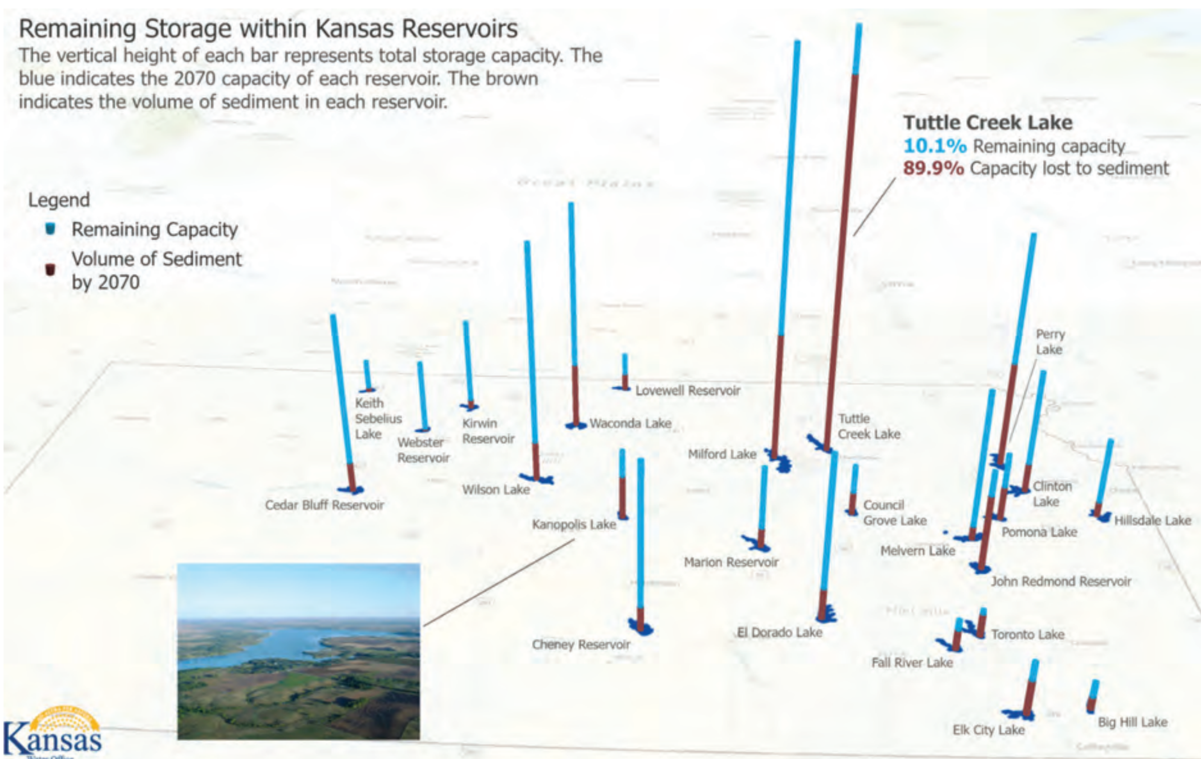

Figure 12 - *Projected reservoir capacity in 2070 due to sediment buildup in the reservoir. As reservoir storage is reduced through sedimentation, it will become more imperative to make sure there is a sufficient amount of storage to manage through future reduced flow events.*

In addition, ongoing reservoir sedimentation has dramatically reduced the reservoir storage volumes available to maintain adequate streamflow through prolonged drought events, with Tuttle Creek Reservoir having lost 48% of its original storage capacity as documented by a 2020 bathymetric survey conducted by the KWO. As reservoir storage is reduced through sedimentation, it will become more imperative to make sure there is a sufficient amount of storage to manage through future reduced flow events. As shown in the map above (**Figure 12**), future reservoir volume projections conducted by the USACE and KWO will increase the need and value of climate uncertainty being incorporated within water supply allocation modeling.

Additionally, much of the state's future population growth is projected to occur in areas that are dependent on reservoir water supplies and their efficient management. The water delivered to these communities needs to be of sufficient quantity and quality, which is managed through balancing reservoir releases through drought events. For the Kansas River basin specifically, there are additional water management issues that will be addressed by this project. With an increasing observed occurrence of Harmful Algal Blooms (HABs) in Milford Reservoir and their releasing of microcystin into public water supplies, this project will allow for improved projections of occurrence in relation to inflow, outflow, and evaporation patterns when coupled to basin level nutrient management modeling being conducted by the Kansas Department of Health and Environment and implementation of nutrient management practices through multiple river basins.

