SOUTHERN NEVADA WATER AUTHORITY®

**Applying Backcasting to Identify Potential Future Water Quality Changes
in the Colorado River Basin**

($307,955)

WaterSMART - Applied Science Grants for Fiscal Year 2023

R23AS00446

October 17, 2023

Applicant:
Southern Nevada Water Authority

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TABLE OF CONTENTS

1. Executive Summary

Date: October 17, 2023
Applicant: Southern Nevada Water Authority (Category A applicant)
Location: 1001 South Valley View Boulevard, Las Vegas, Nevada 89153 (Clark County)

Project Summary:
The Southern Nevada Water Authority (SNWA), with the support of the Bureau of Reclamation (Reclamation), has developed extensive hydrodynamic and water quality modeling capabilities in the Lower Colorado River Basin. Previously, modeling has been approached from a sequential perspective—various potential changes were considered and run through the modeling framework, yielding a result that is then analyzed for the difficulty it may cause water managers and consumers. A different outlook is proposed in this project; instead of looking to potential future conditions, backcasting will be used to create challenge tests. In these tests, scenarios considered likely to cause problems for water managers and water supplies will be rigorously defined. Model simulations using a wide range of drivers will be run with a goal to uncover lake, climate, and watershed conditions that lead to these problematic outcomes. Once significant drivers are identified, the project team will suggest proactive approaches to ensure continuation of high-quality water in the Lower Colorado River Basin. The final piece of this project will be constructing a classification machine learning model that quantifies the importance of each input variable in violating the challenge tests.

Length of Time and Estimated Completion Date: The proposed project encompasses activity from September 2024 through September 2026. All project work will be completed by September 2026.

Federal Facilities: The proposed project is not located on a federal facility. Routine water quality sampling efforts already underway by SNWA and partner agencies will continue in Lake Mead National Recreation Area to support model calibration.

2. Technical Project Description
Applicant Category: SNWA is a Category A applicant.

Eligibility of Applicant: SNWA meets eligibility requirements as it is a regional wholesale water provider in Southern Nevada. The organization is responsible for water treatment and delivery for the Las Vegas Valley, as well as acquiring and managing long-term water resources. SNWA is composed of seven member agencies, including Big Bend Water District, the City of Boulder City, Clark County Water Reclamation, the City of Henderson, the City of Las Vegas, the Las Vegas Valley Water District, and the City of North Las Vegas, which together deliver drinking water to more than 2.3 million residents and 40 million annual visitors. SNWA diverts 90 percent of its water supply from the Reclamation-managed Colorado River system. SNWA receives delivery of Colorado River water from Reclamation under several contracts held by SNWA or its member agencies, as listed below:

SNWA Contracts:
- Contract Number 2-07-30-W0266, Amendment Number 1, Amended and Restated Contract with the Southern Nevada Water Authority, for the Delivery of Colorado River Water
- Contract Number 7-07-30-W0004, Amendatory and Supplemental Contract between the United States and the State of Nevada for the Delivery of Water and Construction of Project Works

SNWA Member Agency Contracts:
- Contract Number 14-06-300-978, "Boulder Canyon Project Arizona-California-Nevada Contract for the Delivery of Water," City of Boulder City
- Contract Number 0-07-30-W0246, Contract for Delivery of Water to City of Henderson
- Contract Number 14-06-300-2130, "Boulder Canyon Project Contract for Delivery of Water to Las Vegas Valley Water District"
- Contract Number 2-07-30-W0269, "Boulder Canyon Project Contract with the Big Bend Water District, Nevada, for the Delivery of Colorado River Water"

The water delivered by SNWA under these contracts is diverted at Reclamation-approved diversion points in the Colorado River at Lake Mead and below Hoover Dam. This includes delivery of water through the Robert B. Griffith Water Project (formerly the Southern Nevada Water Project) constructed by Reclamation, as authorized by an Act of the United States Congress.

Detailed Project Description: The objective of this project is to improve upon existing hydrodynamic and water quality modeling efforts by approaching water management questions differently. Instead of using projected future model inputs, such as air temperature under climate change or influent water temperature because of upstream reservoir volume to project future outcomes, this study will use backcasting. The goal of backcasting is to determine challenge scenarios that could be problematic for water managers in the future, such as water passing through Hoover Dam being too warm for the existing infrastructure, or releases from the Lower Basin being too saline to use in agricultural applications. In order to determine scenarios where these adverse effects may occur, the following models, tools, and data will be used: (1) The Lake Mead Model (LMM), an existing tool for simulating hydrodynamic (water temperature, density, velocity, conservative, and decay tracers) and water quality (dissolved oxygen, salinity, and nutrients) parameters under scenarios that could occur in the future (i.e. warmer inflows, lake drawdown, climate change); (2) The Lower Colorado Regional Water Quality Database, which stores all data collected on Lake Mead by SNWA and stakeholders; (3) Machine learning models, which can be used to generate future projections (within the bounds of the training set) and determine input parameter sensitivity to model output; (4) Markov Chain Monte Carlo, which quantifies uncertainty propagated in models; and (5) statistical tests and methods, including the t-test and Mann-Kendall test, to postprocess and interpret model results.

Goals: Specific goals for this project include:
- Using stakeholder feedback to determine water quality scenarios in the Lower Colorado River Basin that are disadvantageous to a diverse group of water managers. Transforming

stakeholder feedback to a series of model runs, some of which result in the adverse effects in the basin.

- Running the backcast by performing a series of simulations using the LMM, and adding more simulations as needed. SNWA will leverage the high-performance computing capabilities available through the UNLV National Supercomputing Institute.
- Constructing and optimizing a classification-based machine learning model that will act as a surrogate for all LMM simulations and summarize the importance of changes to model inputs on water quality. Improving the machine learning component using a deep learning method. Quantifying uncertainty using Markov Chain Monte Carlo to determine prediction intervals (which rigorously quantify model reliability) for model results where possible.
- Analyzing the results of all modeling efforts to create operational suggestions for water managers to adapt to, maintain or improve water quality in the Lower Colorado River Basin.

3. Project Location
The technical work for the proposed project will occur at SNWA's River Mountains Water Treatment Facility, in Henderson, NV. The project study area includes Lake Mead National Recreation Area and Glen Canyon National Recreation Area. A project location map is included as Figure 1 (Appendix A).

