WWQA Africa Use Cases

Desk Study, Inception Stakeholder Workshops, and Baseline Report for Lake Victoria and Volta Basins

July 2021

Mr Andrew Gemmell

World Water Quality Assessment
Use Case Study

Final Report for Lake Victoria and Volta River Basins

July 2021

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Executive Summary

The selected African Use Cases under the WWQA comprise: Cape Town Main Aquifer Systems; Lake Victoria transboundary lake basin, and the transboundary Volta River basin. This report focusses on the Lake Victoria and Volta Basin Use Cases.

UNEP appointed Andrew Gemmell in October 2019 as specialist hydrologist to facilitate the Lake Victoria and Volta Basin Use Cases.

Aim

The Use Cases are funded as a pilot to demonstrate the value added of an Alliance approach to bridge from data to solutions. The central aim in the initial WWQA Africa Use Cases is the integration of in-situ and remote sensing-based Earth Observation and water quality modelling data to derive the best possible current state of water quality combined with a multi-stakeholder driven process defining demand for water quality services. The ultimate objective was to provide an evidence base that links water quality hotspots to solutions and investment priorities. These results emanating from this approach are due to be shared widely with the World Water Quality Alliance partners for further consideration and illustration of the approach.

This technical summary summarises the stakeholder engagement process, data availability, and identification of water quality products and services to address the problems identified through the stakeholder engagement and data assessment process in the Lake Victoria and Volta Basins. It concludes with summarizing some of the main limitations encountered when trying to access data, and with lessons learned and recommendations regarding the way forward.The full report provides details on these various stages and presents the data collected on water quality and used for the Use Case.

Methodology

Requests for stakeholders and/or data for the Use Cases were sent to relevant working groups carrying out the World Water Quality Assessment as case information. Using the contact details received, these stakeholders identified by the World Water Quality Alliance were then in turn also contacted requesting both data and any additional stakeholders (snowball mechanism), which continued as an iterative process. In addition, a thorough literature review of stakeholders and data was conducted. Through this process, available data (in-situ, modelled, RS/EO) for the Use Cases was collected and shared with the expert teams in charge of the triangle approach in the World Water Quality Assessment (EOMAP, Helmholtz Centre for Environmental Research, and Ruhr University Bochum). In addition, a database of stakeholders and their interest in collaboration was developed, shared with the Alliance community of practice, and enhanced throughout the project. The stakeholder engagement process to identify the key water quality concerns and the need for associated water quality products and services took various forms for the Lake Victoria and Volta Basin Use Cases. This included:

- Attendance at conferences/symposia in Kenya and Ghana,
- Attendance at a Lake Victoria stakeholder workshop in November 2019 in Entebbe Uganda organized by the Great Lakes African Center for Aquatic Research and Education (AGL-ACARE).
- The convening of a Stakeholder Engagement Workshop in Accra, Ghana with the assistance of the Institute for Environment and Sanitation Studies (IESS) University of Ghana.

Lake Victoria Basin

WWQA members Mr Andrew Gemmell (UNEP) and Dr Tallent Dadi (Helmholtz Centre for Environmental Research) were nominated to the AGL-ACARE Lake Victoria Working Group (who's activities continue to date). Mr Gemmell and Dr Dadi continue engagement with the Working group, attending the monthly virtual meetings, and inputting to two draft publications to be submitted to the Journal of Great Lakes Research.

Due to the Covid-19 pandemic, an on-line workshop was conducted with the Lake Victoria Fisheries Organisation (LVFO), with letters requesting collaboration between WWQA and LVFO sent. The LVFO then reached out to country fisheries research institute Directors at KMFRI, TAFIRI and NaFIRRI to introduce the Africa Use Case initiative. The Directors of KMFRI, NaFIRRI and TAFIRI then nominated fisheries specialists within each of their Institutions to act as focal points. Workshops with these individuals were held in August and September 2020 with the aim to re-introduce the concept of the African Use Case concept as it relates to Lake Victoria and how the Alliance can assist; provide examples of what can be achieved through the Alliance; discuss the priority Lake Victoria water quality concerns and hotspots; discuss research and information gaps; and to begin discussions on water quality data and information products and services to be co-developed to target hotspots.

Through the discussions, various limitations to data sharing (both between Fisheries institutions, and between these Institutions and WWQA) were identified which are summarized further below. Where water quality databases were available, these had limited spatial and/or temporal extent. As a result, there was a focus on modelled and RS/EO water quality data, validated by in-situ data (i.e. through the WWQA triangle approach) to derive a water quality baseline. Key water quality challenges agreed upon at Lake Victoria were eutrophication; algal blooms (including cyanobacteria); hypoxia, and siltation/turbidity affecting fish breeding.

The water quality data and information products and services agreed to be co-developed by the riparian fisheries organisations (KMFRI, TAFIRI, NaFIRRI) and WWQA representatives are:

- **Coastal eutrophication assessment**: Available data sources are being assessed to indicate the potential of coastal eutrophication, including the identification of hot spots and potential seasonal patterns. This demand driven tool is being developed to characterise the potential of algal blooms to impact fisheries or to identify potential links between aquaculture and coastal eutrophication.
- **Water temperature and stratification dynamics**: Monitoring activities by different research institutions of the adjacent countries generated a valuable record of water temperatures in Lake Victoria over the past years; including data jointly collected under the coordination of the Lake Victoria Fisheries Organisation (LVFO) which has been shared with the Alliance. The aim is to use a freely available lake model to simulate temperature dynamics in Lake Victoria to inform the extent of stratification and vertical mixing in the water column. Directly interfacing with the Assessment, the following research topics are being targeted by UFZ and LVFO:
    - Model-based reconstruction of water temperatures of Lake Victoria over the past 30-years at daily resolution;
    - Water temperature projections for Lake Victoria until 2100 based on different climate scenarios; and,
    - Potential effects of water temperature dynamics and mixing events on phytoplankton dynamics (derived from satellite-based remote sensing provided by EOMAP)
- **Sediment chemistry**: UFZ has offered to collaborate with KMFRI on collected sediment chemistry, water profile physico-chemical quality parameters in the Nyanza Gulf (Kenya) and sediment and water samples near Kampala, Uganda. There is a potential for the joint assessment of sediment release of nutrients, turnover, and indication through algae blooms obtained from remote sensing (EOMAP).

Volta Basin

The key water quality challenges identified by the Stakeholder Engagement Workshop participants were: poor sanitation resulting in elevated bacterial contamination, mining activities and heavy metal and turbidity impacts, industrial effluent (including plastics and micro-plastics), agricultural runoff of fertilizers and pesticides, leading to increased aquatic alien plants, and water quality impacts to and from aquaculture. A further challenge is there is not a consolidated Ghana government department mandated to water quality monitoring, with this role currently split. Discussions towards potential water quality

product and services are ongoing, in part due to ongoing development of in-country partnerships and collaboration. The initial products and services being investigated to take forward include:

- The Ghana National Disaster Management Organization (NADMO) proposed an innovative tool that translates poor water quality severity (measured through a water quality index) into poor water quality impact (expressed in terms of vulnerability of affected populations). The water quality index would be derived in collaboration with the WWQA representatives, with initial discussions in this regard undertaken with UFZ.
- University of Fada N'Gourma, Burkina Faso proposed a groundwater quality assessment based on remote sensed data, using the DRASTIC vulnerability mapping method in conjunction with land use data to assess pollution risk (Ouedraogo et al., 2016). This is being pursued with the University of Fada N'Gourma, Burkina Faso.

Way forward

Overall, at both the Lake Victoria and Volta Basin Use Cases, there is a reliance on in-situ measurements that leads to limitations in spatial and temporal resolution of water quality. This is exacerbated by concerns around data sharing by data owners. As a result, there was a need to use alternative options to use complementary data sources such as RS/EO, modelling and citizen science. In addition, there is a need for improved capacity building, including in data analysis, data management, and data sharing policies.