2 - How the project will address the Water Management Issues

This project will address water supply uncertainties and increase reliability by developing a framework for simulating future climate scenarios which will be used to determine necessary storage for water users. By using a probabilistic approach to determine forcing data, uncertainties in these data can be evaluated by the state and local water users in more accurately determining future need for storage. This enhanced understanding of future needs and uncertainty will aide in securing water supply reliability for the state. Furthermore, the ability of the KWO model to test future operations will allow this framework to assist in drought management activities, optimizing operations for the future climate. There are five key ways that this project will help address water management issues in the state of Kansas.

I. Completion of this project will also allow the state to better conduct water supply contracting to increase reliability and not over-allocate future reservoir water supply storage, which would create water supply vulnerabilities and reduce drought resiliency for several million Kansans. With several municipalities looking at long-term conjunctive water use planning strategies, this project may give advanced information to research and acquire alternative supplies through groundwater water rights and other sources.

II. For Clinton Reservoir and Hillsdale Reservoir, there are multiple rapidly growing municipal users looking to expand their water use from each reservoir through water marketing contracts. Both of these reservoirs are shown to have a watershed with a higher historic probability for multiple drought years between refilling events. Completion of this project will allow for modifications of future reservoir yield calculations in water marketing activities to increase drought resiliency.

III. The ability to calculate the needed Water Quality reservoir allocations through future climatic scenarios will be greatly improved, leading to significantly improved future forecasting abilities to size reservoir storage agreements and manage reservoir releases.

Providing benefits to many human and biological needs across a large portion of the state, in several of the river basins there are multiple fish and mollusk species of concern for conservation and several threatened mollusk species that are very negatively impacted from reduced water quality and low flow events.

IV. As a state with an extensive system of water rights following the Prior Appropriation Doctrine of the West, the completion of this project will provide more tools to protect against creating an environment of over appropriation, potentially reducing the future need for strict water rights administration to meet senior water right needs.

V. Additionally, downstream interest groups within the states of Missouri and Oklahoma may benefit from sufficient water quality flows in future climatic conditions, allowing for increases in watershed health with sufficient water use allocations formed through incorporation of climatic uncertainty.

3 - Extent the Project will Benefit the Water Management Objectives

The proposed project will have a significant extent and benefit to water supply reliability by providing local water managers with the tools they need to make decisions based on climate uncertainty. These climate-based decisions will ensure continued reliability of water sources by ensuring that water is not over allocated which can lead to a future water crisis that leaves communities without water and increased need to conduct water right administration activities on users. With the findings from the project being incorporated into the analysis of 40-year water supply contracting agreements, there is significant potential for these outcomes to positively impact multiple water management issues for the people of Kansas.

Additionally, the modifications to the KWO water allocation model will allow connection to real time water resource condition data (USGS gage network, USACE reservoir data), which when coupled to the climatic projection data will allow for a greatly improved drought management operational modeling tool with probabilistic forecasting capability. Giving water managers, emergency managers, and local governments a significant improvement in water supply projection capabilities and operating available reservoir storage to increase water supply reliability. The incorporation of climatic uncertainty data with a drought management operational model will allow more time and notice for municipalities to message and implement drought conservation plans and water management messaging to concerned stakeholders, to greatly increase the extent of drought management activities and public outreach.

4 - How the Project Complements Ongoing Projects

Modeling has been ongoing in the six basin model domain for several decades, either through simple spreadsheet yield models or through the current KWO model. In all cases, historical data has been used to determine water allocations for the future. Fortunately, this method of determining and allocating storage space has not been significantly tested since the last major multi-year droughts have occurred in the 1930s and 1950s, before the majority of the reservoirs containing the state's water supply storage were built. This project sets the ground work for a new means of evaluating and determining necessary water supply storage by evaluating a number of future climate scenarios. Below are six examples where this work will complement ongoing projects and help ensure water sustainability for the state of Kansas.

