Nature Based Climate Solution in Tribal Nations via Efficient Mapping and Modeling of Wetlands and Small Waterbodies

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Executive Summary

October 17, 2023

Dr. Adnan Rajib
University of Texas at Arlington
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The applicant (Category B) is proposing this project in partnership with the Blackfeet US Indian Reservation in Montana (Category A). The project also involves task-specific collaboration with the US Fish & Wildlife Service who will participate as the project's Technical Advisor.

Traditional projects of Nature Based Climate Solutions (NBCS) for drought management are often limited to utilizing wetland/riparian storage in small watersheds or site specific-scales. An efficient data and model-driven framework to potentially use most of the natural infrastructures on the landscape for water storage, especially in the rural western US communities, does not exist. **The main goal** of this project is to overcome this limitation and enable the Blackfeet Reservation to **harness water storage capacities of "potential" natural infrastructures – including existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies, and therefore maximize the beneficial use of surface waterbodies as effective and sustained NBCS against future drought hazards.** Specifically, by mapping and modeling the entire 7,800 km^2 area of the Blackfeet Reservation, this project will equip watershed managers and stakeholders with a user-friendly decision support tool, and demonstrate practical applications and broader impacts of the tool by performing four objectives: (1) map location and estimate surface area and water storage capacities of these natural infrastructures using the latest available remote sensing data, topography, field observations, and widely used artificial intelligence technique, (2) incorporate these storage capacities in a hydrologic model to quantify their cumulative drought reduction benefits under future climate projections, (3) run model scenarios of loss and conservation, and from thereon locate areas within the Reservation where implications of conserving these natural infrastructures on water supply reliability would be more significant. Finally, (4) this project will **conduct a series of onsite training activities aiming towards a seamless transition and application of the proposed tool in stakeholders' watershed management and decision-making workflows**. By addressing these critical needs, the proposed project will demonstrate how a Tribal Nation workforce equipped with next-generation data and modeling capabilities can implement NBCS for improved water supply reliability, climate resilience, and environmental justice.

This project will directly support all three Presidential and Department of the Interior priorities. Specifically: (1) **Climate Change**: the project's overarching goal to equip stakeholders with NBCS will improve drought management under future climate projections. (2) **Disadvantaged or Underserved Communities**: The applicant – University of Texas at Arlington is the largest Hispanic Serving Institution in Texas. More importantly, the project's Category A partner – the Blackfeet US Indian Reservation in Montana is widely known for its limited resources to combat climate change. Thus, the federal funding awarded to this project will directly benefit disadvantaged or underserved communities across two US states. As an immediate effort to ensure this, the project commits to recruit Blackfeet and Hispanic female undergraduate and graduate students as Research Assistants. Finally **(3) Tribal Benefits**: the project is based on a strong partnership with the Blackfeet Reservation and is geared fully towards their improved climate resilience and workforce development.

This project fulfills the requirements of three eligible project types as noted in Bureau of Reclamation's Notice of Funding Opportunity – section C.4.2. Specifically, this project strongly aligns with **Eligible Project Type 1 and Type 3 (Modeling, Nature Based Solutions Decision Tool)** as it proposes to enhance existing modeling capabilities by showing how to incorporate natural infrastructures in hydrologic models, assist in the application of NBCS in landscape-scale, and provide stakeholder training on the use of these new capabilities for improved water supply reliability. This project also aligns well with **Eligible Project Type 2 (Data)** as it proposes to develop, for the first time, a dataset including location, surface area, and water storage capacities of potential natural infrastructures (existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies) in the Blackfeet Reservation. In addition to its functionality of mapping and modeling potential natural infrastructures for drought management, a unique feature of the project's methodology lies in its **flexibility and reproducibility** which will allow stakeholders to perform the proposed tasks at different spatial scales for any other region with minimal effort.

The proposed work will be conducted at non-federal facilities in Texas and Montana while some data interpretation and publication work may be conducted at federal facilities of US Fish & Wildlife Service. Federal funds are primarily being requested to support personnel for model/tool development tasks and to organize training workshops for stakeholder outreach and project dissemination. Non-federal cost-share contributions are committed by the applicant organization - the University of Texas at Arlington. The work described in this proposal will be conducted over the course of 24 months and completed no later than September 2026.

1. Technical Project Description

1.1 Applicant Category

The applicant University of Texas at Arlington (**Category B**) is proposing this project in partnership with the Blackfeet US Indian Reservation in Montana (**Category A**) and includes US Fish & Wildlife Service as the project's Technical Advisor. The Blackfeet Reservation is the largest Indian Tribe in Montana and one of the ten largest federally recognized Indian Tribes in the US (see Nature Conservancy, 2023). This proposal includes a letter from the Blackfeet Reservation that clearly states: the Reservation is acting in partnership with the University of Texas at Arlington, agrees to the submittal and content of the proposal, commits to participate in the project coordination efforts, facilitate model evaluation tasks, and host stakeholder workshops.

Importantly, the **letter of partnership is based on the approval of the Blackfeet Tribal Business Council – the tribal government responsible for policies of the Blackfeet Reservation** (see Blackfeet Nation, 2023), which confirms the Category A eligibility criteria. Given the theme of this proposal (Nature Based Climate Solutions), the council has appointed Blackfeet Environmental Office (BEO) to support the tasks mentioned in the letter. BEO is the designated office under the tribal council that has a Wetlands Division and a Climate Change Division with authorities to monitor, conserve, and restore wetlands and other natural landscape features, and implement climate action plans.

1.2 Why is this Project Needed?

Megadroughts are threating water supply reliability in the Western US – the drought during 2000-2021 period was arguably the worst in 1200 years (Williams et al 2022) and the 2021 SECURE Water Act Report suggests that duration, severity, and frequency of droughts will continue to

increase in future years (USBR 2021). While US Bureau of Reclamation's (USBR) comprehensive efforts to *"help the west adapt to drought and climate change"* is widely acknowledged (Benson 2012), these efforts have been focused on new water supply projects, reservoir operations, hydropower resiliency, conservation and efficiency, water reuse, and diversifying supplies (see, e.g., USBR Drought Actions 2023). Federal and state-level efforts to implement **Nature Based Climate Solutions (NBCS) for drought management and to combat climate change, especially in disadvantaged and underserved communities of the western US, remain extremely limited and has only recently been included in the White House directives** (White House Office of Science & Technology Policy 2022).

The project team has identified **four perceptional and technological barriers** due to which effective use of NBCS against drought hazards is not yet gaining motion in the western US.

(1) The perception of implementing NBCS for greater water storage and thus improved water supply reliability is often limited to wetland and stream restoration. As a result, numerous potential natural infrastructures, including "wetland-like" lands, depressional surface features, potholes, and other small waterbodies remain underutilized.

(2) There is no generalizable approach to map the location and estimate surface area and water storage capacities of these natural infrastructures. As a result, studies utilizing the water storage capacities of these diverse and abundant small surface water storage features focus on small watershed scales or site-specific scales, without being able to scale up to landscape-scales over large domains.

(3) Regardless of spatial scales, hydrologic models of drought management and climate change incorporating NBCS heavily rely on traditionally used datasets such as the National Wetland Inventory (NWI) and National Land Cover Dataset (NLCD). Spatial incompleteness of NWI and lack of detailed land classes in NLCD are well-known problems. What is more important is that NWI and NLCD show large inconsistencies in accurately capturing small surface water storage features when compared with new generation, high resolution remotely sensed data (see **Figure 1**).

(4) A decision support tool to quantify drought reduction benefits of NBCS, intuitively run scenarios of loss and conservation of NBCS, and therefore locate areas of priority management attention does not exist.

