# Characterizing surface-water and groundwater regimes in a semi-arid landscape that faces combined threats due to changes in land use and climate: Lower Pecos River, Texas, USA

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***By:***

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SOUTHWEST RESEARCH INSTITUTE

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# Technical Proposal

## Executive Summary

Southwest Research Institute (SwRI), located in San Antonio, Texas requests funding from the US Bureau of Reclamation (BOR) to support our work with Crockett County Groundwater Conservation District and Middle Pecos Groundwater Conservation District. This collaborative effort proposes to refine the water budget of the lower Pecos River from Imperial, Texas to its confluence with the Rio Grande River just northwest of Del Rio, Texas by characterizing quality and quantity of inflows and outflows. Specifically, the proposed study will determine how flow and water quality vary throughout the lower Pecos River and whether flow and water quality changes are naturally occurring or if anthropogenic activities contribute to these changes. Funds committed by BOR and project collaborators will be used to pay for the project team to employ integrated workflows of geochemical frameworks and gain-loss studies to qualitatively and quantitatively characterize complex surface-water/groundwater interactions along the lower Pecos River. In doing so, the project team will produce robust datasets and provide a refined conceptualization of the water budget of the lower Pecos River. This will allow water resource managers to make better informed decisions for desert communities to: (1) ensure that future water resources are sustainable; and (2) make decisions for protecting the health of the lower Pecos River. The project duration is two years, with an estimated completion date of May 2026. The proposed project is not located on a Federal facility.

## Technical project description

**Please indicate whether you are a Category A applicant or a Category B applicant and provide a short narrative summary describing how you meet the eligibility requirements of that applicant category.**

Southwest Research Institute (SwRI) qualifies for the Applied Science Grant as a Category B applicant. SwRI is a private 501(c)(3) research institution organized in the public interest and existing under the laws of the State of Texas, with its general offices and laboratories located at 6220 Culebra Road, San Antonio, Texas, 78238. Its mission is to benefit government, industry, and the public through innovative science and technology.

SwRI will act in partnership with Category A partners Crockett County Groundwater Conservation District (GCD) and Middle Pecos GCD. A GCD is a local unit of government authorized by the Texas Legislature and ratified at the local level to manage and protect groundwater within its jurisdiction, such as by developing management plans and permitting non-exempt water wells. Moreover, as part of a management plan, a GCD has the authority to buy, sell, transport, and distribute groundwater or surface water. A Letter of Partnership from Crockett County GCD and a Letter of Funding Commitment and Partnership from Middle Pecos GCD are included in Appendix A.

**Provide a more comprehensive description of the technical aspects of your project, including the work to be accomplished and the approach to complete the work.**

This study proposes the application of two tools to refine the water budget of the lower Pecos River: (1) the application of a geochemical framework and (2) gain-loss studies. The water budget here is defined to include the quality and quantity of inflows and outflows to the lower Pecos River. A geochemical framework is a structured approach that utilizes geochemical analyses, statistical analyses, and geochemical modeling to characterize surface-water/groundwater flow regimes by identifying different source areas and flow paths to discharge points (e.g., rivers, springs, wells). The application of a geochemical framework provides: (1) a means to differentiate mixing and flow path characteristics that may contribute to the hydrochemical signature of a body of water; and (2) a method to explain temporal variability in hydrochemistry. An integral part of the geochemical framework is the collection and interpretation of robust geochemical data. In the context of this study, "robust" is characterized by: (1) the collective use of an extensive suite of geochemical constituents (i.e., ions, isotopes, physiochemical parameters); (2) an extensive spatial coverage over a large geographic area; and (3) the establishment of time series data by multiple geochemical data collections over time. Water chemistry will be analyzed for two distinct water populations. (1) Water sampled from springs and aquifers that discharge to the river will be sampled for an extensive suite of constituents. These data will enable assessment of interactions with groundwater systems. (2) Water sampled from the river and its tributaries will only be analyzed for standard constituents (i.e., ions and physiochemical parameters). The anticipated limited opportunity to develop greater insight on the surface-water/groundwater regimes by including isotope analysis of river water sample does not justify the high cost of isotope analyses. Geochemical data for the study area with respect to both of these standards is currently limited. *Development of a comprehensive water-chemistry database compiled using analyses for these two water populations is necessary to understand the complex recharge-discharge relationships of the Pecos River watershed.*

If the geochemical signature manifested in a water sample is different from perceived background conditions, the tools assembled during this project will enable identification of which source area(s) has/have caused the change in chemistry (i.e., from altered or diminished flow). This will be achieved by generating the robust geochemical datasets required to: (1) understand and conceptualize complex surface-water/groundwater flow regimes; (2) identify recharge areas and sources of springs; (3) provide estimates of firm yield of groundwater (Mace, 2023); and (4) assemble geochemical framework models that can serve as indicators of impacts to water resources due to changes in land use and climate. The breadth of robust geochemical data, both spatially and temporally, will be expanded by collecting river, spring, and aquifer samples in Crane, Pecos, Upton, Crockett, Terrell, and Val Verde counties (Figure 1).