I. Specifically, the KWO model is currently used for a number of major projects for determining water storage requirements for municipalities, industry, and irrigation including three basin-wide water assurance districts (Kansas River Water Assurance District, Cottonwood and Neosho River Water Assurance District, and Marais des Cygnes River Water Assurance District) made up of municipalities and industry in the three river basins. The three water assurance districts have relatively static demands but all contain integral water supply reservoirs that are dealing with rapid sedimentation and loss of storage (Tuttle Creek Lake in the Kansas basin, John Redmond Lake in the Neosho basin, and Pomona Lake in the Marais des Cygnes basin). This loss of storage means the basins are rapidly approaching insufficient storage for the 1950s drought conditions but it is unknown if they will be sufficient for future droughts.

II. Wolf Creek Nuclear Power Plant is dependent on reservoir releases and storage allocations for maintaining an adequate amount of cooling water. As the reservoirs that this critical energy generation facility is reliant on are impacted by sedimentation, it is imperative that future climatic variables be incorporated into the analysis of its next long-term water supply contract to reduce the potential of drought related water scarcity impacting electrical generation reliability. Wolf Creek uses storage from John Redmond Reservoir to supply the cooling lake for the nuclear power plant. Modeling of the 1950s drought indicates that by 2023 John Redmond will be insufficient to supply all the necessary storage in severe drought but it is unknown the required storage in future climatic conditions and current analysis is incorporating the usage of additional reservoir resources.

III. The Lower Smoky Hill Access District made up of the growing city of Salina and increasing downstream irrigation interests contracts with the KWO to use storage from Kanopolis Reservoir for their water supply needs. Needs that will be impacted by future prolonged low flow climatic events and chloride discharges from underlying aquifers, necessitating that a sufficient amount of reservoir water supply is held in reserve to meet water quality and environmental needs, in addition to the growing water quantity needs.

IV. Elk City Lake in the Verdigris River basin supplies Coffeyville Resources oil refinery along with multiple municipalities, this river basin is projected to have insufficient storage given their current operations by 2041. Enhancing the KWO model in this project will allow for the evaluation of current and future potential operations (already contained in the model) for the future climate. Additionally, there is a municipality that has had some recent water emergency declarations to curtail water usage as it has insufficient water resources secured, this project will help the rural community plan their water future and increase drought resiliency.

V. For the Kansas River basin there is an alluvial groundwater flow model being developed by the Kansas Geological Survey, this project will significantly complement future river flow calculations and water supply management as the alluvial model is incorporated into the KWO model with this climate uncertainty data.

VI. Finally, Clinton Lake and Hillsdale Lake supply large local entities and represent instances where the entire reservoir yields determined by the 1950s drought are already contractually committed. For these lakes, it is extremely important to determine future water supply storage not only for the state's contractual agreement but to ensure the municipalities supplied by the lakes have sufficient storage for future drought and that sufficient water supplies can be procured.

A.5.2 Need for Project and Applicability of Project Results

1 - How the Project Meets an Existing Need Identified by a Water Resource Manager

The Kansas Water Office serves as a water resource manager and wholesale water supplier for municipalities, industry, and irrigators in the eastern half of the state of Kansas. Within KWO there has long been a desired to gain a better understanding of the magnitude and recurrence interval of a 1950s style drought. This project allows KWO to understand how this drought of record will compare to potential future drought periods. Furthermore, members of the state's water assurance districts, which purchase storage from the state and ensure water supply in drought periods for 3 major river basins in eastern Kansas, have expressed the need to have some estimation of uncertainty or a range of possible storage needs rather than the single historically estimated value. (letter of support attached) As such, KWO has an immediate need and is committed to fulfillment of this project. The results of this project will be immediately used to help inform water resource management decisions upon completion of this project and validation of results.

In addition, the results of this project will cover river basins in which the state has a reservoir water supply contract interest, it would be available to do expansion of this work to incorporate additional users and river basins that are currently outside the state's contracting purview to conduct water supply planning. The KWO is responsible for developing and implementing the state of Kansas Water Plan, as such the incorporation of future climate data into the development the Kansas Water Plan would be a potential path to transfer the methodologies developed in this project to other users and locations.

Furthermore, this project is being supported by Category A (Kansas Water Office – state of Kansas statutory water planning and marketing agency) and Category B (University of Kansas – state research university) applicants, so this project will serve the primary beneficiary involved in planning and implementing water resource policy.

