Development of a Reservoir Storage Forecasting System for Integrated Water Resources Management in the Nueces River Basin

Applicant:
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Project Type:

- Modeling
- Forecasting

Targeted water management objectives:

- Watershed health
- Water supply reliability
- Drought management activities
- Environmental flow management

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Executive Summary

Date: October 17, 2023.

Applicant: Texas A&M University – Corpus Christi.

City: Corpus Christi.

County: Nueces.

State: Texas.

Texas A&M University – Corpus Christi, with the support of the Nueces River Authority, will develop a decision support system for reservoir storage forecasts in the Nueces River Basin, Texas. The project will integrate hydrologic modeling and analysis, satellite remote sensing, WebGIS, NOAA weather forecasts, and climate change projections to create probabilistic forecasts of the reservoir storge level over medium and long ranges. The decision support system will ensure sufficient freshwater inflow for maintaining ecological health and productivity of the Nueces Estuary, improve the reliability of water supply for the Coastal Bend region, and enhance the adaption and resilience capacity of local communities to extreme events (e.g., droughts and floods) and climate change.

Project location: Nueces River Basin, Texas.

Project Period: 10/1/2024 – 9/30/2026 (24 months).

The proposed project is not located on a federal facility.

Technical Proposal

1. Applicant Category

Texas A&M University is a Category B applicant. The Category A partner of this project is the Nueces River Authority (NRA). Created by the Texas legislature in 1935, NRA utilizes its statutory charge to provide trusted services to meet the needs of the people and environment of the Nueces River basin, ensuring that future citizens will have adequate supplies of clean water where both people and wildlife can live, prosper, and enjoy the natural beauty and biologically rich environment. NRA has broad authority to preserve, protect, and develop water resources in the Nueces River Basin, including the management of the CCR-LCC reservoir system, and is a key decision maker on the regulation of the environmental flow for the Nueces Estuary.

2. Project Description

2.1 Background

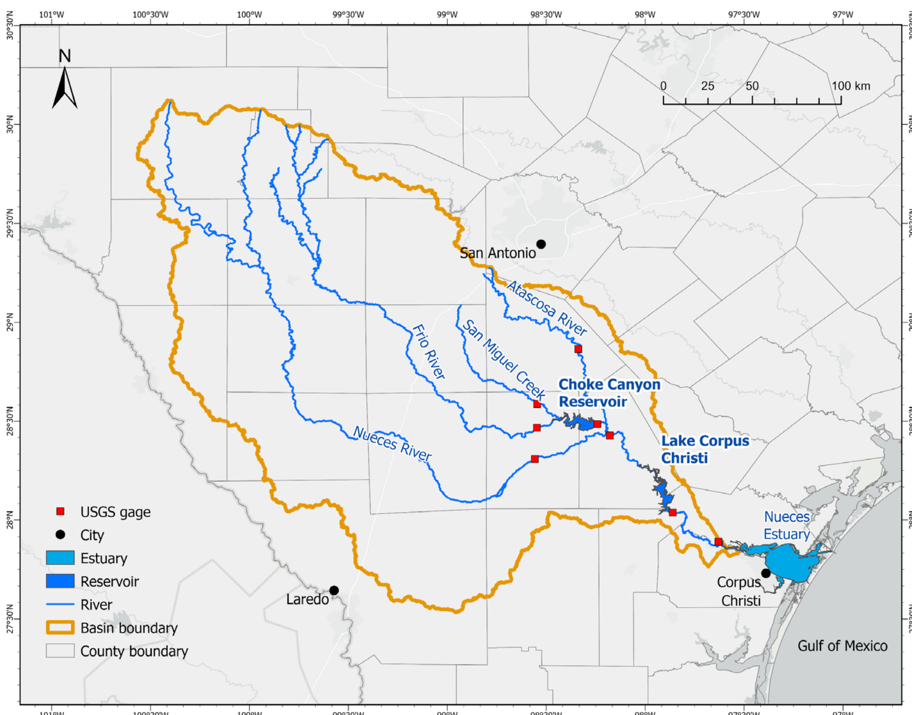

Figure 1. The Nueces River Basin in Texas.

Nueces Estuary is one of seven major estuarine systems along the Texas Coast and a highly productive ecosystem with significantly ecological, environmental, and economic impacts. Freshwater inflow through the Nueces River serves a variety of important functions to the Nueces Estuary by creating and preserving low-salinity nurseries, transporting sediments and nutrients, and affecting estuarine species movements and reproductive timing (Montagna, 2009). Based on the results from the Estuarine Mathematical Programming or Optimization Model (TPWD, 2010).

a minimum amount of freshwater inflow is required to maintain the ecological health and productivity of living resources in the Nueces Estuary.

The freshwater inflow is controlled by a cascade reservoir system on the Nueces River, consisting of the downstream Lake Corpus Christi (LCC) with a conservation capacity of 256,062 ac-ft and the upstream Choke Canyon Reservoir (CCR) with a conservation capacity of 662,821 ac-ft (Fig. 1). According to the historic agreement with the NRA and the City of Corpus Christi (TNRCC, 2001), when the combined storge of this reservoir system is greater than 70% of the system's storage capacity, 138,000 acre-feet of freshwater per calendar year should be delivered to the estuary. When the combined storage is less than 70% but greater than 40% of the storage capacity, the targeted annual inflow is reduced to 97,000 acre-feet. When the combined storge is less than 40% but greater than 30% of the storage capacity, the targeted annual inflow is further reduced to 14,400 acre-feet. When the combined storage is below 30% of the storage capacity, the reservoir system will not release water for the estuary. Based on the annual amount, monthly targets are developed for the reservoir system to allow freshwater to "pass through" and reach the estuary, coupled with potential adjustments for other factors (e.g., observed estuarine salinity levels and return flow). Moreover, these tiered storage-based thresholds are used as triggers in the drought contingency plan of the City of Corpus Christi (Corpus Christi, 2018). When the storage level is below 40%, the city enters Stage 1 (Mild Water Shortage Watch), and a set of responses will be taken to achieve a 10% reduction of daily demand of treated water. When the storage level is below 30%, the city enters Stage 2 (Moderate Water Shortage Watch), and the daily water demand will be reduced by 20%. When the storage level is below 20%, the city enters Stage 3 (Critical Water Shortage Watch), and the daily water demand will be reduced by 30%. Therefore, through controlling both environmental flow and water supply, the storage level of the CCR-LCC reservoir system plays a critical role in the water resources management in the Nueces River Basin.