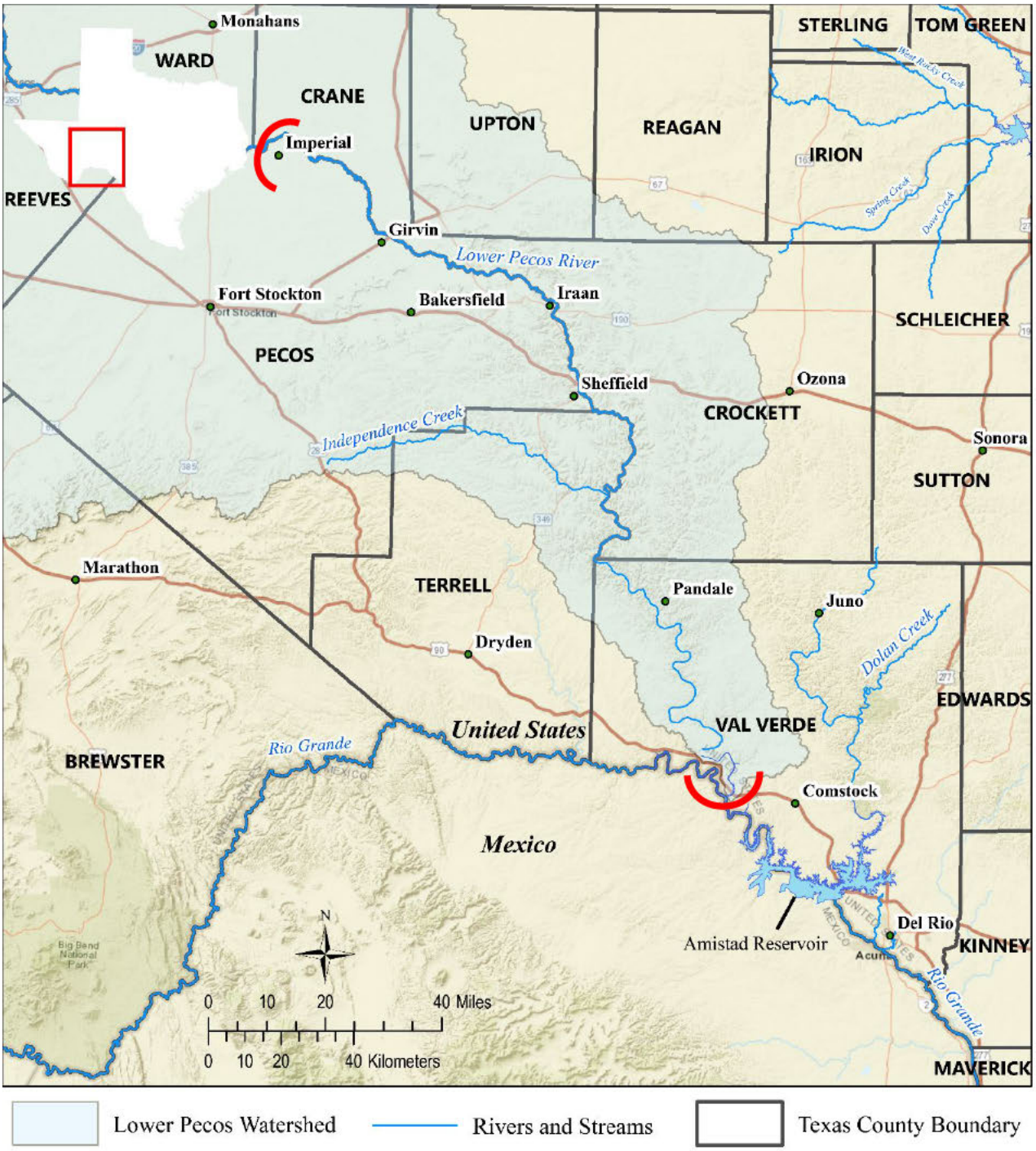


**Figure 1. The proposed study will focus on the lower Pecos River reach from Imperial, Texas to its confluence with the Rio Grande River near Amistad Reservoir. The area of interest along the Pecos River is bounded by red brackets.**

Gain-loss measurements are made to identify river reaches or points where there are inflows into the river or outflows from the river. These inflows and outflows are typically from and to the groundwater regime. Data are obtained by actively measuring the quantity of water flowing in

the river at a specified transect. Measurements can be made using a permanent gauging station or by using transient and mobile instrumentation. Protocols for both approaches are well established (Rantz et al., 1982). Conducting gain-loss measurements in the river above and below locations where significant inflows or outflows occur provides the basis to establish the river water budget throughout the reach of interest and investigation.

Chemistry and gain-loss data from these studies will be reviewed and used to construct a preliminary geochemical framework for the Imperial, Texas to Rio Grande reach of the lower Pecos River as well as to identify specific locations where additional flow and water quality data are needed. Once candidate chemistry and gain-loss measurement sites are identified, the project team will coordinate their efforts with cooperating agencies and local stakeholders to identify sites that are accessible and can be synoptically measured and sampled by our team. To minimize the effects of bank storage release on estimated stream gains and the effects of groundwater pumping for irrigation on stream loss, the project team will identify several 10-day periods during which the flow in the Pecos River reflects baseflow conditions and when flow is relatively unaffected by reservoir releases or other anthropogenic effects on flow. Where possible, aquifer samples will be collected from wells near the Pecos River measurement sites to augment the geochemical framework and examine the connectivity of local aquifers (i.e., Edwards-Trinity (Plateau) Aquifer) and the river. In addition, the application of a geochemical framework in concert with gain-loss studies will be used to determine if changes in water chemistry along the Pecos River are naturally occurring, and, if not, whether there are indications that changes in recharge are caused or influenced by changes in land use or climate.

**Discuss the preliminary goals and objectives of the project.**

The objective of the proposed Applied Science Grant is to characterize the lower reach of the Pecos River, from Imperial, Texas to its confluence with the Rio Grande (Figure 1). The surface-water/groundwater relationships of this reach are complex. Some reaches in the Pecos River are naturally saline, with anthropogenic activities reducing flow and increasing salinity of the river over time (Miyamoto et al., 2008; Houston et al., 2019). The locations of and the degree to which these activities have altered the health of the river are not well defined. Left unchecked, it's likely the salinity of the Pecos River will continue to increase and river flow will decrease thereby impacting not only the communities reliant on the lower Pecos River, but also those reliant on Amistad Reservoir of which the Pecos River is a major contributor (Jensen et al., 2006; Cheek and Taylor, 2015; Walker et al., 2021).

The preliminary goals of the project are to collect robust water-quality and flow data to refine the water budget conceptualization of the lower Pecos River. This entails identifying the quality and quantity of all major inflows and outflows, natural or otherwise. A literature search and discussions with landowners will be used to identify major features. Quantifying the inflows and outflows will be achieved by sampling and analyzing inflows to and discharge the river and by analyzing river-water chemistry and flow at sufficient spatial and temporal resolution to determine changes in river character due to increases or losses to river inflows and outflows. Accordingly, the impacts of land use and climate change will be addressed as part of this undertaking.

This study proposes to characterize the Imperial, Texas to Rio Grande reach of the Pecos River to provide a baseline for science-based management of this valuable resource. This will be achieved by the following technical approach:

1) Literature search, data compilation, reconnaissance trip (one week), and community outreach to identify data gaps and all major surface-water and groundwater inflows to the lower Pecos River in the study area.
2) Conduct field campaigns each year. During each campaign the project team will: a) collect geochemical data from each major inflow to and along the lower Pecos River; and b) conduct gain-loss measurements of flow upstream and downstream of each major inflow to the river to determine the quantity and quality of water provided by the inflow.
3) Apply geochemical frameworks and analyze gain-loss results to characterize the quality and quantity of river flow as it changes along this reach and refine conceptualization of the water budget of the lower Pecos River.
4) Summarize the robust database of streamflow measurements and water-quality data to establish the variable state of the river along the Imperial, Texas to Rio Grande reach.
5) Share project results and products with stakeholders and local communities through town hall meetings and project status and final reports.

## Project Location

The project location will focus on the lower reach of the Pecos River, from Imperial, Texas to its confluence with the Rio Grande upstream from Amistad Reservoir in Del Rio, Texas (Figure 1). The lower Pecos River provides a suitable study area for the application of geochemical frameworks and gain-loss studies because it is: (1) an iconic water feature in an arid to semi-arid environment where surface water is limited; (2) central to the economic viability of the local communities; (3) subject to threats from increased water demands due to potential increases in agricultural, oil/gas activities, and population and consequently vulnerable to anthropogenic impacts; (4) subject to decreased recharge due to climate change; and (5) subject to several recent and ongoing investigative studies fueled by its recognized importance.

## Data Management Practices

Any spatially explicit data or tools developed in the performance of an award made under this NOFO will be developed in industry standard formats that are compatible with Geographic Information System (GIS) platforms.