Overcoming these barriers and enabling water managers and stakeholders in the western US to effectively use NBCS for improved water supply reliability will require a dedicated data, modeling, and decision support tool. Needless to say, rural communities in the western US – especially the tribal nations are not well-resourced to conduct such model and tool development tasks. This project intends to overcome these barriers by taking Blackfeet Reservation in Montana as an example.

1.3 Goals & Objectives

The overarching goal of this project is to enable the Blackfeet Reservation to **harness water storage capacities of "potential" natural infrastructures – including existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies, and therefore maximize the beneficial use of surface waterbodies as effective and sustained NBCS against future drought hazards**.

Specifically, by mapping and modeling the entire 7,800 km^2 area of the Blackfeet Reservation,

this project will equip watershed managers and stakeholders with a user-friendly decision support tool, and demonstrate practical applications and broader impacts of the tool by performing four objectives.

(1) Map locations and estimate surface areas and water storage capacities of these natural infrastructures using the latest available remote sensing data, topography, field observations, and widely used artificial intelligence technique.

(2) Incorporate these storage capacities in a hydrologic model to quantify their cumulative drought reduction benefits under future climate projections.

(3) Run model scenarios of loss and conservation, and from thereon locate areas within the Reservation where implications of conserving these natural infrastructures on water supply reliability would be more significant.

(4) Conduct a series of onsite workshops for stakeholder training, collecting stakeholder feedback, and results dissemination.

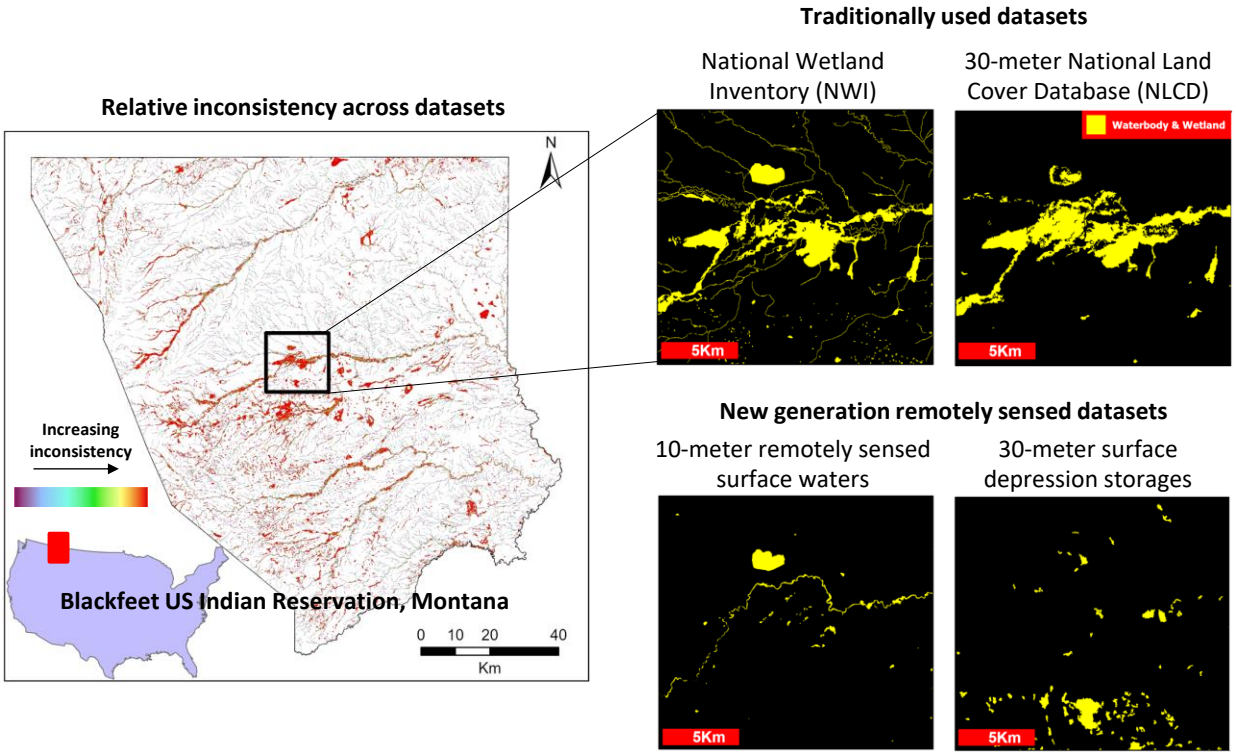

Figure 1. *Datasets traditionally used to incorporate Nature Based Climate Solutions for drought (and flood) management are highly inconsistent.*

1.4 Methodology

This applied science project will leverage **existing, widely acknowledged, and mature techniques** to accomplish the four objectives. Along these veins, note that parts of the methodology are based on the Principal Investigator's peer-reviewed published research, which indicates the robustness and limited risks of the project from an implementation standpoint.

1.4.1 Objective 1: Estimate water storage capacities of potential natural infrastructures

Natural infrastructures, as outlined above, will be defined as existing non-floodplain and

floodplain wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies. Looking at the incompleteness and inconsistencies in traditional datasets like NWI and NLCD (see, e.g., Figure 1), it is clear that none of the existing datasets can offer stakeholders a consolidated, ready-to-use estimate of water storage capacities **by bringing most of the potential natural infrastructures under one framework**. The term "most" is highlighted here because not all natural infrastructures can be identified due to coarse data resolution and methodological limitations among other reasons, and the term "potential" is used because not all of the identified small storage features can hold water under temporal variability. Nonetheless, in Objective 1, a new dataset will be developed combining location, surface area, and water storage capacities of most of the potential natural infrastructures within the Blackfeet Reservation. This will be done in **three steps via an open-source Artificial Intelligence (AI) technique widely used by water and climate science community** (Mainali et al 2023, O'Neil et al 2020).

Step 1. The AI will integrate four primary predictors, i.e., (1) hydrogeomorphic, (2) soil, (3) hydrologic, and (4) vegetation drivers of landscape water storage. These primary predictors will be derived from 11 recently published, open-source datasets available for the Continental US (**Figure 2**). Further details about these datasets are provided in Section 4.3.

Step 2. The AI will be trained and verified with NWI and NLCD data. With the assistance of the Category A partner Blackfeet Reservation and the Technical Advisor US Fish & Wildlife Service, the project team will collect field data during Summer 2025. These *in-situ* data will be used to both train and verify the AI as well as to verify the hydrologic model results in Objectives 2-3. The final output of the AI will be the location and surface area extents (in m^2 unit) of potential natural infrastructures.

Step 3. The surface area extents of the potential natural infrastructures will be fed into a widely used geostatistical tool (Cohen et al 2018). This tool uses topography data to calculate the maximum depth of a wetland, surface depression, or an inundated area, and subsequently converts surface area into water storage capacity (in m^3 unit). 10-meter resolution topography data will be used to avoid computational burden, which may impart some inaccuracies in storage capacity estimation especially for very small depressional storage features. The field data collected in Step 2 will be used to produce some accuracy assessments. Note, the geographical extent of the Blackfeet Reservation includes eight large lakes. Water storage capacities of these large lakes are already known (via previous state and federally funded projects; data available to the Category A partner); hence these large lakes will not be part of the geostatistical volume estimation tool.

1.4.2 Objective 2: Incorporating Nature Based Climate Solutions in hydrologic modeling

The locations, surface areas, and water storage capacities of potential natural infrastructures obtained from Objective 1 will be incorporated in the Soil & Water Assessment Tool (SWAT) hydrologic model using an approach recently developed by the Principal Investigator (Rajib et al 2020). This approach was developed in collaboration with US EPA Office of Research & Development and has been widely acknowledged as an efficient way of implementing NBCS in large-scale hydrologic studies (Golden et al 2021, Evenson et al 2021).