2 - Applied Science Tools of the Project

The results of the project will be used in addition to or replace the current methodology of using the historic 1950s drought as the metric of drought tolerance. Results from the KWO-CMIP5 model will be used for the six river systems simulated currently in the KWO model to inform the state's water resource planning and management as well as the local districts and water users. Successful completion of the project will allow for immediate use and application of the results to assist in water management in the six river systems. Because of the large scale of the project and versatility of the KWO model, additional water users within the model domain can be easier accommodated after the project is completed. The methods and model modifications developed for the project could also be applied to other locations in the future. KWO will be directly involved in the planning and implementation of the project by collaborating in the model coupling and ensuring climatic model accurately represents severe drought conditions forcing the model.

A.5.3 Project Implementation

1 - Project Objectives

The objective of this project is to work with KWO to include climate uncertainty into the water allocation procedure in Kansas. An overview of how this will be done is given in **Figure 1b**. The completion of this objective is based on the successful implementation of four key components including, 1) quantify climate uncertainty using historical climate and climate projections from state of the art climate models, 2) use a hydrologic modeling framework to estimate the uncertainty in streamflow and evaporation due to climate uncertainty, 3) modify the existing KWO water allocation model to use an ensemble of streamflow and evaporation inputs, and 4) quantify the uncertainty in future water allocations due to climate based on a Bayesian probabilistic framework. The historical and future climate uncertainty will be accounted for by developing data sets of temperature, precipitation and wind based on observed gridded data, historical and future projects from climate model simulations from CMIP5 (more details can be found in section A.2.2). The variables will be used to quantify the climate uncertainty and to drive the VIC hydrologic model and produce streamflow and evaporation estimates for the different climate scenarios. The modeling component will also include calibration and validation of the streamflow from the model against observed streamflow from the USGS (more details can be found in section A.2.3). The outputs from the hydrologic modeling objective will then be used to evaluate climate scenarios for water allocation in Kansas using the KWO model. The challenge in doing this analysis will be to transform the outputs from the hydrologic modeling objective to a format that can be used by the KWO model and facilitate the running of thousands of ensemble members. This will be done by automating the process by modifying the KWO model to incorporate positional analysis mode as developed by Hazen and Sawyer for OASIS modeling framework. The final objective is to use the output from water allocation model under different climate scenarios to develop a probabilistic framework for evaluating climate uncertainty on water allocation in Kansas. This will be done by using a Bayesian Framework to quantify the uncertainty in water allocation in collaboration with local users (more details can be found in section A.2.5).

2 - Work Plan

The projects objectives will be completed according to the schedule given in **Figure 10**. The schedule is broken up into Fall, Spring and Summer periods and the primary advisor of the work (KU or KWO). Most of the work done by the student with KWO will be done remotely, but as needed the student will make the short trip to the KWO office and work with KWO directly. In Fall of 2021, the work will focus on downloading and organizing the climate data, getting the hydrologic model running and comparing the model output with observations. At the same time, KWO will work with the contractors to update the OASIS modeling framework so it can run in ensemble mode. In Spring of 2022, the work will focus on setting up the interface between the hydrologic model outputs and the KWO water allocation model and compare the outputs to the current methods for water allocation. This work will be done primarily be done at KWO. In Summer 2022 and Fall 2022 the work will focus on calibrating the hydrologic model, running the historical and future climate scenarios, and organize and evaluate the model outputs. This work will primarily be done at KU. Fall of 2022 and Spring of 2023 will also be spent working with KWO on running all of the climate scenarios with the water allocation model and will utilize the high performance computing available at KU. The last period (Summer 2023) will focus on completing the probabilistic framework, writing up the results for publication, and making the data and codes publicly available.

3 - Availability of Existing Data and Models

The climate data including the historical observations, historical climate and future projections are freely available at (ftp://gdo-dcp.ucllnl.org/pub/dcp/archive/cmip5/loca). The NASA LIS framework is freely available at (https://lis.gsfc.nasa.gov) and is already setup to run at KU. Computational resources to process the data and run the hydrologic model will be available through Dr. Roundy's research group, including priority access to seven computer nodes, with 24 to 40 cores each, 128 GB of memory per node and 6 TB of global high-performance storage. In addition to priority access nodes, the needed computations can leverage an additional 1400 general-access cores as a computational resource. Dr. Roundy's research group also maintains a data server with 30TB of data storage and research file storage for efficient access, proper management, and ideal security for project-generated data. These resources will be sufficient for fulfilling the stated research and education objectives.