# Evaluation Criteria

## Evaluation Criterion A—Water Management Challenge(s)

**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?**

Rivers in west Texas provide considerable recharge to Amistad Reservoir, which, in turn, provides water for the lower Rio Grande/Rio Bravo, a major transboundary water source for Mexico and the United States. A large number of underserved communities on the lower Rio Grande/Rio Bravo are reliant on this threatened source of water (Green et al., 2016; Sandoval-Solis et al., 2022). The Pecos River accounts for 11 percent (195,000 acre-feet/year) of the annual inflow, but 30 percent of the salt loading, to Amistad Reservoir (Miyamoto et al., 2006). Amistad Reservoir, in turn, provides water supplies for municipal, agricultural, tribal, environmental and recreational water uses in the lower Rio Grande/Rio Bravo. Recent trends indicate that the annual inflow from the Pecos River to Amistad Reservoir has decreased over time (Miyamoto et al., 2006; IBWC, 2023). When coupled with the tendency for salinity to increase when river flow decreases, these trends do not bode well for the health of either the Pecos River or Amistad Reservoir. The increase in salinity of Amistad Reservoir from 560 mg/L to 1,000 mg/L since the initiation of monitoring substantiates this unwelcome trend (Miyamoto et al., 2006; Hoagstrom, 2009; Houston et al., 2019). Unfortunately, the locations, quality, and quantity of inflows to the Pecos River are not sufficiently characterized to support science-based management of the river or the watersheds and groundwater capture areas that discharge to the river.

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

The environments of the western half of Texas and much of the western United States are classified as arid to semi-arid (Köppen, 1931). Water resources for these areas are limited while demand is increasing due to oil/gas development, population growth, increased agricultural activity, and changes in climate. Severe water shortages could be experienced if threats from climate change and land use are not recognized and addressed. The first step is to establish a clear and accurate characterization of the surface-water and groundwater regimes of the threatened areas. Once characterization is completed, changes in the long-term availability and quality of water can be forecast considering impacts due to climate (i.e., recharge) and land use (i.e., demand and water quality) changes.

**Explain how your project will address the water management issues identified in your response to the preceding bullets and provide support for your response**.

The project will address the following water management issues:

*a. water supply reliability for municipal, agricultural, tribal, environmental or recreational water uses*

The lower Pecos River watershed community is highly reliant on the river to provide for municipal, agricultural, tribal, environmental, or recreational water uses (Green et al., 2016; Houston et al., 2019). The Pecos River cannot be reasonably managed if its quality and quantity are not adequately characterized. In addition, the future sustainability of this resource cannot be ensured in the face of changes in land use and climate if the surface-water/groundwater regimes and their interactions are not adequately characterized.

*b. management of water deliveries*

The proposed project will focus on characterizing the groundwater resources of the lower Pecos River watershed, which will, by definition, includes evaluation of the surface-water/groundwater inter-relationships that govern the river. Water delivery, per se, will not be a focus of this project.

*c. water marketing activities*

Virtually all water resources of the arid and semi-arid regions in western Texas and the western United States are under threat by over development, changes in land use, and climate change. Water marketing schemes often misrepresent either the availability of water resources, minimize the impact of development, or both. It is difficult, if not impossible, to make informed decisions on how to develop and manage water resources if the surface-water/groundwater regimes are not adequately characterized. This project would provide the basic data needed to enable better informed decisions on water marketing.

*d. drought management activities*

Common to all water-resource management decision making, activities designed for drought management are not feasible if the surface-water/groundwater regimes are not adequately characterized. This project would make drought management decision-making better informed.

*e. conjunctive use of ground and surface water*

Communities in the lower Pecos River watershed and downstream in the Rio Grande/Rio Bravo valley rely on conjunctive use of ground and surface water for municipal, agricultural, tribal, environmental, or recreational water uses. Poorly informed use of these resources can have profound effects on the integrated surface-water/groundwater regimes. For example, much of the targeted reach of the Pecos River is classified as gaining (Houston et al., 2019). Over-development of water extraction by pumping could have deleterious effects on the health of the river. This project would make decisions to extract water from either the river or from adjoining aquifers better informed by characterizing source areas for major inflows to the river.

*f. water rights administration*

The State of Texas assigns the rights to groundwater to land ownership while the State retains the rights to surface water. This already complicated and complex legal framework is difficult to enforce when the surface-water/groundwater regimes and their relationships are well characterized. Administering water rights can be ill-informed and mis-guided when these two regimes are not adequately characterized. This project will make better and more defensible administration of water rights possible.

*g. ability to meet endangered species requirements*

The Nature Conservancy (TNC) is currently engaged in developing a Habitat Conservation Plan (HCP) for the lower Pecos River. TNC supports the project because it would provide information on the surface-water/groundwater regimes on the lower Pecos River that are critical to the successful development and implementation of the HCP. This project will enable development and implementation of an HCP for the lower Pecos River to meet endangered species requirements.

*h. watershed health*

The health of the lower Pecos River watershed, similar to most watersheds in arid and semi-arid environments, is fragile (Meehl and Tebaldi, 2004; Loarie et al., 2009; D'Odorico and Bhattachan, 2012; Andela et al., 2013; Green et al., 2016; Houston et al., 2019). Characterization of surface-water/groundwater regimes of the lower Pecos River watershed and databases developed during this project will enable improved water-resource management decisions to be made. Better management of the water resources will protect the health of the watershed.

## Evaluation Criterion B—Project Benefits

**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?**

Entire communities in arid and semi-arid environments are dependent on the water resources provided by desert rivers and springs (Sandoval-Solis et al., 2022). Stakeholders who have expressed concern about the future sustainability of their water resources include groundwater conservation districts (Crockett County GCD, Middle Pecos GCD), landowners (Lower Pecos Landowner Group), and non-governmental organizations (Friends of the Pecos River, TNC). The focus and scope of the proposed project were developed in concert with these stakeholders.

**Describe how the tool, method, or information will be applied and when will it be applied.**

The principal products of the project will be the integrated workflow, a supporting robust database, and a refined conceptualization of the water budget that will assist policy makers when making water-resource management decisions. Complementary and supporting products will be guidance available to stakeholders to effectively use project deliverables. Currently, there are insufficient data and conceptualizations of the surface-water/groundwater systems that sustain water resources in these arid and semi-arid environments; those that do exist are poorly constrained. The database and tools developed during this project will greatly inform the resource allocation decisions made by water-resource managers by having improved conceptualizations of their water resources (i.e., recharge rates, impacts of changes in land use and climate on available recharge, how the hydrochemistry of the Pecos River, springs, and aquifers can portend changes in surface-water/groundwater interactions). Although additional data and future improvements in conceptualizations would enhance the tools developed in the proposed project, no additional work will be required to effectively use the products developed by this project. The project team anticipates that the stakeholders will integrate project data and results immediately.

**Will the tool or information be used immediately or will additional work need to be done before the tool will be used?**

The principal products of the project will be integrated workflows, a supporting robust database, and a refined conceptualization of the water budget that will assist policy makers when making water-resource management decisions. Complementary and supporting products will be guidance available to stakeholders to effectively use the tools and databases. Currently, there are insufficient data and conceptualizations of the surface-water/groundwater systems that sustain the water resources in these arid and semi-arid environments; those that do exist are poorly constrained. The database and tools developed during this project will be available immediately as the project proceeds to inform resource allocation decisions made by water-resource managers by having improved conceptualizations of their water resources (i.e., recharge rates, impacts of changes in land use and climate on available recharge, how the hydrochemistry of spring discharge can portend changes in recharge to the springs). Although additional data and future improvements in conceptualizations would enhance the tools developed in the proposed project, no additional work will be required to effectively use the products developed by this project.

