World Water Forum College Grant Program
2017-2019 Grant Proposals

College	SAN DIEGO STATE UNIVERSITY
Faculty	Dr. Garoma
Project #014	New Approach to Seawater Desalination

A New Approach for Seawater Desalination

Application Strand: Local

A Proposal Submitted to World Water Forum

Faculty Project Manager
Dr. Temesgen Garoma
San Diego State University
Department of Civil, Construction and Environmental Engineering
5500 Campanile Drive,
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December 2017

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1. Project Summary

1.1 Project Overview

California faces water scarcity. Persistent drought that affects the state's main water sources – surface water, snowpack, and groundwater – is the root cause of the problem. The state is taking measures to alleviate the challenge through water conservation and infrastructure projects. These measures are important; however, they can only improve the use of the existing water sources. The only method to increase the state's water supply beyond the current sources is seawater desalination, which offers unlimited and steady supply of water.

In the past few decades, advancements have been made on desalination technologies substantially reducing the cost and energy input during the desalination process. Despite these advancements, seawater desalination is still more energy intensive and expensive compared to conventional technologies employed for treatment of fresh water. Therefore, an outside-the-box and transformative solution is necessary for treatment of seawater.

In the research, we propose to use low-grade waste heat in a flue gas stream for heating seawater in a heat exchanger unit, converting the water to vapor, and condensing the vapor to form pure water. To achieve this, we will complete the following three major objectives: (1) size and select a heat exchanger unit, (2) test the concept using synthetic seawater, and (3) estimate the potential benefits of the project.

1.2 Application Strand

Application Strand	Identify Region
LOCAL Project Name	A New Approach for Seawater Desalination
GLOBAL Project Name	

2. Contact Information

Faculty Project Manager	Temesgen Garoma Professor Blasker Chair in Environmental Engineering Director of the Environmental Engineering Program Department of Civil, Construction and Environmental Engineering 5500 Campanile Drive San Diego, CA 92182 Phone: 619-594-0957 E-mail: tgaroma@mail.sdsu.edu
Student Project Manager	Marina Balcazar Department of Civil, Construction and Environmental Engineering 5500 Campanile Drive San Diego, CA 92182 Phone: 916-709-0492 E-mail: marinabalcazar1@gmail.com
College	San Diego State University
Department	Department of Civil, Construction and Environmental Engineering 5500 Campanile Drive San Diego, CA 92182-1324
Overview/History	San Diego State University (SDSU) is a public research university in San Diego, California, and is the largest and oldest higher education institution in San Diego County. Founded in 1897, it is the third-oldest university in the 23-member California State University system. The mission of SDSU is to provide well balanced, high quality education for undergraduate and graduate students, and to contribute to knowledge and the solution of problems through excellence and distinction in teaching, research, and service.
Make Check Payable To:	San Diego State University Research Foundation Attn: Sandra Nordah, Sponsored Research Contracting and Compliance 5250 Campanile Drive San Diego, CA 92182 Phone: 619-594-4172 E-mail: Snordahl@foundation.sdsu.edu

3. Letters of Support: Member Agency/ Local Water Agency

SAN ELIJO JOINT POWERS AUTHORITY

November 30, 2017

World Water Forum
Metropolitan Water District of Southern California
700 North Alamada Street
Los Angles, California 90012

Re: World Water Forum Proposal

Dear Ms. Horn:

On behalf of the San Elijo Joint Powers Authority (SEJPA), I am very pleased to provide this support and commitment letter to Dr. Garoma's grant application for a project that seeks to investigate the integration of heat exchanger and low-grade heat in a flue gas stream for the separation of dissolved salts from seawater. The proposed research is timely and the results from the research will benefit California in diversifying its water sources.

The SEJPA is fully committed to the research proposed by Dr. Garoma and will provide the necessary support for the proposed study. We are committed to providing any in-kind services needed for the successful completion of the project.