However, this management strategy totally relies on the current status of the system (i.e., the present storage level of the reservoir system) to inform the decisions on future operations of the system. As indicated in Fig. 2, it has been a challenging task to meet the environmental flow requirements at the monthly level. As for in any reservoir systems, the current storage level is only one of the many factors that contribute to the variations and uncertainty of the future storage level and thus the water availability for competing demands. The observation-based strategy is unable to address the dynamic nature of the basin hydrologic processes, utilize hydroclimatic forecast data and tools that are increasingly available, and allow decision makers to develop proactive strategies for effective water

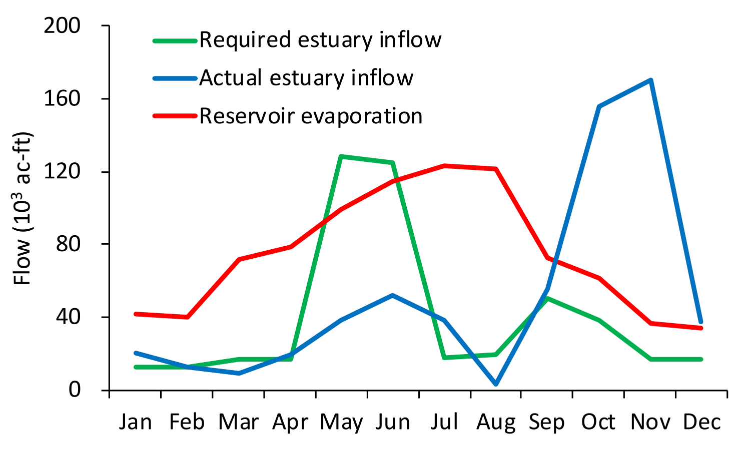

Figure 2. Average monthly estuary inflows and reservoir evaporation loss from 2018 to 2023.

resources management. This is particularly true for the Nueces reservoir system and similar systems across the West, which are facing the nexus of growing water demands from difference sectors, intensifying extreme events (e.g., droughts and floods), and increasing impacts of climate change. There is an urgent need to improve the reservoir operation through the incorporation of modeling and forecasting tools.

2.2 Methods

The proposed work aims at developing an integrated reservoir forecasting system that can generate medium- and long-range forecast of the storage level of the Nueces reservoir system, using a combination of hydrologic modeling, remote sensing, geographical information system, and publicly available datasets (Fig. 3). The medium-range forecasts will be probabilistic projections of the reservoir storage levels at Day 7, e.g., the chance of the storage level above 40% of the storage capacity. The long-range forecasts will be anomaly of the reservoir storage levels at Day 30, e.g., the chance of the storage level above or below the normal of the targeted month. The modeling and forecasting efforts will emphasize the estimation of highly variable reservoir inflows from rainfall-runoff processes at the watershed scale and substantial evaporation loss in both reservoirs, consisting of four core components:

<u>(1) Reservoir inflow forecast</u> – For the medium-range forecast, ensemble predictions will be established by combining distributed watershed hydrologic simulation results from the HEC-HMS model and the National Water Model (NWM). A set of HEC-HMS simulations will be driven by NOAA Weather Prediction Center's medium-range quantitative precipitation forecasts and use the datasets of watershed elevation, land cover, soil, and stream networks exacted from national or state databases. The NWM simulations will be extracted from the NWM's real-time national data portal. Based on their validation performance using USGS streamflow observations, the HEC-HMS and NWM results will be integrated to generate probabilistic ensemble inflow forecasts at the weekly level, reflecting uncertainties in the precipitation forecasts and watershed rainfall-runoff processes. For the long-range forecast, the HEC-HMS model will be applied. The normal conditions of precipitation and temperature of the targeted month will be obtained from the gridded national climate normals database. These monthly normals will be adjusted using NOAA's 30-day precipitation and temperature outlooks. Driven by these adjusted monthly normals, HEC-HMS simulations will be conducted to generate probabilistic monthly inflow forecasts.

<u>(2) Reservoir evaporation forecast</u> – High-resolution multispectral satellite images will be collected and analyzed to determine the surface areas of CCR and LCC on a weekly basis. These satellite-based measurements are direct observations of the actual reservoir areas, in contrast to the elevation-derived indirect estimates that are used in current practices. Using the standard energy balance method, weekly evaporation rates will be calculated based on NOAA's medium range graphical forecasts of temperature and wind speed, and the monthly evaporation rates will be estimated based on NOAA's 30-day precipitation and temperature outlooks. Combining the estimates of evaporate rates and reservoir areas will lead to the forecasts of evaporation loss in each reservoir at both weekly and monthly levels, assuming negligible changes of the reservoir areas over the forecast horizon. Also, pan evaporation observations by TWDB and the City of Corpus Christi will be used for the verification of the estimated evaporation rate.

(3) Reservoir storage forecast – Using a combination of statistical analysis and hydrologic analysis, the weekly to monthly water balances of the reservoirs will be analyzed based on the forecasts of reservoir inflow and evaporation loss and the current targets of environmental flow and municipal water supply. The final output will be the probabilistic projection of the reservoir storage level over a range of plausible values for decision support. The storage forecasts will be verified using the elevation-based storage estimates at the end of each forecast period, providing important feedback to improve the efforts of hydrologic modeling and analysis. The medium-range (weekly) forecast will be delivered at the end of each week, and the long-range (monthly) forecast will be delivered at the end of the third week in each month.