Limitations to data sharing were discussed with in-country stakeholders at each of the Use Cases, with the following solutions proposed:

- Ongoing development of in-country partnerships and trusted collaboration, especially with water resource decision-makers to solve real-world problems for real impact, thereby benefiting in-country stakeholders and data providers to break the north-south divide. This should utilize the existing guidance (e.g. The 2016 World Bank Group document *The Art of Knowledge Exchange – A Results-Focused Planning Guide for Development Practitioners in the Water Sector*), as well as build on the lessons learnt through the Africa Use Cases knowledge exchange process.
- This needs sustainable funding and long-term investment with a need for additional contributions (including international funding to bolster local government contributions). Initial exchange with UN Resident Coordinators are encouraging and suggest, in future, to regularly engage UN Country Teams in this process if possible.
- To formalize engagement letters of collaboration were drafted. These introduced the concept of the World Water Quality Alliance Africa Use Cases and respectfully requested the collaboration with the relevant stakeholder. These were drafted on UNEP letterheads and signed by Andrew Gemmell. However, to better drive collaboration, it is recommended that Memorandums of Understanding are rather drafted and signed by senior representatives.
- There is a need to investigate options for integrating data derived from the WWQA triangle approach into a single dataset that can be used for water quality decision-making.
- There is a need to improve the impact of research through more effective science-policy interface, as well as better communication of the science to policy makers via impact stories.
- A standard protocol for data sharing to ensure data providers retain data ownership and recognition. An example to use is the GEMS/Water Data Policy which allows data providers to select from three different levels of data sharing.
- There is a need to further develop internal databases to store data in a format shared between organisations/ institutions/ countries. This includes limitations in the availability of hardware, and training on software.
- Development of a common data-management system, with agreed data types and formats that

allows for better collaboration between organisations/ institutions/ countries. This database option should have ownership by the data providers to ensure maintenance and longevity.

- In-country capacity building in the collection and assessment of data (in-situ data, citizen science, modelling and RS/EO).
- Further development of the Africa Use Case concept to cover various water resource types and scales. This may include linking headwater protection to recharge (Cape Town Use Case); transboundary aquifers, the surface water/groundwater interface (e.g. wetlands).
- There is a need to investigate options for integrating data derived from the Assessment triangle approach into a single dataset that can be used for water quality decision-making. One of the success factors for the Cape Town Aquifer Use Case was the ability of the coordination and assessment team to integrate the three different data types of the triangle approach, i.e. in-situ measurements, remote sensing data and numerical modelling, on a sub-catchment scale. This was achieved through an integration team with overlapping experience in the data types.
- The success of the Cape Town Use Case was also driven by a robust stakeholder engagement process that has developed trust and collaboration over many years and included a local stakeholder (communities and institutions) engagement process. This highlights the need for long-term engagement to ensure real impact.

During the Use Case, various lessons were learnt with regards to engagement with Alliance members, the development of stakeholder networks, and suitable data repositories. In addition, important lessons were learnt on how to improve engagement with in-country stakeholders to build collaboration and trust between the Alliance and in-country stakeholders. This improved data sharing and collaborative co-design of the water quality products and services.

At Lake Victoria, stakeholder engagement was good, and most successful with the riparian Fisheries Institutions. The stakeholder network should be expanded to different sectors and including local contacts of WWQA partners. Further involvement of WWQA partners with existing relationships and projects in the region will strengthen collaborative efforts between in-country parties, and build on existing projects and data. This should include aspects of the Social Engagement Platform workstream aims, such as: using experience in global problems to support local solutions; simple language to describe complex systems; and use data to build knowledge and knowledge to inform action.

The Volta Basin use case did not fully succeed in providing a water quality assessment and co-designing and developing products and services relevant to the local stakeholders. As a result, additional efforts are needed to adopt a different approach to the social engagement and co-design process with a view to tackle country-specific challenges via adopting a bottom-up approach. Further involvement of WWQA partners with existing relationships and projects in the Volta Basin is needed to strengthen collaborative efforts between in-country parties, and build on existing projects and data. A comprehensive network of stakeholders should be developed, focusing on local role players that are active in the sphere of environmental support or education, and cultural groups and individual artists that include environmental aspects into their art and performance as well as popular sports celebrities (e.g. soccer).

There are obvious synergies between the Africa Use Cases and the UNEP GEMStat and the GlobeWQ workstream. GEMStat and the GlobeWQ platform aim to bridge the global scale water quality assessment and user-tailored water body and river basin scale information needed by regional authorities. However, geospatial platforms such as GlobeWQ are only relevant if they are being used and updated with recent data. The Lake Victoria and Volta Basin Use Cases may act as case studies for GlobeWQ.

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List of Abbreviations

2iE	International Institute for Water and Environmental Engineering
AGDIC	Africa Geospatial Data and Internet Conference
AGL-ACARE	African Center for Aquatic Research and Education
AMCOW	African Ministers Council on Water
ARDC	African Regional Data Cube
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AU-IBAR	African Union Interafrican Bureau for Animal Resources
BaSIS	Basic Sanitation Information System
BOD	Biological oxygen demand
CEC	Contaminant of Emerging Concern
CEOS	Committee on Earth Observation Satellites
CERGIS	Centre for Remote Sensing and Geographic Information Services
CIA	Central Intelligence Agency
CLTS	Community-Led Total Sanitation
COD	Chemical oxygen demand
COMESA	Common Market for Eastern and Southern Africa
CReWAS	Conference on Climate Resilience and Waste Management for Sustainable Development
CRS	Catholic Relief Service
CSIR	Council for Scientific and Industrial Research
CWSA	Community Water and Sanitation Agency
DANIDA	Danish International Development Agency
EAC	East African Community
ECOWAS	Economic Community of West African States
EPA	Environmental Protection Agency
GEMS/Water	Global Environment Monitoring System for Water
GEO	Group on Earth Observation
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLM	General Lake Model

GMet	Ghana Meteorological Agency
HYCOS	Hydrological Cycle Observing System
ICWGRC	International Centre for Water Resources and Global Change
IESS	Institute for Environmental and Sanitation Studies
IGO	Intergovernmental Organization
IGRAC	International Groundwater Resource Assessment Centre
IIASA	International Institute for Applied Systems Analysis
IUCN	International Union for Conservation of Nature
IMWM	International Water Management Institute
IWRM	Integrated Water Resources Management
KMFRI	Kenya Marine and Fisheries Research Institute
KNUST	Kwame Nkrumah University of Science and Technology
LVBMC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Environmental Management Project
LVFO	Lake Victoria Fisheries Organization
MoU	Memorandum of understanding
NaFIRRI	National Fisheries Resource Research Institute
NDMO	National Disaster Management Organization
NBO	Niger Basin Authority
NGO	Non-Governmental Organisation
QA/QC	Quality assurance/quality control
RCMRD	Regional Centre for Mapping of Resources for Development
RE/EO	Remote Sensing-Based Earth Observation
RUFORUM	Regional Forum for Research and Training specific to Agriculture and Food production
SDG	Sustainable Development Goals
TAFIRI	Tanzania Fisheries Research Institute
TMG	Table Mountain Group
TSM	Total Suspended Matter
UC	Use Case
UENR	University of Energy and Natural Resources
UFDG	University of Fada N'Gourma
UFR/SVT	Université de Ouagadougou. URF Sciences de la Vie et de la Terre
UFZ	Helmholtz Zentrum für Umweltforschung
UNEP	United Nations Environment Programme
UN RCO	United Nations Resident Coordinator's Office
USGS	United Stated Geological Survey
VBISS	Volta Basin Information Sharing System
VRA	Volta River Authority
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use
WCWSS	Western Cape Water Supply System
WRC	Water Resources Commission
WRI	Water Research Institute
WWQA	World Water Quality Alliance

1. INTRODUCTION

1.1. Global Water Quality Assessment

1.1.1. Background

United Nations Environment Programme (UNEP) has global custodianship of data collection for indicators regarding the Sustainable Development Goals (SDG) targets 6.3, 6.5 and 6.6 (all connected to water quality) and received the mandate (UNEP/EA.3/Res.10 Dec 2017) to investigate water quality globally in depth, including and beyond SDG 6.3 into emerging issues, global trends, nexus focus, protection, governance and services.

