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WATERQ2: UNDERSTANDING WATER QUALITY & QUANTITY IN THE LIMPOPO BASIN

Quarterly Report, 01 April – 30 June 2021

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Milestone #20

DISCLAIMER: This work was supported by the United States Agency for International Development (USAID), Southern Africa Regional Mission, Fixed Amount Award 72067419FA00001. This work reflects the work of the authors and does not necessarily reflect the views of USAID or the United States Government.

WaterQ2: Understanding Water Quality and Quantity in the Limpopo Basin

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Project Information

Project Title Water Q2: Understanding Water Quality and Quantity in the Limpopo Basin
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INTRODUCTION

The transboundary Limpopo River Basin crosses Botswana, Mozambique, South Africa, and Zimbabwe. At over 400,000 km², the Limpopo River Basin is home to 18 million people living in both rural and urban areas. Industries in the Basin include businesses in the urban areas and water-intensive uses such as agriculture and mining; industrial water use is growing rapidly. In addition to the human residents, the Basin contains some of the most biodiverse natural areas on the planet.

The rainfall in the Basin is heterogeneous with some sub-basins receiving less than 400 mm on average and other downstream sub-basins in Mozambique receiving over 750 mm annually. Even meteorological stations located in close proximity demonstrate substantial spatial variation within sub-basins. The Basin has experienced severe droughts in the last decade. In addition to the variation in the amount of rainfall, the timing, especially the start of the growing season, has varied significantly. However, there remain many questions about the reliability of rainfall data and other water measurements due in part to the infrequent calibration and validation of field site measurements. **The limited confidence in these data, combined with the substantial variation through time and space necessitates an integrated approach to improve data collection, validation, and overall Basin water resource management in the Basin.**

The goal of this project is to build resilience through the support of Basin stakeholders, including The Limpopo Watercourse Commission (LIMCOM), to improve governance around water resources management and water security in the Basin. A systems approach, such as integrated water resources management (IWRM) is needed to address such complex, large, and interrelated components of water resources. IWRM is recommended by the United States Agency for International Development (USAID) Water and Development Strategy Implementation Guide (2014). This context will be combined with data collection and validation, data sharing, and continuous evaluation of the interrelations that affect water resources.

This project will support water resources monitoring, and the development of methods for water quality and quantity measurement based on *in situ* sensors and satellite measurements. These **measurements** will enable characterization of water resource dynamics at the whole Basin scale and form the foundation for hydrologic **modeling** that can help estimate hard-to-measure parameters and also provide holistic assessments of Basin scale stocks and flows. To support data sharing, the project will use cloud-based, automated data collection and web-based **data sharing**.

The Development of local capacity to maintain water resources and make proactive, scientifically justified management decisions requires a substantial human capital resource that is currently lacking in the Basin. The project will provide training, workshops, and conferences will focus on integrated water resources management (IWRM) and environmental flow analysis.

The results of the water resources and biodiversity studies conducted will be compiled into a report for the Basin stakeholders. Continued high-quality data collection, training, and general logistics depends on dependable physical infrastructure. To support data collection efforts as well as training and collaboration the Limpopo Resilience Lab at the University of Venda will be established. The sustainability of lab activity will continue with the implementation of a small user fee beyond the duration of the project. Annual training workshops and conferences will be located at or nearby the Resilience Lab.

In this report, the collaborators, Duquesne University (Duquesne), University of Venda (Univen), and Rensselaer Polytechnic Institute (RPI) report their activities and progress in the first quarter (Q1) of project year 2021-22 (PY 2021-22).

PROJECT ADMINISTRATION

PROGRESS TOWARDS MILESTONES

Student research has continued during this quarter under the supervision of the PIs. The specific projects will be reported within the module which they support. Water resources monitoring will continue with remote sensing (satellites) and ground-based stations that are equipped with telemetry devices; however, not all instruments are compatible with telemetry or placed in an area that communications are available; these instruments require a physical connection for downloads and the project continues to lose data from those instruments.

The project hosted a successful training program in March 2021 on data handling with R and RStudio. There were 25 participants and the South African Department of Water and Sanitation requested that we offer the course again to their hydrologists. This is currently planned for August 2021.

Planning continues for the final stakeholder workshop, which will begin with agency/organization meetings this August. The culmination will be with a workshop in January to present the project's basin report and the range of tools that have developed from the research.

To support networking between basin scientists and the global academic community, the project plans to support, through sponsorship of side events and presentations, the Water and Health Conference at the University of North Carolina, Chapel Hill. This is presented by the Water Institute at UNC, led by Aaron Salzberg, formerly the *Special Coordinator for Water* at the United States Department of State. The conference is completely online 04-08 October 2021.