1.4.3 Objective 3: Scenarios of loss and conservation of surface water storage

Based on the technical input of the Category A partner - Blackfeet Reservation and the Technical Advisor - US Fish & Wildlife Service, numerous scenarios of loss and conservation of natural infrastructures will be constructed (e.g., assuming loss of small non-floodplain wetlands and

depressions upstream of a watershed, and conservation of relatively larger wetlands and depressions closer to the stream downstream of a watershed; see Lane et al 2023). These scenarios will be incorporated in the SWAT model following the approach used in Objective 2. Next, drought hazards will be simulated by feeding the model with future climate projections (see CMIP6 2023). **Focus will be strictly on drought simulations during summer months to avoid snow accumulation and snowmelt runoff effects**. From model results, hotspots of surface water storage, more specifically, the locations where conservation of natural infrastructures will have significant drought reduction benefits will be identified and mapped.

The model and the associated climate change and NBCS scenarios will be compiled into an intuitive web-based decision support tool via mygeohub which is a National Science Foundation-supported geospatial platform for climate, water, and environmental sustainability (https://mygeohub.org). The Principal Investigator has been developing similar hydrologic decision support tools in mygeohub through other projects funded by NASA and Bureau of Reclamation (see https://youtu.be/jqR33B4HpkQ).

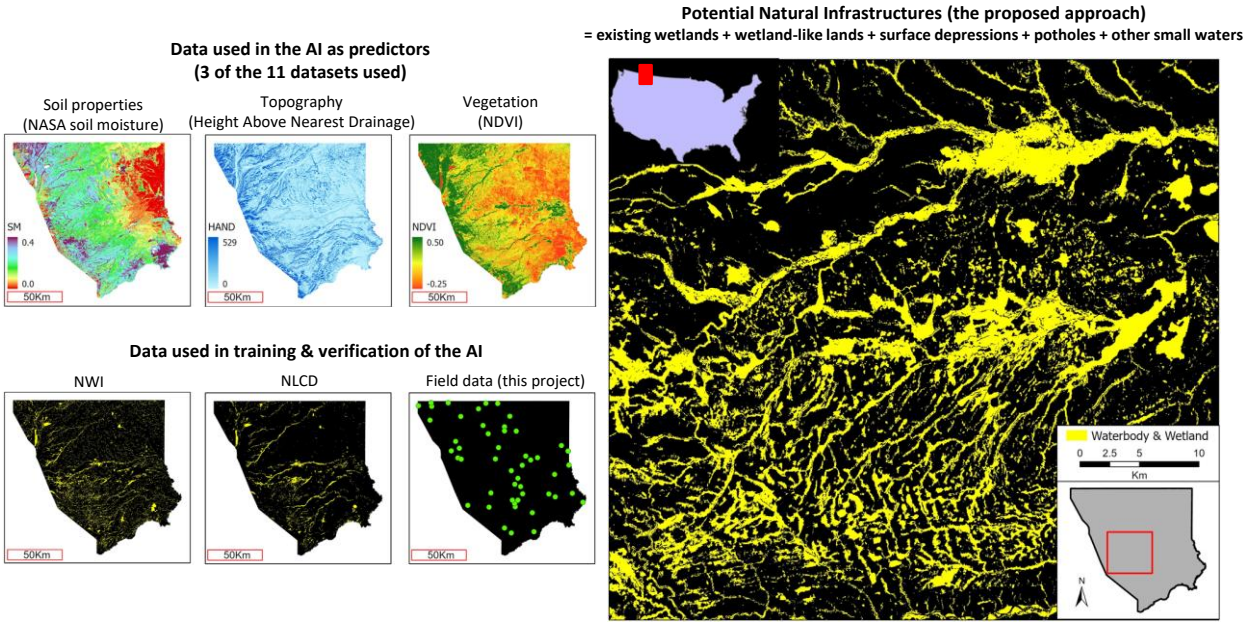

Figure 2. *Preliminary results: Potential natural infrastructures identified via an AI approach.*

1.4.4 Objective 4: Stakeholder training workshops

With the assistance of the Category A partner - Blackfeet Reservation, three workshops will be organized respectively to (1) include stakeholders' inputs on technical design of the project, (2) train the stakeholders on AI to map and estimate water storage capacities of potential natural infrastructures, and (3) train the stakeholders on how to incorporate NBCS in a hydrologic model and simulate drought hazards by running scenarios for loss/conservation of natural infrastructures. Further details about these workshops are provided with the project timeline and milestones as well as in Section 4.4.

While this methodology will continue to evolve as the project progresses, the tangible initial work done by the project team, as shown in Figure 1 and Figure 2, indicates the potential for successful

implementation of this proposal. To ensure that the proposed objectives are meticulously met, milestones are achieved, and the outputs produced are technically sound, the project has budgeted travel funding for representatives of the Blackfeet Reservation and the project's Technical Advisor from the US Fish & Wildlife Service, and more importantly a Bureau of Reclamation scientist to attend in-person project kickoff/update meetings.

2. Project Location

If successful, this project will be the first hydrologic data and modeling study that brings the entire 7,800 km^2 geographical extent of the Blackfeet Reservation (**Figure 3**) under one decision support tool.

The Reservation is the largest Indian Tribe in Montana and one of the ten largest federally recognized Indian Tribes in the US (Nature Conservancy, 2023). It is located east of the Glacier National Park in Montana. Several waterways drain the area with the largest being the St. Mary River, Two Medicine River, Milk River, Birch Creek, and Cut Bank Creek. There are 282 km of stream network and eight large lakes within the Reservation. USGS has recently installed multiple streamflow gage stations at the Reservation (USGS 2023a) which will be useful in model calibration tasks.

While the Reservation has drafted a climate adaptation plan (see Blackfeet Nation, 2018), there have been limited resources and considerable technological barriers due to which the Reservation has not been able to implement NBCS to improve water supply reliability. This project, if funded, will be able to overcome these problems.

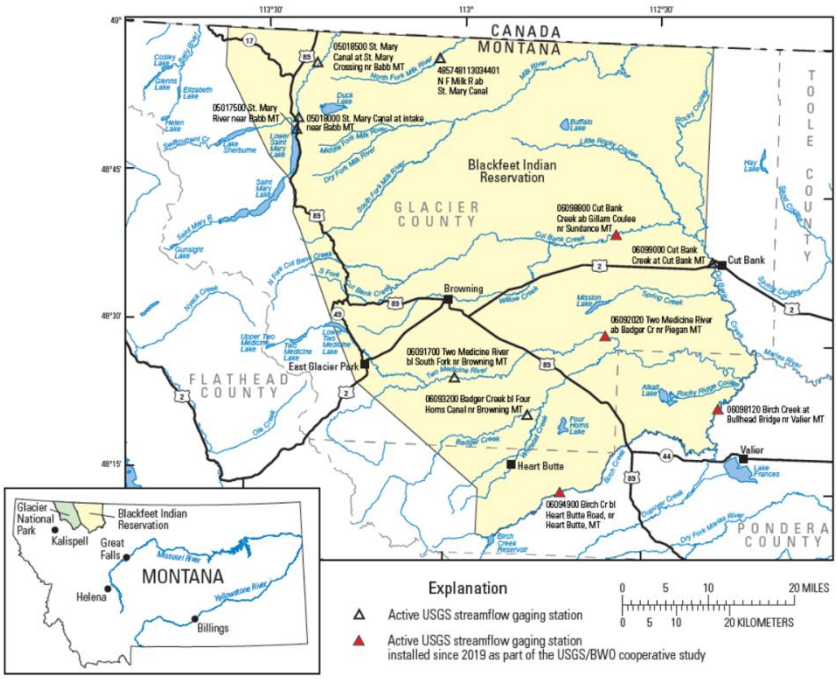

Figure 3. *Project location map (adopted from USGS 2023a).*

3. Data Management Practices

The project team is strongly committed to Open Science and FAIR (Findable, Accessible, Interoperable, and Reusable) principles (Wilkinson et al 2016). The Nature Based Solution decision tool developed via mygeohub will be web-based and open-access. The corresponding end products from each of the four objectives, i.e., (1) natural infrastructure water storage capacity dataset, (2) SWAT model integrated with NBCS and future climate projections, (3) model results on reduced drought and improved water supply reliability for different scenarios of NBCS, and (4) stakeholder survey outcomes will be shared publicly.