A preliminary *Snapshot of the World's Water Quality: Towards a Global Assessment* was published in 2016 (UNEP, 2016) revealing the lack of monitoring data particularly in developing countries, rendering the sole reliance on measured data impossible. The full Global Water Quality Assessment (GWQA) thus needs to employ a data fusion approach combining in-situ monitoring, modelling and remote sensing and is designed to illustrate causal chain cases from drivers to impacts.

The major components of the Global Water Quality Assessment are:

1) Baseline Assessment of worldwide water quality in surface and groundwater bodies,
2) Scenario Analysis of future pathways of water quality in the freshwater system and its compartments, and
3) Mitigation Options, i.e. information on how to protect or restore water quality.

The ambition of the Global Water Quality Assessment is to work at different scales:

1) The global scale to provide a consistent context regarding the state of water quality and to identify the water bodies being at risk;
2) The water body to river basin scale with the engagement of stakeholders to use and to tie the information produced in order to achieve their needs and inform the implementation of the 2030 Agenda for Sustainable Development at relevant scales.

Following UNEA Resolution 3/10 on "Addressing water pollution to protect and restore water-related ecosystems" and building upon the report "A Snapshot of the World's Water Quality" (UNEP, 2016), the United Nations Environment Programme is cooperating with relevant organizations in the World Water Quality Alliance (WWQA, in the following also referred to as "Alliance", see below) to develop a Global Water Quality Assessment (GWQA) for consideration by UNEA 6 in 2023 (see **Figure 1-1**).

Where relevant and applicable, the GWQA will draw upon UNEP's recent work on harmonizing environmental assessments and the management of freshwater ecosystems, namely the Guidelines for Conducting Integrated Environmental Assessments as well as the Framework for Freshwater Ecosystem Management (FFEM). It also builds on related activities of the Global Environment Monitoring System for Water (GEMS/Water) to enhance the capacity to collect and share water quality monitoring data and of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) and its Global Wastewater Initiative (GW2I) and the Global Partnership on Nutrient Management (GPNM).

The World Water Quality Alliance (WWQA) was convened by UNEP as a voluntary and flexible global multi-stakeholder platform representing experts, practitioners and policy networks with the central aim to support delivery of the World Water Quality Assessment

('the Assessment') following the mandate from UNEA Resolution 3/10. As part of the delivery of this mandate, the WWQA will focus on generating and testing a data fusion approach combining different sources of water quality data contributing to the Assessment; horizon scanning, agenda setting and investigating selected priority topics to identify persistent or emerging water quality issues of key environmental and socio-economic concern; and co-designing and operationalizing water quality related services and products, based on a moderated in-country stakeholder driven process.

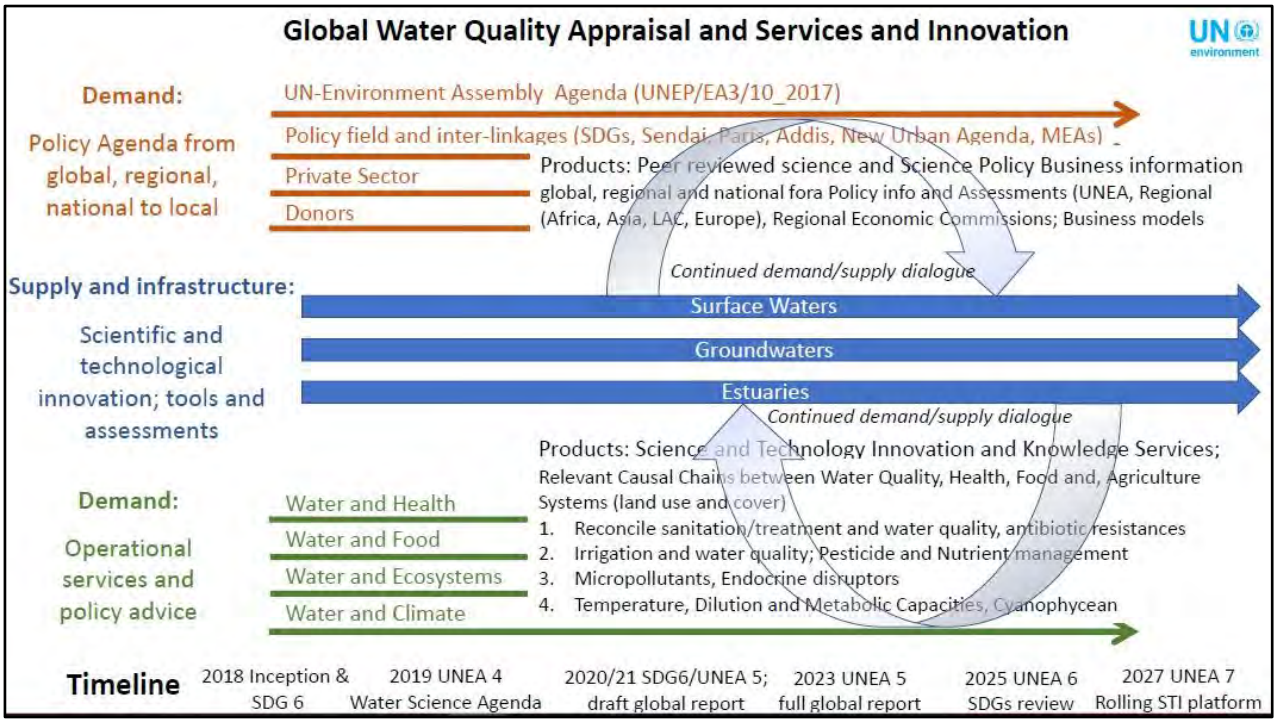


Figure 1-1: Processes and Aspects of Global Water Quality Assessment (Kremer, 2018)

1.1.2. World Water Quality Alliance

To kick off the development of the assessment, UNEP, with support from the World Meteorological Organization (WMO), organized an inception workshop in November 2018. During the workshop, UNEP convened around 50 organizations (UN, research, civil society, private sector), which had expressed interest to engage in the assessment and to also work with UNEP in co-designing agendas and action around emerging issues. This process with strong support from donors marks the emergence of a World Water Quality Alliance as an open community of practice. UNEP, and more specifically the Global Environment Monitoring Unit in Science Division, fulfils the coordination function of the Alliance, through the WWQA Coordination Team.

The World Water Quality Alliance (WWQA) represents a voluntary and flexible global multi-stakeholders network that advocates the central role of freshwater quality in achieving prosperity and sustainability; it explores and communicates water quality risks in global regional, national and local contexts and points towards solutions for maintaining and restoring ecosystem and human health and well-being with an aim to serve countries throughout the lifetime of the 2030 Agenda for Sustainable Development and beyond.

The Alliance focuses on deliverables on three levels:

a. A global assessment of freshwater quality drawing on science – technology – innovation, including a data fusion approach combining in-situ monitoring, modelling and remote sensing. It will expand to additional sources and illustrate causal chain cases to highlight water quality risks and opportunities
b. Horizon scanning, agenda setting and investigating selected priority topics based on a collective prioritization process to identify persistent or emerging water quality issues of key environmental and socio-economic concern and,
c. Following a bottom up-approach, co-designing and operationalization of water quality related services and products, based on a moderated in-country stakeholder driven bottom-up process to identify local demands and needs.

The Alliance was officially launched at the 2nd global meeting at the Joint Research Centre (JRC) of the European Commission in Ispra, Italy on 19 September 2019.

Mission Statement of World Water Quality Alliance:

The World Water Quality Alliance (WWQA) forms an open, global consortium, pooling expertise on water quality science and technology innovation. It aims at providing a participatory platform for water quality assessments and co-design of tailored and demand-driven services. It addresses priority topics relevant to water governance, scalable water solutions and emerging issues in water management.

1.2. WWQA – African Use Cases

During the WWQA Inception Workshop held in November 2018 in Geneva, the Alliance decided to pilot and demonstrate current capabilities and future water quality information services through three case studies in Africa (in the following referred to as Use Cases). These Use Cases provide an initial testbed that puts the quality of surface and ground waters into the context of the local 2030 Agenda and its multiple linkages across the Sustainable Development Goals (SDG). Central in these initial test cases will be the integration of in-situ and remote sensing-based Earth Observation and water quality modelling data to derive the best possible current state of water quality (baseline) with a multi-stakeholder driven process defining demand for water quality services. The ultimate objective is to provide an evidence base that links water quality hotspots to solutions and investment priorities. The results produced by the Use Cases in this two-pronged approach are meant to be shared widely with the World Water Quality Alliance for further consideration.