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

5. Technical Proposal: Evaluation Criteria
E.1.1. Evaluation Criterion A—Water Management Challenge(s)
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.
The term "Millennium Drought" (Wheeler, et al., 2022) describes the extended drought in the Colorado River Basin which began in 2000. As a result of the Millennium Drought, Lake Mead has declined over 70 percent in volume (Hannoun & Tietjen, 2022a). Lake Mead acts as an important resource, delivering 90 percent of drinking water to the Las Vegas Valley (Valley), which has a population of over 2 million (Center for Business and Economic Research, 2022) and entertains over 40 million tourists from around the world annually (Las Vegas Convention and Visitors Authority, 2023). Additionally, nearly 25 million users downstream in Arizona, California, and Mexico depend on Lake Mead for agricultural and municipal water (National Park Service, 2023). With this decline in volume and heavy reliance on Lake Mead to sustain life and economic viability in the desert southwest, Reclamation declared a Level 2a water shortage for Lake Mead for calendar year 2023. This is the first time in history that the Level 2a shortage was declared for Lake Mead, and the proclamation includes mandatory curtailments in consumptive water use for Arizona, Mexico, and Nevada (U.S. Department of the Interior, 2022). The severity of the Millennium Drought raises important questions regarding the quality of water used in the Lower Colorado River Basin. For example, it is well-established that further

decline of Lake Mead will lead to warmer water withdrawals for treatment and distribution for the Valley, which could pose significant challenges for water managers as warmer water is more expensive and difficult to treat (Hannoun & Tietjen, 2022b). Downstream, concerns over salinity are troubling not only for farmers in Southern California, but also in meeting salinity requirements for delivery to Mexico (Kelley & Nye, 1984). This project will determine water quality scenarios in the Lower Colorado River Basin that may be problematic for water managers and use a series of models to identify the triggers behind these undesirable water quality outcomes. Data from the proposed project will aid water managers in avoiding scenarios where potentially negative outcomes could occur.

2. Describe the concerns or outcomes if this water management challenge is not addressed?
After speaking with internal staff and stakeholders, the project team has identified negative concerns and outcomes. Personal communication with Reclamation's Boulder City, NV office elucidated a concern at Hoover Dam if water pulled in through the turbines maintains a temperature of 26°C or more for three or more consecutive days. SNWA is concerned not only with increasing raw water temperatures; but also increased total organic carbon (TOC) concentrations, which are projected because of continued decline in Lake Mead's volume and is a concern for disinfection byproduct formation in the drinking water. Other concerns include the continued potential for harmful algal blooms in Lake Mead due to climate change and decline in volume. Warmer inflow from upstream Lake Powell because of Powell's declining elevation may exacerbate these problems (Hannoun & Tietjen, 2022b). Communication with stakeholders downstream of Lake Mead shows they are concerned with rising water temperatures, perchlorate, and salinity. This challenge will help not only SNWA, but also collaborative stakeholders by determining the driving forces behind these concerns and outcomes so they may be avoided, even under future drought conditions.

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.
<u>Water supply reliability</u> for numerous users will be bolstered and improved due to this project as the main goal is to elucidate and mitigate factors leading to negative water quality outcomes. The Lower Colorado River Basin is comprised of local water delivery entities, such as SNWA, Met, and Central Arizona Project (CAP), among others; agricultural districts such as the Imperial Irrigation District and Coachella Valley Water District; tribal entities such as the Colorado River Indian Tribes; and environmental and recreational locations including Lake Mead National Recreation Area and Lake Havasu. These entities will benefit from the project, as shown in letters of support from Clark County Water Reclamation District, National Park Service (Boulder City/Lake Mead National Recreation Area office), City of North Las Vegas, Clean Colorado River Sustainability Coalition, Clark County Regional Flood Control District, Met, and University of Nevada, Las Vegas.

<u>Drought management and mitigation</u> will be informed because of this project. While SNWA does not control water quantity in Lake Mead, only operational suggestions, SNWA will provide resulting data from the proposed project to Reclamation as requested. For example, modeling efforts will yield a required maintained elevation at Lake Mead to ensure continued delivery of high-quality water to downstream users, as well as maintaining Hoover Dam's infrastructure.

Watershed health is an important consideration that will also be addressed in the proposed project. Endangered species, such as the razorback sucker (*Xyrauchen texanus*), live only in the warmer water of the Colorado River Basin. Preservation of conditions favorable to the razorback suckers will be determined by modeling efforts performed in this project. Further, improvement of an existing model to simulate and predict phytoplankton concentration will elucidate conditions that may lead to increased risk for harmful algal blooms.

E.1.2. Evaluation Criterion B—Project Benefits

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?

The need for the project was identified from discussion with SNWA internal staff and stakeholders. Communication with Reclamation's Boulder City, NV office identified operational challenges with Hoover Dam resulting from rising water temperatures. Issues identified internally, and are of concern to SNWA include TOC, which is projected to increase because of the continued decline in Lake Mead's volume, and the potential for harmful algal blooms in Lake Mead resulting from climate change. Discussion with stakeholders downstream of Lake Mead shows they are also concerned with rising water temperatures, perchlorate, and salinity. A goal of the proposed project is to determine the driving forces behind these concerns and to identify potential decision paths under challenge conditions. The proposed project would benefit SNWA as well as collaborative stakeholders. UNLV's assistance with the project was identified by meeting with Dr. Hannes Bauser, a faculty member in the Department of Geosciences. Based on his experience and expertise, Dr. Bauser will be enhancing project outcomes by aiding in running simulations on the supercomputer and improving machine learning models through hyperparameter optimization and deep learning capabilities.

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?

Water outflow and inflows to Lake Mead are highly regulated by Reclamation to meet legal and contractual needs of end users in Arizona, California, Nevada, and Mexico (Schmidt et al., 2023). Reclamation oversight, combined with additional nutrient loading of treated wastewater from the Las Vegas Wash, make the water quality of Lake Mead highly susceptible to operations. Inflows could modify thermal structures of lakes and affect stratification, while outflow operations could affect water residence times and water column mixing (Li et al., 2017; Olsson et al., 2022). Through backcasting, water managers would have a better understanding of how artificial controls can be used to produce desired water quality targets to avoid or reduce the severity of challenge scenarios. Once the proposed project is complete, information from the backcasting studies will be available immediately for use, and no additional work is needed.

An example of a challenge scenario and its associated planned model runs is described below. The required model runs in the proposed project may be developed by borrowing ideas from factorial Design of Experiments (DOE) (Lawson & Erjavec, 2017). Here, the LMM is treated as a numerical experiment, where there may be multiple input factors (e.g., air temperature, inflow flowrates, etc.) that influence a single output variable of interest (e.g., temperature at the Hoover Dam outflow). The basic idea is that to assess how changes in the input factors may influence changes in the single output variable of interest, experiments (in this case, simulations) are

conducted where each of the input factors are perturbed at least twice, at their minimum and maximum values. The input factors may be perturbed three or more times, but two perturbations result in the smallest number of experiments that need to be conducted, and is therefore, optimal in this sense.

There are operational challenges when water temperatures being pulled through the Hoover Dam outflows, T_{HD}, are greater than or equal to $26\ ^oC$ for three consecutive days. This situation could represent a challenge scenario, where T_{HD} may depend primarily on several input factors: water surface elevation (WSEL), inflow flowrates from the Colorado River (CR inflow), inflow flowrates from the Las Vegas Wash (LVW inflow), selective withdrawal from SNWA's drinking water intake (Intake 3 outflow), and air temperatures (air temp). Each input factor is perturbed twice, at high (represented as +), and low (represented as -) values shown in Table 1 (Appendix A). 32 simulations are then conducted at all possible combinations of the input factors, and the resulting T_{HD} values from each simulation (e.g., $T_{HD,1}, T_{HD,2}, ..., T_{HD,32}$) are recorded, as shown in Table 2 (Appendix A). Rather than fit a linear model to the experimental data in Table 2 (Appendix A), as done in typical DOE methods, a ML model may be constructed instead, to determine a mathematical relationship between input factors and the output:

$$T_{HD} = f(WSEL,\ CR\inf low,\ LVW\inf low,\ Intake\ 3\ outflow,\ airtemp)$$

The significance of the relationship above is that it may be used to find solutions where certain values of input variables will produce the challenge scenario of interest where $T_{HD} \geq 26^oC$. Simulation runs like those shown in Table 2 (Appendix A) would be developed for each challenge scenario identified by the proposed project. Upon completion of the project, various parameter spaces of input factors and how they can cause undesirable outputs would have been explored.