The data and model products will be released to the public via open access data repositories such as HydroShare: https://www.hydroshare.org/. We will follow the Dublin Core protocol to collect

metadata. Note, this project will entirely rely on widely accepted open-access datasets (e.g., remotely sensed data from NASA), which undergo unique quality control/quality assurance procedures. Given the above, an extensive quality control/quality assurance program will not be necessary for the most part. However, all data products generated in this project will undergo a suite of diagnostics before being released to the public. **The raw field data collected in this project may be available for use with permission of the Blackfeet tribal government**.

Majority of software codes developed in this project (e.g., the AI code in Objective 1) will be made available via Google's open-access cloud computing platform Google Colab: https://colab.google, with necessary documentation and tutorials. The Principal Investigator will continue to maintain the code on Google Colab beyond the project period.

The project team will coordinate with its Category A partner - Blackfeet Reservation to potentially design a landing page and have a dedicated URL to launch the proposed Nature Based decision tool directly from the Reservation's website (although the tool will be hosted and run at the mygeohub platform).

4. Evaluation Criteria

4.1 Evaluation Criterion A – Water Management Challenges

A.1. Describe the water management challenge(s). Describe in detail the **water management challenge** is occurring within your project area. Describe the severity of the challenge to be addressed with supporting details. For example, will your project address water supply shortfalls or uncertainties, the need to meet competing demands for water and the lack of reliable water supplies for municipal, agricultural, tribal, environmental or recreational water uses, complications arising from drought, conflicts over water, or other water management issues?

Our project will address uncertainties in assessing surface water quantity arising from frequent and increasing droughts. Our project location – the Blackfeet Reservation in Montana has been experiencing recurring droughts in consecutive years, and this trend may be increasing in future years. Given the scientific evidence found across the western United States (e.g., the 2021 SECURE Water Act Report, USBR 2021), it is highly likely that these recurring events are altering the Reservation's water availability, thus increasing uncertainties in overall water supply.

The 2017 Montana Climate Assessment (Whitlock et al 2017) and the 2021 special report on Climate Change & Human Health in Montana (Adams et al 2021) predict worsening water supply reliability in the tribal lands of Montana due to **compound impacts floods and droughts**. Warmer temperatures in the spring means snow thawing will occur quicker and earlier in the year. That earlier snowmelt means that the Blackfeet Reservation could be facing spring flooding followed by critically low water levels during the late summer months.

The water bodies within the Blackfeet Reservation are also a major source of water for irrigated agriculture. Through our initial work (Figures 1-2) and collaborative discussions with our local project partners, we found that the recent **major drought events have nearly depleted some of the depressional surface water storage systems traditionally used for irrigation**.

Maintaining water rights is another critical challenge for the Blackfeet Reservation. Although the Reservation has Blackfeet Water Compact and Settlement Act (see Blackfeet Nation, 2017), which secures jurisdiction over Nearly 800,000 acre-feet of water annually within six water basins in and around the reservation, the uncertainties arising from depleting waterbodies are making it extremely difficult to maintain and utilize tribal waters for both domestic and agricultural

purposes.

A.2. Describe the **concerns or outcomes** if this water management challenge is not addressed?

If the water management challenges identified in A.1 remain unaddressed, the Blackfeet Reservation will continue to experience altered and limited water supply for domestic and irrigation use, will be subject to increased compound hazards of flood and droughts, and will have lowered abilities to exercise their water rights.

A.3. Explain **how** your project will address the water management issues identified in your response to the preceding bullets and provide support for your response. For example, will your project improve water management by supporting: (a) water supply reliability for municipal, agricultural, tribal, environmental or recreational water uses, (b) management of water deliveries, (c) water marketing activities, (d) drought management activities, (e) conjunctive use of ground and surface water, (f) water rights administration, (g) ability to meet endangered species requirements, (h) watershed health, (i) Restore a natural features or use a nature-based feature to reduce water supply and demand imbalances, the risk of drought or flood, or to increase water supply reliability for ecological values, (j) conservation and efficiency, (k) other improvements to water supply reliability? In your response, be sure to explain how your project will improve any of the above.

The four proposed objectives (Section 1.3) are specifically geared towards addressing the emergent water supply uncertainties in the Blackfeet Reservation, which indicate **our project's direct contribution to Nature Based Solutions to drought (and flood) hazards and correspondingly drought management activities and water supply reliability, and indirect contribution to water rights administration and management of water deliveries**.

To address the water management issues and to *"hold the water"*, The Blackfeet Nation Climate Change Adaptation Plan 2018 (https://bcapwebsite.files.wordpress.com/2018/04/bcap_final_4-11.pdf) acknowledged the importance of natural infrastructures like wetlands and depressions in the valleys and along the floodplains for increased surface water storage. However, the Reservation has minimal or poor-quality data to confirm whether and to what extent the available potential natural infrastructures can be harnessed for water storage both in floods and drought conditions. Unfortunately, existing state/federal datasets like NWI and NLCD, due to their incompleteness and inconsistencies over tribal lands (revisit Figure 1), are not the cure-all. **Our preliminary results (Figure 4) confirm that this project, once successfully completed, can let the Blackfeet water managers store 300,000 acre-ft of additional surface waters that have remained unknown till date**.

4.2 Evaluation Criterion B – Project Benefits

B.1. Describe how the **need for the project** was identified. Was the proposed project identified using a collaborative process with input from multiple and diverse stakeholders?

Principal Investigator Rajib became involved in drought-focused research in Montana since his participation in the Upper Missouri Headwaters Basin Task Force Meeting in Bozeman, Montana in November 2017. This meeting brought local, state, and federal government entities together with local stakeholders and non-governmental organizations to brainstorm approaches and develop partnerships to build watershed resiliency to drought. Accordingly, Rajib led multiple federal projects on wildfire and drought resilience funded through a Bureau of Reclamation grant in 2021 and a NASA grant in 2023. These were collaborative projects in which Rajib partnered with USGS,

City of Missoula, The Clark Fork Coalition, The Nature Conservancy, and the Montana Department of Natural Resources and Conservation. Such partnerships invoked cross-disciplinary discussions on drought, climate change, and water supply reliability issues in Montana, laid out a foundation for Rajib to find tribal partners and technical advisors, and served as the initial motivation for this proposal.

After developing the outline of this proposal and its tentative deliverables, Rajib discussed the proposed research project with his existing partners and collaborators mentioned above, who were able to clarify the need for this proposal and bring new partners into the discussion. Following these discussions, Rajib organized multiple online meetings with the Blackfeet Reservation and US Fish & Wildlife Service's National Wetland Inventory division during August-October 2023. These entities confirmed the potential value of this proposal and agreed to contribute to the proposal (if funded) respectively as the Category A partner and Technical Advisor (see the attached letters).

B.2. Describe **how** the tool, method, or information will be applied and **when** it will be applied. Will the tool or information be used immediately or will additional work need to be done before the tool will be used?