The Use Cases are funded as a pilot to demonstrate the value added of an Alliance approach to bridge from data to solutions. The Africa Use Case process comprised transdisciplinary engagement with in-country partners through a bottom-up approach aimed at using experience in global problems to support local solutions.They combine data assimilation with transdisciplinary engagement and joint design of water quality products for operational use. Integral to the projects is a moderated, in-country, stakeholder-driven process to identify and address local needs (local solutions to global problems). The co benefit for the assessment originates in the decision to align the Use Case approach to the selection of case studies of the assessment and follow the triangulation approach (see below). In addition, and - different from the assessment - the Use Cases also test out the on-ground stakeholder engagement process towards piloting and testing co-designed products to address key water quality issues.

1.2.1. Objectives

The project aims are expanded upon within the UNEP/WWQA case studies work package draft:

Africa Use Cases Aim:

- *Build the "use case" for a Global Water Quality Assessment by means of the piloting and demonstration of current capabilities, future information and services of the World Water Quality Alliance (the "Alliance") through these three (and other potential) case studies.*
- *Proof of concept for the WWQA to contribute into the innovation data assimilation platform from different available sources (in-situ, modelling and EO). This work will feed into a broader project under development providing a global water quality baseline, and several more pilots globally that aim to look into causal chain relations and solutions along nexus interactions.*
- *Provide an evidence base that links water quality hotspots to solutions and investment priorities. Crucial is a multi-stakeholder in-country driven process defining demand for water quality services, with potential stakeholders including government, academia, civil society and (inter)national organisations.*

1.2.2. Selection

Based on the objective and aim for use cases and the identified criteria, the participants of the 1st WWQA Workshop in Geneva on 28-29 November 2018 selected three Africa Use Cases comprising different water quality challenges, existing data and information, governance aspects and hydrological conditions.

African Use Cases were selected, as meeting the water challenge in Africa requires the availability of a sufficient quantity and quality of water for health, economic activities, human well-being and ecosystems, while resisting hydrological extremes. Several national, regional and global trends however pose substantial risk:

- Rising water needs and usage by the extension of agricultural irrigation,
- Expansion of industry and mining activities,
- Rapid urbanization: African cities among the fastest growing in the world,
- Expanding extraction of raw materials, with effects on water quantity and quality.

Climate change and mismanagement of water resources increase the risk of water scarcity resulting in changing amount and distribution of water regionally. Deterioration of ambient water quality and of aquatic ecosystems can be attributed to lack of infrastructure for urban and industrial wastewater treatment and increasingly improper use of fertilizers and pesticides in agriculture.Safe drinking water and sanitation is particularly low in rural areas and informal urban settlements in Sub-Saharan Africa with negative consequences for education, health and economic development. The extent of aquatic ecosystems and thus ecosystem resilience is increasingly limited by competing land use affecting river corridors, flow regulation for irrigation, and power generation.

The selected African Use Cases comprise:

- Volta Basin: Transboundary river basin, shared between Burkina Faso, Togo, Mali, Cote D'Ivoire and Ghana; main water quality issue are pathogens
- Lake Victoria: Transboundary lake, shared between Kenya, Tanzania, Uganda, Rwanda and Burundi; main water quality issue is impact on ecosystem health
- Cape Town Main Aquifer Systems: Variety of aquifer systems in and around Cape Town; earmarked for water supply to Cape Town; water quality issues are pollution due to land use activities, geogenic elevated concentrations, impact on surface ecosystems

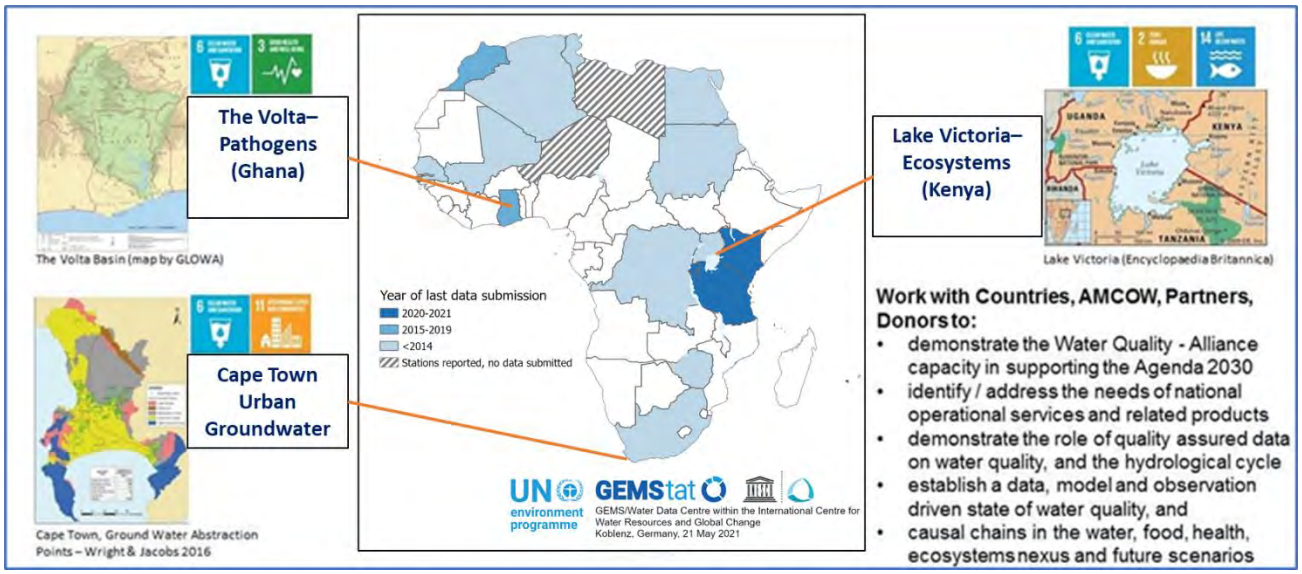


Figure 1-2: Selection of the three African Use Cases (Kremer, 2018)

1.2.3. General Study Process

The use cases followed a three-phase approach, which included an assessment of data availability, stakeholder engagement, a water quality assessment through a combination in-situ data analysis, earth observation (EO) data and modelling, and final reporting. The process was stakeholder focussed so that products and solutions could be co-designed and co-created between the WWQA partners and the local stakeholders (see **Figure 1.3**).