(4) Decision support – The generated forecasts will provide decision support in three ways. First, they will be used to evaluate if the planned reservoir pass-through flow for the current month will achieve the required monthly target, and if not, the magnitude of the shortage. Second, the forecasts will be used to guide the development of alternative reservoir operation schemes. Those scheme can be examined through hydrologic modeling and analysis as described in pervious tasks. Third, the monthly forecasts will be regenerated by incorporating the projected temperature and precipitation shifts under different climate change scenarios. The resulted change in reservoir storage levels will provide important information for assessing climate change impacts on regional water security, drought mitigation, and other aspects of water resources management. Furthermore, A WebGIS interface will be developed for the visualization and distribution of those forecast and data products and transform the project outputs into a decision support system. This system will allow decision makers, stakeholders, and the public to assess data through interactive online maps and generate recommendations on estuary inflow management, municipal drought contingency plans, and other related water resources management strategies in the Nueces River Basin.

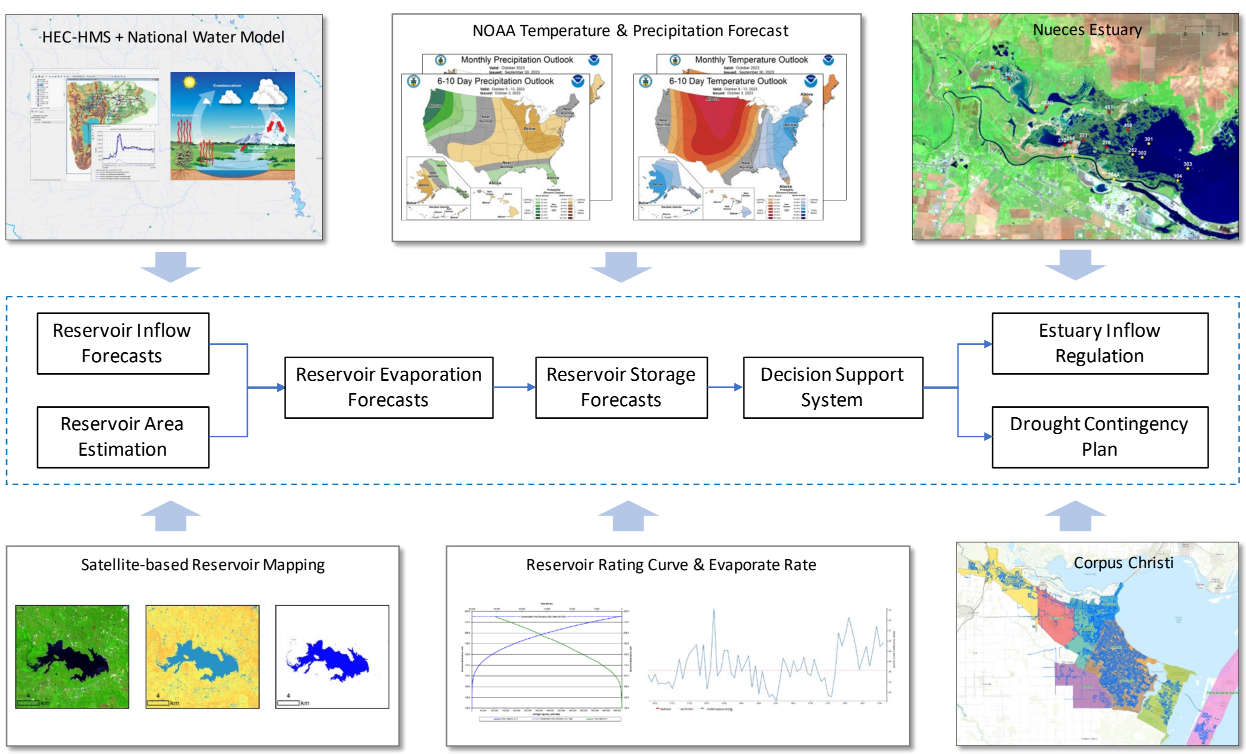

Figure 3. Methodological framework.

2.3 Models, data, and tools

The implementation of the project tasks is built on the utilization of a variety of publicly available models, tools and datasets that have been widely used or comprehensively verified (Tab. 1).

Table 1. Description of models, data, and tools for the proposed project.

Item	Description	Availability	Task(s)
HEC-HMS (version 4.11)	A watershed hydrologic model developed by US Army Corps of Engineers to simulate the complete hydrologic processes of dendritic watershed systems	https://www.hec.usace.army.mil/software/hec-hms/	1, 3
National Water Model	A hydrologic modeling framework developed by NOAA that simulates observed and forecast streamflow over the entire continental United States	https://water.noaa.gov/about/nwm	1
Precipitation forecasts	NOAA National Weather Service's quantitative precipitation forecasts (1-7 days)	https://www.wpc.ncep.noaa.gov/qpf/day1-7.shtml	1, 2
Temperature and wind speed forecasts	NOAA National Weather Service's medium range graphical forecasts of maximum temperature, minimum temperature, and wind speed (1-7 days)	https://digital.mdl.nws.noaa.gov/	1, 2
Monthly precipitation and temperature outlooks	NOAA National Weather Service's 30-day outlooks of precipitation and temperature outlooks	https://www.cpc.ncep.noaa.gov/products/predictions/long_range/lead14/	1, 2
Land cover data	USGS 2021 National Land Cover Database (NLCD)	https://www.mrlc.gov/	1
Soil data	USDA Soil Survey Geographic Database (SSURGO)	https://www.mrlc.gov/data)	1
Historical streamflow data	USGS national streamflow database	https://dashboard.waterdata.usgs.gov	1
Stream network data	USGS National Hydrography Dataset (NHD)	https://www.usgs.gov/national-hydrography/national-hydrography-dataset	1
Historical daily weather data	University of Utah MesoWest database	https://mesowest.utah.edu/	1,2
Monthly climate normals	NOAA NECI U.S. Climate Normals	https://www.ncei.noaa.gov/products/land-based-station/us-climate-normals	1, 2, 4
Climate change projections	U.S. Climate Resilience Toolkit – Climate Explorer	https://crt-climate-explorer.nemac.org/	4
Elevation data	Texas Natural Resources Information System's 1-m LiDAR digital elevation model	https://data.tnris.org/	1
Elevation data	USGS 10-m 3DEP digital elevation model	https://www.usgs.gov/3d-elevation-program	1
Satellite imagery	Ready-to-use 3.7-m multispectral images collected by the Planet Lab	https://www.planet.com	2
Reservoir rating curves	Elevation-storage-area curves TWDB reservoir database	https://waterdatafortexas.org/reservoirs/statewide	2, 3
Reservoir evaporation rates	TWDB lake evaporation and precipitation database	https://waterdatafortexas.org/lake-evaporation-rainfall	2
ArcGIS Pro and ArcGIS Online	Desktop and web-based GIS software developed by Esri	https://www.arcgis.com	1, 2, 3, 4