Yes. The project outcomes will be immediately available and useful. To ensure this, stakeholder training workshops are included as one of the project objectives. The workshops will take place at the Blackfeet Nation tribal council (Category A partner) facility in Browning, Montana tentatively in September 2024, September 2025, and March 2026. The workshop participants will mainly include water supply and watershed management stakeholders within the Blackfeet Reservation and in the state of Montana in general.

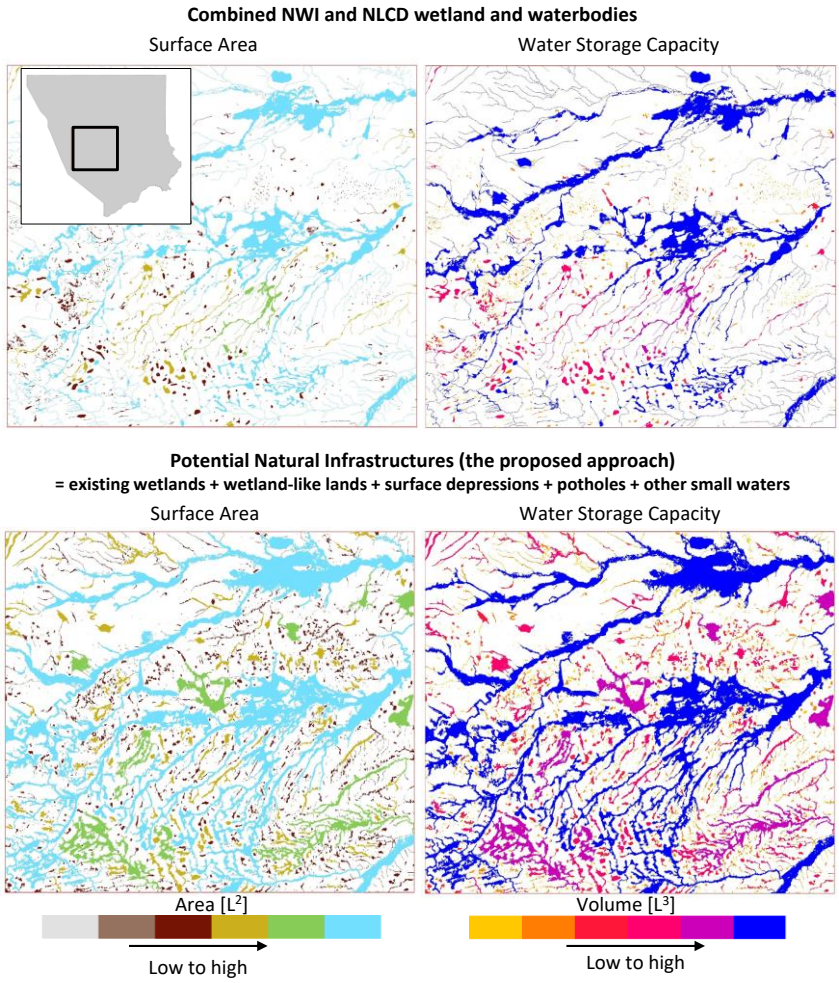

Figure 4. *Additional water storage available as Nature Based Climate Solutions to drought (and flood) hazards.*

B.3. Describe, in detail, the extent of benefits that can be expected to occur upon implementation of the project, and provide support for your responses.

The project team was able to produce some preliminary results based on a protype methodology (revisit our methodology in section 1.4). The sole purpose of this preliminary work was to gain

some quantitative evidence of the extent to which the project would reduce water supply uncertainties and improve water supply reliability.

B.3.a. Who will use the tool or data developed under this proposal and how will they benefit from the project? Support could include but is not limited to letters from stakeholders expressing support for the project and explaining how they will benefit.

The project outcomes will be directly beneficial to the water managers and stakeholders of the Blackfeet Reservation. In their letter, Blackfeet reservation mentioned that the tribal lands and waters are experiencing serious drought impacts. These impacts are expected to worsen as climate continues to change. Although the Reservation is participating in various regional, state, and national efforts to find ways to reduce water supply uncertainties by storing water in wetlands and other natural water storage systems, and accordingly has formulated a Climate Change Adaptation Plan (https://bcapwebsite.files.wordpress.com/2018/04/bcap_final_4-11.pdf), the **Reservation is in dire need of an efficient, user-friendly decision tool that will allow incorporation of Nature Based Solutions in the climate adaptation plan**. The Blackfeet Reservation confirmed that the proposed project has great potential to fulfil this need and can make Blackfeet Nation climate resilient in the long term.

Because the proposed methodology is fully reproducible and scalable, the outcomes of the project can be immediately reproduced by other tribal lands in the western US. For example, the project's Technical Advisor Sara Owen – the US Fish & Wildlife NWI Field & Regional Operations Lead, in her letter, confirmed that the products of this project will aid the tribal nations in completing updated NWI maps for their lands. A complete and updated inventory of wetland and natural infrastructure resources on their lands will aid their efforts in identifying and implementing Nature Based Solutions as part of their ongoing combat to climate change.

If the project gets funded, the project team will **leverage its existing partnerships with other Montana organizations, e.g., City of Missoula, The Clark Fork Coalition, The Nature Conservancy, and the Montana Department of Natural Resources and Conservation**, to invite more stakeholders in the proposed workshops and dissemination activities.

B.3.b. How will the project improve **water management decisions**?

Our preliminary results (see, e.g., **Figure 4**) suggest that, by quantifying water storage capacities of potential natural infrastructures (including existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies) and incorporating them in a hydrologic model, stakeholders can find where and to what extent these abundant but traditionally unutilized/underutilized storages can reduce future drought impacts.

An important objective of the project is to train the stakeholders via a series of in-person workshops hosted at the Blackfeet Tribal Council facility. Upon completion of these workshops, the stakeholders will not only gain new insights on the value of Nature Based Climate Solutions (NBCS) but also receive hands-on technical skills to actually implement NBCS in their water management decision workflows.

B.3.c. Describe if the results of your project will be **applicable elsewhere**. What additional work would need to be done to make the project results transferable to others?

The corresponding end products from each of the four objectives, i.e., (1) natural infrastructure water storage capacity dataset, (2) SWAT model integrated with NBCS and future climate projections, (3) model results on reduced drought and improved water supply reliability for

different scenarios of NBCS, and (4) stakeholder survey outcomes will be specific to the Blackfeet Reservation, hence these will not be transferrable. The overall methodological workflow, however, can be reproduced for any other region with minimal effort. This will be feasible because the proposed AI approach to locate and quantify water storage capacities of potential natural infrastructures is solely based on recent, open-access datasets (**Table 1**) available across the continental US. Furthermore, the approach to incorporate NBCS in drought hazard modeling through process-based hydrologic models has been used in other large basins (see Rajib et al., 2020). The data management section describes how interested stakeholders can access the project outputs and reproduce them for any region of interest within the US.

B.3.d. To what extent will the project address the water management challenges described in Evaluation Criteria A?

As noted before, the four proposed objectives (Section 1.3) are specifically geared towards addressing the emergent water supply uncertainties in the Blackfeet Reservation, which indicate our project's direct contribution to nature based solutions to drought (and flood) hazards and correspondingly drought management activities and water supply reliability, and indirect contribution to water rights administration and management of water deliveries.

While Figure 4 shows a quantitative example of the direct contributions of the project (i.e., holding more water across natural infrastructures than what was previously known), **Figure 5** adds a unique example of the project's indirect contribution by helping in the management of water deliveries. Specifically, the project will allow stakeholder to distinguish between the relative benefits of conserving/restoring floodplain versus non-floodplain water storages, which will let them take **more informed and accurate decisions on water deliveries from different sources**.

