OPPORTUNITIES TO ENHANCE RECHARGE IN ARIZONA IN RESPONSE TO ARIZONA DEPARTMENT OF WATER RESOURCES REQUEST ON ENHANCING RECHARGE IN ARIZONA

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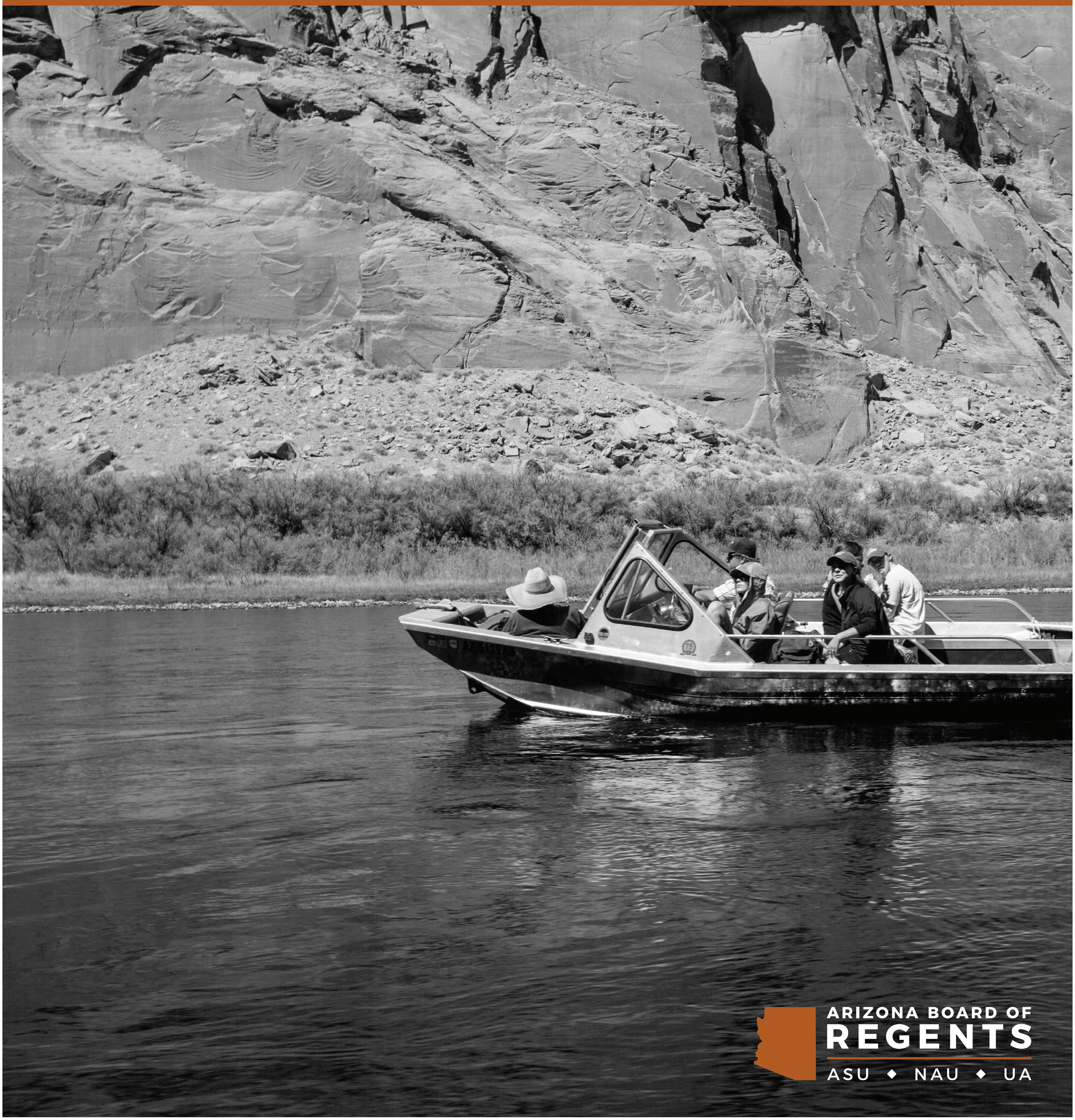