The SEJPA own and operates a 5 mgd design capacity WWTP located at 2695 Manchester Ave, Cardiff by the Sea, CA 92007. The treatment processes at the WWTP include primary and secondary treatments for liquid stream and anaerobic digestion for solids handling. Up to 3 mgd of the secondary effluent receives tertiary treatment for water reuse purpose.

Finally, I am extremely grateful for the opportunity that MWD is providing with this grant, and I strongly recommend the awarding of this grant to Dr. Garoma.

Sincerely,

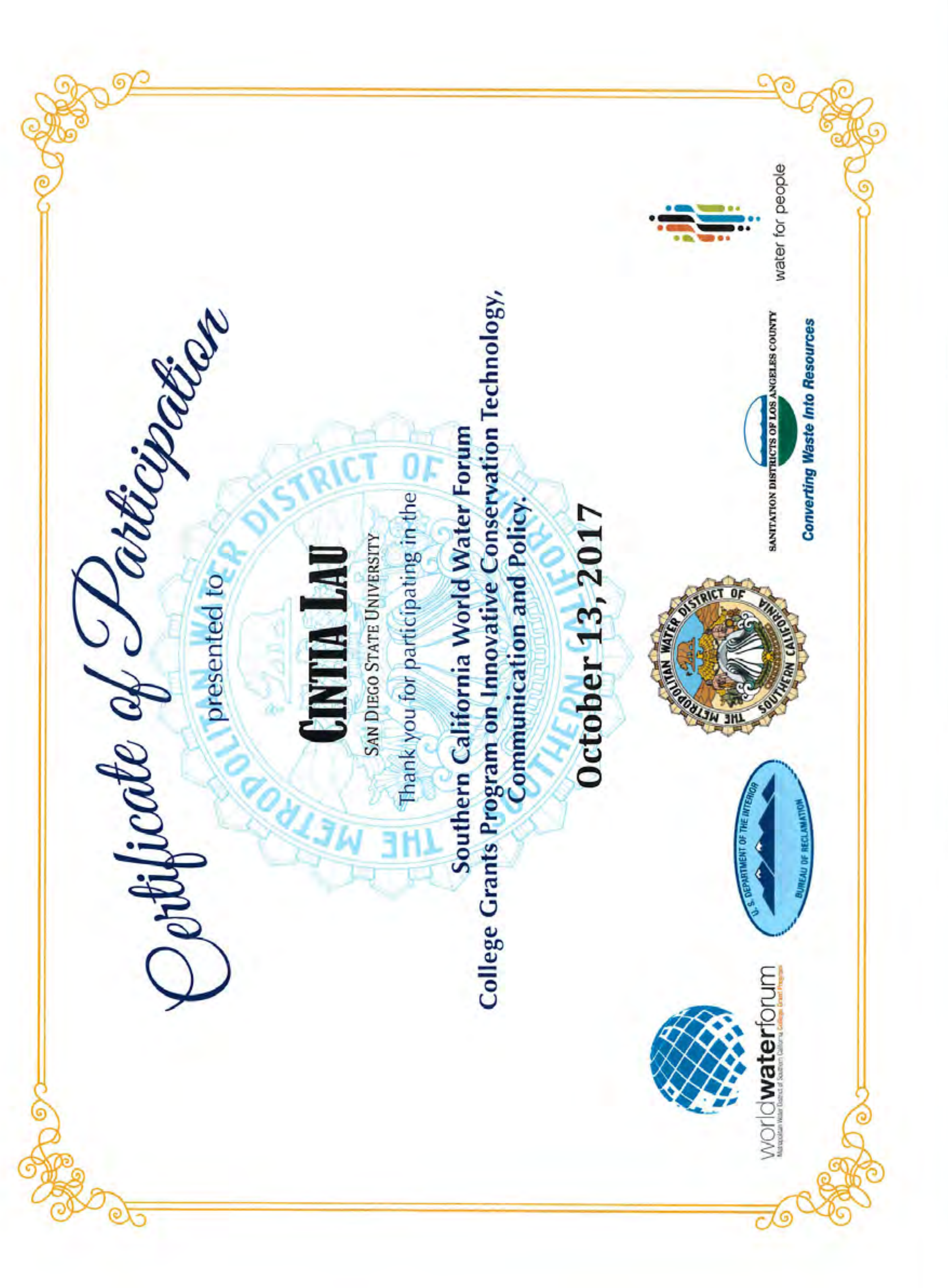
SAN ELIJO JOINT POWERS AUTHORITY

Michael T. Thornton, P.E.
General Manager

2695 Manchester Avenue · P.O. Box 1077 · Cardiff by the Sea · CA 92007-7077 · (760) 753-6203 · (760) 753-5935 FAX

4. Certification of Attendance

Cintia Chin has attended the October 13, 2017 outreach event representing SDSU, and the certificate of attendance is below.



Certificate of Participation

presented to

CINTIA LAU

SAN DIEGO STATE UNIVERSITY

Thank you for participating in the

Southern California World Water Forum
College Grants Program on Innovative Conservation Technology, Communication and Policy.

October 13, 2017

5. Project Description

5.1 Which water-related issue or challenge have you selected?

Water scarcity is one of the most serious global challenges of our time. Currently, two thirds of the world's population live in areas that experience water scarcity for at least one month in a year [1]. By 2030, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people [2]. Population growth, industrialization, contamination of fresh water sources, and climate change are further compounding the challenge for providing safe and adequate water.

California also faces water scarcity. The root cause of the state's water crisis is drought, which affects the main sources of water in the state, namely surface water, snowpack, and groundwater. The state is taking measures to alleviate the challenge through water conservation [3] and water supply infrastructure projects [4], such as public water system improvements, surface and groundwater storage, water recycling and advanced water treatment technology, water supply management and conveyance, and ecosystem and watershed protection and restoration. These measures are important; however, they can only improve the use of the existing water sources. Moreover, these measures may not able to withstand extended drought events since the state's current water sources identified above directly or indirectly depend on precipitation. The only method to increase water supply for the state beyond the current sources is seawater desalination. Seawater desalination offers unlimited and steady supply of water.