STAFFING

Gabriella Zuccolotto has joined the project team. Ms. Zuccolotto is pursuing an MS degree at Duquesne University and is funded by the university. Specifically, she will work on water resources in the Xai-Xai area and potential causes of flooding and seawater inundation.

COVID-19 PLANS

On 28 June 2021, South Africa declared an “adjusted alert level 1”, which places significant restrictions on activities within South Africa. The warning by the United States Department of State issued in December 2020: “Level 3: Reconsider Travel” remains in place through this quarter.

The United States Department of State issued a “Level 4: Do Not Travel” warning for Mozambique on 28 June 2021. The Department of State issued Level 4 warnings for Botswana and South Africa while this report was in preparation (06 July 2021).

CIVIL UNREST

The civil unrest in South Africa has been reported widely in the media. This makes travel planning for the US-based researchers at this time impossible.

MODULE I: WATER MONITORING

HYDROMETEOROLOGICAL STATION NETWORK

Data from stations established in this project continue to be monitored remotely and by staff in South Africa. Data are now available through the project website and hosted on the Development Data Library, (DDL, data.usaid.gov). Data from telemetry sites were updated this quarter.

REMOTE SENSING RIVER GAGE

Research staff has continued to obtain data from Planet Labs satellites for discharge research for several sites in South Africa where continuous monitoring is available and one site in the United States for contrast. Planet data were made available through Planet Labs' Education and Research Program. Ms. Martin has made progress on an algorithm to identify the edge of water values Planet Labs' images and measure the width of a river along a transect perpendicular to the mean flow. The algorithm is being developed in the open-source platform, R, and will be released publicly following testing and peer-review. A manuscript and MS thesis is currently in preparation.

REMOTE SENSING WATER QUALITY

Staff has used Landsat for water quality through Google Earth Engine. Mr. Glines has sought the target parameters of water clarity, chlorophyll, and turbidity. Calibration data were obtained through collaborations with the Department of Water and Sanitation, South Africa.

GROUNDWATER MEASUREMENTS

Fortunately, South Africa lifted some restrictions on travel and Univen scientists were able to collaborate with scientists from Kruger National Park for surface and groundwater investigations in November. This included use of electrical resistivity tomography (ERT) to profile the water table at the confluence of the Levuvhu and Limpopo Rivers at Makuleke Contractual Park, which includes the Makulek wetlands, a Ramsar-recognized wetland of importance. The results of this work will be made available as an appendix in the next report and data will be available through the Kruger National Park data repository and the Development Data Library (USAID).

Staff is also examining groundwater recharge zones and precipitation patterns throughout the region. Satellite-based measurements include water data from NASA's Gravity Recovery and Climate Experiment (GRACE). The GRACE satellites measure changes in gravity based on monthly changes in mass. The mass changes are measured in terms of "water-equivalent thickness" changes that occur in a concentrated layer of water near the Earth's surface. Most of the monthly gravity changes are caused by changes in water storage, moving ocean, atmospheric and land ice masses, and by mass exchanges between these. By tracking water equivalent thickness at different points on Earth's surface, GRACE data can provide a picture of what groundwater storage may look like at a specific location. The Global Land Data Assimilation System (GLDAS) combines satellite and ground-based observational data via land surface modeling and data assimilation techniques to generate a model of land surface states and fluxes in order to support proposed weather and climate prediction. Ground-based measurements include precipitation data and aquifer location and characteristics from electrical resistivity tomography (ERT). The data collected will aid in the development of a groundwater model of the Limpopo River Basin using

HEC-HMS hydrologic modeling software. The developed model will identify key recharge zones for water resources in the Limpopo River Basin.

COASTAL WATER RESILIENCE

In various regions around the world (e.g. the Central Valley of California, the North China Plain and Mexico City), excessive groundwater extraction has resulted in aquifer depletion and land subsidence. Along with damage to infrastructure, land subsidence can be especially devastating to coastal regions where rising sea levels can submerge coastlines and saltwater can intrude into important freshwater sources. Groundwater availability and subsidence have historically been monitored using networks of boreholes and GPS stations. In southern Mozambique, groundwater extraction is insufficiently monitored, and the aquifer is unconsolidated, sedimentary; furthermore, increased demand for freshwater during the dry season could make this region susceptible to depletion and subsidence. Such effects would be devastating to those residing in the region, as 60% of the country's population relies on groundwater for domestic use and agriculture according to the Census of 2007. In this study, changes in groundwater storage in southern Mozambique are monitored using NASA's Gravity Recovery and Climate Experiment (GRACE) satellite. To assess the potential effects of groundwater withdrawal, differential interferometry from ESA's Sentinel-1 Synthetic Aperture Radar is used to monitor changes in ground deformation over three major coastal cities in Mozambique: Maputo, Xai Xai and Inhambane. This study serves as the first attempt to quantify changes in groundwater availability using remote sensing techniques in southern Mozambique - an approach which may prove to be useful for future water management decisions in a country where in situ monitoring is limited.