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

At this time, there are limited efforts to protect the quantity and quality of recharge to the Imperial, Texas to Rio Grande reach of the lower Pecos River. This project will help develop the database and accompanying conceptualization to identify where and how inflows and outflows to this reach occur. Once this understanding is established, various entities (governmental and nongovernmental organizations) and landowners can realize how their activities impact the health of the river. There are recent efforts by the Friends of the Pecos, Lower Pecos Landowner Group, and TNC to protect source areas to the river. In fact, the first conservation easements in the lower reach are to be established in 2023. By having the database and conceptualizations that would be provided by this project, those lands and areas of greatest importance to recharge of the river can be identified and targeted for protection.

**Who will use the tool or data developed under this proposal and how will they benefit from the project?**

As stated above, organizations such as Friends of the Pecos River, Lower Pecos Landowner Group, and TNC will use the database, conceptualizations, and conclusions of this study to determine strategic land restoration strategies that have potential to enhance flow and protect the quality of recharge and spring discharge. At a minimum, the database and conceptualizations developed by this project will empower stakeholders to limit future activities and water-resource management decisions that would otherwise continue to degrade the quantity and quality of inflows to the river. These entities support this project and will directly and immediately benefit from the outcomes of the project.

**How will the project improve water management decisions?**

Groundwater conservation districts will benefit by having the integrated workflows, robust databases, and conceptualizations of inflows and outflows to and from the river to be able to make better informed decisions on management of the water resources. Decisions include how and where groundwater is pumped and the nature and locations of oil/gas activities. These benefits will be immediate. Also, as stated above, Friends of the Pecos River, Lower Pecos

Landowner Group, and TNC will use the database, conceptualizations, and conclusions of this study to determine strategic land restoration strategies that have potential to enhance flow and protect the quality of recharge and spring discharge. At a minimum, the database and conceptualizations developed by this project will empower stakeholders to limit future activities and water-resource management decisions that would otherwise continue to degrade the quantity and quality of inflows to the river.

**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 integrated workflow of applying geochemical frameworks and gain-loss studies to qualitatively and quantitatively characterize complex surface-water/groundwater interactions that will be generated in this project are clearly applicable elsewhere. Localities where this approach is most applicable are the arid and semi-arid environments of western Texas (e.g., greater Trans-Pecos region and El Paso), and the western United States in general (e.g., border communities in New Mexico, Arizona, and California), where water resources are limited and threatened by increased demands and changes in land use and climate. The results will be applicable beyond the United States as well, including the transboundary river basins shared with Mexico. Additional work to apply this approach elsewhere would include the acquisition of water-quality and river-flow data to develop the databases needed to develop conceptualizations of the integrated surface-water/groundwater regimes, which tend to be complex in these demanding environments.

**To what extent will the project address the water management challenges described in E.1.1.?**

In the absence of knowing the extent of surface-water/groundwater interactions along the lower Pecos River, water-resource managers are hard pressed when making informed decisions regarding the reliability of water supplies, water-rights administration of the lower Pecos River and interactions with groundwater, and how to efficiently exploit and conserve these water resources. This uncertainty is exacerbated when changes in land use and climate are involved. Compilation of robust temporal and spatially extensive flow and water-quality databases enables constraint on conceptual and numerical models of cause(s) of changes in discharge or chemistry. The refined water budget developed using geochemical frameworks and gain-loss studies will enable water-resource managers to protect and improve watershed health while increasing the ability to meet endangered species requirements and ensure water-marketing activities or other changes (e.g., drought) do not threaten the sustainability of water resources.

**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?**

The proposed project would complement other efforts in the lower Pecos River watershed by augmenting scientific understanding of the understudied reach from Imperial, Texas to its confluence with the Rio Grande. Some efforts have focused hydrology and ecology research on the reaches of the upper Pecos River in New Mexico (USBOR and NMISC, 2021; TNC and

USACE, 2022) or on the Permian Basin (Pskowski, 2023). Other investigators have conducted research examining the whole watershed at a coarser scale (Houston et al., 2019), while efforts under the Pecos Watershed Conservation Initiative have been directed towards grassroots habitat restoration and ecosystem conservation efforts along the Pecos River (NFWF, 2023). The proposed project would be unique in its high-resolution focus on and characterization of an understudied segment of the lower Pecos River watershed. The resulting workflow, database, and conceptualization of the project will empower regional communities to develop and design other projects regarding water security, infrastructure, and ecosystem health in the lower Pecos River watershed and in the greater Rio Grande watershed region.

SwRI has conducted research on the transboundary Amistad Reservoir for several years (Flores et al., 2020). The reservoir is critical to the water security of the surrounding areas and downstream communities in both the United States and Mexico. Despite this importance, the water resources of the reservoir region have been poorly characterized, especially with respect to the surface-water/groundwater interactions of transboundary aquifers in the area (e.g., the Edwards-Trinity Aquifer) and the source areas of major springs (e.g., Goodenough Spring and San Felipe Springs). Previous and ongoing team efforts have focused on applying geochemical frameworks in both the U.S. and Mexico portions of the Amistad Reservoir region in order to: (1) improve scientific understanding of cross-border hydrologic dynamics; and (2) constrain the source areas of major springs. This effort has included fieldwork in both countries and collaborations with the U.S. National Park Service and International Boundary and Water Commission. This proposed Applied Science Grant would complement ongoing efforts in the region by filling in significant spatial and temporal gaps of physical and geochemical data in lower Pecos River watershed. Advancing these research efforts would contribute directly to refining the Amistad Reservoir's water budget and consequently, the water budget of downstream reservoirs and communities. The proposed project is thus expected to have binational, transboundary impact.

## Evaluation Criterion C—Project Implementation

**Briefly describe and provide support for the approach and methodology that will be used to meet the objectives of the project. However, you should provide support for your chosen methodology, including use of any specific models, data, or tools**.

Since the mid-1960s, there have been four synoptic studies of both the upper and lower reaches of the Pecos River's water chemistry, the river's gains from tributaries, spring flows, and groundwater inflows, and its losses to irrigation diversions, riparian evapotranspiration, and groundwater outflows, from New Mexico to its confluence with the Rio Grande. During February-March of 1964 and May 1965, Grozier et al. (1966) conducted high-flow (127 cfs reservoir release) and low-flow (2.58 cfs reservoir release) synoptic surveys of water delivery and the variation of flowrates and water chemistry at specific locations along the Pecos River between Red Bluff Reservoir, located just south of the border between Texas and New Mexico, and the city of Girvin, TX, located 188 miles downstream. In April 1967, Grozier et al. (1968) conducted a high-flow (547 cfs reservoir release) synoptic water chemistry and gain-loss study between Red Bluff Reservoir and Girvin, Texas. In early February of 1968, Spiers and Hejl

(1970) conducted low-flow (25.4 cfs near Girvin) synoptic water quality and gain-loss studies between Girvin, Texas and the mouth of the Pecos River at the International Boundary and Water Commission stream-gaging station near Comstock, Texas. In late February 2015, Houston et al. (2019) conducted a comprehensive synoptic assessment of the salinity of the Pecos River from Santa Rosa Lake, New Mexico to its confluence with the Rio Grande in Texas. Unfortunately, Houston et al. (2019) took no measurements of river discharge or water chemistry below Sheffield, Texas, which is more than 70 river miles downstream of Girvin, Texas. It is within this 126-mile-long reach from Sheffield, Texas to the Rio Grande that the Pecos River typically gains substantial fresh streamflow from Edwards Plateau and Stockton Plateau tributary watersheds and relatively low-TDS spring and groundwater inflow from the Edwards-Trinity (Plateau) aquifer.