Currently, the contribution of seawater desalination to the state's water supply is negligible. Based on a report compiled by the California Coastal Commission (CCC) in 2004 [5], there are about ten, mostly small, desalination facilities along state's coast with a total capacity of 6.1 million gallon per day (mgd). Since then two desalination facilities have been built; a small plant in Sand City with a capacity of 0.3 mgd and a much larger 50 mgd plant in Carlsbad, bring the state's cumulative desalination capacity to 56.4 mgd. By comparison, urban and agriculture water use in the state in 2015 was 35,000 mgd [6].

In the past few decades, technological advancements have been made on materials used for membrane manufacturing substantially reducing membrane cost and energy input during the desalination process. Despite these advancements, seawater desalination is still more energy intensive and expensive compared to conventional technologies employed for treatment of fresh water.

Incremental advancement on membrane materials and improvements in energy efficiency due to energy recovery may not able make seawater desalination competitive with fresh water technologies. Therefore, an outside-the-box and transformative solution is necessary for treatment of seawater.

The **long-term goal** of this research is to develop **an original and innovative** approach for the separation of dissolved salts from seawater by using low-grade waste heat in a flue gas stream as main source of energy input. The flue gas stream, the source of the low-grade waste heat, is cheap and readily available at stationary sources, *e.g.* thermal power plants. In the research, we propose to use low-grade waste heat in a flue gas stream for heating seawater in a heat exchanger unit, converting the water to vapor, and condensing the vapor to form pure water, leaving behind salts/solids. This is an original research, and we are not aware of any published/unpublished work that used this approach for separation of dissolved slats from seawater.

To achieve the goal, we will complete the following three major **objectives**: (1) size and select a heat exchanger unit, (2) test the concept using synthetic seawater, and (3) estimate the potential benefits of the project.

5.2 Is it a local or global focus per the RFP guidelines?

The focus of the project is **local**; however, the project outcomes/results can be adopted <u>globally</u>.