2.4 Workplan

The proposed project will include four interlinked tasks over two years, starting with Task 1 on simulation-based reservoir inflow forecast and Task 2 on satellite-aided reservoir evaporation forecast, transitioning into Task 3 on reservoir storage forecast, and culminating in Task 4 on the decision support for improving reservoir operation.

3. Goals

Built on the partnership with NRA, this project aims to develop medium- and long-range predictions of the storage level of the Nueces reservoir system, providing scientific support to improve reservoir operation for the security of environmental flow and water supply.

Project Location

The project location is the Nueces River Basin in south Texas (Figure 1). A PDF map of the project location is included in this proposal.

Date management Practices

The data management plan conforms to Bureau of Reclamation's policies on the dissemination and sharing of project data results. TAMUCC will take responsibility for the collection, storage, and dissemination of data stemming from project activities.

Data and Other Information Products - Data used in this project will primarily consist of a variety of publicly available data sets from governments and scientific literature, as described in the proposal. Additional numerical data and geospatial data will be generated in project activities of hydrologic modeling, hydrologic analysis, and geospatial analysis. The project will make full use of existing data and metadata standards for geospatial data. Primary geospatial data will be GeoTiff for raster data and shapefile for vector data. All geospatial data generated from this project will be compatible with ESRI ArcGIS. Qualitative descriptions will be validated through comparative descriptions of collected materials. Raw numerical data from modeling efforts will be transferred into .txt file format or in Microsoft Excel .xls/.xlsx format and then will be further converted into Microsoft Access Database format.

Metadata **-** Metadata will conform to ISO 19115 standards. Descriptive fields will be created when each data set is generated or processed and help users to decide if a dataset is appropriate for their proposed use. Metadata will be presented in standard xml files and text-based documents to ensure readability and compatibility.

Short-term Management **-** Access to the project database will be available for educational, research, and non-profit purposes. Data of this project will be obtainable no later than six months after project completion through a data portal developed for this project and hosted by TAMUCC. Users of the data portal will primarily be city managers, stakeholders, and researchers in related fields. Peer-reviewed journal articles, technical reports, and conference presentations will be released describing the project methods and data sources.

Long-term Management - All raw data files and data processing programs will be versioned over time and maintained in a date-stamped file structure. All database tables will be exported to a consistently delimited text format and all image products will be stored in individual zip files to ensure accessibility of the data by other software programs. Data will be retained in a TAMUCC digital library archive for three years after the conclusion of the award. The project manager will identify appropriate archiving institutions that might serve as a mirror repository.

Evaluation Criterion

E.1.1. Evaluation Criterion A—Water Management Challenge(s)

Up to **30 points** may be awarded based on the water management challenge. Applicants that demonstrate a water management challenge and the immediacy of the need will receive the most points under this criterion. Please respond and provide support for your responses to each of the following sub-criteria.

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?

Response: The cascade reservoir system on the Nueces River is the central component of water resources management in the Nueces River Basin. Based on the results from the Mathematical Programming Optimization Model (GRG-2) of the Texas Water Development Board (TWDB), minimum environmental flows (i.e., freshwater inflows) are required to pass through the reservoirs for maintaining the ecological health and productivity of living resources in the Nueces Estuary. The reservoir system is also the major source for water supply for the City of Corpus Christi and the surrounding Coastal Bend region. A set of thresholds of the reservoir storage level have been used as the basis for the establishment and regulation of estuarine freshwater inflow targets at both monthly and annual levels, as well as the triggers of the municipal drought contingency plan, playing a critical role in the water resources management in the Nueces River Basin.

However, this management strategy totally relies on the current status of the system (i.e., the present storage level of the reservoir system) to inform the decisions on future operations of the system. It has been a challenging task to meet the environmental flow requirements at the monthly level (Fig. 2). As for in any reservoir systems, the current storage level is only one of the many factors that contribute to the variations and uncertainty of the future storage level and thus the water availability for competing demands. The observation-based strategy is unable to address the dynamic nature of the basin hydrologic processes, utilize hydroclimatic forecast data and tools that are increasingly available, and allow decision makers to develop proactive strategies for effective water resources management. This is particularly true for the Nueces reservoir system and similar systems across the West, which are facing the nexus of growing water demands from difference sectors, intensifying extreme events (e.g., droughts and floods), and increasing impacts of climate change. There is an urgent need to improve the reservoir operation through the incorporation of modeling and forecasting tools to support integrated water resources management.

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

Response: If the water management challenge is not addressed, the ineffective operation of the Nueces reservoir system could result in several significant consequences:

(1) Insufficient freshwater inflow to the Nueces Estuary, seriously affecting the estuary's ecological values in creating and preserving low-salinity nurseries, transporting sediments and nutrients, and supporting estuarine species movements and reproduction.

(2) Unreliable water supply to the City of Corpus Christi, triggering either unnecessary or excessive drought adaptation responses that could have significant economic and social impacts on approximately 500,000 residents across the Coastal Bend region.

(3) Inadequate resilience capacity of communities (particularly disadvantage communities) and ecosystems, leading to their long-term vulnerability to drought, flood, and climate change.