Chemistry and gain-loss data from these studies will be reviewed and used to construct a preliminary geochemical framework and water budget for the Pecos River reach between Imperial, Texas and its confluence with the Rio Grande/Rio Bravo as well as to identify specific locations where additional data are needed. Once candidate chemistry and gain-loss measurement sites are identified, the project team will coordinate their efforts with cooperating agencies and local stakeholders to identify which sites are accessible and the number of the accessible sites that can be measured synoptically by our team. To minimize the effects of bank storage release on estimated stream gains and reduce the effects of groundwater pumping for irrigation on stream loss, the project team will identify several periods during which the flow in the Pecos River reflects baseflow conditions and is relatively unaffected by reservoir releases or other anthropogenic discharges. Where possible, samples will be collected from springs and wells near the Pecos River measurement sites to augment the geochemical framework and further examine surface-water and groundwater interactions.

**Describe the work plan for implementing the proposed scope of work.**

Task 1: Literature search, historical data collection, and reconnaissance trip – $28,873
The project team will conduct an extensive literature search, data compilation, and a one-week long reconnaissance trip to identify all major surface-water and groundwater inflows to the lower Pecos River in the study area.

Task 2: Field data collection – $216,082
The project team will conduct field campaigns in each year of the project. During each campaign the project team will: a) collect geochemical data from each major inflow to and along the lower Pecos River; and b) conduct gain-loss measurements of flow upstream and downstream of each major inflow to the river to determine the quantity and quality of water provided by the inflow. The project team estimates that 30 geochemical samples from the Pecos River and 15 geochemical samples from springs and aquifers will be collected each year. The number and location of transects at which river flow will be measured will be determined as part of Task 1.

Task 3: Apply geochemical frameworks and analyze gain-loss results to characterize the quality and quantity of river flow and develop a refined conceptualization of the water budget – $110,407

Maps of geochemical data will be developed to characterize spatial variations and regional patterns. Piper diagrams and bivariate plots will be employed to categorize springs, wells, and the Pecos River by hydrochemical assemblages. Application of multivariate statistics (e.g., principal component analysis) will be used to differentiate important components that can fingerprint sources of inflows and outflows along the Pecos River. The flow measurements made at each transect will be used to develop a gain-loss map of the river. Water-chemistry data will be incorporated with the gain-loss river map to provide the basis for water budget conceptualization.

Task 4: Stakeholder engagement – $10,278

Successful execution of this project will not succeed without landowner engagement. This will be a priority throughout the project. The project team will also present project findings and results at two town hall meetings in the study area. Stakeholders will have the opportunity to provide input and ask questions about the progress and impact of the proposed project.

Task 5: Project management and reporting – $34,359

The project team will summarize the robust database of water-quality data and streamflow measurements in two interim status reports and a final report to establish the variable state of the river along the Imperial, Texas to Rio Grande reach. Reports and presentations will be conveyed to BOR and project collaborators and stakeholders.

The estimated project schedule and milestone completions are outlined in Table 1.

**Table 1. Estimated project schedule. Green shading indicates the duration(s) of each task. Milestone completions (described hereafter in Table 2) for each task are denoted by 'x'.**

| Task | Month of the Project | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | | | x | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | x | | | | | | | | | | x | | | | | | | | | |
| 3 | | | | | | | | | | | | x | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | x | | | | | | | | | | x | |
| 5 | | | | | | | | | | | | | | | | | | | | | | x | | x |

Major project milestones and estimated dates of completion are outlined in Table 2.

**Table 2. Major milestones and estimated start and completion dates of the proposed project.**

| Task | Milestone | Estimated Start Date | Estimated End Date |
|---|---|---|---|
| 1 | Identification of sample locations for field data collection | Month 1 | Month 3 |
| 2 | Collection of geochemical and streamflow data | Month 4 (Year 1)<br>Month 14 (Year 2) | Month 5 (Year 1)<br>Month 15 (Year 2) |
| 3 | Interim report on Year 1 field data collection | Month 10 | Month 12 |
| 4 | First stakeholder town hall | Month 13 | Month 13 |
| 3 | Interim report on Year 2 field data collection | Month 16 | Month 18 |

| Task | Milestone | Estimated Start Date | Estimated End Date |
|---|---|---|---|
| 5 | Draft Final Report | Month 20 | Month 22 |
| 4 | Second stakeholder town hall | Month 23 | Month 23 |
| 5 | Final Report | Month 22 | Month 24 |

**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.**

A summary description of the products that are anticipated to result from the project are included in Table 3.

**Table 3. Anticipated products and results from the proposed project.**

| Anticipated Products | Anticipated Results |
|---|---|
| A database of geochemical samples from the study area (including extensive data already compiled by the project team and data from any samples collected and analyzed as part of the project) and streamflow measurements will be compiled in a geodatabase. Geochemical data will include temperature, pH, specific conductivity, major ions, trace metals, and isotopes (i.e., stable and radiogenic). | The geodatabase, which will be compatible with industry accepted GIS platforms, will include geochemical observations of key springs and wells to provide the basis for identification of surface-water and groundwater interactions and analysis of temporal changes in flow regimes. |
| Maps and visualizations of source areas will be created. Source areas and flow regimes will be identified, to the degree possible, using results from database and model interpretations. | Temporal variations in water chemistry will be identified by time series analysis of the compiled and robust geochemical data. |
| A refined water budget will be produced throughout the study area. The water budget conceptualization will show what and where flows are along the lower Pecos River and which reaches are gaining and losing. Quantity and quality of measured flows will be illustrated graphically in regional maps and tabulated by spreadsheets. | A refined water budget will allow water-resource managers to make better informed decisions with regards to potential changes in land use (e.g., water well field development). By improving the conceptualization of the surface-water and groundwater regimes using the water budget, water-resource managers will also be better positioned to make effective decisions on the impacts of climate change (e.g., diminished recharge) on their resources. |
| A final report that summarizes project findings and recommendations for water resource allocation will be made publicly available. | Changes in chemistry due to potential changes in climate (i.e., recharge rates at select source areas) or land use (i.e., pumping at select locations) will be calculated using the mixing and reaction path models developed for current conditions. |

**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**.

Crockett County GCD and Middle Pecos GCD are involved in the project as Category A Partners. Stakeholders that will also have an active role in the project are TNC, Friends of the Pecos River, and Lower Pecos Landowner Group. Project partners and stakeholders will assist the project team in gaining access to wells and springs to allow site inspection and water sample collection. This assistance is important given that many sample locations are remote and located on private lands. Site access can prove to be a project breaker if local collaborators are not on the team. Wells, springs, and river access points that have been identified for inclusion in the project will be selected after consultation with the project partners and stakeholders. These collaborators will be engaged during the entirety of the project to provide feedback on preliminary findings that may affect the use and management of lower Pecos River watershed water resources.

**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.**

Ms. Nunu is a groundwater hydrologist with experience and interests in karst hydrogeology, aqueous geochemistry, regional surface-water and groundwater flow systems, and surface-water/groundwater interactions. As a Research Scientist at Southwest Research Institute, she quantifies water resources using geochemical indicators and geographic information systems to provide refined conceptualizations of hydrologic systems. Ms. Nunu's recent work focuses on characterization of aquifer recharge-discharge relations using geochemical indicators and multivariate statistical analyses with particular interest in arid and semi-arid environments.