5.3 Which content strand (technology, policy or communications) have you chosen as the research focus for creating your project?

The focus of the project is technology development. To fully demonstrate the proposed concept and achieve the project goal, we will complete the following three major tasks, which parallel the three project objectives identified in Section 5.1.

Task 1 – Size and select a heat exchanger unit

We will size and select a heat exchanger for the research in this task. The scientific theory for liquid-gas heat exchangers is well-documented, and it will be used for sizing the unit. The total heat transferred, *Q* and the inlet and outlet temperatures can be related by Eq. 1 [7].

$$Q = m_l C_{pl}(T_{l0} - T_{lL}) = m_g C_{pg}(T_{g0} - T_{gL}) \quad (1)$$

where *Q* is the heat transferred from the flue gas stream to the seawater (J/s); m_l and m_g are the mass flow rates, in g/s, of the seawater and the flue gas, respectively; C_{pl} and C_{pg} are the specific heats, in J/gK, of the seawater and the flue gas, respectively; T_{l0} and T_{g0} are the temperatures, in K, of the algal suspension and flue gas at a distance x = 0 along the length of the heat exchanger, respectively; and T_{lL} and T_{gL} are the temperatures, in K, of the seawater and flue gas at a distance x = L along the length of the heat exchanger, respectively. For this research, the inlet and outlet temperatures of the flue gas stream, the mass flow rates for flue gas and the seawater, and the inlet temperature of the algal suspension can be fixed. That means, the quantity of heat transferred from the flue gas to the algal suspension and the exit temperature of the seawater can be determined using Eq. 1.

The heat exchanger can be sized using the logarithmic mean temperature difference (LMTD) method, Eqs. 2 through 5 [7].

$$LMTD = \frac{[(T_{gL} - T_{lL}) - (T_{g0} - T_{l0})]}{\ln[(T_{gL} - T_{lL})/(T_{g0} - T_{l0})]} \quad (2) \qquad | \qquad A = LP = \frac{Q}{U.LMTD} \quad (3)$$

$$P = \sum \pi D \quad (4) \qquad | \qquad \frac{1}{U} = \left(\frac{1}{h}\right)_{fluid\ 1} + \left(\frac{1}{h}\right)_{fluid\ 2} + \frac{\delta_{tube}}{K_{tube}} \quad (5)$$

where *A* is heat transfer surface area (m^2); *L* is the effective length of the heat exchanger (m); *P* is the perimeter of the heat exchanger tube (m); *U* is the overall heat transfer coefficient (W/m^2K); δ_{tube} is thickness of the tube (m); K_{tube} is thermal conductivity of the tube (W/mK); and *h* is the heat transfer coefficient determined by eq. 6 (for laminar flow) and eq. 7 (for turbulent flow) (W/m^2K). In these eqs., *V* is velocity of the fluid (m/s); ρ is the density of the fluid (g/m^3); *D* is diameter of the tube (m); and ν is kinematic viscosity of the fluid (m^2/s).

$$h = \frac{3.66K}{D} \quad (6) \qquad | \qquad h = \frac{0.023V^{0.8}K^{0.6}(\rho C_p)^{0.4}}{(D^{0.2}\nu^{0.4})} \quad (7)$$

Once *Q* from Eq.1 and *A* from Eq. 3 are determined, then we can select the appropriate heat exchanger for the research.

Task 2 – Test the concept using synthetic seawater

We will prepare synthetic seawater by dissolving sodium chloride in DI water. We will run several experiments under varying conditions, such as flue gas and seawater flow rates, countercurrent and concurrent flow conditions, different inlet temperatures for the flue gas stream, etc.

Heat exchangers are widely used for transferring heat between liquid and gas phases. The main problems affecting their performances are usually fouling, leakage, and/or dead zones [8, 9]. In this research, we will identify and address whether these and other challenges may affect the performance of the integrated heat exchanger and flue gas system as a method for the separation of dissolved salts from seawater.