B.4. Explain how your project complements other similar efforts in the area where the project is located. Will your project complement or add value to other, similar efforts in the area, rather than duplicate or complicate those efforts? Are there other similar efforts in the area that have used a similar methodology successfully which can be complimented? Applicants should make a reasonable effort to explore and briefly describe related ongoing projects. Consider efforts by any Federal, state, local agency, or non-governmental organizations.

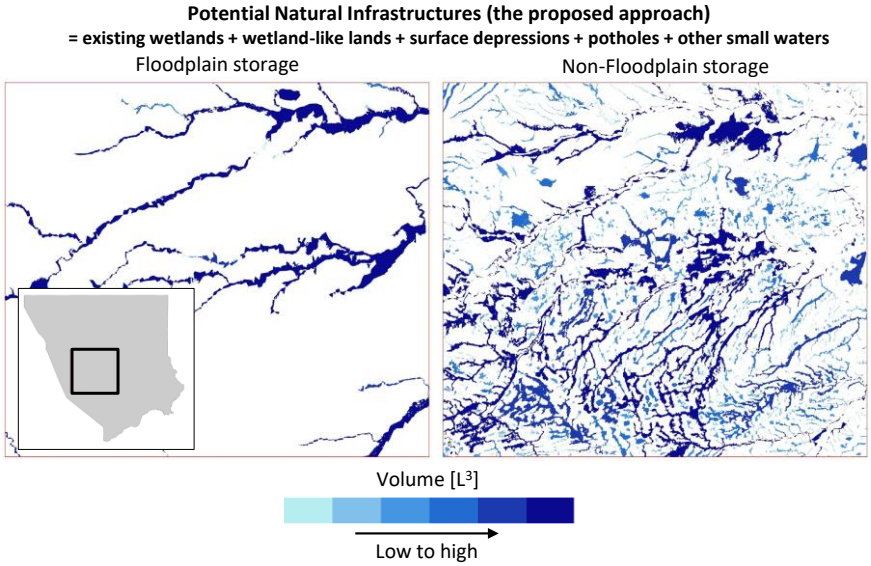

Figure 5. *Differentiating floodplain versus non-floodplain storage can improve water management decisions.*

Local, state, federal agencies, and nongovernmental organizations in Montana are responding to drought and climate change through management decisions focusing on improved resiliency on public lands and waterways. Principal Investigator Rajib is directly involved in some of these

initiatives through other federally funded projects (noted in B.1). Rajib's discussions with these agencies confirmed that an initiative specifically focusing on improved drought resilience via Nature Based Climate Solutions (NBCS) at large domains is extremely limited in the western US (not just in Montana) and is definitely non-existent in the Blackfeet Reservation. Especially, **none of the agencies were able to mention an initiative that aims to quantify water storage capacities of potential natural infrastructures (including existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies) and show where and to what extent these abundant but traditionally unutilized/underutilized storages can reduce future drought impacts**. Clearly, the proposed project can fill a major gap.

Nonetheless, the project team including Rajib, the Blackfeet stakeholders, and the Technical Advisor from US Fish & Wildlife made a consolidated effort by engaging with local, state, federal agencies, and nongovernmental organizations mentioned in B.1, and identified at least two important initiatives that can be directly and immediately benefited from the proposed project.

(1) The Missouri Headwaters Drought Resilience Demonstration Project (https://uppermissouriheadwaters.org/drought-resiliency/) – An effort focused on developing drought plans, implementing small watershed-scale projects to enhance water storage.

(2) The Blackfeet Nation Climate Change Adaptation Plan 2018 (https://bcapwebsite.files.wordpress.com/2018/04/bcap_final_4-11.pdf) – A well-documented pathway to make Blackfeet waters (tribal waters in general) drought resilient which emphasized on the urgency to conserve wetlands and other natural surface water storages (hence, NBCS).

The proposed work will not duplicate any of these initiatives. There is rather a great potential for integrating local experiences from Blackfeet Reservation stakeholders, and data products produced by NASA, USGS and US Fish & Wildlife into the proposed tasks, and effectively fill existing water management gaps by providing critical data on Nature Based Climate Solutions.

4.3 Evaluation Criterion C – Project Implementation

C.1. Briefly describe and provide support for the approach and methodology that will be used to meet the objectives of the project. You do not need to repeat the full technical project description included in the Technical Project Description. However, you should provide support for your chosen methodology, including use of any specific models, data, or tools.

As we noted before, our technical approach and methodology are based on proven, widely accepted research. However, for further justification, below we reintroduce specific topics and provide supporting information based on peer-reviewed literature and our own work.

(1) Data used by Artificial Intelligence (AI) to find potential natural infrastructures

Table 1 lists the predictor, training, and verification datasets used by our AI approach for the identification of natural infrastructures (including existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies).

Table 1. *Predictor, training, and verification datasets used in the identification of small surface water storage features. Some datasets are temporally continuous and variable; the long-term*

average condition will be assumed from those datasets. All data are openly available.

Dataset	Resolution		Year	Source
	Spatial (m)	**Temporal**		
Hydrogeomorphic predictors				
Slope	10			National Elevation Dataset
HAND	30			
Soil predictors				
Hydric Condition	10		2021	gSSURGO
Soil Drainage	10		2021	
Soil Organic Carbon	10		2021	
Hydraulic Conductivity	30		2019	POLARIS, Chaney et al (2019)
NASA Soil Moisture	30	Daily	2015-present	SMAP HydroBlocks, Vergopolan et al (2021)
Hydrologic predictors				
Curve Number for Runoff Generation	250		2019	Jaafar et al (2019)
Landsat DSWE	30	16-day	1982-present	USGS (2023b)
Vegetation predictors				
Landsat NDVI	30	8-day	2013-2022	USGS (2022a)
Landsat NDWI				USGS (2022b)
Training & verification data				
NWI	N/A		1970-2022	USFWS (2019)
NLCD	30		2001-2021	USGS (2023c)
Field collected data	N/A		2025 (planned)	This project

Note, HAND= Height Above Nearest Drainage, DSWE = Dynamic Surface Water Extent, NDVI = Normalized Difference Vegetation Index, NDWI = Normalized Difference Water Index, NWI = National Wetland Inventory, NLCD = National Land Cover Dataset

(2) SWAT as a suitable model for incorporating Nature Based Climate Solutions (NBCS)

Selecting SWAT for our hydrologic modeling task is justified because of the following two reasons: (a) it is one of the few models which can be installed and simulated via web-based platforms associated with cloud/high performance computing resources (see Rajib et al., 2022), and (b) there is a recent trend of using SWAT for modeling drought impacts in complex terrain watersheds similar to our project location (Tan et al 2020). More importantly, an approach to incorporate NBCS in SWAT model developed by Principal Investigator Rajib has been widely used by the water and climate science community and found to be very efficient for stakeholder applications (Rajib et al 2020, Golden et al 2021, Evenson et al 2021).

(3) Use of *mygeohub* to host the proposed Nature Based Solution decision tool

The prototype version of decision tool will be operationalized at mygeohub, a proven, production-quality cyberinfrastructure supported by the National Science Foundation for hosting geospatial modeling and decision-making tools (Biehl et al 2017, Kalyanam et al 2018, Villoria et al 2017,

2017). Principal Investigator Rajib is already using this platform for other Bureau of Reclamation and NASA funded drought and climate change projects. This platform is fully open access and will be available to the project team and the stakeholders free of cost. When required, the tool can be exported to any other platform suggested by the Bureau of Reclamation with minimal work.

C.2. Describe the work plan for implementing the proposed scope of work. Such plans may include, but are not limited to: (a) an estimated project schedule that shows the stages and duration of the proposed work, (b) milestones for each major task, (c) start and end dates for each task and milestones, and (d) costs for each task.