Dr. Wittmeyer is a hydrologist with expertise in developing and applying computational methods to assess the fate and transport of contaminants in the subsurface environment, performing hydrologic inverse modeling, conducting environmental risk assessments using probabilistic methods, and developing practical methods for grid-scale energy storage. He has extensive experience assembling and leading multidisciplinary teams of scientists and engineers to solve complex engineering and environmental problems. As a Senior Scientist, Dr. Wittmeyer is responsible for identifying new technologies and markets that will sustain the viability of the Center for Nuclear Regulatory Analyses (CNWRA®) and enhance the technical expertise and utilization of its staff. Dr. Wittmeyer recently proposed constructing closed-loop pumped storage hydropower units in west Texas that use excess production brine from oil and gas operations in the Permian Basin to fill the upper and lower reservoirs, and, as a result, is familiar with the hydrology of the study area.

Dr. Green has over 40 years of experience in water-resource investigations with the most recent 25 years focusing on the water resources of arid and semi-arid environments including central and west Texas. These investigations incorporated a range of field-data acquisition campaigns that included gain-loss surveys, hydrological assessments, water-chemistry analyses, and

geological structural studies to support development of conceptual and analytical models of complex surface-water/groundwater regimes. Dr. Green is a registered geoscientist in Texas.

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

The project team has conducted extensive investigations of the water resources of Reeves, Pecos, Crockett, and adjoining counties for the past decade. In addition, the fundamental focus of this previous work has been the development of conceptual models and water-budget analyses for sub-domains within the greater Edwards Plateau area. Following is a listing of notable projects.

BOR Applied Science Grant. The project team has used geochemical frameworks to characterize groundwater and surface-water interactions and source areas to iconic springs in similar semi-arid landscapes (Nunu et al., 2019; Nunu and Green, 2020; Nunu, 2020). These studies include springs in Reeves, Jeff Davis, and Pecos counties. The evaluation is predicated on robust sampling and analysis of the chemistries of the water discharged at these springs supplemented by comparable sampling and analysis of groundwater from wells located in the purported source areas of the targeted springs.

Pecos River Watershed Assessment and Model. A reconnaissance groundwater numerical model was developed for the lower Pecos River Watershed to provide insight on the water budget and the surface-water/groundwater flow regimes (Green et al., 2016). The project team developed the model for the lower Pecos River watershed from upstream of Sheffield to the confluence with the Rio Grande. The project included resistivity surveys of Live Oak Creek and Independence Creek channels to help determine the quantity of fresh water discharged by those two tributaries to the Pecos River. The model, which was predicated on limited river flow and salinity information that was available at that time, was used to simulate how much freshwater from Independence Creek and Live Oak Creek might be necessary to improve the quality of water in Pecos River by the time it discharges to the Rio Grande. The study identified how important actual river flow and salinity values are to any model or analytical tool to be used to inform river management decisions.

Devils River Watershed Assessment and Model. The project team has conducted several studies focused on the Devils River watershed over the past decade. The hydrogeology of the watershed was characterized using water chemistry, geophysical imaging of the subsurface, aquifer hydraulics, recharge evaluations, and water-budget analyses (Green et al., 2014, 2019). Numerical models were developed to replicate the hydraulics of the conceptual model (Fratesi et al., 2015; Toll et al., 2017).

Devils River Gain-Loss Study. A 2014 Journal of Hydrology article by the project team on the hydrogeology of the Devils River watershed is of particular relevance to the proposed project (Green et al., 2014). The study described in the article provided a conceptual model of the hydrogeology and the surface-water/groundwater regimes of the karstic carbonate Edwards-Trinty Aquifer in the Devils River watershed. The Edwards-Trinity Aquifer is also the principal aquifer in the lower Pecos River watershed. The article included a gain-loss survey of the Devils River conducted by the project team with assistance from staff from the National Park Service and Sul Ross University.

Western Edwards-Trinity Aquifer Evaluation. In 2010, the project team conducted an evaluation of the water resources of eight counties (i.e., Crockett, Edwards, Kimble, Menard, Real, Schleicher, Sutton, and Val Verde) that rely on the Edwards-Trinity Aquifer for their water resources. Estimates of recharge rates versus precipitation rates and the water budgets were provided by this evaluation (Green and Bertetti, 2010; Green et al., 2012).

**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, the project team can immediately proceed with tasks within the proposed project upon entering into a financial assistance agreement.

## Evaluation Criterion D—Dissemination of Results

**Describe how the tools, frameworks, or analyses developed under the proposed scope of work will be disseminated, communicated, or made available to water resources managers who may be interested in the results.**

Friends of the Pecos River, with support from and coordination with Crockett County GCD and Middle Pecos GCD, will help the project team host two town hall meetings during the project for landowners, water-resource managers, scientists, community members, and other interested stakeholders. Both town hall meetings will be held within the study area to encourage local participation and get feedback from local communities. The first town hall meeting will be held at the end of the first year of the project. Results from the first sampling campaign and gain-loss study will be presented at this meeting. The second town hall meeting will be held near the end of the project after preparation of the draft final report. Public and peer review comments will be solicited for incorporation into the final report. Such involvement will provide stakeholders with tools to make decisions that will protect and maintain the viability of their water resources. Most importantly, all products developed by the project will be made publicly available for access by all stakeholders and interested parties. Town hall meetings will be made virtual as appropriate.

**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 of the project.

**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.**

The project team will conduct two town hall meetings in the communities within the study area. All stakeholders will be invited. One town hall meeting will be conducted at the end of the first year of the project. The second town hall meeting will be held at the conclusion of the project at a time when the penultimate final report is available. Friends of the Pecos will help facilitate the town hall meetings and pursue local media releases to share key takeaways and enhance visibility of the proposed research. Status reports and final presentations will be conveyed to the

project collaborators supporting the project. Feedback and input from project collaborators and other stakeholders will be solicited during these interactions. The project team will publish a final report that will be publicly available. This will allow for broad peer review. The report will be posted on a publicly available website such as those hosted by local GCDs.

**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.**

BOR will directly receive the results of the proposed project which can be used to manage the salinity of the Pecos River, the salinity of Amistad Reservoir, and the salinity of the reservoir releases from Amistad Reservoir. The results of the proposed study will provide more accurate assessment of the degree to which low salinity groundwater and tributary gains to the Pecos River in the study area ameliorate the water quality of the Pecos River and Amistad Reservoir. The project will also help BOR understand how groundwater and surface-water interactions impact the salinity of the Pecos River. This project will provide BOR with the tools, techniques, and integrated workflow needed to characterize natural systems and potential anthropogenic impacts of similar areas in the West. All project products will be included in the final report. Project results will also be presented at conferences and as a journal article, as appropriate.