Flue gas generation: For this research, the flue gas will be generated in the laboratory using a portable device, *e.g.* Honda EU1000i generator. Power plants are the major stationary flue gas sources in the US. Currently, there are over 3,000 power plants emitting about 2,700 million metric ton of CO_2 annually [10]. We envision that, at full-scale implementation, the technology will use CO_2 and low-grade waste heat from power plants. Therefore, the portable device will use the same fuel sources used at most power plants to mimic the flue gas composition at power plants.

Task 3 – Estimate the potential benefits of the project

In this task, we will estimate the economic, environmental, societal benefits resulting from the project. The proposed approach has a potential to develop a novel seawater purification method, helping California to diversify its water sources. In this task, we will estimate the benefits of the project, including but not limited to: (a) potential increase in seawater as source water for California and (b) potential range of economic benefits provided by the project – creation of jobs, enhancement of economic developments, and promotion of entrepreneurship.

5.4 Where will the research and data collection take place?

The project will be conducted in the PI's laboratory, housed in the College of Engineering, SDSU. It occupies 1000 sq. ft. with research compartments dedicated to biomass processing and engineering, water quality, analytical instrumentation, chemical oxidation, and microbiology. It is also equipped with the state-of-the-art instrumentation for general microbiology, molecular microbiology, and analytical chemistry analyses.

5.5 What is the anticipated outcome of your research? An outcome may be short-term (i.e., changes in knowledge or attitude) or long-term (i.e., changes in condition of natural resources).

As stated earlier, this is an original research, and we are not aware of any published/unpublished work that used this approach for the separation of dissolved slats from seawater. Therefore, the proposed research fills knowledge gaps and advances our understanding on the use of an integrated heat exchanger and flue gas system for the production of drinking water from seawater. The **anticipated outcomes** of the research are: (a) prove the concept of the proposed technology, (b) identify key challenges in the adoption of the technology, (c) estimate the overall energy input per unit volume of water produced, and (d) identify and quantify the economic, environmental, and societal benefits of the project.

5.6 Estimate of the Project Projection Benefits selected from the USBR Quantitative Benefits chart

There are several anticipated benefits from the project. The results from the research will provide important information on the potential of using low-grade, low-cost waste heat along with a heat exchanger for the production of clean water from seawater, resulting in energy saving. The flue gas stream, the source of the low-grade waste heat, is cheap and readily available at stationary sources, *e.g.* thermal power plants. Moreover, the project can provide a range of economic benefits to California – creation of jobs, enhancement of economic developments, and promotion of entrepreneurship. Finally, the data gathered in the research will be disseminated to the scientific community and wastewater utilities. The primary mechanism for communication of the technical component of the research will be sharing the results with local wastewater utilities as well as publication in peer-reviewed journals and presentation at local and national conferences. The Principal PI will also integrate components of the research into an undergraduate course. The PI teaches an undergraduate course, entitled **ENVE 441 – Waste Treatment Engineering**, and will incorporate elements of the project into the classroom, providing students the opportunity to participate in current research methodology and design.

Performance Measure	Quantitative/Qualitative Outcome	Impact
Fill knowledge gaps and advances our understanding on the use of low-grade waste heat along heat exchanger for separation of dissolved salts from seawater	New water source and energy saving	Local/ Global
Integrate components of the research into an undergraduate course	About 50 students per semester enroll in the class	Local
Disseminate the findings of the research through publication in peer-reviewed journals and presentation at local and national conferences	Submit one article for publication in peer-reviewed journal and make a presentation at local and/or national conferences	Local/ Global

5.7 *Describe your team's experience and technical capabilities (including in-house and/or outside hired individuals) to accomplish the project. List the roles and responsibilities of each team member.*

The long-term research emphasis of the PI's lab is on water and wastewater treatment, resource recovery, and renewable energy. The current research focus in the PI's is on resource recovery from wastewater, integration of wastewater treatment with energy production, and on biofuels production from algal biomass. In the past, the PI's team has worked on several research projects that focused on the application of advanced oxidation processes, *e.g.* ozone/UV, ozone/H_2O_2, and H_2O_2/Fenton and on the formation of disinfection byproducts during ozonation and chlorination of drinking water and wastewater effluents.
We have assembled a team with extensive experience in water and wastewater treatment, resource recovery, and renewable energy. The team also has vast experience with tools and techniques necessary for the successful completion of the project, including planning, designing, and conducting experiments; data collection and analyses; biological, chemical, and physical analyses of the bioproducts; and technical and economic analyses of the proposed process.