Suppose the challenge scenario described above was forecasted in a simulation or encountered. A possible decision path for this particular use case and its relation to the proposed project is depicted in the flow chart shown in Figure 2 (Appendix A).

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.
The results developed from the proposed project would benefit the Lower Basin as a tool to inform reservoir management decisions to mitigate or avoid water quality challenge situations. The project would benefit Reclamation's management of Hoover Dam. The project would also benefit downstream entities such as Met, Imperial District, and Colorado River Indian Tribes, among others, for salinity control.

Other specific examples are as follows. Data developed under this proposal can be used to identify factors at the outflow of Lake Mead with the potential to trigger undesirable algal growth downstream. Algal growth not only impact water quality but has been observed to cause

operational difficulties in the Big Bend Water District (e.g., clogged water filters). Additionally, results from the proposed project may be used to determine how population growth could trigger significant negative impacts on water quality.

Letters of support from entities benefitting from the project are included in Appendix B.

How will the project improve water management decisions?
A set of water quality challenge scenarios, onset variables leading to such scenarios, and mitigating strategies will be identified in the proposed project. This information will aid water managers in making informed decisions to either prevent challenge scenarios from occurring altogether, or to take appropriate intervening measures to reduce the impact of challenge scenarios on water quality within Lake Mead and downstream users.

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 results of the project would be disseminated through papers and conferences to help others managing reservoirs in extreme conditions like Lake Mead. The project will also be important in enhancing the forecasting capabilities of the LMM. For example, the results in the proposed project could be used to identify challenge scenarios in the forecasting results of the LMM. In this case, the project results and the LMM function as an early warning system.

The results of the project can also be used as input to a quantitative microbial risk assessment (QMRA) model of the drinking water from Mead, and further enhancements through calibration would also improve the Lake Mohave model. Both the QMRA and Lake Mohave models are under development by SNWA, under agreements with Reclamation. The results of the proposed project are standalone and would be directly transferable to the other efforts mentioned without additional work. While not directly applicable to other systems without additional work to gather data, create input files, and calibrate additional models, the flexibility to explore scenarios a well-developed model can provide guidance to other water managers contemplating similar problems or environmental shifts.

To what extent will the project address the water management challenges described in E.1.1.?
The results from the proposed project will have direct consequences on the issues addressed in E.1.1. The primary goal of the project is to identify drivers behind negative water quality outcomes and to determine methods to alleviate these issues should they arise.

Water supply reliability would be improved from this project. Results of the project will be applied primarily to the management of Mead and would have widespread significance to water users who depend on the Colorado River in the Lower Basin. Entities such as SNWA, Metropolitan Water District of Southern California (Met), and Central Arizona Project (CAP), among others, would benefit. Agricultural districts such as Imperial District and Coachella Valley Water District, as well as tribal communities such as the Colorado River Indian Tribes would also benefit.

Drought management would be directly addressed in the project. Challenge scenarios associated with drought would be identified and the project results will be used to inform operations. For example, effects of rising air temperatures, warmer water temperatures, and lower water surface elevations on water quality in Mead would be explored to determine operating conditions that favor water quality and infrastructure preservation (e.g., Hoover Dam) in times of drought. Modeling efforts will advance drought management decisions by providing information on the impact of decisions based on water quality and quantity, where past decisions could only incorporate quantity.

Watershed health is also directly addressed in this project. Endangered species, such as the razorback sucker (*Xyrauchen txanus*), live only in the warmer waters of the Colorado River Basin. Currently, the razorback sucker is known to recruit to adulthood only within Lake Mead (Pennock et al., 2023), and its recruitment success is believed to be tied to reservoir management operations (Albrecht et al., 2010). Reservoir operating conditions that favor razorback sucker will be determined by the modeling effort in this project. The proposed project will also improve an existing model to simulate and predict phytoplankton concentration to understand conditions that may lead to increased risk of harmful algal blooms.

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?
The results from the proposed project would complement SNWA's existing modeling and water quality forecasting tool that uses the LMM. For example, challenge scenarios along with mitigating strategies may be identified in forecasted simulations, using the known results from backcasting. Model calibrations performed during the backcasting effort will also serve to further improve the accuracy of the LMM.

There is ongoing work at SNWA to model Lake Mohave using AEM3D, with the eventual goal of coupling the LMM with the Lake Mohave model (funded by Reclamation WaterSMART agreement R23AP000043). Improved accuracy of the LMM through calibration will produce improved input data into the Lake Mohave model, leading to improved predictions of water quality changes for users downstream of Mead.

Calibration of LMM would also provide improved input data into a QMRA model currently being developed by SNWA (funded by Reclamation WaterSMART agreement R22AP00236), to quantify the risk of infection and illness when a population is exposed to microorganisms in the drinking water system. Extreme events such as high and low relative humidities (i.e., wet vs. dry conditions), spikes in run-off flowrates (i.e., storm events), and drought-driven lake drawdown are factors that would be explored under the proposed project. Results from these extreme events and their associated effect on drinking water quality may then be used as inputs to the QMRA model. Risk can also be assessed by thinking about how increasing water temperatures may negatively affect engineered structures in Southern Nevada, including SNWA's drinking water

intake and the Hoover Dam. Improved calibration of models can further decrease uncertainty in these projections, leading to more sound water management decisions.

E.1.3. Evaluation Criterion C—Project Implementation

1. Briefly describe and provide support for the approach and methodology that will be used to meet the objectives of the project.

The Aquatic Ecosystem Model 3D (AEM3D) is a tool for creating three-dimensional hydrodynamic and water quality models for lakes, reservoirs, and coastal ocean systems. AEM3D has been used to model, study, and make future projections for water quality for lakes and reservoirs around the world, including modeling ecological parameters (Allan, Hamilton and Muraoka 2017), harmful algal blooms (Chung, Imberger, et al. 2014), the fate and transport of turbid inflows (Chung, Hipsey and Imberger 2009), modeling hydrodynamics and tracer dispersion (Zhao, Rao and Wassenaar 2012), water surface elevations and their relation to water quality (Saber, James and Hannoun 2020), and water age and its relation to water quality (Gao, et al. 2018; Li, et al. 2010). A full three-dimensional hydrodynamic and water quality model for Lake Mead utilizing AEM3D, the LMM, has been rigorously calibrated and is used as a tool to guide future operations planning. The LMM was used to determine optimal placement of a drinking water intake deep in Lake Mead to protect the Valley from the effects of drought (Preston, et al. 2014), and more recently has been used to study the effects of extreme drawdown and climate change on water quality at the drinking water intake (Hannoun, Tietjen and Brooks 2021) and the whole lake (Hannoun, Tietjen and Brooks 2022). Studies have also been performed using the LMM to determine how Colorado River-driven turbidity could affect water treatment processes at the drinking water intake (Hannoun, Belding, et al. 2022). Finally, inflow and outflow projections from Reclamation were incorporated into the LMM to yield projections for future water quality in Lake Mead under future projected flow scenarios (Hannoun & Tietjen, 2022b). SNWA has formidable expertise in hydrodynamic and water quality modeling, ensuring the proposed project will be successfully completed.