## Evaluation Criterion E—Presidential and Department of the Interior Priorities

### Climate Change

**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?**

Protecting the quality and quantity of the Pecos River will increase the resilience of affected water users to anticipated increased aridity. Doing so will also secure environmental justice and spur economic opportunity for disadvantaged communities of the lower Pecos River watershed and the lower Rio Grande valley that have been historically marginalized and overburdened by pollution and degradation of water and wastewater infrastructure associated with the outflow of Amistad Reservoir to the Rio Grande. The biodiversity of the lower Pecos River watershed, and the Rio Grande downstream from its confluence with the Pecos River, suffer when the quality and quantity of the lower Pecos River is degraded (Cheek and Taylor, 2015; Sandoval-Solis et al., 2022). Data and conceptualization of the lower Pecos River will enable informed resource management of the surface-water/groundwater regimes of the Pecos River watershed to ensure that this degradation is avoided. To a lesser degree, a healthy riparian environment in the lower Pecos River watershed will help combat the climate crisis and reduce greenhouse gas emissions, by sequestering carbon in soils, grasses, trees, and other vegetation.

**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.**

Communities in the lower Pecos River watershed are reliant on groundwater in the watershed and surface water in the river. Lack of adequate characterization of the surface-water/groundwater regimes of the watershed precludes effective management of these critical

resources. Data and information gained by this project will inform management decisions to enable resilience to drought and ensure protection of water quality. Benefits are anticipated to extend well beyond the project performance period as the integrated workflow can be augmented as new data becomes available in the future. The project will build resilience by developing the necessary databases and conceptualizations of the surface-water/groundwater regimes of the semi-arid Pecos River watershed. In the absence of these data and conceptualizations, ill-advised land-use development, such as groundwater extraction and oil/gas development, could be undertaken with disastrous consequences on the quality and quantity of river flow.

**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?**

This project contributes to climate resiliency and water security by compiling data and information to improve conceptualization of the surface-water/groundwater regimes of the lower Pecos River watershed. This will enable informed management decisions to reduce or mitigate water pollution. A healthy riparian environment in the lower Pecos River watershed will help combat the climate crisis and reduce greenhouse gas emissions, by sequestering carbon in soils, grasses, trees, and other vegetation. Although this project is not directly focused on the reduction in greenhouse gas emissions via sequestration of carbon in soil, grasses, trees, or other vegetation, the project data products and workflows provide the basis for informed management decisions that include riparian environments in this arid to semi-arid region.

### Disadvantaged or Underserved Communities

**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.**

The seventeen disadvantaged communities that will benefit from the project are outlined in Table 4. All communities listed meet at least one (and often several) burden threshold(s) and the associated socioeconomic threshold.

**Table 4. Disadvantaged communities in the study area. Census tract numbers denoted with an asterisk (*) are downgradient from the study area and Amistad Reservoir but would still benefit from the project.**

| Census Tract | County | Population | Burden Threshold(s) |
|---|---|---|---|
| **48443950100** | Terrell | 896 | Climate Change, Energy, Health |
| **48371950500** | Pecos | 6,195 | Legacy Pollution, Transportation |
| **48465950301** | Val Verde | 4,860 | Climate Change, Health, Workforce Development |
| **48465950302** | Val Verde | 4,378 | Climate Change, Health, Housing, Transportation |
| **48465950700** | Val Verde | 6,367 | Climate Change, Health, Housing, Workforce Development |
| **48465950400** | Val Verde | 4,149 | Climate Change, Health, Workforce Development |
| **48465950601** | Val Verde | 3,932 | Climate Change, Health, Workforce Development |

| Census Tract | County | Population | Burden Threshold(s) |
|---|---|---|---|
| **48465950602** | Val Verde | 3,726 | Climate Change, Energy, Health, Housing, Workforce Development |
| **48465950500** | Val Verde | 7,695 | Climate Change |
| **48271950100*** | Kinney | 3,659 | Climate Change, Energy, Health, Legacy Pollution, Workforce Development |
| **48323950700*** | Maverick | 10,491 | Legacy Pollution, Workforce Development |
| **48323950500*** | Maverick | 6,144 | Health, Workforce Development |
| **48323950400*** | Maverick | 3,831 | Energy, Health, Housing, Workforce Development |
| **48323950601*** | Maverick | 2,833 | Energy, Health, Housing, Workforce Development |
| **48323950204*** | Maverick | 4,634 | Energy, Health, Workforce Development |
| **48323950205*** | Maverick | 8,785 | Health, Housing, Workforce Development |
| **48323950201*** | Maverick | 8,566 | Health, Workforce Development |

**If applicable, describe how the project benefits those disadvantaged or underserved communities identified using the tool.**

Increasing the resilience of communities reliant on the lower Pecos River by protecting the quality and quantity of river flow will secure environmental justice and spur economic opportunity for disadvantaged communities of the lower Pecos River watershed and the lower Rio Grande valley that have been historically marginalized and overburdened by pollution and degradation of water and wastewater infrastructure associated with the outflow of Amistad Reservoir to the Rio Grande. The products of the project will empower these underserved and disadvantaged communities to improve local understanding of the area's water resources and consequently, develop more sustainable water resource management frameworks. This will directly increase reliability of water supplies, improve water quality, provide economic growth opportunities, improve or expand public access to natural areas or recreation, and provide other benefits in a disadvantaged and underserved communities reliant on the lower Pecos River and the Rio Grande downstream of its confluence with the Pecos River.

### Tribal Benefits

**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 Kickapoo Traditional Tribe of Texas (KTTT) is located immediately downstream from Amistad Reservoir. Given that 10 percent of the flow and 30 percent of the salinity to Amistad Reservoir comes from the Pecos River, the importance of the quality and quantity of flow from the Pecos River is a key factor for honoring the U.S. government's commitment to the KTTT.

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

Ensuring the reliance of water from the lower Pecos River will support BOR's trust responsibilities with the KTTT by ensuring the good quantity and quality of water from the lower Pecos River, Amistad Reservoir, and lower Rio Grande on which these people rely.

# Project Budget

## Funding plan

[redacted]

## Budget proposal

The total project cost is the sum of voluntary committed cost sharing, which includes third-party contributions (Table 5). The itemized budget proposal is outlined in the budget narrative in Attachment B.

**Table 5. Total project cost table.**

[redacted]

## Budget narrative

The budget has been developed with the assumption that the project would be announced early 2024 and would begin summer 2024. The budget narrative is included in Attachment B.

### Salaries and Wages

Salaries and wages include the project manager and principal investigator, Rebecca Nunu, Research Scientist at SwRI. Other personnel include Gordon Wittmeyer, Senior Scientist, Mauricio Flores, Scientist, and Ronald Green, Consultant at SwRI. Please see itemized budget in Attachment B for salaries and wages, estimated hours, and compensation rates. The labor rates included in the budget proposal represent the actual labor rates of the identified personnel/positions and are consistently applied to Federal and non-Federal activities.

### Fringe Benefits

The "Established Fringe Burden Rate for Bidding and Billing Purposes Dated May 5, 2023" letter (included in the proposal submission) covers a description and breakdown of fringe benefits.

### Travel

Travel expenses are outlined in Attachment B and have been calculated using per diem rates as set forth by the General Services Administration for Ozona, Texas in Crockett County. The project team will make numerous trips to the lower Pecos River to conduct geochemical

sampling campaigns and gain-loss surveys. The project team will stay at a hotel located in Ozona, Texas, which is located at the approximate midpoint of the Pecos River in the study area. Travel to the study area is required to collect flow and geochemical data to fill in spatial and temporal data gaps needed to meet the project objectives.

### Equipment

SwRI and collaborating agencies own all necessary equipment needed for the project, so equipment will not be purchased or rented.