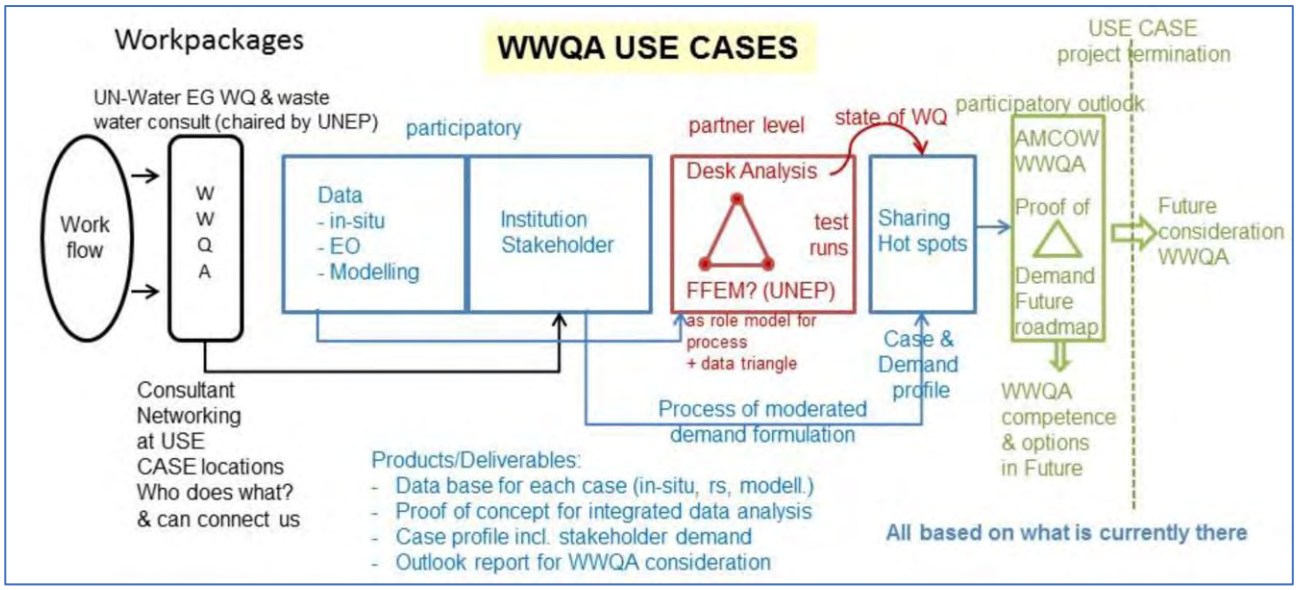
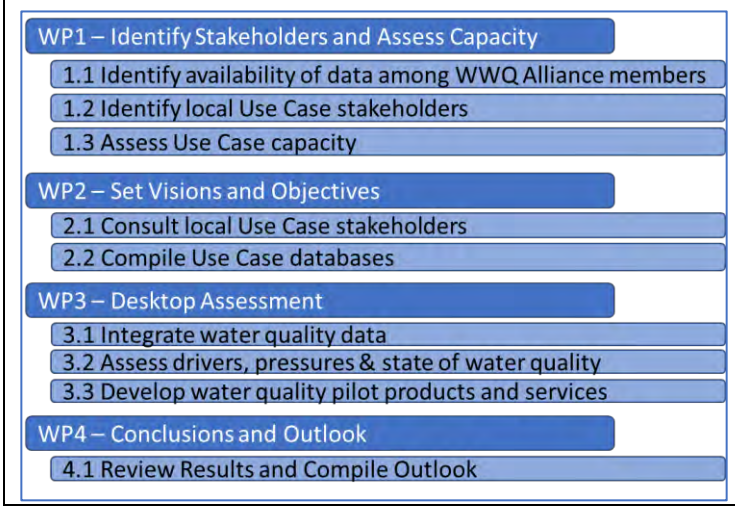


Figure 1-3: Process and Work Packages of Use Cases (Kremer, 2018)

As the use cases were meant to demonstrate the approach and support of the WWQA, the collection of additional data was not undertaken. The process was divided into four work packages (see **Figure 1.4**), resulting in a final report and outlook, for presentation at the annual WWQA meeting and input to submissions for UNEA 5. Due to the Covid-19 pandemic which has restricted travel and movement

during the year 2020, the final report timeline delivery had to be adjusted versus the original plan laid out below.



Initiation of process: August 2019 - Data availability - Initial stakeholder engagement Report: December 2019
- Identification of products and services - Database, data repository Report: March 2020
- Water quality assessment / model - Develop products and services Report: June 2020
- Summary and outlook Report: August 2020

Figure 1-4: General work packages and original schedule for deliverables for WWQA Use Cases

1.3. Project Team Meetings and Workshops

An **initiation meeting** was held with UNEP on 1 – 3 August 2019 at the UNEP offices in Nairobi. This included discussions with Hartwig Kremer, Kilian Christ and Wanjiku Njuguna of UNEP and a telephonic conference with Ilona Bärlund of the UFZ. The objectives of the discussions were to introduce the WWQA and the Africa Use Case concept; discuss roles and responsibilities; discuss tentatively identified stakeholders and engagement strategies, and database options.

A **preparatory call for the WWQA second global meeting**, involving Alliance members, was held on 13 August 2019. This was used to finalize plans for the Ispra meeting in Italy, provide feedback on the WWQA Structure and Activities and for Andrew Gemmell to introduce the Africa Use Cases and to request information on existing data, any projects in the Use Case areas, as well as relevant stakeholders in those regions.

On 4 – 6 September 2019, Dylan Blake presented on the Africa Use Cases at the **2nd SADC-GMI Groundwater Conference** Johannesburg, South Africa. This included a presentation on the Cape Town Use Case, including a description of the WWQA. Further, this was used by both Andrew Gemmell and Dylan Blake as an opportunity to engage with potential in-country stakeholders.

Andrew Gemmell and Kornelius Riemann met with **ICWRGC representatives** at the ICWRGC offices in Koblenz, Germany from 11 – 13 September 2019, the objective of which was to understand GEMS/Water and GEMStat.

From 16 – 18 September 2019 Andrew Gemmell and Kornelius Riemann attended the **WWQA 2nd Global Workshop** in Ispra, Italy. This included a presentation on the Africa Use Case concept and to network with key Alliance members; opportunity to drive the engagement of WWQA members in sharing information on relevant stakeholders and data; and discussions to enhance the participation of AMCOW and their initiative within the African Development Bank, the Africa Water Facility.

Andrew Gemmell and Kornelius Riemann met with UNEP representatives on 20 and 21 February 2020 at the UNEP offices in Nairobi in the form of **project meetings and workshops**. The objectives were to outline work to date, and to define the next steps and delivery plan.

Ongoing telecons have been undertaken with the **Use Case Partners** UFZ, EOMAP and RUB who are undertaking the integration of in-situ, remote sensing-based Earth Observation and water

quality modelling data respectively, as well as GEMS/Water, who have existing relationships with data providers.

On 2 April 2020 Andrew Gemmell convened an additional meeting with representatives UFZ, EOMAP and RUB and GEMS/Water to outline the outcomes of the workshops, focusing on the Volta Basin stakeholder workshop (since the Lake Victoria Stakeholder Workshop feedback had been reported, UNEP, 2019). In addition, Andrew Gemmell outlined the stakeholders identified to date and the data types identified. Through this discussion, priority data types were identified for targeted data acquisition. This was followed by online meetings with the WWQA representatives from UFZ, EOMAP and RUB on 9 June 2020 and 23 July 2021.

Andrew Gemmell continued collaborations with UFZ on Work Package three (WP3, Desktop Assessment) of the Africa Use Cases with various meetings undertaken in 2020 and 2021.

There was ongoing engagement (virtual due to Covid-19 pandemic) to discuss the co-design of water quality products and services with the Lake Victoria Fisheries Organisations (July, August and September 2020), as well as interested stakeholders in Ghana (9 July 2020). These will be described in more detail in **Section 3** and **4** respectively).

Andrew Gemmell presented a summary of the outcomes of the Lake Victoria and Volta River Basin studies at January 2021 Virtual (due to Covid-19) World Water Quality Alliance 2nd Annual Global Meeting.

1.4. Report Aims and Objectives

The aim of this report is to summarize the outcomes of Work Package 1, 2 and 3 i.e.

- Provide an overview of the identified network of contributing Alliance partners and local Use Case stakeholders. This will include a description of the various stakeholder engagements undertaken to date.
- Summarise the existing monitoring and assessment capacities and availability of data from the multiple sources.
- Describe the current state of knowledge and to set the objectives for the information services to be developed.
- Provide a preliminary (baseline) assessment of drivers, pressures and state of water quality to identify freshwater ecosystem hotspots by testing the triangle approach (in-situ, RS/EO, modelling) to develop pilot products and services for local/national application.

1.5. Knowledge Exchange Process

The knowledge exchange process followed for the Use Cases was largely based on The World Bank Group (2016) approach *The Art of Knowledge Exchange – A Results-Focused Planning Guide for Development Practitioners in the Water Sector*, which can be summarised as:

1) Anchor
   a) Identify and agree on the development goal that the knowledge exchange will support and how it links to the development objective.
   b) Define the institutional challenge(s) to meet the development goal (e.g. environment of change, policy instruments, organisational arrangements).
   c) Determine what will change as a result of the knowledge exchange initiative.
2) Define

a) Identify the groups of people who are needed to achieve the change (who will lead, influence, convene, act etc.). This needs change agents at various levels (from technical staff to executive level) in various stakeholder groups (e.g. government, private sector, etc).

b) Determine the intermediate outcomes that participants will seek from the exchange (e.g. new knowledge, enhanced skill, enhanced connectivity etc).

c) Identify groups and individuals with relevant and transferable knowledge and experience to share.