SNWA has used machine learning models in several applications. The first is to project water temperature entering Lake Mead based on Julian date and Lake Powell's elevation (Hannoun & Tietjen, 2022b). The second machine learning model simulates and projects phytoplankton biovolume based on a range of environmental conditions. This paper is in preparation and will be sent out for peer review shortly. The project partner at UNLV has experience with deep learning methods in different applications (Kreyenberg at al., 2019; Kim et al., 2023).

Backcasting is a new concept at SNWA, but has support across academic disciplines as a rigorous way to work backwards, i.e. identify a problem then engineer scenarios where the problem may occur (Dreborg, 1996), including a recently published paper where backcasting was specifically applied to machine learning (Twumasi & Twumasi, 2022). The proposed project team seeks to further extend the theory of backcasting to hydrologic problems and show its usefulness for managing water issues.

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

Table 3. Work Plan

Task	Task Description	Milestones	Start and End Date	Estimated % of Total Cost
1	With stakeholder input, identify future problematic scenarios	1a: Stakeholder meetings 1b: Develop scenario list	9/2024-1/2025	10
2	Using backcasting, develop model runs based on feedback from Task #1	2: Planned model runs table	10/2024-4/2025	15
3	Perform model runs	3a: Improve LMM calibration 3b: Perform LMM simulations 3c: Improve and expand upon phytoplankton machine learning regression model	11/2024-8/2026	40
4	Create machine learning classification model to summarize all LMM results from Task #3	4a: Create machine learning model 4b: Optimize machine learning model through hyperparameter tuning and deep learning methods 4c: Validate model and present results for delivery/publication	11/2025-4/2026	25
5	Communicate results to stakeholders	5: Meetings	3/2026-7/2026	10
6	Communicate results to broader technical audience	6a: Publications 6b: National conferences	ongoing	N/A

3. Provide a summary description of the products.

Table 4. Anticipated Products

Product	Audience
Water Quality Projections	SNWA staff, Las Vegas Valley stakeholders (CCWRD, COH, COLV, CCRFCD, Nevada Division of Environmental Protection, Colorado River Commission of Nevada), Lower Colorado River stakeholders (MWD, CAP, Colorado River Indian Tribes)
Presentations at Local Meetings	Stormwater Advisory Council, Research and Environmental Monitoring Study Team, California Lake Management Society, Las Vegas Valley Watershed Advisory Committee

Presentations at National Meetings	North American Lake Management Society, Water Quality Technology Conference, Joint Aquatic Sciences Meeting, Ecological Society of America
Publications in Peer-Reviewed Journals	(Potential) Lake and Reservoir Management, Frontiers in Water, Journal of the American Water Resources Association, AWWA Water Science

Presentations at local meetings is important. The Valley is unique in that there are several existing regular meetings in which different municipalities and utilities supporting this project work collaboratively to solve regional challenges. Drought in the western United States is an important media topic. Some of the local meetings, such as Stormwater Advisory Council and Las Vegas Valley Watershed Advisory Committee, are free and open to the public, providing an opportunity for outreach and education regarding this project.

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?
UNLV will play an important part in the proposed project. UNLV is a doctoral-degree-granting minority-serving institution with approximately 30,000 students and holds the prestigious "R1" designation for research universities from the Carnegie Foundation. UNLV is nationally and internationally recognized for its research and policy contributions related to the "One Water" concept, which highlights the value and interconnectedness of conventional and unconventional water sources. The UNLV National Supercomputing Institute will also provide access to high-performance computing through the Cherry Creek Cluster.

Technical work will take place at SNWA and UNLV; however, stakeholder feedback is a crucial part of Tasks 1 and 5. Stakeholders will be invited to biannual meetings where water quality concerns will be discussed and recorded (Task 1). Throughout the project, the project team plans communication with stakeholders to keep them apprised of discoveries, present preliminary results, receive feedback, and adapt to any changes circumstances that may arise after initial meetings. The project team will meet with stakeholders to communicate final results (Task 5).

5. Identify staff with appropriate credentials and experience and describe their qualifications. Have the project team members accomplished projects similar in scope to the proposed project in the past either as a lead or team member?
Yes. Both Dr. Deena Hannoun and Dr. Todd Tietjen, permanent staff members at SNWA, have substantial experience working with stakeholder in the Lower Colorado Basin to complete Task 1 successfully. Dr. Hannoun has considerable expertise in 3D lake modeling and machine learning to oversee Tasks 2, 3, and 4. Dr. Tietjen has substantial limnological experience to assist with these three tasks. Ms. Charlotte van der Nagel is currently working on her Ph.D. with Dr. Hannoun and Dr. Tietjen as mentors; her growing skill set includes operating, altering, and analyzing results of the LMM. Ms. van der Nagel also created the phytoplankton machine learning model as part of her Ph.D. work. Dr. Hannes Bauser has extensive experience in hydrologic modeling, Monte Carlo methods, and machine learning, and will oversee the graduate student's assistance with Tasks 3 and 4. Tasks 5 and 6 will be performed by the entire project

team, all of whom have experience publishing academic papers and presenting to both technical and non-technical audiences.

Mr. Shanahan, Ms. Brooks, Dr. Dickenson, and Dr. Gerrity are all permanent, full-time employees at SNWA and will serve as the technical project advisory committee. Mr. Shanahan's expertise is Colorado River water resources, Ms. Brooks' expertise in climate change, Dr. Dickenson's expertise is water quality and treatment techniques, and Dr. Gerrity's expertise is microbiology and pathogenic research in wastewater and drinking water.

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.
Dr. Hannoun and Dr. Tietjen can begin on Tasks 1-3 immediately upon entering into an assistance agreement. Ms. van der Nagel will complete her Ph.D. in summer 2024 and begin as a Postdoctoral Researcher at SNWA in fall 2024. She will be performing the bulk of Task 3 with support from Drs. Hannoun and Tietjen that fall. The project timeline has been created to reflect these considerations. The graduate student and Dr. Bauser will join the project team in summer 2024 due to the nature of the academic calendar. Dr. Bauser and Dr. Hannoun will advertise the graduate student position though professional societies such as the American Geophysical Union and other listservs. Candidates will be selected for virtual interviews (plus an in-person UNLV recruiting event in February 2024), and then Dr. Bauser and Dr. Hannoun will select an ideal candidate and invite them to join the project team.

E.1.4. Evaluation Criterion D—Dissemination of Results
Explain how project results will be disseminated. 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.
Dissemination of results is a core task of this project. Project results are of interest for SNWA's Water Treatment Division to guide potential future modifications to treatment processes. Throughout the project duration, results will be shared to the treatment division during regular meetings. Results will also be presented internally to SNWA's Research & Development and Water Resources Divisions.