The SDSU project team will work closely with MWD, other project sponsors, and the San Elijo Joint Powers Authority (a local wastewater agency) on the project. We have assembled a well-qualified team with a number of years of research and professional experience. A brief highlight of the qualifications and responsibilities of each team members is presented below.

Temesgen Garoma, PhD, P.E. – Faculty Project Manager: Dr. Garoma is the Blasker Chair in Environmental Engineering and serves as the Director of the Environmental Engineering Program and Director of the Biomass Engineering Laboratory at SDSU. He has unique history of experiences, close to 20 years, that tie all the technologies being presented in the research. He has served as a PI and project manager, providing both technical and managerial guidance, on several research projects that focused on developing alternative and renewable sources of energy, developing sustainable water and waste treatment processes, and recovering resources from waste. He has investigated the use of algal biomass as feedstock for biodiesel, ethanol, and biomethane production. In addition, he has developed processes for the fractionation of algal biomass into molecular components – carbohydrates, lipids, and proteins – to facilitate the production of platform chemicals. Dr. Garoma has also extensive practical experiences, including managing the design of water and wastewater treatment processes, wastewater facilities master planning, recycled water feasibility studies, and water distribution and wastewater collection system modeling. Dr. Garoma is a registered Professional Engineer in the State of California. He earned a PhD in Environmental Engineering from University of California, San Diego and San Diego State University in 2004.

Michael T. Thornton, P.E. – Local Water Agency Representative: Mr. Thornton joined the San Elijo Joint Powers Authority (SEJPA) management team in October 2000 and was appointed by the Board of Director as General Manager in December 2002. The General Manager serves as the agency's chief executive officer and oversees the day-to-day operations of all departments. His duties include responsibility for the planning, engineering, financing, and management of the wastewater and recycled water utilities.

Mr. Thornton earned his Bachelor's degree in civil engineering from San Diego State University and he is a licensed civil engineer in the state of California. He has 20 years of combined engineering and management experience, covering both the public and private sectors, focusing primarily on wastewater and recycled water infrastructure. He currently serves on the Board of Trustees for WateReuse California and the Southern California Alliance of Publicly Owned Treatment Works. His professional affiliations include the Water Environment Foundation, California Association of Sanitation Agencies, and American Society of Civil Engineers.

The SEJPA own and operates a 5 mgd design capacity WWTP located at 2695 Manchester Ave, Cardiff by the Sea, CA 92007. The treatment processes at the WWTP include primary and secondary treatments for liquid stream and anaerobic digestion for solids handling. Currently, the amount of biogas produced at our facility does not justify the installation of biogas to power conversion facilities, and as a result, part of the biogas is flared. We would be very much interested in adopting the results from this research to increase the biogas production at our facility.

Youxian Wu, PhD – Director of Environmental Engineering Laboratories: Dr. Wu will be responsible for overall management of sample collection, sample analysis, instrument operation and maintenance, and student training in instrument operation. He has extensive experience in water quality monitoring, water quality analysis, and used state-of-the-art analytical instrumentations (GC/MS, LC/MS, GC/FID, ICPMS, TOC, HPLC, etc).

Marina Balcazar – Student Project Manager: Marina is an undergraduate student in the Environmental Engineering Program at SDSU. She will assist the student project manager in sample collection, lab experiments, and data analysis.

Steve Vasquez – Project Administrator: Steve will handle project administration activities, such as budget control, student timesheet, and purchase of supplies.