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:

    - water supply reliability for municipal, agricultural, tribal, environmental or recreational water uses,
    - management of water deliveries,
    - water marketing activities,
    - drought management activities,
    - conjunctive use of ground and surface water,
    - water rights administration,
    - ability to meet endangered species requirements,
    - watershed health,
    - 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,
    - conservation and efficiency, or
    - other improvements to water supply reliability?

In your response, be sure to explain how your project will improve any of the above.

Response: In terms of ensuring freshwater inflow to the Nueces Estuary, the storage forecasts from this project can be used by NRA, the City of Corpus Christi, and other stakeholders as a scientific basis to (i) estimate the future availability of surface water to meet the required demand of environmental flow, (ii) evaluate and adjust the current reservoir operation practices to better address the variability and uncertainty of the hydrologic and ecosystems, and (iii) explore new practices and technologies (e.g., sediment control and evaporation reduction) that could improve the ecological values of the reservoir systems based on forecasting and modeling efforts.

In terms of improving the reliability of municipal water supply, the tools and results from this project can help the decision makers and stakeholders to incorporate the projected water stress into the design and implementation of the drought contingency plan. This could help avoid unnecessary and excessive drought responses, reduce the interruptions to various economic sectors, and understand the need for alternative sources for enhancing water supply.

Moreover, the decision support system derived from this project will provide a flexible and friendly information platform to facilitate science-based decision-making processes, inform and train water managers using advanced methods and data products, and promote communications and discussions toward effective strategies for integrated water resources management.

E.1.2. Evaluation Criterion B - Project Benefits

Up to **30 points** may be awarded based on the extent to which the project will result in a tool or information that will benefit stakeholders and the extent to which the tool and information will be used beyond project conclusion. Applicants that demonstrate clear benefit(s) for the project, including documentation and support for those benefits, and can explain how the project tool, information, or results will be readily applied will receive the most points under this criterion.

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?

Response: The need for the project was identified through discussions with the Nueces River Authority, the Category A partner. The project manager had several meetings with NRA staff and attended the Regional Water Resources Group meeting led by NRA. Those communications focused on the limitations of the current reservoir management, the availability of local datasets, and the need for simulation and forecasting tools to support NRA's missions.

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

Response: The proposed tools and methods will be developed and applied across two years through four interlinked tasks:

- Month 1-6: Reservoir inflow forecast (Task 1)
- Month 7-11: Reservoir evaporation forecast (Task 2)
- Month 12-15: Reservoir storage forecast (Task 3)
- Month 16-24: Decision support (Task 4)

Following the workplan, the tools will be used immediately at the end of the related task(s). No additional work will be needed.

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.

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

Response: The proposed decision support system will be primarily used by the Nueces River Authority and will also be accessible for City of Corpus Christi and other regional water resources managers in the Nueces River Basin and Coastal Bend Region.

The forecasting effort will emphasize the estimation of highly variable reservoir inflows from rainfall-runoff processes at the basin scale and substantial evaporation loss in both reservoirs. The medium-range forecast will be probabilistic projections of the reservoir storage levels at Day 7, e.g., the chance of the storage level above 40% of the storage capacity. The long-range forecast will be anomaly of the reservoir storage levels at the Day 30, e.g., the chance of the storage level above or below the normal. The medium-range weekly forecast will be delivered at the end of each week, and the long-range monthly forecast will be delivered at the end of the third week in each month. In doing so, the project will help ensure the freshwater inflows for maintaining ecological health and productivity of living resources in the Nueces Estuary and enhancing the reliability of water supply in the Coastal Bend region.

The implementation of the project tasks will utilize a variety of existing models, tools and datasets that have been widely used or comprehensively verified. This will facilitate easy applications of the methodology framework to other regions where the environmental water and water supply rely on surface water controlled by a reservoir system.

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.

Response: Ongoing efforts by the Nueces River Authority and the City of Corpus Christi have focused on improving technical support or making adjustments to the current operation strategy, including: (i) the application of time series analysis to reservoir inflow data; (ii) planning for additional LiDAR surveys to improve the reservoir rating curves; (iii) exploring supplemental water resources including groundwater and the reuse of industrial wastewater; (iv) minor adjustment to the tiered storage thresholds in the drought contingency plan; and (v) continued salinity monitoring in the Nueces Estuary.

During the project period, the project results will be communicated to NRA and other local water resources managers through several ways: (i) monthly project meetings with NRA, (ii) regular meetings of the Regional Water Resources Group led by NRA, and (iii) most importantly, the WebGIS-based decision support system that will be accessible for everyone.

E.1.3. Evaluation Criterion C—Project Implementation

Up to **20 points** may be awarded based upon the extent to which the applicant is capable of proceeding with the project upon entering into a financial assistance agreement. Applicants that describe a detailed work plan (e.g., estimated schedule that shows the stages and duration of the proposed work and identifies major tasks, milestones, and dates) and a budget that is appropriate for the work proposed and has a reasonable level of detail will receive the most points under this criterion. Your responses should reflect an understanding of the tasks required to complete the project within the required 2-year timeframe. **Please respond and provide support for your responses to each of the following sub-criteria**.

Describe your project implementation plan:

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 *Section D.2.2.4* under the Technical Project Description. However, you should provide support for your chosen methodology, including use of any specific models, data, or tools.

Response: The proposed work aims at developing an integrated reservoir forecasting system that can predict the reservoir storage levels of CCR and LCC, using a combination of hydrologic modeling, remote sensing, geographical information system, and publicly available datasets (Fig. 3). The medium-range forecasts will be probabilistic projections of the reservoir storage levels at Day 7, e.g., the chance of the storage level above 40% of the storage capacity. The long-range forecasts will be anomaly of the reservoir storage levels at the Day 30, e.g., the chance of the storage level above or below the normal. The medium-range weekly forecast will be delivered at the end of each week, and the long-range monthly forecast will be delivered at the end of the third week in each month.