Local stakeholders will provide input of potential water issues of concern for the Colorado River Basin. Keeping stakeholders informed on preliminary and final results are an essential part of this project. Results will be shared directly with stakeholders through regular meetings, as well as through existing interdisciplinary meetings where different municipalities and utilities from the Valley are present. Such meetings are important in keeping other stakeholders (that were initially not included in the project) informed of the project, as well as provide new opportunities for collaboration. Meetings include the Las Vegas Valley Watershed Advisory Committee, the Las Vegas Wash Coordination Committee, the Stormwater Advisory Committee, the WateReuse Association: Nevada Chapter, and the Research and Environmental Monitoring Study Team.

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.
The results and framework of this project will be shared to stakeholders and water managers in the West at the Lower Colorado River Partnership and the Clean Colorado River Sustainability meetings. Results will also be shared through regular meetings with the Grand Canyon Monitoring and Research Center (United States Geological Survey); their modeling group is responsible for modeling water quality in Lake Powell, where a similar study could be beneficial.

In addition to publishing study results in at least two peer-reviewed journals, results will be presented at conferences. Regionally, results will be presented to technical and non-technical audiences at conferences of the Nevada Water Resources Association and the California Lake Management Society. Nationally, results will be presented at conferences of the North American Lake Management Society, the Ecological Society of America, and the American Geophysical Union's annual meeting.

E.1.5. Evaluation Criterion E—Presidential and Department of the Interior Priorities 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?
One of the most important effects of climate change in the Southwest is the intensification of droughts (Williams et al., 2022). The effects of climate change are evaluated in this project through multiple modeling scenarios. For example, a scenario will determine what drives temperature of raw water at the drinking water intake to pass the desired temperature for treatment processes. Climate change will play a crucial role in many drivers, such as decreasing lake elevation of Lake Powell, thereby releasing warming water, and increasing air temperatures. Through analysis of multiple modeling scenarios, the proposed project will increase drought resiliency of the Lower Colorado River Basin by identifying drivers of potential water quality changes. This is important as drought conditions are expected to continue or worsen throughout this century (Wahl et al., 2022). The project will combine input from many stakeholders, with intense hydrodynamical modeling to help prevent future degradation of water quality. The outcome of the study will contain a framework of conditions for which unwanted changes in water quality are highly probable. Results of this study can aid future management decisions in aiming to prevent the identified conditions.

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.
Results of the proposed study will be used to aid long-term management decisions in the Lower Colorado River Basin. Workflow processes to identify drivers of potential water quality changes will remain available after the completion of this project. Therefore, in case novel problem scenarios are identified in the future, the methods outlined in this project can aid future work and continue to help increase the resiliency to climate change and drought, long after completion of

the project. Additionally, climate change and drought are expected to continue to increase the number of lakes and reservoirs negatively affected by drought globally (Mosley, 2015). Results of this study will be presented at conferences and published in internationally reaching journals, and methods will be publicly available. As such, the results of this project can be implemented for similar river basins and reservoirs or can help to create a framework and inspiration for similar studies globally.

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?
The outcome of the proposed project will indicate areas of concern for water pollution in the Colorado River. Areas where nutrient pollution from cities and agriculture is combined with pollution caused by reduced water volume and altered hydrodynamics due to drought are particularly vulnerable. This project will aid in understanding drivers of water pollution, allowing for better management decisions to divert negative consequences of pollution. Currently, SNWA is collecting data on per- and polyfluoroalkyl substances (PFAS) concentrations in the Las Vegas Wash, since it is a contaminant known to be environmentally persistent, and toxic at certain dosages. A goal is to include PFAS as a tracer within the LMM once sufficient PFAS data are collected.

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 reference Figure 3 in Appendix A for a snapshot of the SNWA service area on the Climate and Economic Justice Screening Tool.

If applicable, describe how the project benefits those disadvantaged or underserved communities identified using the tool.
The proposed project provides benefits to disadvantaged communities. As shown in Figure 3 (Appendix A), numerous census tracts in the SNWA Service Area are considered disadvantaged (shaded blue) for being at or above the threshold for one or more burdens (housing, transportation, and health appear frequently) and are at or above the socioeconomic burden.

The proposed project provides indirect benefits to disadvantaged communities due to the benefits to the entire service area, including better water quality in Lake Mead and ecosystem benefits. By investing in modeling that supports water quality predictive data and water management flexibility, the proposed project will also build long-term resilience to drought. Ninety percent of Southern Nevada's water supply comes from the Colorado River. This allocation will be reduced as water elevations in Lake Mead continue to decline. Using tools like those in the proposed project to adapt to the new reality is of benefit to everyone in the SNWA service area.

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.

The proposed project will not directly serve or benefit a Tribe or directly support resilience to climate change or drought impacts. However, the proposed project will indirectly benefit Indian tribes by reducing the consumptive use on the Colorado River, to which Indian tribes have rights, which include the Fort Mojave Indian Tribe, Colorado River Indian Tribes, Chemehuevi Indian Tribe, Quechan Indian Tribe, and Cocopah Indian Tribe in the Lower Basin. Additionally, the Southern Paiute Tribe will indirectly benefit from the proposed project as their nation is in an SNWA member agency service area.

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

This project does not help fulfill any of Reclamation's legal or contractual obligations such as providing water for tribes.

6. Project Budget

SNWA as an organization is funded by diverse sources, including a quarter-cent sales tax, wholesale delivery charges, connection fees, commodity fees, and reliability charges. Matching contributions for this project will be provided by SNWA. No non-Federal funding will be provided by a source other than the applicant, so no letters of commitment are required.

Table 5. Summary of Non-Federal and Federal Funding Sources

	AMOUNT
Non-Federal Entities	
1 SNWA	$405,840
Non-Federal Subtotal	$405,840
REQUESTED RECLAMATION FUNDING	$307,955

The full Project Budget is included in Attachment A, Budget Detail and Narrative, which was submitted via grants.gov.

Budget Narrative Summary

All costs included in this proposal are directly related to the project and necessary for its implementation. The non-federal contribution is 57 percent; the federal contribution is 43 percent. The full Budget Narrative is included in Attachment A, Budget Detail and Narrative, which was submitted via grants.gov.

7. 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.

The proposed project consists of water quality modeling and water sampling from Lakes Mead and Mohave. Current modeling capabilities would be expanded to increase future planning

capabilities and to identify and avoid undesirable water quality scenarios. During the project period, weekly and monthly water samples would be collected from the lakes. The collected water samples would be analyzed at the River Mountains Water Treatment Facility (RMWTF) lab and the results used for the modeling work. The proposed project would not involve any earth disturbing work. There would be no impacts to soil, air, or water quality. The proposed project would require removing a combined total of approximately 3,200 liters of water from Lake Mead and Lake Mohave each year, which is permitted by an interlocal agreement between SNWA and the National Park Service (NPS). The total quantity of water collected would be insignificant compared to the volume of water contained in the two lakes. The lakes provide designated critical habitat for two federally endangered fish: (1) the bonytail chub (*Gila elegans*) that inhabits Lake Mohave and (2) the razorback sucker (*Xyrauchen texanus*) that inhabits both Lake Mead and Lake Mohave. The insignificant amount of water removed from the lakes and the staggered collection of the samples over a 24-month period would not cause adverse impacts to either species or their designated critical habitat. No new roads would be needed, and no roads would be blocked by the proposed project activities. Vehicles would use existing paved and dirt roads to access boat ramps at Lake Mead and Lake Mohave for water sampling.