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PROJECT OVERVIEW

A three-University team from the University of Arizona, Arizona State University, and Northern Arizona University will collaborate to address the needs expressed by the Arizona Department of Water Resources (DWR) to identify where: (1) unappropriated runoff available for recharge occurs in the state; (2) suitable locations for recharge are; (3) those two overlap; and (4) land cover/land use managementoptions might create opportunities for recharge now and in the future. These objectives will be metthrough a team science approach as follows. First, we will describe runoff patterns in the state usingdischarge observations from the USGS and others, reanalyze model data sets, and conduct additionalsurface water modeling across the state as appropriate. Second, we will use existing geologic maps ofthe state, estimates of geologic units' hydraulic properties, and estimates of water table depth toidentify suitable recharge locations. Third, we will combine the first two objectives to understand wheresuitable recharge locations intersect with available runoff for recharge in proximity to potential usersand environmental assets. Fourth, we will use existing runoff data, computational models, simulationsof recharge processes, and land cover/land use information to estimate evaporation and availablerunoff for recharge in urban areas of the state and runoff volumes from wildfire and forest managementchanges for current and future climates.

A prerequisite of this effort will be several steps to review the current state of knowledge through workshops, published literature, and discussions with DWR. A key point of understanding for the natural scientists engaged in this work will be understanding the underlying nature of water rights in Arizona and the various available definitions of water available for recharge depending on location. The research team will also conduct literature reviews of existing efforts at managed recharge, stormwater, macro-rainwater harvesting, and flood recharge in similar environments in the Southwest and elsewhere. Finally, a compilation of studies of rainfall/snowfall partitioning with emphasis on loss to the atmosphere (e.g., evaporation, transpiration, sublimation), generation and spatial redistribution of runoff, and mechanisms of recharge generally and specifically as embodied in existing studies and models across the State of Arizona will be needed. This baseline knowledge assessment may inform additional research to reduce the uncertainties in forecast models.

Current runoff in the state is observed using USGS stream gauges and other sources. Daily and sub-daily runoff data can be used to estimate runoff volumes and natural recharge. These data will be used to develop an empirical understanding of current and potential runoff volumes available for recharge, rates and types of natural recharge, and of transmission losses in stream channels monitored by multiple gauges. Since gauge networks only cover a fraction of the state, we will supplement observed data with the 42-year state-of-the-art hydrologic reanalysis of the NOAA National Water Model (NWM). We will first assess confidence in the NWM by comparing its simulated discharge against observations and the simulated 1-km maps of land surface temperature and evapotranspiration against remote sensing data. Then, we will utilize the spatial outputs to identify locations where runoff generated locally has a high chance not to reach the channel. The NWM simulations will be supplemented by fine resolution streamflow modelling where needed/as data are available. Additional simulations at the land-atmosphere interface will be needed to understand partitioning of precipitation between runoff, evaporation, and transpiration to understand amount of runoff that could be recharged (physically and legally).

Where this runoff can be recharged depends on the suitability of locations for recharge due to the availability of suitable geologic strata (e.g. unconsolidated coarse sediments) for recharge and the lack of confining layers to minimize vegetative and vadose zone losses during recharge. We will work to map areas in and near water courses across the state to estimate suitability for locations for recharge (with particular focus on areas where there is a current or projected water supply/demand imbalance). Critically, limestone karst systems (sinkholes and enhanced fractures) play an important role in recharge across the state, requiring detailed mapping of surface features, local hydrogeology, and the interplay with land cover, snow cover, and vegetation. Integrated observational and computational tools (including deep learning AI tools) may offer a path forward to better describing karst recharge processes, and will be considered.

Suitable recharge locations and available runoff for recharge must intersect with local needs to make a suitable recharge project location. This combination of results will be needed to provide DWR with actionable information about locations for suitable in- and off-channel recharge projects in Arizona including sustainability for recharge and minimizing clogging potential. Additional factors to incorporate in this overlay of available runoff and recharge include the suitability of land, land ownership, and potential community acceptance of recharge projects in their setting.

Changes in land use, land cover, and land management strategies can increase runoff in Arizona. Available data for southern Arizona show that increases in runoff vary with geographic scale. As the size of a watershed increases runoff volumes increase but infiltration losses increase. We will investigate available urban runoff to understand the interaction of runoff with watershed size. Additionally, we propose integrated modelling to understand the interaction of spatial scale of runoff with volumes of water available for recharge and the design and operation of suitable recharge facilities. This evaluation will include an assessment of rainwater harvesting at multiple scales.