4 - Project Team

The project team consists of Dr. Joshua Roundy at KU, Richard Rockel at KWO and a graduate student in Civil Engineering at KU to be determined later. Dr. Roundy has extensive experience with hydrologic, land surface and coupled regional climate modeling (Roundy et al. 2018; Chaney et al. 2015; Yuan et al. 2015, 2013). He also has extensive experience in working with large data sets for data analysis in hydro-climatology (Roundy and Santanello 2017; Roundy et al. 2015, 2013). Dr. Roundy has also taken part in similar projects that have used climate models for evaluation of the hydrologic cycle (Demaria et al. 2016, 2015). Richard Rockel has extensive experience working with the KWO water allocation model, water resource management needs across the state, and water allocation contracting ability. The graduate student will be selected for this project based on their interests, computational abilities, and commitment to work on the project for the next two years. Potential students that meet the selection criteria will be identified from a list of graduate students interested in water research. The student will be mentored by Dr. Roundy during the academic year and by Richard Rockel during the work at KWO. Dr. Roundy has extensive experience mentoring students through the completion of research projects. The project team will be capable of proceeding with the proposed tasks immediately upon entering into a financial assistance agreement.

5 - Description of Generated Products

The proposed project will generate water allocation scenarios based on climate uncertainty that can be used by local water managers for planning purposes. This data will be delivered in a way that best supports the decision making planners and will be flexible to accommodate different needs. The proposed work will also produce at least one publication in a relevant journal led by the graduate student. This will provide a unique opportunity for the student to develop themselves as a researcher and set them up for a productive career in water resources management.

A.5.4 Dissemination of Results

1 – Dissemination of Results

As a state planning agency, the Kansas Water Office works directly with local water managers and users. By including changes in climatic conditions and uncertainty in the model output, it has the potential to benefit all users for the model from general basin wide planning to assessment of storage needs to local water users and districts which include municipal, industrial, and irrigation water users. This project has the potential to vastly improve the quality of information provided to local stakeholders and decision makers and lead to more informed decision making. The dissemination of the results will be done primarily through four key methods as described below.

I. The KWO administers Regional Planning Advisory Committees for the six concerned river basins. Each of these committees includes representatives from many of the impacted stakeholder groups and will be the first path for dissemination of these results through presentations at the regular committee meetings. These committee representatives will then be able to use these results to modify their regional water resource management goals to more accurately anticipate future resource conditions and variability. Additionally, these committee meetings will serve as an efficient platform to communicate to recreational and industrial interest groups.

II. At least one climate variability impacts to water resources webinar will be conducted through the Water in Kansas Webinar Series, which will allow for an overview of findings on multiple basins. It is anticipated that as additional data requests are received, more individual basin focused webinars will be conducted and tailored to a specific basin's river operational constraints and user needs.

III. This project will have a presentation and/or student research poster at the "Governor's Conference on the Future of Water in Kansas", which has historically drawn over 600 participants from many water resource user and research groups. This conference is organized by the KWO and will be an efficient means to disseminate the results to a very diverse impacted audience in the State of Kansas.

IV. The ongoing Kansas River Watershed study being conducted by the USACE on USACE and BOR federal reservoirs in Kansas and Nebraska will be an additional outlet for disseminating the results, allowing for more incorporation of future climatic variability into federal level water supply planning initiatives. (letter of support attached)

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B. Project Budget

B.1. Funding Plan and Letters of Funding Commitment

The non-Federal share of the project costs will be obtained through cost sharing from the University of Kansas and the Kansas Water Office. The University of Kansas cost share will be made through academic time commitment for the Project Manager. The Kansas Water Office will contribute to the cost share through salary and fringe for one employee to work on the project as well as funds to upgrade the OASIS modeling framework through a contract with Hazen and Sawyer.