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?
The project area for the proposed action includes the RMWTF, and Lakes Mead and Mohave. The RMWTF is an existing built facility, and its perimeter has both security and tortoise fencing. There is no critical habitat within the RMWTF site. The federally endangered bonytail chub and its designated critical habitat occur within Lake Mohave while the federally endangered razorback sucker and its designated critical habitat occur in both Lake Mead and Lake Mohave. Water sampling for the proposed project would remove a combined total of approximately 3,200 liters of water from the lakes each year, which is permitted by an interlocal agreement between SNWA and NPS. Therefore, the proposed project would not cause impacts to either species or their designated critical habitat.

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.
There are no wetlands or surface waters at SNWA's RMWTF. The water samples will not be collected from sensitive wetland areas, but Lakes Mead and Mohave are surface waters that fall under Clean Water Act jurisdiction as "Waters of the United States." The proposed project would require removal of a combined total of approximately 3,200 liters of water from the lakes each year, which is insignificant compared to the total volume of water in the two lakes, and therefore no impacts to Waters of the United States would occur.

When was the water delivery system constructed?
In 1991, seven local water and wastewater agencies formed SNWA to address water issues on a regional basis. Collectively, the member agencies serve more than 2.2 million residents in Southern Nevada. As the wholesale water provider, SNWA is responsible for water treatment and delivery through the Southern Nevada System that began in 1971, as well as acquiring and

managing long-term water resources. The Las Vegas Valley Water District commenced operations in 1954 and has served the region's largest municipal water provider since then.

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.
The proposed project would not result in the modification of an irrigation system.

Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places?
There are no known buildings, structures, or features associated with the proposed project or within the proposed project area listed or eligible for listing on the National Register of Historic Places.

Are there any known archeological sites in the proposed project area?
There are no known archaeological sites in the proposed project area.

Will the proposed project have a disproportionately high and adverse effect on low income and minority populations?
The proposed project would not have a disproportionately high or adverse effect on low income and minority populations; modeling efforts would benefit the entire SNWA service area.

Will the proposed project limit access to and ceremonial use of Indian sacred sites or result in other impacts to tribal lands?
The proposed project would not limit access to and ceremonial use of Indian sacred sites and would not result in any impacts on tribal lands.

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?
The proposed project consists of water quality modeling supported by routine sampling efforts from Lakes Mead and Mohave. There are no noxious weeds within the proposed project area; however, the nonnative invasive quagga mussel (*Dreissena rostriformis bugensis*) does occur in both lakes. The proposed project involves boating on both lakes to fill water sample collection bottles. The boats would be launched at the Las Vegas Boat Harbor boat ramp in Lake Mead and at the Cottonwood Cove boat ramp in Lake Mohave. The boat and sampling equipment would be free of noxious weeds and non-native invasive species prior to arriving at the two boat launch points and prior to departing. Therefore, the proposed project would not contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species.

8. Required Permits or Approvals
None are anticipated for the proposed project.

9. Overlap or Duplication of Effort Statement
This project builds on existing Reclamation-funded work, agreements R22AP00236 and R2300043. This project is not a duplication but rather an extension of efforts.

10. Conflict of Interest Disclosure

To the best of our knowledge, no actual or potential conflict of interest exists at the time of submission. If awarded, SNWA will disclose, in writing, any conflicts of interest that may arise during the life of the award.

11. Uniform Audit Reporting Statement

SNWA was required to complete a Single Audit for the most recently closed fiscal year (ending June 30, 2021). The Single Audit for the fiscal year ending June 30, 2023, is in progress at the time of writing this proposal. SNWA's EIN is 88-0278492 and the report is available through the Federal Audit Clearinghouse website.

12. Certification Regarding Lobbying

As this application requests more than $100,000 in Federal funding, the applicant certifies the statements in 43 CFR Part 18, Appendix A. Standard Form-LLL, "Disclosure Form to Report Lobbying" was submitted with this application.

13. Letters of Support

Included in Appendix B.

14. Official Resolution

An official resolution authorizing the submission of this proposal and confirming the subject matching requirements will go before the SNWA Board of Directors at its November 2023 meeting. A copy will be forwarded to Reclamation at that time.

15. Unique Entity Identifier

SNWA maintains an active registration in SAM.gov. Its Cage Code is 3NRT9. SNWA's SAM Unique Identifier is SM1CPB4X7E88

16. Supporting Documents

Attached as Appendices A-C.

RESOLUTION IN SUPPORT OF APPLICATION FOR WATERSMART APPLIED SCIENCE GRANT FUNDING TO THE BUREAU OF RECLAMATION

WHEREAS, the Bureau of Reclamation's (Reclamation) WaterSMART Applied Science Grants program is soliciting proposals for and may provide financial assistance to irrigation districts, water districts, and other organizations to implement projects that develop hydrologic information and water management tools and improve modeling and forecasting capabilities; and

WHEREAS, the WaterSMART Applied Science Grants program specifically allows for project proposals that improve modeling and forecasting capabilities in which results will be used by water managers to increase reliability and improve management; and

WHEREAS, the Southern Nevada Water Authority (Authority) adopted its Water Resource Plan, which prioritizes maintaining the highest water quality and reliability standards; and

WHEREAS, the Authority will benefit significantly from financial assistance to support modeling efforts in Southern Nevada.

NOW, THEREFORE, BE IT RESOLVED that the Authority's Board of Directors agrees, authorizes, and verifies:

1. That, if awarded, the Authority's General Manager, John J. Entsminger, or his designee, has the authority to enter into and execute an assistance agreement or similar agreement on behalf of the Authority with Reclamation for WaterSMART Applied Science Grants funding.

2. That the Authority's application requesting $307,955 to support its proposed project, "Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin", has been reviewed and approved by appropriate Authority staff and the Authority's Board of Directors supports submission to Reclamation's WaterSMART Applied Science Grants program of the application.

3. That the application includes a funding plan that outlines the Authority's ability to contribute up to $405,840 and that, if awarded, the Authority has the financial capability to provide the matching contribution, as specified in the funding plan.

4. That, if awarded, the Authority will work with Reclamation to meet established deadlines for entering into an assistance agreement or similar agreement.

Introduced and passed this 16th day of November 2023.