Outside of urban areas there are range and forest management practices and responses to climate change that could lead to changes in evapotranspiration and recharge. For example, forest management needed to decrease fire risk may increase runoff and recharge, but may also increase sublimation of snowpack. Similarly, there may be opportunities related to brush clearing on rangelands, improved erosion protection, and rangeland health to increase recharge. Finally, post fire hydrologic response and management may create temporary opportunities to increase recharge. These potential changes require an understanding of how vegetation changes impact runoff and recharge through both simulation and empirical studies including the use of water isotopic analysis and understanding sediment loads. In both urban and rural parts of the state, the intersection of land surface properties with the expected intensification of droughts and precipitation may lead to the need to respond to increase recharge to adapt to and take advantage of these expected changes. Recharge is dynamic and is expected to change over time, and we will provide recommendations on how often the final products (maps/estimates) will need to be updated in the future.

Deliverables & Metrics of Success

Performance Period	Anticipated Deliverables	Metrics (if applicable)
Year 1	• Hold workshops with DWR staff and other stakeholders/experts to refine agency needs and identify existing state of knowledge • Develop initial maps of basin runoff efficiency using hydrologic observations and the NWM • Conduct baseflow separation analyses of relevant instrumented stream gauging stations to interpret recharge locations and processes • Develop initial map of potential recharge sites in the state • Refine empirical analysis of urban runoff produced across spatial scales • Develop statewide VIC/SWAT or NOAH-MP model for runoff analysis focused on urban areas • Start development of maps and models of potential runoff produced from changes in forest management • Initiate relationships with relevant USFS, BLM, State Land Trust, or other federal land managers to discuss their interests in the project and outcomes • Offer to meet with relevant Tribal authorities regarding their willingness/interest in participation in the study	• Initiate staff and student hiring processes (by month 3) • 3 workshops before the end of 2023 with DWR staff and other stakeholders/experts to refine agency needs and identify existing knowledge • Quarterly all team (3-university) meetings throughout project (can be combined with workshops) • Monthly meetings for runoff, recharge, and land use change working groups as needed • Quarterly meetings of team reps with DWR project lead throughout project • 2 meetings per year with full DWR team to report on progress and get feedback • 1 meeting per year to report on progress with university research offices and ABOR staff

Year 2	• Continue to hold workshops at least every 6 months to facilitate group cohesion internally and refine objectives with DWR team • Meet with relevant USFS, BLM, State Land Trust, or other federal land managers to discuss project objectives and outcomes • Meet with Tribal authorities/staff who are interested in participating in the study; obtain required permissions • Refine maps of basin runoff efficiency and extend analyses to the entire state using the National Water Model • Refine map of recharge potential with combined pedotransfer function estimates and field validation as appropriate. • Refine estimates of urban recharge potential by matching available runoff to suitable recharge locations	• Hold meetings with at least 3 public land managers • Produce draft maps of basin runoff efficiency • Produce draft map of areas of recharge potential • Produce draft estimates of urban recharge potential • Produce draft assessment of the potential impacts of alternative land treatments on water availability
	• Investigate impact of land use change and alternative management techniques on water available for recharge using integrated hydrologic models • Develop existing recharge estimates for selected locations with associated uncertainty through analysis of models and instrumented groundwater-supported stream gauges • Simulate and use empirical studies to understand influence of forest management, climate change on evaporation, runoff, and recharge across grasslands and higher terrain of Arizona	

Year 3		
Final Product(s) / Deliverable(s)	• Map of excess and available runoff for enhanced recharge across the state • Map of suitable recharge locations in the state • Intersection of runoff and recharge locations with suggestions for prioritization • Estimate of available current and future runoff in selected urban areas of the state along with suitable recharge system designs • Estimate of how changes in forest and land management practices and ecosystem responses to climate change could influence runoff and recharge in selected areas of the state • Outreach and engagement of Federal, State and Tribal land managers and others as determined through project	• Produce all identified deliverables (see below) in draft within 3 months of the end of final funding cycle. • Produce final deliverables within 6 months of the end of final funding cycle.

Representatives of the team will meet regularly (quarterly) with the appropriate agency designee to discuss progress on the project. We also plan to meet monthly as sub-teams across universities to facilitate tight coordination of University-developed knowledge so it can be quickly shared with by DWR staff as appropriate. In addition, the team will report on progress to a selected contact at the research offices of the three universities, and ABOR staff, on tri-university coordination at least once per year.

Budget: 3-year budget $3,717,472

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