3) Design & develop

a) Select the participants.

b) Verify the change objective and desired outcomes (What do the participants want to learn? How do they hope to grow? What do they need to act, convene, influence, or lead?).

c) Organize the design and delivery team (e.g. instructional designer, local delivery partners, facilitator, project leader, communications coordinator).

d) Assemble the knowledge exchange initiative: What blend of instruments, activities, and delivery modes will help achieve the desired intermediate outcomes? (depending on budget, people, time, technology/resources, operating environment). The World Bank has developed toolbox of knowledge exchange instruments (short-, medium- and long-term engagement) and activities (presentation types, discussion types, experimental options, and analytical options).

4) Implement

a) Guide the participants along their learning journey.

b) Orchestrate engagement and build relationships.

c) Document implementation and track results.

5) Measure & report the results.

a) Synthesize implementation data.

b) Measure effectiveness across expected and unexpected results.

c) Report results.

2. LAKE VICTORIA BASIN

This section provides a summary of the literature review on the Lake Victoria water quality challenges, outcomes of the stakeholder identification process, a summary of data availability associated with water quality, a summary of the stakeholder engagements, the identification of water quality products and services and initial co-design process.

2.1. Literature Review on Water Quality Challenges

This section includes a summary of the identified water quality challenges both current and future.

2.1.1. Current Water Quality Challenges

Lake Victoria is the second largest freshwater lake in the world and has the world's largest freshwater fishery, largely based on the introduction of Nile perch, which supports an economically and socially important export fishery for the riparian countries. The lake basin supports about 30 million people and is the source of the Nile River (SERVIR Global, 2019).

The human population in the catchment is growing rapidly, with the lake itself attracting people because of the economic opportunities it offers. The lake's water residence time (how long it takes for a particle that just entered the lake to leave) is 23 years, while its flushing time (how long it takes for the whole lake water to be renewed) is 123 years. Because of its long retention time, pollutants entering the lake remain for a long time (SERVIR Global, 2019).

The threats facing the lake have caused considerable hardship for the populations dependent on it for their livelihoods, and also have reduced the biodiversity of the lake's fauna, most notably the phytoplankton and fish (SERVIR Global, 2019).

The primary challenges to the lake identified are summarized in the following sections.

2.1.1.1. Nutrient Inflows

Domestic and industrial wastewater, solid wastes, sediments from soil erosion in the catchment area, agricultural wastes and atmospheric deposition are the major nutrient sources (SERVIR Global, 2019).

Sediment runoff increases the water turbidity and salinity, decreases the pH, elevates water temperature, and increases nutrient loads and concentrations of pollutants such as toxic heavy metals and the number of disease-carrying micro-organisms (Chamier *et al.*, 2012).

The increased nutrient load and sediment to the lake promotes algal blooms (SERVIR Global, 2019). The algal blooms result in a depletion of dissolved oxygen, which result in large-scale mortalities of fish, changes in biotic species composition, and increasing human health risks (Kayombo and Jorgensen, 2005; Shepherd, 2008).

As a result, parts of Lake Victoria, especially the deeper areas, are now considered dead zones, unable to sustain life due to oxygen deficiency in the water. (Njiru *et al*., 2012).

2.1.1.2. Aquatic Alien Plants

Water hyacinth is the primary aquatic alien plant identified within the Lake. The first record of water hyacinth infestation in the lake was in the late 1980s and it is believed that the plant entered the lake from Rwanda through River Kagera (Ambrose, 2008).

The proliferation of this plant can result in clogged waterways impeding water flow which increases in the rate of siltation, inhibiting oxygen diffusion into the water resulting in depleted dissolved

oxygen (Chamier et al., 2012; Tobias et al., 2019). In addition, the plant can result in disrupted fishing activities, transport, irrigation, water treatment, enhanced breeding grounds for vectors of human diseases (including malaria and bilharzia), and impacted on biodiversity (Opande et al., 2004).

2.1.1.3. Heavy Metals and Organics

Industrial waste, mining activities and agro-chemicals are a source of heavy metals and organic contaminants to the lake. This results in the bioaccumulation of metals and persistent organic pollutants (POPs) including organochlorine pesticides and polychlorinated biphenyls (Abong'o, 2009; Abong'o et al., 2015; Arinaitwe et al., 2016; Osoro et al., 2016; El-noshokaty, 2017).

2.1.2. Potential future water quality challenges identified

Climatic change, including increased rainfall, has the potential to cause increases in sediments, nutrient and pollutant loading leading to changes in physiochemical parameters like dissolved oxygen, colour, odour and turbidity, heavy metal pollution, eutrophication and algal blooms (Lake Victoria Basin Commission, 2007; Farmer, 2017).

An increasing population within the contributing catchment has the potential to result in increased effluent from wastewater treatment works, leading to increases in emerging pollutants (such as pharmaceuticals and personal care products, plasticizers, brominated compounds and chlorinated paraffins, pesticides), industrial waste, domestic solid waste and wastewater, and mercury-containing products (petrol, skin-lightening cream, and agricultural biocides). Some emerging pollutants have the tendency to persist in the environment and can reach levels that render water resources unfit for human consumption (Kanangire et al., 2015).

Within the catchment, there is an increase in land use impacts due to increased population. This includes wetland conversion and deforestation for agriculture. Wetland conversion or degradation has the potential to results in accumulation of silt affecting transparency, turbidity and dissolved oxygen, as well as increased nutrient loading resulting in eutrophication, proliferation of water hyacinth (Thenya et al., 2001; Lake Victoria Basin Commission, 2007). Deforestation can lead to increased soil erosion leading to sedimentation of water bodies and eutrophication, (Lake Victoria Basin Commission, 2007).

Increased use of the lake for aquaculture has the potential to results in discharge of particulate and dissolved nutrients through uneaten waste feed, faecal matter, and excretory products. This in turn results in a reduction in dissolved oxygen and transparency, eutrophication and dominance of cyanophytes (blue-green algae) (Kashindye et al., 2015).

2.2. Stakeholder Identification

Requests for stakeholders and/or data for the Use Cases were sent to WWQA members. Using the contact details received, these stakeholders identified by WWQA members were then in turn also contacted requesting both data and any additional stakeholders, which continued as an iterative process. In addition, a thorough literature review of stakeholders and data was conducted. Through this process, available data (in-situ, modelled, RS/EO) for the Use Cases was collected and shared with the WWQA triangle partners (EOMAP, Helmholtz Centre for Environmental Research, and Ruhr University Bochum). In addition, a database of stakeholders and their interest in collaboration was developed, shared between WWQA members, and enhanced throughout the project.

Stakeholders identified through feedback from the WWQA, as well as through the stakeholder engagement process (both online and in-country) is summarized in **Annex A**. This includes the stakeholder details (name and contact details) as well as a summary of their proposed input to the

Use Case. Stakeholders are divided into research, government, non-governmental/inter-governmental organizations and private companies

Andrew Gemmell attended the Global Lakes of the World symposium on "*Emerging frontiers for African Great Lakes: Promoting Blue Economy, food security and Conservation*" in Kisumu, Kenya on 5 – 7 August 2019. The outcomes of this attendance was an enhanced understanding of the water quality challenges at Lake Victoria and it's catchment; the opportunity to discuss the WWQA and Africa Use Cases with attendees and to develop a stakeholder network and assess data sources and types associated with Lake Victoria. In addition, a connection was made with Dr Ted Lawrence from African Great Lakes African Center for Aquatic Research and Education (AGL-ACARE) who share similar goals to the Africa Use Case initiative. A key aim of what AGL-ACARE want to do at Lake Victoria (and other African Great Lakes) is to combine various datasets and share these via a network of African Great Lakes Basin Stakeholders. AGL-ACARE had arranged a stakeholder workshop on 5-7 November 2019 in Entebbe Uganda called "African Great Lakes Stakeholder Network Workshop: Strengthening Capacity in Research, Policy, and Management through Development of a Network of African Great Lakes Basin Stakeholders" and discussions commenced for Andrew Gemmell to present on the WWQA Use Case (attendance at which is included later in this chapter).