The forecasting effort will emphasize the estimation of highly variable reservoir inflows from rainfall-runoff processes at the basin scale and substantial evaporation loss in both reservoirs, consisting of three/four core components. (1) Reservoir inflow forecast – For the medium-range forecast, ensemble predictions will be established by combining the distributed watershed hydrologic simulation results from the HEC-HMS model and the National Water Model (NWM). For the long-range forecast, the HEC-HMS model will be applied. (2) Reservoir evaporation forecast – High-resolution satellite measurements of reservoir area will be combined with estimated evaporate rates to estimate reservoir evaporation loss over medium and long ranges. (3) Reservoir storage forecast – The daily water balance of the reservoir will be analyzed based on the forecasts of reservoir inflow and evaporation loss, combined with the current goals of environmental flow and municipal water supply. (4) Decision support – The generated weekly and monthly forecasts will be used to evaluate if the planned reservoir flow release for the current month will achieve the required monthly target, facilitate the development of alternative reservoir operation schemes, and support the assessment of climate change impacts on water resources management. A WebGIS interface will be developed for the visualization and distribution of those forecast and data products and transform the project outputs into a decision support system. This system will allow decision makers, stakeholders, and the public to assess data through interactive online maps and generate recommendations on estuary inflow management, municipal drought contingency plans, and other related water resources management strategies in the Nueces River Basin.

The implementation of the proposed project tasks will utilize a variety of publicly available models, tools and datasets that have been widely used or comprehensively verified. Their details are presented in Table 1.

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

Response:

Task	2024			2025												2026									Start Date	End Date	Cost ($)
	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9			
1						*a*																			10/1/2024	3/31/2025	146,568
2											*b*														4/1/2025	8/31/2025	106,568
3															*c*										9/1/2025	12/31/2025	100,015
4																								*d*	1/1/206	9/30/2026	180,164

Milestones: *a* – weekly reservoir inflow forecasts by 3/31/2025; *b* - weekly reservoir evaporation forecasts by 8/31/2025; *c* – weekly reservoir storage forecasts by 12/31/2025; *d* – reservoir decision support system by 9/30/2026.

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.*

Response: Please see below a table of the anticipated products.

Product		Anticipated Date
weekly reservoir inflow forecasts		3/31/2025
weekly reservoir evaporation forecasts		8/31/2025
weekly reservoir storage forecasts		12/31/2025
Journal paper #1 on inflow and evaporation forecasts		3/31/2026
WebGIS-based decision support system		9/30/2026
Journal paper #2 on freshwater inflow management		9/30/2026
Final project report		9/30/2026

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.

Response: The Category A partner of the proposed project is the Nueces River Authority (NRA). For Tasks 1-3, NRA will provide data, input, and feedback. For Task 4, NRA will incorporate project results into the related decision-making processes and promote the connections between the project team and community stakeholders. Throughout the project period, the project team will have monthly meetings with NRA staff and develop particularly close collaboration with NRA's Division of Water Resources Planning. In addition, as NRA is the coordinator of the Regional Water Resources Group, the project team will be invited to attend the group's quarterly meetings, promote the project results, and explore opportunities for achieving broader impacts.

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:
    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?
    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.

Response: Dr. Hua Zhang is an Associate Professor of Civil Engineering and the Director of the Water and Environmental Systems Lab (wesa.tamucc.edu) at Texas A&M University-Corpus Christi. He received his Ph.D. in Environmental Engineering from University of Regina and completed his postdoc training at Stanford University. His research has aimed at understanding the interactions between hydrology, society, and ecosystems with case studies across North America, East Asia, and Middle East. He has published over 50 papers on peer-reviewed international journals on hydrology, water resources, environmental quality, and biological conservation. Please see the References section for some of his publications that are most relevant to this project.

The project team will include two existing members from Dr. Zhang's research lab: a postdoc that has over seven years of solid experience in computer science and geospatial analysis and a master's student that has good skills in hydrology. Two team members will be recruited: (i) the research associate is expected to have solid experience in data analysis and management and (ii) an undergraduate student with a background in civil engineering.

(a) Dr. Zhang has been a PI or co-PI in multiple projects on hydrology and water resources, funded by NSF, NOAA, NASA, and other agencies with over $7 million in total.

(b) The project team is capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement.

E.1.4. Evaluation Criterion D—Dissemination of Results

Up to **10** points may be awarded for proposals that can articulate how the results will be disseminated, transferred, and communicated directly with partners and resource managers within the Western United States. **Please respond and provide support for your responses to each of the following sub-criteria**. *Note: All applicants whose projects are selected for funding will be expected to participate in at least one Reclamation-sponsored webinar to disseminate deliverable(s) and discuss ways to apply deliverables to management questions. Under this criterion, proposals will be evaluated based on other efforts, beyond the required webinar, that they will take to disseminate the results of their project.*

Explain how project results will be disseminated, including:

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.

- 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.

Response: N/A.

- 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.

Response: The project results will be communicated to NRA and other local water resources managers through several ways: (i) monthly project meetings with NRA, (ii) regular meetings of the Regional Water Resources Group led by NRA, and (iii) most importantly, the WebGIS-based data portal that will be accessible for everyone.

- 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.

Response: The proposed decision support system is a WebGIS-based data portal that will be accessible for all water managers in the West.

E.1.5. Evaluation Criterion E—Presidential and Department of the Interior Priorities

Up to **10 points** may be awarded based on the extent that the project demonstrates support for the Biden-Harris Administration's priorities, including E.O. 14008: *Tackling the Climate Crisis at Home and Abroad* and E.O. 13985: *Advancing Racial Equity and Support for Underserved Communities Through the Federal Government,* and the President's memorandum, *Tribal Consultation and Strengthening Nation-to Nation Relationships.*

Please address only those priorities that are applicable to your project. It is not necessary to address priorities that are not applicable to your project. A project will not necessarily receive more points simply because multiple priorities are addressed. Points will be allocated based on the degree to which the project supports one or more of the priorities listed, and whether the connection to the priority(ies) is well supported in the application.

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.

- 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?