As outlined in Section 1.3, this project has four objectives. The overall project schedule is provided in **Table 2**. The project team will consider the successful organization of the three stakeholder workshops as three milestones. These workshops will be hosted at the Blackfeet Tribal Council facility (Category A partner) in Browning, Montana. Importantly, Objective 1 will involve field work to collect data on wetland and depression inundation at the Reservation. The field work will be conducted in the Summer of 2025. The budget narrative provides supporting details of how these different tasks will be resourced.

Table 2. *Project schedule and milestone with approximate cost distribution per objective.*

	Months	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	% Funding
Objective 1	Water storage capacities (AI, field data)									20%
Objective 2	Hydrologic modeling of NBS									25%
Objective 3	Drought scenarios and NBS tool									45%
Objective 4	Stakeholder training workshops									10%
			MS1				**MS2**		**MS3**	

C.3. Provide a summary description of the products that are anticipated to result from the project. These may include data, metadata, digital or electronic products, reports, and publications. Note: using a table to list anticipated products is suggested.

Below is a list of products that the project will deliver. This is not an exhaustive list. Additional items may be included based on stakeholders' inputs.

(1) The potential natural infrastructure water storage capacity dataset: A set of GIS files and corresponding excel files showing the locations, surface areas (m^2 unit) and water storage capacities (m^3 unit) of natural infrastructures (including existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies) derived from an AI approach.

(2) The AI code: The AI code written in Python programming language will be made available via Google's open access cloud computing platform - Google Colab.

(3) SWAT model: The Blackfeet reservation SWAT model along with all input files.

(4) Hydrologic time-series/maps showing drought reduction benefits of Nature Based Climate Solutions: Data/GIS maps showing changes in drought indicators (soil moisture, evapotranspiration) with and without incorporating small surface storages (product 1; Figure 4).

(5) Tutorials: Instruction materials, presentation files, and videos used in the stakeholder training workshops.

C.4. Who will be involved in the project as project partners? What will each partner or stakeholder's role in the project be? How will project partners and stakeholder be engaged in the project and at what stages? If you are a Category B applicant, be sure to explain how your Category A partners will be engaged in the project.

The **Blackfeet Reservation** agreed to participate in the project as its Category A partner. Specifically, the Reservation, through Blackfeet Environmental Office which is the designated authority to implement Nature Based Climate Solutions and climate adaptation plans, will participate in all planning and coordination meetings organized by the project team (including the kick-off meeting at the University of Texas at Arlington) and facilitate field data collection and model evaluation tasks. They will also host three stakeholder training workshops at the Blackfeet Tribal Council facility in Browning, Montana.

Sara Owen – the **US Fish & Wildlife NWI Field & Regional Operations Group Lead** would serve as the Technical Advisor. Aside from virtual meetings on a need-basis, she would meet the project team in-person three times over the 2-year project duration – in the project kick-off meeting at the University of Texas Arlington during May 2024 to provide initial technical inputs, during June 2025 in Browning, Montana to guide the field-scale *in-situ* data collection and at the AGU conference during December 2025 to present project outcomes.

The budget narrative provides supporting details of how these participations will be ensured.

C.5. Identify staff with appropriate credentials and experience and describe their qualifications. Describe the process and criteria that will be used to select appropriate staff members for any positions that have not yet been filled. Describe any plans to request additional technical assistance from Reclamation or via a contract. Please answer the following:

Adnan Rajib, Ph.D. is a tenure-track Assistant Professor and the Director of the Hydrology & Hydroinformatics Innovation (H2I) Lab in the Department of Civil Engineering, University of Texas at Arlington. Dr. Rajib received PhD in Civil Engineering from Purdue University in Spring 2017. Before joining UT Arlington, Dr. Rajib was a Tenure-track Assistant Professor at the Texas A&M University, Kingsville during 2019-2023, and a Post-doctoral Scientist at the US EPA Office of Research and Development during 2017-2019. Dr. Rajib's research focuses primarily on sustainable earth with emphasis on Nature Based Climate Solutions to flood and drought hazards. His most recent work employing new-generation remote sensing data, computer models, and AI to predict water quality in river networks has been featured in the NASA Discovery platform. Rajib recently received the University of Texas Rising STARs award in recognition of his research contributions.

Gerlad Wagner is the Director of the Blackfeet Environmental Office (BEO) and has a track record of managing and implementing drought and climate related state/federal projects. He led the development of the Blackfeet Nation Climate Adaptation Plan which is the only benchmark for the Reservation to design drought and climate resilience activities. **Emerald Grant** is the Wetland Division Head at the BEO who coordinates wetland and surface water conservation/restoration activities within the Reservation and serves as the tribe's liaison with the US Fish & Wildlife National Wetland Inventory.

Sara Owen is the US Fish & Wildlife (USFW) National Wetland Inventory (NWI) Field &

Regional Operations Group Lead, based in Helena, Montana. She has extensive experience applying diverse sources of remotely sensed data and field data to map wetlands and surface water bodies. She also has extensive experience in developing data sharing and quality control protocol. Owen maintains strong collaborations with tribal governments across the western US for various activities involving Nature Based Climate Solutions.

The project funding will also create mentored positions for three PhD and one Masters student positions at the University of Texas at Arlington. Summer research interns will be recruited from the Blackfeet Community College in Montana to assist the field data collection.

As recommended in the Notice of Funding Opportunity, **funding is budgeted for a US Bureau of Reclamation (USBR) scientist**. The funding is available as a travel allowance through which the USBR scientist would meet the project team in-person twice over the 2-year project duration – in the project kick-off meeting at the University of Texas Arlington during May 2024 to provide initial technical inputs and in one of the stakeholder training workshops during March 2026 to evaluate project success. An appropriate Reclamation scientist will be identified during the first 30 days of project execution.

C.5.a. Have the project team members accomplished projects similar in scope to the proposed project in the past either as a lead or team member?

In his 4-year service as a tenure-track faculty, Dr. Rajib has secured several competitive federal grants as the Principal Investigator, which includes grants from NASA, NSF, Department of Defense, Department of Agriculture, and US Bureau of Reclamation. Wagner and Grant are well-trained professionals with years of experience in state/federal project management. Owen frequently deals with large projects at the US Fish & Wildlife Service. In short, the project team has the experience of managing federal and state-funded projects that are similar in scope to the proposed project.

C.5.b. Is the project team capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement? If not, please explain the reason for any anticipated delay.

Yes.

4.4 Evaluation Criterion D – Dissemination of Results

D.1. Describe how the tools, frameworks, or analyses being developed will be disseminated, communicated, or made available to water resources managers who may be interested in the results.

D.1.a. If the applicant is the primary beneficiary of the project, explain how the project results will be communicated internally, and to interested stakeholders and interested water resources managers in the area, if appropriate.

The applicant is not the primary beneficiary.

D.1.b. If the applicant is not the primary beneficiary of the project (e.g., universities or research institutes), describe how project results will be communicated to project partners and interested water resources managers in the area.

Dissemination is one of the four objectives of this project. Therefore, the project team is committed to actively running a targeted dissemination effort. This dissemination effort will mainly include

three onsite stakeholder training workshops. These workshops will include live demonstration of the proposed Nature Based Solution decision tool, stakeholder training using relevant instructional/reading materials, and discussion on the tool's practical applications beyond what is covered in project objectives. The workshops will take place at the Blackfeet Nation tribal council (Category A partner) facility in Browning, Montana tentatively in September 2024, September 2025, and March 2026. The workshop participants will mainly include water supply and watershed management stakeholders within the Blackfeet Reservation and in the state of Montana in general. All the instruction materials and presentation files used in these workshops will be made publicly available through HydroShare for future use. Additionally, the project team will aim towards conference presentations and publishing project results in peer-review journals to enable a broader outreach.