All in-country stakeholders identified and shared by Alliance members, as well as those identified through engagement at conferences, workshops and meetings were formally approached via e-mail. The mail included a 1-pager (**Annex B**) specific to the Use Case prepared by Mr Andrew Gemmell, outlining the WWQA, the Africa Use Cases, water quality challenges per Use Case, and the work plan. The objective of this communication was to find out how partners are able to contribute (i.e. existing data, projects and relevant stakeholders in these regions) and would like to see certain aspects of their work featured in these use cases.

2.3. Data availability

This section outlines the data that has been identified to date for the Lake Victoria Use Case. This includes data identified via a literature review, as well as through engagement with Alliance members and in-country stakeholders. This is tabulated in **Annex C**.

2.3.1. In-situ measurements

2.3.1.1. Literature Review

In-situ measurements of pollution load to Lake Victoria have been carried out by several studies in the past. However, most of the findings of the studies are published in official reports that are not easily accessible.

The East African Community and Lake Victoria Basin Commission (LVBC) with the aid of the World Bank have commissioned several studies in the Lake Victoria basin as part of the Lake Victoria Environmental Management Project (LVEMP) Phase I (1995-2005), the majority of the data is detailed in the following reports:

- Lake Victoria Environment Report – Uganda Water Quality and Ecosystems Status (Muyodi and Hecky, 2005),
- Lake Victoria Environment Report - Kenya National Water Quality Synthesis Report (Aboudha and Hecky, 2005),
- Study on Water Quality and Human Health Around Lake Victoria (Lake Victoria Environmental Management Project (LVEMP), 2004)

- Water quality management and sustainability: The experience of LVEMP – Tanzania (Machiwa, 2003)

Other similar past studies include Africa Water Network (1998), Bootsma et al. (1996), Calamari et al. (1995), Scheren (2005, 2003) and Scheren *et al*. (2000, 1995).

The Center for International Forestry Research worked with citizens in Kenya who contributed valuable water level and water-quality data (Rufino *et al.*, 2018).

2.3.1.2. Engagement with Stakeholders

Based on feedback from **Christopher Aura** of KMFRI, there is data available on the KMFRI website. This includes data on water quality, pesticides, wild major fisheries, cage culture, pond data, riverine and river mouth data. **Zachary Ogari** of KMFRI is spearheading a data archive facility for all datasets generated under the Fresh Water Systems Division of KMFRI including water quality data, which should assist in data accessibility/sharing within KMFRI.

Prof. R.E. Hecky of the Large Lakes Observatory and Biology Department of the University of Minnesota at Duluth and editor of the Journal of Great Lakes Research, after discussions at the Global Lakes of the World symposium in Kisumu, Kenya (5 – 7 August 2019) provided various reports specific to Lake Victoria, including:

- Lake Victoria Environmental Management Project (LVEMP) Water Quality and Ecosystem Status (2005);
- Lake Victoria Environmental Management Project (LVEMP), July 2005;
- Lake Victoria Regional Water Quality Synthesis Report, 2005;
- Various reports specific to Nyanza Gulf (and Napoleon Gulf for mercury).

The University of Nairobi and the African Center for Aquatic Research and Education own and manage the internet platform called "*African Great Lakes Inform*[1]". The site helps users access spatial data; information on past, present and future projects; and all aspects of the adaptive management process. The website allows access to data and information divided into each of the Great Lakes (including Lake Victoria) as well as six themes that support natural resource planning, implementation and decision-making processes.

The FAO operates the **GeoNetwork**[2]. This tool includes interactive maps, GIS datasets, satellite imagery and related applications. There is data available specific to hydrology and water resources. The overall aim of GeoNetwork is to:

- Improve access to and integrated use of spatial data and information;
- Support decision making;
- Promote multidisciplinary approaches to sustainable development;
- Enhance understanding of the benefits of geographic information;
- Easily share geographically referenced thematic information between different organizations.

Josiane Nikiema (IWMI-Ghana) stated that IWMI and the other CGIAR organizations are currently working on a platform for data sharing (waterdata.iwmi.org). However, this has not been made public at the time of reporting.

[1] www.africangreatlakesinform.org
[2] www.fao.org/geonetwork/srv/en/main.home

Dr Mwemezi J. Rwiza of the Nelson Mandela African Institution of Science and Technology shared various references to documents that can be made available associated with the water quality of Lake Victoria, including:

- Monitoring of pollutants e.g. heavy metals; water quality; nutrients; water use; lake level; pollutant sources and fate; influence of climate change
- The control of water hyacinth; water use/abstraction; conservation; lake biodiversity;
- Management of the issues of stakeholders' involvement; watershed approaches; water use; water quality; land-use; water resources e.g. fishing and human settlement.

NASA Globe (Global Learning and Observations to benefit the Environment) Program is a worldwide program that brings together students, teachers, scientists and citizens to promote science and learning about the environment. Through a hands-on approach to inquiry, participants are encouraged to engage in local investigations that includes water quality. Observations made locally are submitted to the GLOBE data and information system and can be accessed freely online. This serves as a potential source of useful citizen science data; however, notable is that the information in the Lake Victoria and Volta Basin are limited.

As of 30 November 2020 the data received by WWQA Members and Stakeholders is summarised below:

- Zachary Ogari of KMFRI: Lake Victoria data focussed in Kenya related to cage culture, fisheries data, pesticide data, riverine data, water quality data. Some data lacks GIS locations and/or units.
- CHEN Shuang Sophia from NIGLAS: water quality data of the Mwanza Gulf of Lake Victoria (Kenya).
- Ting Tang of IIASA: Link to hydrological and water demand data and reports related to project East Africa Future Water Scenarios to 2050. Two possible development scenarios for the extended Lake Victoria Basin. Each scenario combines a plausible socio-economic development pathway with climate change impacts calculated for the GHG concentration pathway. Unfortunately nutrient export data is not ready for sharing at this moment
- Willian Okello, NaFIRRI: Water quality data for 2007 and 2008 from two sites in the northern inshore areas, both of which were the pilot zones for the Lake Victoria Environmental Management Project (LVEMP). This included Murchison Bay near Kampala, and the Napoleon Gulf near Jinja.

2.3.2. Water quality modelling

2.3.2.1. Literature Review

The World Bank funded a project in June 1999 for the development and implementation of a framework model for the simulation of the physical processes and water quality in Lake Victoria. The model was developed and installed in the three riparian countries. by a consortium consisting of Delft Hydraulics, HydroQual and IHE (LVEMP, 2002).

2.3.2.2. Engagement with Stakeholders

Based on feedback received from the Ting Tang of the International Institute for Applied Systems Analysis (**IIASA**), there is the following data available:

- Modelled long-term trends for nutrient export (mainly nitrogen) to Lake Victoria and the basin using global nutrient dataset (fertilizer, nitrogen deposition, manure, nitrogen fixation, nutrient in human waste, etc.); including the influence of global/regional changes and local/regional solution options (10-year interval, current - 2050). This uses International Institute for Applied Systems Analysis
  IIASA data using internal and external global/regional model inputs.
- Modelled current and future hydrology and sectoral water demand considering climate change, water and food demands, agricultural management, etc. based on regional development scenarios (daily, current – 2050). IIASA data using internal and external global/regional model inputs

Joost van den Roovaart of **Deltares** shared information on 3D modelling undertaken in 1999 using Delft3D to simulate water hyacinth. While not yet applied to Lake Victoria, according to Deltares it can be quickly set up to do so.

2.3.3. Earth observation/remote sensing data

2.3.3.1. Engagement with Stakeholders

Based on feedback received Ting Tang of IIASA, the following data is available:

- Global Lake water quality dataset based on Remote Sensing available at a monthly resolution from 2002 - 2011 for Lake Victoria. This is will be made available via a World Bank project intended to be published as open source. Data is available for the following water quality parameters:
  - Lake Surface Water Temperature
  - Chlorophyll A
  - Total Suspended Matter
  - Turbidity
  - Coloured Dissolved Organic Matter
  - Immersed and Floating Cyanobacteria (Probability Only)
  - Floating Vegetation (Probability Only)
- Ugandan district-level survey data on wastewater treatment and sanitation accessible through an IIASA collaboration, intended to be published as open source.