5.8 Provide a project schedule with key dates and deliverables

Task Name	**Start**	**End**
Task 1 – Size and select a heat exchanger unit	9/1/18	12/31/18
Task 2 – Test the concept using synthetic seawater	01/1/19	3/31/19
Task 3 – Estimate the potential benefits of the project	4/1/19	6/30/19
MWD Staff site visits SDSU campus	Spring 2019	
MWD Expo	Spring 2019	
Final Project Report	4/1/19	6/30/19

6. Financial Criteria

The total cost of the project is $13,636 and we are requesting $10,000 from MWD. The rest will be covered through forgone indirect cost at a rate 40% (50% - 10%) of the total direct cost, which is equivalent to $3,636. Our total proposed match for the project is 36.4% of the total grant requested.

6.1 Budget Overview

Description	Amount	Notes
Grant funds requested	$10,000	Requested from MWD
Matching fund	$3,636	Forgone indirect cost
Project Total	$13,636	Total project cost

6.2 Budget Breakdown

Line Item	Amount	Description
Matching fund	$3,636	Forgone indirect cost
Stipends for students	$4,691	This is intended to cover stipends and fringe benefits for one students for the duration of the project.
Lab supplies	$4,400	The project requires planning and conducting a number of laboratory experiments under various operational conditions. The requested fund will be used to purchase lab supplies, such as chemicals, vials, gloves, bickers, and other miscellaneous supplies needed to conduct the experiments.
Overhead Fee	$909	Overhead to cover administrative cost.
Total	$13,636	Total project cost

Dear World Water Forum Colleges,

This budget template is a sample / guide. Your line items may vary; however, you must **calculate the per unit cost**. Feel free to add or delete line (items) on this document.

DIRECT COSTS						
	COMPUTATION					
BUDGET ITEM DESCRIPTION	**$/hour**	**Hours**	**QTY**	**MWD/ WWF**	**College**	**TOTAL COST**
SALARIES AND WAGES						
Student	$17.70	264.4	$4,680	$ 4,680	$ -	$ 4,680
Subtotal			**Subtotal**	$ 4,680	$ -	$ 4,680
TRAVEL						
Airfare\Lodging (not						
Subtotal	0		**Subtotal**	0	0	$ -
SUPPLIES/MATERIALS - Describe all major types of supplies/materials, unit price, # of units, etc., to be used on this assisted activity.						
Lab supplies, such as chemicals, vials, gloves, bickers, and other miscellaneous supplies needed to conduct the experiments	Various	Various	Various	$ 4,411	$ -	$ 4,411
Subtotal			**Subtotal**	$4,411	$0	**$4,411**
CONTRACTUAL/ CONSTRUCTION						
Subtotal			**Subtotal**	$0	$0	**$0**
TOTAL DIRECT COSTS:				**$9,091**	**$0**	**$9,091**
INDIRECT COSTS -						
F&A				**$ 909**	**$ -**	**$ 909**
F&A Forgone				**$ -**	**$ 3,682**	**$ 3,682**
Subtotal				**$ 909**	**$ 3,682**	**$ 4,591**
TOTAL INDIRECT COSTS				**$ 909**	**$ 3,682**	**$ 4,591**
TOTAL ESTIMATED PROJECT/ACTIVITY COSTS:				**$ 10,000**	**$ 3,682**	**$ 13,682**

7. **Signature Block**

	Name/Title	**Signature**	**Date**
Faculty Project Manager	Temesgen Garoma/ Professor	Garoma	12/13/17
Authorizing Official	Rick Gulizia, Director of Research Affairs	Rick Gulizia	12/13/17
Student Project Manager	Marina Balcazar/ Student	[illegible]	12/13/17

8. Local Water Agency /Member Agency Representative

Name of Local Water/Member Agency: San Elijo Joint Powers Authority	
Name of Contact Person: Michael T. Thornton, PE	*Title*: General Manager
Signature	*Date*: 12/26/2017

9. Literature Cited

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