B.2. Budget Proposal

BUDGET ITEM DESCRIPTION	COMPUTATION		Quantity Type	TOTAL COST
	$/Unit	Quantity		
Agency Requested Funds				
Salaries & Wages				
Josh Roundy, PI	$ 10,477.00	1.04718	month	$ 10,971
Graduate Student (at 50% time)	$ 4,060.00	15	month	$ 30,450
Fringe Benefits				
Full-Time Employee	0.37	$ 10,971	percentage	$ 4,059
Part-Time Employee	0.07	$ 30,450	percentage	$ 2,132
Tuition				
Tuition for Graduate Student				$ 13,357
Travel				
Domestic Travel	$ 1,000	2	trip	$ 2,000
Supplies and Materials				
Research Materials & Supplies				$ 400
Contractual				
Kansas Water Office (KWO)				$ 3,741
Other				
Computational Resources				$ 2,000
Indirect Costs				
MTDC-51.5%	0.515		percentage	$ 28,712
Total Agency Requested Funds				**$ 97,822**
Matched Funds				
University of Kansas (PI Salary)	$ 10,477.00	1.7551	month	$ 18,388
University of Kansas (PI Fringe)	0.37	$ 18,388	percentage	$ 6,804
University of Kansas (Associated F&A)	0.515		percentage	$ 12,975
Kansas Water Office Salary	$ 5,331.73	6	month	$ 31,990
Kansas Water Office Indirect	0.1334		percentage	$ 4,269
KWO Contract with Hazen and Sawyer				$ 23,400
Total Matched Funds				**$ 97,826**
TOTAL ESTIMATED PROJECT COSTS				**$ 195,648**

B.3. Budget Narrative

1. Senior Personnel

Dr. Joshua Roundy, Project Manager (0.52 summer months requested and 0.88 academic months cost-share per year in years 1-2), will lead and organize the project and serve as the main advisor to the graduate student. Advising will include facilitating the development of the students' research, computational, and data analysis skills to enable the fulfillment of the stated objectives. The student will be mentored through their academic degree and preparing them for the next step in their career. The PI will also be responsible for ensuring that the code and data from this project are available through the research group's website. Senior personnel salary increases at 3% annually for a total over the two-year project of **$29,359** ($10,971-Agency, $18,388-Cost Share).

2. Other Personnel

Graduate Research Assistant: Funds are requested for a total of 15 months of GRA support at 50% effort throughout the project. Graduate Research Assistant salary escalates 3% annually. It is anticipated that the GRA will fund a Master's student during the project. The graduate student will participate in various research tasks related to the project and will work closely with Dr. Roundy and Richard Rockel on generating the climate inputs to KWO model and disseminating the results to end users. This approach will not only benefit the project, but will provide a unique opportunity for the graduate student to work with KWO and others in the community to kick start the student's career. This work will also serve as the basis for the student's Masters theses. Total cost over two-years is **$30,450** ($30,450-Agency, $0-Cost Share).

3. Fringe Benefits

Fringe Benefits are calculated at a rate of 37% for faculty and postdoctoral researchers and at a rate of 7% for graduate and undergraduate students working less than 75% FTE. Total cost over two-years is **$12,995** ($6,191-Agency, 6,804-Cost Share).

4. Equipment

No equipment is requested.

5. Travel

Annual travel expenses are requested for the PI and student to attend a regional annual Professional Conference to present the proposed work. This travel will occur in both years 1 and 2 and will include 2 domestic trips that last 2 days with estimated costs of $100 for transportation, $150 for lodging, $50/day per diem, and $200 for registration and abstract fees for a total of $500 per trip per person. Lodging and Per Diem will follow the Current GSA/CONUS rates at time of travel. All other estimates are based on the PI's past travel experience. Attendance at these regional meetings will provide an opportunity to disseminate the proposed research and collaborate with others to ensure continued development and relevance of the project. We will target meetings like the Governors Water Conference and regional meetings of ASCE. The proposed travel is not only important for the dissemination of the proposed work, but will provide an essential opportunity for the program manager and students to advance their careers through networking and serving on committees. Total travel request over two years is **$2,000** ($2,000-Agency, $0-Cost Share).

6. Other Direct Costs

Materials and Supplies: A nominal amount of $200 is requested annually to cover basic supply expenses. This estimate is based on the PI's experience of typical research expenses occurred during a year. Total two-year cost is **$400** ($400-Agency, $0-Cost Share).

Research Computations and Storage: Funding of $1000 per year is requested to maintain the computational and storage requirements of the proposed work. This amount includes the cost of continued priority access to the KU Advanced Computing Facility, maintenance of a data server and research file storage for efficient access, proper management and ideal security for project generated data. A total two year cost of **$2,000** ($2,000-Agency, $0-Cost Share).

Tuition: Funding is requested for each year to pay for tuition for the Graduate Research Assistants as required by the University of Kansas. Tuition is listed at the rates approved by the University of Kansas Registrar's Office. Total Tuition request over five years is **$13,357** ($13,357-Agency, $0-Cost Share).