RIVER HEALTH MONITORING

Water samples were obtained along the Levhuvu River as it enters Kruger National Park. The samples were tested for fluoride, chloride, nitrate, nitrite, phosphate, and other ions by ion chromatography and trace metals by induced coupled plasma mass spectroscopy with microwave digestion. The ongoing sampling at these sites will support Mr. Hilton's thesis research.

CITIZEN SCIENCE

The RPI student team has continued to work on the citizen science project for water resources monitoring. Most code is available: <https://github.com/CSSAWV>. The original project team attempted to find images for use in a training algorithm for a neural network; an adequate number of training images is not available. At this time, the image-based program will not be continued. A text-based data collection is available.

MODULE 2: TRAINING, WORKSHOPS, AND CONFERENCES

R FOR DATA ANALYSIS

Based on the success of the March 2021 R Workshop, the Department of Water and Sanitation has requested a special workshop for their hydrology staff. This is currently planned for August 2021. Such a request is encouraging for the sustainability of the Limpopo Resilience Lab.

SCIENTIFIC CONFERENCE

The Scientific Conference for this project year has been selected. The project will sponsor a side-event and have presentations at the University of North Carolina's (UNC) Water Institute's Water and Health Conference. This will be held in October 2021.

MODULE 3: BASIN-LEVEL REPORT

The WaterQ2 team has begun to prepare the draft report on water resources management based on our findings during the first year of the project. Currently, the report is being prepared in parallel with a draft of a manuscript that will be prepared for publication in a peer-reviewed journal.

MODULE 4: LIMPOPO RESILIENCE LAB

University of Venda is expanding their analytical water chemistry capabilities and computational resources. Quotes have been obtained for an ion chromatograph and several computer resources. The project is prioritizing and budgeting the Limpopo Resilience Lab expansion.

MONITORING AND EVALUATION

MODULES 1 AND 3: WATER MONITORING

There are four primary research activities that have continued in this quarter that are supported through this project. They all fall into USAID category, *Production Systems Research*, as they are a component of natural resources management. The research activities are:

- Remote sensing river gage (*Under field testing*)
- Remote sensing water quality (*Under field testing*)
- Remote sensing and models to estimate groundwater resources (*Under research*)
- Remote sensing to support coastal water resilience (*Under research*)

TABLE 1: MODULES 1&3 INDICATORS

INDICATOR	DISAGGREGATION	CURRENT VALUE	PROJECT TOTAL
Number of technologies, practices, and approaches under various phases of research, development, and uptake as a result of USG assistance	Phase: Under research	2	4
	Under field testing	2	2
	Made available	0	0
	Demonstrated uptake	0	0
Number of peer-reviewed scientific publications resulting from USG support to research and implementation programs	None	0	0
Number of hectares of land under improved technologies or management practices with USG assistance		0	0
Number of datasets shared, which were generated as a result of USG assistance	Basin country	0	4

MODULE 2. IWRM TRAINING, WORKSHOPS, AND CONFERENCES

Module 2 contains two primary components: convene stakeholder workshops and trainings; and convene future collaborators at conferences. No workshops, meetings, or conferences have been held this quarter.

TABLE 2: MODULE 2 INDICATORS

INDICATOR	DISAGGREGATION	CURRENT VALUE		PROJECT TOTAL	
		Male	Female	Male	Female
Number of people trained in sustainable natural resources management and/or biodiversity conservation as a result of USG assistance	Sex	0	0	38	17
Number of water and sanitation sector institutions strengthened to manage water resources of improve water supply and sanitation services as a result of USG assistance	Institutional scale	0		2	

PROJECT PROGRESS

WORK PLAN PROGRESS

Table 3 outlines progress on work plan activities (outlined in the Mobilization Plan) and the ongoing research activities. As specified in the Project Description, the following activities were planned.