Response: The projections of future climate will be incorporated into Task 4 – Decision Support. The monthly forecasts will be regenerated by incorporating the projected temperature and precipitation shifts under different climate change scenarios. The resulted change in reservoir storage levels and water security will provide information for assessing climate change impacts on water resources management. By facilitating a better understanding of the response of reservoir storage under various climate change scenarios by 2100, the communities will be better prepared to develop adaptation strategies for managing drought and flood risks in the Nueces River Basin.

- 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.

Response: By providing scientific data and tools to promote proactive and sustainable reservoir management, this project will help build community capacity of drought resilience. As the decision support system utilizes mature tools and datasets that are available for free, it will continue to provide benefits as long as those inputs are available, for example, the climate change projections through 2100. This will benefit all counties in the Nueces River Basin that have been experiencing limited water supply and competing water demands exacerbated by drought.

- 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?

Response: By facilitating a better understanding of the changes in reservoir inflow and storage under a variety of climate change scenarios by 2100, the communities will be better prepared to develop adaptation and mitigation strategies for climate change resilience.

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.

- 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.

Response: According to the Climate and Economic Justice Screening Tool, the project area includes a large number of disadvantaged communities in rural and urban areas (Fig. 4).

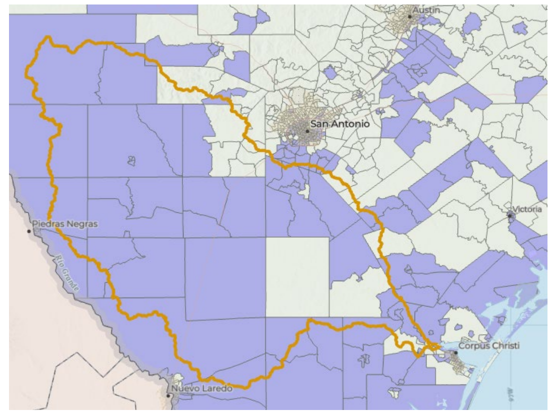

Figure 4. Disadvantaged communities (in purple) in the project area.

- 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?

Response: Through enhancing the operation effectiveness of the Nueces reservoir system, the project will benefit those disadvantaged communities through (i) improving the reliability of water supplies across medium and long ranges and reducing the socioeconomic consequences of water shortage and (iii) improving the resilience of community economic sectors that rely on a healthy and productive ecosystem in the Nueces Estuary.

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.

- 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.

Response: N/A.

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

Response: N/A.

Statements

As the proposed project does not include measurement, monitoring, and field work, the applicant declares that the compliance issues listed in Section H.1. Environmental and Cultural Resources Considerations are not applicable to this project.

The applicant declares that the proposed project does not require any permits or approvals.

The applicant declares that 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.

The applicant declares that there is no actual or potential conflict of interest at the time of submission.

References

City of Corpus Christi. (2018). Drought Contingency Plan. https://www.cctexas.com/conserve. Accessed on September 15, 2023.

Texas Natural Resource Conservation Commission. (2001). Amending the operational procedures and continuing an Advisory Council pertaining to Special Condition 5B., Certificate of Adjudication No. 21-3214; Docket No. 2001-0230-WR.

Texas Park and Wildlife. (2010). Freshwater Inflow Recommendation for the Nueces Estuary https://tpwd.texas.gov/landwater/water/conservation/freshwater_inflow/nueces/index.phtml. Accessed on September 30, 2023.

Montagna, P.A, Hill, E.M. Hill, Moulton, B. (2009). Role of science-based and adaptive management in allocating environmental flows to the Nueces Estuary, Texas, USA. Ecosystems and Sustainable Development VII, WIT Press.

<u>PI's selected publications related to this project</u>:

Avisse, N., Tilmant, A., Müller, M.F., **Zhang, H**. (2017). Monitoring small reservoirs' storage with satellite remote sensing in inaccessible areas. *Hydrology and Earth System Sciences*, 21(12): 6445.

Han, J.C., Huang, G.H., **Zhang, H.**, Zhuge, Y.S., He, L. (2012). Fuzzy constrained optimization of eco-friendly reservoir operation using self-adaptive genetic algorithm: a case study of a cascade reservoir system in the Yalong River, China. *Ecohydrology*, 5(6): 768-778. DOI: doi.org/10.1002/eco.267.

Liang, J., Liu, Q., **Zhang, H.**, Li, X.D., Qian, Z., Lei, M.Q., Li, X., Peng, Y.H., Li, S., Zeng, G.M. (2020). Interactive effects of climate variability and human activities on blue and green water scarcity in rapidly developing watersheds. *Journal of Cleaner Production*, 265, 121834.

Zhang, H., Gorelick, S.M., Avisse, N., Tilmant, A., Rajsekhar, D., Yoon, J. (2016). A new temperature-vegetation triangle algorithm with variable edges (TAVE) for satellite-based actual evapotranspiration estimation. *Remote Sensing*, 8(9): 735.

Zhang, H., Gorelick, S.M., Zimba, P.V., Zhang, X. (2017). A remote sensing method for estimating regional reservoir area and evaporative loss. *Journal of Hydrology*, 555: 213-227.

Zhang, H., Huang, G.H., Wang, D., Zhang, X. (2011). Uncertainty assessment of climate change impacts on the hydrology of small prairie wetlands. *Journal of hydrology*, 396(1-2): 94-103.

Zhang, H., Huang, G.H., Wang, D., Zhang, X., Li, G., An, C., Cui, Z., Liao, R., Nie, X. (2012). An integrated multi-level watershed-reservoir modeling system for examining hydrological and biogeochemical processes in small prairie watersheds. *Water Research*, 46(4): 1207-1224.

Zhang, H., Zimba, P.V. (2017). Analyzing the effects of estuarine freshwater fluxes on fish abundance using artificial neural network ensembles. *Ecological Modelling*, 359: 103-116.