7. Subaward – Kansas Water Office

A subaward for the Kansas Water Office is requested to cover contract and personnel cost for the agency to implement the proposed changes to their water allocation system. This includes cost to upgrade OASIS KWO model by Hazen and Sawyer ($23,400), salary and fringe for Richard Rockel at the Kansas Water Office to work on the project during the two years ($36,259) and funds to upgrade the model dashboard ($3,741). The total two-year cost for the Kansas Water Office sub-award is **$63,400** ($3,741-Agency, $59,659-Cost Share).

8. Indirect Costs

Indirect costs are calculated @ 51.5% of modified total direct costs (MTDC), where MTDC equals total direct costs excluding equipment, participant support costs, tuition and subcontracts in excess of $25,000. This rate was determined by the indirect cost rate agreement negotiated with DHHS for The University of Kansas Center for Research, dated March 22, 2016. Total indirect cost over the two-year project is **$41,687** ($28,712-Agency, $12,975-Cost Share).

Total Project Cost: $195,648

Total Cost Share: $97,826

Cost Share-KU: $38,167
Cost Share-KWO: $59,659

Total Requested Cost: $97,822

C. Environmental and Cultural Resources Compliance

There is no Environmental and Cultural Resource Compliance for the proposed project.

D. Required Permits or Approvals

There are no required permits or approvals for the proposed project.

E. Letters of Support

Kansas Water Office

900 SW Jackson Street, Suite 404
Topeka, KS 66612

Phone: (785)-296-3185
Fax: (785)-296-0878
www.kwo.ks.gov

Connie Owen, Director

Laura Kelly, Governor

April 19, 2021

Joshua Roundy
University of Kansas
1530 W. 15th
2150 Learned
Lawrence, KS 66045

Dear Josh,

This letter will confirm that the Kansas Water Office (KWO) will provide $59,659 worth of Cost-Share for the project titled *Incorporating Climate Uncertainty into Water Allocations in Kansas* over the proposed two-year project timeline (2021 – 2023). This project would be funded under a WaterSMART – Applied Science Grant, Funding Opportunity Announcement number R21AS00289.

KWO is excited to be partnering with the University of Kansas on this project that could have a significant impact on water allocation in the future.

Sincerely,

Connie Owen
Director

900 SW Jackson Street, Suite 404
Topeka, KS 66612
Connie Owen, Director

Kansas
Water Office

Phone: (785)-296-3185
Fax: (785)-296-0878
www.kwo.ks.gov
Laura Kelly, Governor

April 19, 2021

Bureau of Reclamation
Water Resources and Planning Division
Attn: Ms. Avra Morgan
P.O. Box 25007, MS 86-69200
Denver, CO 80225

RE: Letter of Support for Incorporating Climate Uncertainty into Water Allocations in Kansas

Ms. Morgan,

The Kansas Water Office is looking forward to partnering with the University of Kansas on the proposed *Incorporating Climate Uncertainty into Water Allocations in Kansas* WaterSMART Applied Science grant project. We feel this project has far reaching implications on the future of water management in our state and will meet the needs identified by water users in multiple river basins within the state of Kansas.

This project has direct applications to water management as the state looks to expand the incorporation of future climate and development scenarios into long-term water supply planning initiatives, while increasing its drought resiliency and drought management toolbox for a significant portion of the future Kansas population. This collaborative project will advance water supply planning initiatives for multiple regions of the state that are projected to have increasing water demands and increasing climate variabilities, allowing for improved planning, management, and marketing to meet water quantity and quality needs.

Thank you,

Richard Rockel
Water Resource Planner – Technical Lead
785 296 0876

Kansas Water Office
900 SW Jackson, STE 404
Topeka, KS 66612
www.kwo.ks.gov

The Kansas River Water Assurance District No. 1

212 SW 7th Street - Topeka, Kansas 66603-3717

April 16, 2021

Re: Support for a grant on "Incorporating Climate Uncertainty with Water Allocations in Kansas"

> This letter is to express support for the University of Kansas and the Kansas Water Office (KWO) application for the Bureau of Reclamation WaterSMART Applied Science grant titled "Incorporating Climate Uncertainty with Water Allocation in Kansas".