Attest: Southern Nevada Water Authority

John J. Entsminger, Secretary   Marilyn Kirkpatrick, Chair

Gregory J. Walch, General Counsel

Appendix A

Project Location Map, Figures, and Tables

Southern Nevada Water Authority

Applying Backcasting to Identify Potential Future Water Quality Changes
in the Colorado River Basin

WaterSMART Applied Science FY23 Application

Figure 1. Map of the Project Area

Figure 2. Decision path for challenge case where $T_{HD} \geq 26^oC$

Figure 3. Climate and Economic Justice Screening Tool – SNWA Service Area

Table 1. Input variable maximum (+) and minimum (-) values

	+	-
WSEL	1100 ft	1000 ft
CR inflow	500 m^3/s	300 m^3/s
LVW inflow	12 m^3/s	7 m^3/s
Intake 3 outflow	25 m^3/s	10 m^3/s
air temp	32° C	14° C

Table 2. Simulation runs for challenge case where $T_{HD} \geq 26\,^oC$

Simulations	WSEL	CR inflow	LVW inflow	Intake 3 outflow	air temp	T_{HD}
1	+	+	+	+	+	$T_{HD,1}$
2	-	+	+	+	+	$T_{HD,2}$
3	+	-	+	+	+	$T_{HD,3}$
4	-	-	+	+	+	$T_{HD,4}$
5	+	+	-	+	+	$T_{HD,5}$
6	-	+	-	+	+	$T_{HD,6}$
7	+	-	-	+	+	$T_{HD,7}$
8	-	-	-	+	+	$T_{HD,8}$
9	+	+	+	-	+	$T_{HD,9}$
10	-	+	+	-	+	$T_{HD,10}$
11	+	-	+	-	+	$T_{HD,11}$
12	-	-	+	-	+	$T_{HD,12}$
13	+	+	-	-	+	$T_{HD,13}$
14	-	+	-	-	+	$T_{HD,14}$
15	+	-	-	-	+	$T_{HD,15}$
16	-	-	-	-	+	$T_{HD,16}$
17	+	+	+	+	-	$T_{HD,17}$
18	-	+	+	+	-	$T_{HD,18}$
19	+	-	+	+	-	$T_{HD,19}$
20	-	-	+	+	-	$T_{HD,20}$
21	+	+	-	+	-	$T_{HD,21}$
22	-	+	-	+	-	$T_{HD,22}$
23	+	-	-	+	-	$T_{HD,23}$
24	-	-	-	+	-	$T_{HD,24}$
25	+	+	+	-	-	$T_{HD,25}$
26	-	+	+	-	-	$T_{HD,26}$
27	+	-	+	-	-	$T_{HD,27}$
28	-	-	+	-	-	$T_{HD,28}$
29	+	+	-	-	-	$T_{HD,29}$
30	-	+	-	-	-	$T_{HD,30}$
31	+	-	-	-	-	$T_{HD,31}$
32	-	-	-	-	-	$T_{HD,32}$

Appendix B

Letters of Support

Southern Nevada Water Authority

Applying Backcasting to Identify Potential Future Water Quality Changes
in the Colorado River Basin

WaterSMART Applied Science FY23 Application

August 8, 2023

Re: Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin

To whom it may concern:

The Clark County Water Reclamation District (District) is pleased to support the Southern Nevada Water Authority (SNWA) in efforts to obtain funding through the US Bureau of Reclamation (Reclamation) WaterSMART Applied Science Grants for the proposed project entitled: Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin.

The District collects and treats wastewater at seven plants in unincorporated Clark County, Nevada, serving visitors to the Las Vegas Strip and one million residents. Our main plant discharges over 100 million gallons of reclaimed water per day into the Las Vegas Wash which empties into Las Vegas Bay of Boulder Basin in Lake Mead. Our plant in Laughlin, Nevada discharges 1.5 million gallons of reclaimed water per day directly into the Colorado River below Davis Dam. The District is The Clean Water Team and we play a critical role in protecting public health and environment related to the to the Wash, Bay, Lake, and the downstream Colorado River.

SNWA, with the support of Reclamation, has developed extensive hydrodynamic and water quality modelling capabilities in the Lower Colorado River Basin. Previously, modeling has been approached from a sequential perspective—various potential changes were considered and run through the modelling framework, yielding a result that is then analyzed for the difficulty it may cause water managers and consumers. A different outlook is proposed in this project; instead of looking to potential future conditions, backcasting will be used to create challenge tests. In these tests, scenarios considered likely to cause problems for water managers and water supplies will be rigorously defined. Model simulations using a wide range drivers will be run with a goal to uncover lake, climate, and watershed conditions that lead to these problematic outcomes. Once significant drivers are identified, the project team will suggest proactive approaches to ensure continuation of high water quality in the Lower Colorado River Basin. As an example, elevated water temperature is a concern to both SNWA and Reclamation for operational reasons. If a water temperature of 26°C or above is determined to be problematic, the project team can model a range of different water surface elevations, water column temperatures, and climate drivers to develop a matrix of conditions that will result in problems for water managers. The final piece of this project will be constructing a classification machine learning model that quantifies the importance of each input variable in violating the challenge tests.

If you have any questions, please contact me at dfischer@cleanwaterteam.com or (702) 668-8455.

Sincerely,

Daniel C. Fischer
Deputy General Manager

cc: Denna Hannoun, Ph.D., Southern Nevada Water Authority

NATIONAL PARK SERVICE
Lake Mead National Recreation Area
601 Nevada Way
Boulder City, Nevada 89005

IN REPLY REFER TO:

1.A.2

September 14, 2023

Nathan Moeller
Bureau of Reclamation
Columbia-Pacific Regional Office
1150 N. Curtis Road
Boise, Idaho 83706

Dear Mr. Moeller and review panel:

I am pleased to provide this enthusiastic letter of support for the Southern Nevada Water Authority (SNWA) WaterSMART Applied Science grant proposal entitled "Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin." Results from this innovative project will provide critical information which will help protect both drinking water quality and recreational water quality in Lakes Mead and Mohave within Lake Mead National Recreation Area.

Lakes Mead and Mohave are major water storage reservoirs within the Lower Colorado River Basin, and water quality within these reservoirs is important for both domestic supply and for water-based recreation within the recreation area. Declining inflow, lowering reservoir elevations, and warming water temperature are all factors which may negatively affect water quality resulting in challenges for SNWA and the National Park Service (NPS) in producing safe drinking water and challenges for the NPS in providing safe water-based recreational experiences for the public.

Current methodologies for modeling and predicting water quality are proving insufficient for developing management strategies and resulting in agencies operating in 'reactive' rather than 'proactive' modes. Furthermore, information on drivers of water quality is currently insufficient for modeling taking place for the U.S. Bureau of Reclamation (USBR) Post-2026 Environmental Impact Statement for Colorado River operations.

The NPS in cooperation with the USBR Lower Colorado Regional Office and SNWA is currently working to replace meteorological and water quality buoys in Lakes Mead and Mohave. Additionally, NPS is funding enhanced water quality monitoring within high recreational use areas of the lakes over the next three to four years. These efforts will provide better near-real-time data across basins within the lakes and finer grained data within high-use areas for current and future modeling efforts, including for the proposed backcasting models.

Results from the proposed study would significantly enhance both the ability of SNWA and the NPS to develop proactive management strategies for potential water quality issues in the future as reservoirs continue to decline. Additionally, information from the study will provide the USBR enhanced tools to evaluate Colorado River operations and to potentially adjust reservoir operations to better maintain water quality needed to ensure a safe water supply for both domestic and recreational use.

Sincerely,

MICHAEL GAUTHIER

Digitally signed by MICHAEL GAUTHIER
Date: 2023.09.25 10:16:14 -07'00'

Mike Gauthier
Superintendent

Clean Colorado River Sustainability Coalition Members

Anglers United Lake Havasu Chapter

•

Arizona State University, Lake Havasu City, Arizona

•

Buckskin Sanitary District, Arizona

•

Central Arizona Project

•

Chemehuevi Indian Tribe

•

City of Bullhead City, Arizona

•

City of Needles, California

•

Clark County Water Reclamation District

•

Colorado River Sewage Systems Joint Venture

•

La Paz County, Arizona

•

Lake Havasu City, Arizona

•

Lake Havasu Marine Association

•

Metropolitan Water District of Southern California

•

Mohave County, Arizona

•

Southern Nevada Water Authority

•

Town of Parker, Arizona

August 21, 2023

To Whom It May Concern:

The Clean Colorado River Sustainability Coalition (CCRSCo) is pleased to support Southern Nevada Water Authority's (SNWA) efforts to obtain funding through Bureau of Reclamation WaterSMART Applied Sciences Grants Fiscal Year 2023-- R23AS00446 for the project, "APPLYING BACKCASTING TO IDENTIFY POTENTIAL FUTURE WATER QUALITY CHANGES IN THE COLORADO RIVER BASIN."