D.1.c. Describe how the project results will be shared with other water managers in the West that could use the information to support water management objectives.

If the project gets funded, the project team will leverage its existing partnerships with other Montana organizations, e.g., City of Missoula, The Clark Fork Coalition, The Nature Conservancy, and the Montana Department of Natural Resources and Conservation, to invite more stakeholders in the proposed workshops. All the instruction materials, presentation files, and videos used in these workshops will be made publicly available through HydroShare so that workshop materials can be used by any stakeholder in a self-paced mode.

4.5 Evaluation Criterion E – Presidential and Department of the Interior Priorities

E.1. **Climate Change**: E.O. 14008 emphasizes the need to prioritize and take robust actions to reduce climate pollution; increase resilience to the impacts of climate change; protect public health; and conserve our lands, waters, oceans, and biodiversity.

E.1.a. If applicable, describe how the project addresses climate change and increases resiliency. For example, does the project help communities respond to or recover from drought or reduce flood risk?

The project has immediate drought and flood hazard reduction benefits. For example, our preliminary results (**Figure 4**) confirm that our project, once successfully completed, can let the Blackfeet water managers store 300,000 acre-ft of additional surface waters that have remained unknown till date. This "extra storage space" is "missing" (see **Figure 1**) from traditional datasets like NWI and NLCD because these datasets are either incomplete or inadequately detailed to capture potential natural infrastructures.

E.1.b. How will the project build long-term resilience to drought? How many years will the project continue to provide benefits? Please estimate the extent to which the project will build resilience to drought and provide support for your estimate.

Knowing how to incorporate natural infrastructures into hydrologic modeling and water management decisions from the project's Objectives 2-3, stakeholders can efficiently adopt Nature Based Climate Solutions (NBCS) to drought and flood hazards. The NBCS considered in this project include existing wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies. These natural features are known to be **permanent solutions** to drought (and flood) hazards when protected and conserved.

E.1.c. Will the proposed project reduce greenhouse gas emissions by sequestering carbon in soils, grasses, trees, and other vegetation? Does the proposed project seek to reduce or mitigate climate

pollutions such as air or water pollution? Does the proposed project contribute to climate change resiliency in other ways not described above?

Wetlands, wetland-like lands, depressional surface features, potholes, and other small waterbodies are known to be the one of the most powerful sinks for carbon and GHG sequestration and water pollutants. Although these are not exclusively included in our proposed scope of work, our Objective 1 to develop the first publicly available location, surface area, and water storage capacity dataset of potential natural infrastructures (beyond what is mapped in traditional datasets like NWI and NLCD) – and that for one of the largest tribal lands in the western US – can be a major contribution to the current state of climate science. Such a dataset, once produced, can directly help projects on carbon and GHG sequestration and water pollutants.

E.2. **Disadvantaged or Underserved Communities**: E.O. 14008 and E.O. 13985 affirm the advancement of environmental justice and equity for all through the development and funding of programs to invest in disadvantaged or underserved communities.

E.2.a. Please use the Council on Environmental Quality's interactive Climate and Economic Justice Screening Tool, available online at Explore the map - Climate & Economic Justice Screening Tool (geoplatform.gov) to identify any disadvantaged communities that will benefit from your project.

According to the Climate and Economic Justice Screening Tool, our project location – the Blackfeet Reservation in Montana is identified as a disadvantaged community (see https://screeningtool.geoplatform.gov/en/#8.04/48.626/-113.041).

E.2.b. If applicable, describe how the project benefits those disadvantaged or underserved communities identified using the tool. For example, does the project increase reliability of water supplies, improve water quality, provide economic growth opportunities, improve, or expand public access to natural areas or recreation, or provide other benefits in a disadvantaged or underserved community?

The four objectives (Section 1.3) of this project are specifically geared towards addressing the emergent water supply uncertainties in the Blackfeet Reservation, which indicate our project's direct contribution to nature based solutions to drought (and flood) hazards and correspondingly drought management activities and water supply reliability, and indirect contribution to water rights administration and management of water deliveries.

E.3. **Tribal Benefits**: The Department of the Interior is committed to strengthening tribal sovereignty and the fulfillment of Federal Tribal trust responsibilities. The President's memorandum, Tribal Consultation and Strengthening Nation-to Nation Relationships, asserts the importance of honoring the Federal government's commitments to Tribal Nations.

E.3.1. If applicable, describe how the project directly serves and/or benefits a Tribe, supports Tribally led conservation and restoration priorities, and/or if the project incorporates or benefits Indigenous Traditional Knowledge and practices.

The project is entirely focused on the Blackfeet US Indian reservation and includes their tribal government as the Category A partner.

E.3.2. Does the proposed project support Reclamation's Tribal trust responsibilities or a Reclamation activity with a Tribe?

Yes

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BLACKFEET NATION

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October 16, 2023

Dr. Adnan Rajib
Department of Civil Engineering
University of Texas at Arlington
REF: Letter of Participation for proposal "Nature Based Climate Solution in Tribal Nations via Efficient Mapping and Modeling of Wetlands and Small Waterbodies"

Dr. Rajib,

I, on behalf of the Blackfeet Nation, write this letter to express my intent to participate with your team in the proposed project titled: "Nature Based Climate Solution in Tribal Nations via Efficient Mapping and Modeling of Wetlands and Small Waterbodies".

The Blackfeet Nation is experiencing serious drought impacts on its water resources. These impacts are expected to worsen as climate continues to change. We are participating in various regional, state, and national efforts to find ways to reduce water supply uncertainties by storing water in wetlands and other natural water storage systems. The proposed project supports our ongoing efforts and has great potential to make Blackfeet Nation climate resilient.

The Blackfeet Nation agrees to the submittal of the proposal to the Bureau of Reclamation and will participate in the project during April 2024-September 2026 as its Category A partner. Specifically, the Blackfeet Nation, through Blackfeet Environmental Office, will participate in all planning and coordination meetings organized by the project team and facilitate model evaluation tasks. The Blackfeet Environmental Office will also assist in hosting stakeholder training workshops.

Thank you for your consideration.

Sincerely,

(acting)

Gerald Wagner

Director, Blackfeet Environmental Office
Beo.director@gmail.com
406-338-7421

United States Department of the Interior

FISH AND WILDLIFE SERVICE

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In Reply Refer To:
FWS/AES/BGMTS/079773

October 12, 2023

U.S. Bureau of Reclamation
WaterSMART – Applied Science Grants Program

Dear Grants Committee Members,

I am writing in support of the proposed project: **"**Nature Based Climate Solution in Tribal Nations via Efficient Mapping and Modeling of Wetlands and Small Waterbodies." For the past few years I have been working with the Blackfeet Nation of Montana to update National Wetlands Inventory (NWI) mapping for Tribal lands, with particular interest in drier wetlands or those in headwater areas that may be important as they plan for future climate-driven changes that may alter these wetlands' spatial, temporal, or seasonal patterns.

The U.S. Fish and Wildlife Service (USFWS) is in full support of projects that utilize NWI maps to aid decision-making to solve real-world problems. Additionally, the products of this research will also aid the Tribe in completing updated NWI maps for their lands. A complete and updated inventory of wetland resources on their lands will aid their efforts in identifying wetlands for preservation, restoration, and mitigation as part of their comprehensive wetlands management plan.

During the 2-year project period I will collaborate with the project team as the Technical Advisor. Please note that participation of USFWS in this project does not involve any financial compensation for my time.

I look forward to continuing NWI's collaborations with the Blackfeet Nation.

Best regards,

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