The Kansas River Water Assurance District No. 1 (KRWAD No. 1) is a joint-action, non-profit corporation established under the authority of the laws of Kansas, K.S.A. 1986 Supp. 82a-1336 to 82a-1369, (the Act). The Act requires eligible water right holders to be members of a water assurance district. The purpose of the district is to allow coordinated operation of state-owned or controlled water storage space in Federal reservoirs, within a designated basin, to satisfy downstream municipal and industrial water rights during drought conditions. The KRWAD No. 1 purchased storage in three Federal reservoirs within the Kansas River Basin through direct purchases exceeding eight million dollars. Incorporating a climate specific model into the existing KWO OASIS model to monitor future climate related impacts and help project storage requirements under various climate specific scenarios is important to our members.

Therefore, KRWAD No. 1 supports this grant request to Incorporate Climate Uncertainty with Water Allocations in Kansas into the KWO's OASIS model.

Mike Lawless, PE
President
Kansas River Water Assurance District No. 1

Phone - 232-9947 • Fax - 232-1922

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, KANSAS CITY DISTRICT
635 FEDERAL BLDG
601 E 12TH STREET
KANSAS CITY, MISSOURI 64106-2824

Planning, Programs and Project Management Division
Planning Branch, Formulation Section

March 19, 2021

Subject: Letter of Support for U.S. Bureau of Reclamation WaterSmart Applied Sciences Grant

The Kansas City District, U.S. Army Corps of Engineers (USACE) is providing this letter of support to the Kansas Water Office for their application for the U.S. Bureau of Reclamation WaterSmart Applied Sciences Grant. The Kansas City District, USACE is partnering with the Kansas Water Office to conduct the Kansas River Reservoirs Flood and Sediment Study (Watershed Study).

The Watershed Study will investigate water and related land resource issues and opportunities in the Kansas River Basin to recommend comprehensive, long-term, and sustainable water resource solutions and management based on a Shared Vision for the basin. These long-term solutions may include recommendations for potential involvement by the USACE, other federal agencies, or non-federal interests.

Significant need and opportunities exist in the Kansas River Basin to develop hydrologic information and water management tools and improvement of modeling and forecasting capabilities. These projects will provide better accounting for uncertainty, and accommodate the concepts of adaptive management, stakeholder collaboration, and systems analysis for watershed-scale planning and evaluation. The incorporation of future climate scenario data would be beneficial to the continuation of the Watershed Study and the recommendations for future water supply and quality needs of the Kansas River system.

Should you have any other questions; please contact Laura Totten at 816-389-2137 or by way of e-mail at Laura.A.Totten@usace.army.mil.

Sincerely,

Laura Totten

Laura Totten
Planner/Project Manager, Planning Branch

F. Official Resolution

KU CENTER FOR .ESEARC.H INC.

The University f Kansas

April 20, 2021
Bureau of Reclamation e
Denver Federal Center
6th Avenue & Kipling St. e
Denver, CO 80225 e

To Whom It May Concern: e

The University of Kansas Center foe Research, Inc. eas eeviewed and approved the proposal entitled e "***Incorporating Climate Uncertainty into Water Allocations in Kansas***" submitted under the direction of Dr. e Joshua Roundy to the U.S. eDepartment of the Inteeior. eThe approved budget reflects a total federal request of $97,822. Cost Share commitments totaling 50% of the total project cost are provided by the University of Kansas e ($38,167) and the Kansas Water Office ($59,659) for the project duration of 09/01/2021 to 08/31/2023. e

The University of Kansas Center foe Research, Inc. es a non-profit organization affiliated with the University of Kansas, and handles the administrative and financial functions of geants foe the university. e

- e I am the authorized official to sign grant applications, awards, contracts, and agreements for The University of Kansas and the University of Kansas Center for Research, Inc.;e
- e I am the appropriate official who eas eeviewed and supports the application submitted;
- e The University of Kansas has the capacity to provide the in-kind contributions specified ie the fundinge lan; ande
- e The University of Kansas Center for Researche Inc., will work with Reclamation to meet established deadlines for entereng into a grant or cooperative agreement once an award has been made.e

Should this e oposal eesult in an award, please direct all payments to the following address: e
University of Kansas Center for Research, Inc.
Accounting Services e
2385 Irving Hill Road e
Lawrence, KS 66045-7552 e
EIN: 48-0680117 e
System foe Award Management (SAM) Status: *Active*. Expiration Date: e*02-23-2022*

Sincerely, e

Alicia M. Reed
Director, Research Administration e

Youngberg Hall
2385 Irving Hill Road
Lawrence, KS 045
785-864-3441 phone
research.ku.edu