Sustainable good water quality of the Lower Colorado River is the coalition's prime focus and the research and work undertaken through this effort will provide much needed information for the future of water quality management along the Lower Colorado River.

Thank you for your consideration.

Respectfully,

Cal Sheehy

Cal Sheehy
Chairman, CCRSCo
Mayor, Lake Havasu City

Cc: CCRSCo Board

Mayor
Pamela A. Goynes-Brown

Council Members
Isaac E. Barron
Ruth Garcia-Anderson
Scott Black
Richard J. Cherchio

City Manager
Ryann Juden, J.D., Ph.D.

CITY OF
NORTH LAS VEGAS

Utilities Department
2829 Fort Sumter Drive • North Las Vegas, Nevada 89030
Telephone: (702) 633-1275 • Fax: (702) 649-9784 • TDD (800) 326-6868
www.cityofnorthlasvegas.com

August 8, 2023

Re: Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin

To Whom It May Concern:

The City of North Las Vegas (City) is pleased to support the Southern Nevada Water Authority (SNWA) with their efforts to obtain funding for the upcoming WaterSMART Applied Sciences grant for the proposed project entitled: Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin.

The City collects and treats wastewater at our Water Reclamation Facility (WRF) serving thousands of our residents. The WRF discharges over 18.4 million gallons of reclaimed water per day into the Las Vegas Wash. The City recognizes the importance of protecting public health and environment as it relates to the Las Vegas Wash.

Should you need further information, please contact me at llamadoj@cityofnorthlasvegas.com or (702) 633-1230.

Sincerely,

Joemel D. Llamado, P.E.
Deputy Director, Utilities Department

Cc: Denna Hannoun, Ph.D., Southern Nevada Water Authority

REGIONAL FLOOD CONTROL DISTRICT

Steven C. Parrish, P.E.
General Manager/Chief
Engineer

BOARD OF DIRECTORS

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Clark County

**Councilman
Dan Shaw**
City of Henderson

**Councilman
Paul Wanlass**
City of Mesquite

August 21, 2023

RE: Support for "Robust Updates to Advance Lake Models to Inform Future Drinking Water Treatment Needs."

To Whom It May Concern:

The Clark County Regional Flood Control District (District) is pleased to support the Southern Nevada Water Authority (SNWA) in efforts to obtain funding through the United States Bureau of Reclamation (Reclamation) Water SMART Applied Science Grants for the proposed project entitled "Applying Back casting to Identify Potential Future Water Quality Changes in the Colorado River Basin."

Established in 1986, the District is the regional agency responsible for planning, funding, implementing, and maintaining infrastructure in Southern Nevada to protect residents and visitors from the ravages of flooding. The District is also a Permittee to a National Pollutant Discharge Elimination System permit for the discharge of stormwater to the Las Vegas Wash and Lake Mead. The District is particularly interested in greater understanding of the impacts of stormwater quality on the Las Vegas Wash and Lake Mead in the face of drought and climate change. The proposal by SNWA will help better understand the water quality dynamics of climate change and drought on Lake Mead in order to help managers better plan for potential impacts. These modeling efforts ensure long-term maintenance of water quality and serve as a framework for utilities concerned with the effects of drought and climate change.

I strongly encourage Reclamation to fund the SNWA proposal. If you have any questions, please contact me at (702) 685-0023 or jtennert@regionalflood.org.

Sincerely,

John Tennert
John Tennert (Aug 22, 2023 06:35 PDT)

John Tennert, Ph.D.
Environmental Mitigation Manager

cc: Deena Hannoun, Ph.D., Southern Nevada Water Authority

September 20, 2023

Deena Hannoun, Ph.D.   Reply to: 700 Moreno Avenue
Limnology Modeling Project Manager   La Verne, CA 91750
Southern Nevada Water Authority
PO Box 99954
La Vegas, NV 89193

Dear Ms. Hannoun:

Support for *Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin*

The Metropolitan Water District of Southern California (Metropolitan) is pleased to support Southern Nevada Water Authority's (SNWA) project, *Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin* for consideration of a U.S. Bureau of Reclamation WaterSMART Applied Sciences Grant.

Metropolitan is the nation's largest wholesale water supplier, responsible for serving safe and reliable drinking water to nearly 19 million people throughout six counties in Southern California. Metropolitan owns and operates an extensive water system including the Colorado River Aqueduct, 15 hydroelectric facilities, nine reservoirs, 830 miles of large-scale pipes, and five regional water treatment plants. We are committed to providing high quality drinking water to our customers and share a vested interest with SNWA in protecting Colorado River water quality.

Metropolitan works closely with SNWA to monitor Colorado River water quality conditions and supports additional modeling and investigations of the Colorado River Basin to adequately assess and respond to changes in water quality. SNWA's proposal to identify historic challenge tests and their drivers will be of use to Colorado River stakeholders as they meet the current challenges of managing an increasingly variable Colorado River.

We appreciate SNWA's efforts to pursue this project and backcast water quality changes and their impacts to Colorado River stakeholders.

If you have any questions, please contact me at (909) 392-5155 or via e-mail at prochelle@mwdh2o.com, or Maria Lopez at (909) 392-5447 or via e-mail at mtlopez@mwdh2o.com.

Sincerely,

Paul Rochelle, Ph.D.
Water Quality Section Manager

MS:smh
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Page 8

UNLV
UNIVERSITY OF NEVADA, LAS VEGAS

Department *of*
GEOSCIENCE

September 22, 2023

To Whom It May Concern,

I am pleased to support the Southern Nevada Water Authority (SNWA) with their efforts to obtain funding through the WaterSMART Applied Sciences Grant for the project "Applying Backcasting to Identify Potential Future Water Quality Changes in the Colorado River Basin".

The project will provide crucial information to ensure continued high water quality in the Colorado River Basin, which is a key resource for both the Las Vegas Valley as well as downstream users, but challenged through extended drought and rising temperatures due to climate change.

If the project is funded, I will collaborate with SNWA and supervise a graduate student working on the project. The graduate student will perform additional model simulations with the Lake Mead Model as well as use these simulations to improve and develop machine learning models needed in the project. The student will have access to computing resources in my lab as well as the high-performance computing capabilities at the University of Nevada, Las Vegas (UNLV).

Sincerely,

Dr. Hannes H. Bauser
Assistant Professor, Sustainability in Arid Lands, UNLV Department of Geoscience

Appendix C

Works Cited

Southern Nevada Water Authority

Applying Backcasting to Identify Potential Future Water Quality Changes
in the Colorado River Basin

WaterSMART Applied Science FY23 Application

Works Cited

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