TABLE 3: PROJECT ACTIVITIES														
#	ACTIVITY	2019				2020				2021				
		1	2	3	4	1	2	3	4	1	2	3	4	
	Startup activities: Mobilization Plan, Staffing, EMMP	█												
1	Establish meteorological, river, and groundwater stations, <i>Water Monitoring and Algorithm Development Report</i>		*				*							
1	Groundwater measurements (ERT), to be included in <i>Water Monitoring Report</i>		**		**			█			█		█	
1	Develop satellite algorithms	█									█			
1	Develop hydrologic and water quality models	█									█			
2	Convene stakeholders in workshops		█				█						***	
2	Scientific conferences					****		█				◆		
2	Training workshops		█		█				†		█			
3	Publish and present basin report									‡		█	█	
4	Launch Limpopo Resilience Lab												█	
		█	Completed						█	In-progress/planned				

Notes:

* Hydrometeorological stations have been installed; however, some stations were scheduled for installation but cancelled due to COVID-19 pandemic travel restrictions. It is unclear if the project will have time to establish these stations and may refocus these resources to Kruger National Park and the Soutpansburg Mountains.

** ERT measurements were delayed at first due to shipping delays with Tazmanian Logistics and then due to COVID-19 pandemic travel restrictions. Project staff is now making routine trips to Kruger National Park to collect data.

** The stakeholder meeting for PY 2021-22 has been moved to January 2022 to showcase the results of the project and determine how best to integrate these results into water resources management.

*** The project convened a special side event at the Water Institute of Southern Africa conference. The conference was delayed due to COVID-19. The side event was a great success when the conference was held in December 2020.

❖ The PY 2021-22 conference will be in conjunction with the University of North Carolina's Water Institute's *Water and Health Conference*, 04-08 October 2021.

† The training workshops are now up to date after rescheduling due to COVID-19.

‡ The basin report has been delayed.

MILESTONE PLAN

TABLE 4: MILESTONE PLAN													
#	MILESTONE	2019				2020				2021			
	Project year quarter	1	2	3	4	1	2	3	4	1	2	3	4
1	Mobilization Plan	Apr											
2	Environmental Mitigation and Monitoring Plan	Jun											
3	Quarterly Report	Jul											
4	Water Monitoring and Algorithm Development Report		Dec*										
5	Stakeholder Workshop Report		Nov										
6	Annual Work Plan		Aug										
7	Quarterly Report		Dec*										
8	Quarterly Report			Apr*									
9	Quarterly Report [^]				Apr								
10	LRL Website and Planning				Apr								
11	Scientific Conference								Dec				
12	Basin Report					Jul							
13	Quarterly Report					Jul							
14	Stakeholder Workshop Report									Sep			
15	Annual Work Plan								Aug				
16	Quarterly Report								Oct				
17	Quarterly Report									Jan			
18	Quarterly Report [^]										Apr		
19	Scientific Conference											Jul	
20	Quarterly Report											Jul	
21	Stakeholder Workshop Report												Sep

22	Water Monitoring: Two manuscripts	Aug
23	Annual Work Plan	Aug
24	Quarterly Report	Sep
25	Quarterly Report	Jan
26	Basin Report	Mar
27	LRL Continuity Report	Mar
28	Quarterly Report	Apr

Notes:

Shaded items are completed or pending approval.

Item 10 was delayed to collect more information and await publication of datasets on data.usaid.gov.

This report is upcoming.

Item 12, the draft of the basin report, was delayed to address comments from the thesis committee.

Item 14 includes the training, which is planned for March 2021. The report will be completed now that the training is complete.

FINANCIAL

PRIME RECIPIENT

Duquesne University has used project funds for the expenditures in Table 5.

TABLE 5: PROJECT EXPENDITURES		
ITEM	Q4 EXPENDITURE	PROJECT TOTAL
Summer research salary for Dr. Kahler	\$0	\$14,760.01
GRA Stipend support	\$3,443.78	\$78,905.86
Tuition	\$14,112.00	\$47,310.00
Fringe	\$0	\$2,940.44
Equipment (ERT)	\$0	\$47,185.00
Lab/Research Supplies	\$247.36	\$15,751.56
Travel	\$0	\$25,837.30
Subaward: Univen	\$0	\$74,534.08
Subaward: RPI	\$50,293.73	\$218,487.59
Indirect to Duquesne University	\$3,915.41	\$83,490.91
Total	\$72,012.28	\$609,202.75

Note, the incorrect project total was reported on the PY 2020-21 Q4 report, the correct project total was \$537,190.47.

APPROVAL

This Quarterly Report has been received and approved by USAID. This satisfies the requirements set forth in the Milestone Plan, item #20: Completion of Quarterly Report (Q1).

Signature: _____

Name: _____
Agreement Officer's Representative

Date: _____

WaterQ2: Understanding Water Quality and Quantity in the Limpopo Basin