Nueces River Authority

Since 1935

October 11, 2023

To whom it may concern,

The Nueces River Authority is pleased to support the proposal titled, *"Development of a Reservoir storage forecasting system for integrated water resources management in the Nueces River Basin"* submitted by Texas A & M Corpus Christi team led by Dr. Hua Zhang.

The Nueces River Authority strives to preserve a healthy environment for its citizens. Our partnership with TAMU-CC team led by Dr. Hua Zhang to help manage Nueces Reservoir Storage Forecast Grant provides an excellent opportunity to explore new and innovative ways to provide data, input, and feedback. Also, to incorporate project results into the related decision-making processes and promoting the connections between the project team and our community stakeholders. We look forward to taking the results of this study into consideration as future management decisions are made.

Your favorable consideration of this proposal is greatly appreciated.

Sincerely,

John. J Byrum II
Executive Director

General Office
539 S. Highway 83, Uvalde, TX 78801
P 830-278-6810 F 830-278-2025

Coastal Bend Office
500 IH 69, Suite 805, Robstown, TX 78380
P 361-653-2110

Leakey Water Treatment Site
350 Stanford Hollow Road, Leakey, TX 78873
P 830-232-5672

www.nueces-ra.org

Budget Narrative

Table 1. Summary of Non-Federal and Federal Funding Sources

FUNDING SOURCES	AMOUNT
Non-Federal Entities	
1. Texas A&M University - Corpus Christi	$133,329
Non-Federal Subtotal	$133,329
REQUESTED RECLAMATION FUNDING	$399,986

Budget Justification

a. Personnel

Dr. Hua Zhang will be the project manager and responsible for the overall direction of the project and lead the tasks of hydrological modeling and decision support. His salary is $148,505 for Year 1 with an annual increase of 3% for Year 2. It is anticipated that he will spend 4.17% of his time on the project in both Year 1 ($6,374) and Year 2 ($6,565), approximately $12,939 for the entire project period. The budgeted rates represent the actual labor rates for the identified personnel and positions and are consistently applied to Federal and non-Federal activities.

A research specialist will participate in the tasks of hydrological modeling, evaporation estimation, geospatial analysis, decision support, and stakeholder engagement. The salary is $40,800 for Year 1 with an annual increase of 3% for Year 2. The time commitment of the research specialist will be 41.67% in both Year 1 ($17,000) and Year 2 ($17,510), approximately $34,510 for the entire project period. The budgeted rates represent the actual labor rates for the identified personnel and positions and are consistently applied to Federal and non-Federal activities.

A postdoc researcher will lead the task of geospatial analysis and evaporation estimation and participate in other tasks. The salary is $56,000 for Year 1 with an annual increase of 3% for Year 2. The time commitment of the postdoc researcher will be 100% in Year 1 ($56,000) and 75% in Year 2 ($43,260), approximately $99,260 for the entire project period. The budgeted rates represent the actual labor rates for the identified personnel and positions and are consistently applied to Federal and non-Federal activities.

A graduate research assistant will participate in the tasks of hydrological modeling, evaporation estimation, and decision support. The salary is $28,800 for Year 1 with an annual increase of 3% for Year 2. The time commitment of this student will be 50% in both Year 1 ($14,400) and Year 2 ($14,832), approximately $29,232 for the entire project period. The budgeted rates represent the actual labor rates for the identified personnel and positions and are consistently applied to Federal and non-Federal activities.

An undergraduate research assistant will participate in data collection and analysis. The hourly rate is $12 for Year 1 with an annual increase of 3% for Year 2. The hourly rate is based on the average of all personnel occupying this position. Compensation rates are consistently applied to Federal and non-Federal activities.

b. Fringe Benefits

The benefits rate for the faculty and staff is 19.7% of salary requested, plus an additional $1,033/month for medical insurance. For the Graduate Assistants, fringe benefits are calculated at 10.7% of salary requested plus an additional $564/month for medical insurance. For undergraduate student workers fringe is just 10.7% for salary requested.

c. Travel

The travel costs for field trips to the project sites are estimated at $500 per year for both Year 1 and Year 2.

The travel costs for conference trips are estimated at $2,000 per year for both Year 1 and Year 2, including airfare, lodging, rental car, and per diem based on GSA rates.

d. Supplies

Computers x 3 =	$7,500
General supplies for Year 1 =	$2,000
General supplies for Year 2 =	$2,000
Total	**$11,500**

e. Other

Conference fees for Year 1 =	$500
Conference fees for Year 2 =	$500
Student tuition for Year 1 =	$10,176
Student tuition for Year 2 =	$10,685
Total	**$21,861**

f. Indirect Costs

Indirect costs are charged at Texas A&M University – Corpus Christi's federally negotiated rate of 38.0% of Modified Total Direct Costs (MTDC) in Year 1 and 41% of MTDC in Year 2. MTDC consists of all direct salaries and wages, applicable fringe benefits, materials and supplies, services, travel and up to the first $25,000 of each subaward. Modified Total Direct Costs shall exclude equipment, capital expenditures, charges for patient care, rental costs, tuition remission, scholarships and fellowships, participant support costs and the portion of each subaward in excess of $25,000.

Kimberly Hawkenson
Director
Sponsored Research Administration
6300 Ocean Drive, Unit 5844
Corpus Christi, Texas 78412
O 361.825.2730 • F 361.825.3920

October 17, 2023

Avra Morgan
WaterSMART Program
Water Resources and Planning Office
Bureau of Reclamation
Department of Interior
P.O. Box 25007
Denver, CO 80225-0007

Dear Ms. Morgan,

Texas A&M University-Corpus Christi (TAMU-CC) expends more than $750,000 per year in Federal expenditures. Per Uniform Guidance, 2 CFR § 200.501, TAMU-CC does have an annual single audit which is part of the statewide single audit performed. The Texas A&M System Fiscal Year runs from September 1st-August 31st. Single audits are normally published on the Federal Audit Clearinghouse every year in February.

Should you need additional information, please feel free to contact my office at 361-825-2751.

Sincerely,

Kimberly Hawkenson
Director, Office of Sponsored Research Administration
Texas A&M University- Corpus Christi