### Supplies

Samples will be sent to four laboratories for chemical analysis. The cost per sample for the geochemical constituent(s) is provided in Table 6 and Attachment B. The lower Pecos River will only be sampled for cations, anions, trace elements, alkalinity, and nutrients ($411/sample) due to the potential for atmospheric effects to alter isotopic compositions. Springs and aquifers will be sampled for all geochemical constituents ($1,836/sample) listed in Table 6. These prices are provided from quotes previously received from each laboratory in summer 2023.

**Table 6. Recommended geochemical constituents to collect from the river, springs, and aquifers.**

| Geochemical Constituent | Contract Laboratory | Cost per analysis ($) |
|---|---|---|
| Cations, anions, trace metals, alkalinity, nutrients | Lower Colorado River Authority Environmental Laboratory Services (Austin, TX) | 411 |
| Deuterium ($\delta^2H$), oxygen-18 ($\delta^{18}O$), carbon-13 ($\delta^{13}C$), carbon-14 ($^{14}C$) in water | Beta Analytic (Miami, FL) | 675 |
| Tritium ($^3H$) in water | University of Miami (Miami, FL) | 350 |
| Strontium-87 ($^{87}Sr/^{86}Sr$) in water | Massachusetts Institute of Technology (Cambridge, MA) | 400 |
| | | **TOTAL: $1,836** |

### Contractual

Consultants and contractors will help to accomplish project objectives and tasks by assisting with field work and providing technical support and guidance throughout the project. Dr. Ronald Green, a recent retiree of SwRI, has been active in water resource analyses of the Pecos River and adjoining areas for the past two decades. He currently provides on-going support as a consultant to numerous SwRI projects.

Lower Colorado River Authority Environmental Lab Services in Austin, Texas is a contractor SwRI has utilized for the last 5 years for geochemical analyses. They have consistently provided reliable, high quality, and robust analyses of groundwater samples for a reasonable cost.

Beta Analytic in Miami, Florida is a contractor SwRI has utilized for the last 5 years for geochemical analyses. They have consistently provided reliable, high quality, and robust analyses of stable and radiogenic isotopes in groundwater samples for a reasonable cost.

University of Miami Tritium Laboratory in Miami, Florida is a contractor SwRI has utilized for the last 5 years for geochemical analyses. They have consistently provided reliable, high quality, and robust analyses of 3H isotopes in groundwater samples for a reasonable cost.

Massachusetts Institute of Technology Isotope Laboratory in Cambridge, Massachusetts is a contractor SwRI has utilized for the last 5 years for geochemical analyses. They have consistently provided reliable, high quality, and robust analyses of 87Sr/86Sr isotopes in groundwater samples for a reasonable cost.

### Construction

Construction expenses are not anticipated for the project.

### Other

Other expenses or direct costs are not anticipated for the project.

### Indirect costs

The forward pricing rate request letter (included in the proposal submission) covers indirect costs.

## Environmental and Cultural Resources Compliance

**Will the proposed project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)? Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the project area. Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.**

This project will not negatively impact the environment, and there will be no additional disturbances of air, water, or animal habitat. SwRI will extract small volumes of water (< 5 L per water sample site) from the lower Pecos River, and springs and aquifers in the study area during geochemical sample collection. For aquifer sampling, standard protocols require purging a well of at least three casing volumes to accurately assess water quality properties. However, the stress imposed on the aquifers is brief and water level recovery resumes once the well is no longer being purged. The time of water-level recovery can range from minutes to several hours. Gain-loss studies will require the project team to measure streamflow but will not impact habitats or the surrounding environment while doing so. The successful execution of the project will benefit the environment by providing the basis for improved management and understanding of surface and groundwater resources.

**Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the project area? If so, would they be affected by any activities associated with the proposed project?**

Key species in the Pecos River Watershed listed or proposed as threatened or endangered are outlined in Table 7. These species would be not affected by sample collection efforts associated with the proposed project.

Table 7. Threatened or endangered species in the study area (TPWD, 2023; USFWS, 2023).

| Scientific Name | Common Name | Type | Species Status |
|---|---|---|---|
| ***Popenaias popeii*** | Texas hornshell | Mollusk | Endangered |
| ***Helianthus paradoxus*** | Pecos sunflower | Plant | Threatened |
| ***Gambusia nobilis*** | Pecos gambusia | Fish | Endangered |
| ***Pseudotryonia adamantina*** | Diamond Tryonia | Mollusk | Endangered |
| ***Tryonia circumstriata (=stocktonensis)*** | Gonzales tryonia | Mollusk | Endangered |
| ***Cyprinodon bovinus*** | Leon Springs pupfish | Fish | Endangered |
| ***Assiminea pecos*** | Pecos assiminea snail | Mollusk | Endangered |
| ***Gammarus pecos*** | Pecos amphipod | Crustacean | Endangered |
| ***Notropis simus pecosensis*** | Pecos bluntnose shiner | Fish | Threatened |

**Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States"? If so, please describe and estimate any impacts the proposed project may have.**

Yes, the project study area includes surface waters that fall under CWA jurisdiction as "Waters of the United States". There are no anticipated impacts on these waters as a result of this project, as the volumes collected for surface-water samples will be small (<5 L per water sample set).

**When was the water delivery system constructed?**

Private water wells and conveyance infrastructure to be used during the execution of this project were constructed beginning in the early 1900s.

**Will the proposed project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)? If so, state when those features were constructed and describe the nature and timing of any extensive alterations or modifications to those features completed previously.**

No.

**Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places? A cultural resources specialist at your local Reclamation office or the State Historic Preservation Office can assist in answering this question.**

No.

**Are there any known archeological sites in the proposed project area?**

Yes, known archeological sites such as rock art sites and shelters (e.g., Arenosa Shelter) or caves of archeological significance are present in the greater region of the study area. However, the project activities will not involve or impact these archeological sites.

**Will the proposed project have a disproportionately high and adverse effect on low income or minority populations?**

No.

**Will the proposed project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?**

No.

## Required Permits or Approvals

SwRI will work closely with Crockett County GCD, Middle Pecos GCD, Lower Pecos Landowner Group, Friends of the Pecos, and TNC to acquire approvals for private property access in the study area. Other permits are not anticipated for the project.

## Overlap or Duplication of Effort Statement

There is no overlap between the proposed project and any other active or anticipated proposals or projects in terms of activities, costs, or commitment of key personnel.

## Conflict of Interest Disclosure Statement

No actual or potential conflict of interest exists at the time of this proposal submission.

## Letters of Partnership and Funding Commitment

Letters of Partnership and Funding Commitment are included in Appendix A and provided by:

- Anne Brown, Director of the Horizon Foundation
- Ty Edwards, General Manager of Middle Pecos GCD
- Slate Williams, General Manager of Crockett County GCD

## Letters of Support

Letters of Support are provided by the following collaborators and stakeholders and included in Appendix B:

- Martin Castro, Watershed Science Director of Rio Grande International Science Center
- Karen Chapman, Coordinator of Rio Grande Joint Venture
- Jessica Hamlin, Executive Director of Shumla Archaeological Research & Education Center
- James King, Landowner of Lower Pecos Landowners Group
- Mickey Jack Perry, Precinct No. 3 Pecos County Commissioner
- Ryan Smith, Director of Water and Science of The Nature Conservancy of Texas
- Kevin Urbanczyk, Director of Rio Grande Research Center
- Ira Yates, President of Friends of the Pecos, Inc.

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