Dr. Kenneth Mubea from the Global Partnership for Sustainable Development Data provided details on the free and open source African Regional Data Cube (ARDC)). ARDC was developed by the Committee on Earth Observation Satellites (CEOS) in partnership with the Group on Earth Observations, Amazon Web Services, Strathmore University in Kenya, Office of the Deputy President - Kenya, and the Global Partnership for Sustainable Development Data. The ARDC is a tool that harnesses the latest Earth observation data and satellite technology to help various countries including Kenya and Tanzania address various issues relating to agriculture, food security, deforestation, urbanization, water access, and more. ARDC can be used to assess the water quality SDG 6.3.2 and water extent SDG 6.6.1.

SERVIR Global has the SERVIR Global Service Catalogue, a searchable collection of demand-driven geospatial services that use earth observations to support decision making and resilient development in agriculture and food security, land cover land use change and ecosystems, water and water related disasters, and weather and climate. This includes water quality data for Lake

Victoria (temperature, chlorophyl-a and total suspended matter), macrophytes, and basin land cover (various years). SERVIR has developed an automated system that maps water quality status in Lake Victoria. It ingests Near Real Time raw satellite data from the Regional Centre for Mapping of Resources for Development (RCMRD)[3] MODIS receiver station, processes it to geophysical values, and maps. The SERVIR Global data is then placed in a spatial database and made public through a visualization web application. This data is freely shared on the visualization tool (http://apps.rcmrd.org/waterquality), and is available for download.

Joost van den Roovaart of Deltares shared information related to remote sensing (1970-now) based on Google Earth engine to track water hyacinth.

Kerstin Stelzer of Brockmann-Consult advised that Lake Victoria has been included int the CGLOPS Data set, with time series and maps available for chlorophyll-a and total suspended matter (TSM). However, it needs some data handling to get the information out of the global products to perform analyses for individual lakes.

Thomas Heege of EOMAP provided feedback that EOMAP can share UNESCO world water quality data[4] over Africa. In addition, EOMAP can share the eoLytics tool which enables countries/organizations to produce for water quality monitoring with selectable time frame, resolution, frequency. Further, EOMAP has other earth observation water quality data as well online and free on other portals which can be shared, including two web applications with free data available[5][6]

Steve Greb of the University of Wisconsin-Madison Aquatic Sciences Center and Space Science and Engineering is open to collaborate, especially earth observation data. GEO AquaWatch is building a global WQ monitoring service, merging in situ and remote sensed data.

2.3.3.2. SERVIR Stakeholder Mapping

SERVIR-Eastern and Southern Africa (E&SA) has prioritized user engagements in the design and development of services in four service areas that include Land Cover Land use and Ecosystems, Agriculture and Food Security, Weather and Climate, and Water and Hydro-climatic Disasters.

SERVIR E&SA has conducted needs assessment in Tanzania, Kenya, Uganda, and Rwanda to identify and understand existing and emerging needs in the use of Earth Observation and geospatial technologies in informing decision making in the aforementioned four service areas. The assessments took the form of stakeholder presentations to understand the roles, achievements, challenges and existing initiatives that use or are potential users of geospatial technologies and to understand decision making context in addressing environmental management issues and how geo-information is used to inform decision making processes. Out of this exercise water quality was identified as one of the issues / developmental problems of concern to the four countries.

A number of activities have been conducted from SERVIR Phase I in this service area. First, an automated system that maps water quality status in Lake Victoria and Lake Malawi was created (http://apps.rcmrd.org/waterquality) as discussed in the previous section.

The orientation of the SERVIR Phase II project to need-based activities led to stakeholder mapping in the five countries (Kenya, Uganda, Tanzania, and Rwanda). SERVIR-Eastern and Southern Africa undertook a Stakeholder Engagement workshop in Tanzania on 29-30 May, 2018. The workshop objectives were:

1. Stakeholder Mapping of national and regional stakeholders.
2. Within the scope of Earth Observation, Remote Sensing and GIS:

[3] http://opendata.rcmrd.org/
[4] www.worldwaterquality.org
[5] https://eoapp2.eomap.com/
[6] https://eoapp.eomap.com/

   a. Addressing gaps and challenges in water quality monitoring and management;
   b. Establishing the decision-making context of institutions working in the water quality monitoring and analysis;
   c. Identification of information sharing platforms, tools and methods relevant in the water quality thematic area.
3. Activities that were done in this workshop have been guided by SERVIR's service planning toolkit.

The outcomes included Stakeholder Maps for each country. These identified the following key stakeholders:

- **Regional:** East Africa Commission, Lake Victoria Fisheries Organization, Lake Victoria Basin Commission and Lake Victoria Environmental Management Program (LVEMP) were identified as key regional partners in water quality issues with collaborations with relevant ministries at national level.
- **Kenya:** Kenya Marine and Fisheries Institute and Ministry of Water identified as the most important stakeholders in Kenya in water quality issues.
- **Rwanda** Water and Forestry Authority and Ministry of Environment as key stakeholders in Rwanda: Rwanda.
- **Tanzania:** Ministry of Water and Irrigation and Tanzania Fisheries and Research Institute stakeholders were identified as the most significant in water quality issues in Tanzania
- **Uganda:** Ministry of Water and Environment and National Fisheries Resource and Research Institute stakeholders were identified for Uganda.

A summary of water quality issues identified were as follows:

- **Kenya:** Enhance biocontrol of water hyacinth; validate chlorophyll-a and algal productivity data; recommend best sites for fish cages; recommend best practices for riverine habitat protection.
- **Rwanda:** Policy formulation; implementation of laws related to water resources management; how to manage water resources; guidelines of water pollution; closing of non-compliance activities; water pollutant charges.
- **Tanzania:** Hydrobiology and water pollution; aquatic ecosystems and biodiversity; climate change and environment; aquaculture; management of reservoir; water quality; monitoring stock assessment and fisheries; statistics; impose water quality awareness.
- **Uganda:** Recommending protection/ enforcement and restoration of buffer zones and catchments for rivers and lakes; sites suitable and capable for cage fish farming; designating fish breeding areas; monitoring water quality; stopping deposition of untreated wastewater in aquatic systems; management of invasive species and algal blooms; processing samples for heavy metals and agro-chemicals; raising capacity for geospatial tools and data and obtaining earth observation data; conducting country comparisons for Lake Victoria riparian countries.

The way forward specific to water quality included:

- Data inventory: preparation of data inventory spreadsheet to help capture what, who and accessibility issues in data;
- Data inventory analysis: looking at the inventory created and agreeing on the next best step;
- Capacity building in basic RS/GIS: training will be on basic theories and software usage;

- Advanced and integrated training in the use of EO in water quality/modelling.

2.3.4. Online Data Repositories

Based on an on-line search as well as feedback from stakeholders and project partners, the following online data repositories have been identified:

Lake Victoria:

- http://lvbc.wris.info/ LVBC Water Resources Information System containing data. Described here:
    - https://iiasa.ac.at/web/home/research/3.2_LVBC_WRIS_Water_Resources_Information_System__Eng._Calis.pdf/
    - https://iiasa.ac.at/web/home/research/researchPrograms/water/1.4_Lake_Victoria_Basin_Water_Resources_Information_System__.pdf
- Kenya Marine and Fisheries Research Institute: http://41.89.141.8/kmfri/ has water quality reports. Zachary Oragi of KMFRI is developing a more user friendly data portal: https://kenyasdata.com;
- http://www.africangreatlakesinform.org/resources Proposes to act as a lake-specific repository. Due to lack of funds/resources, currently creates links to existing data sources e.g. http://www.fao.org/geonetwork/srv/en/main.home
- https://www.arcgis.com/apps/MapJournal/index.html?appid=71137dc4a053423eb01b4612313fd9de# Lake Victoria Environmental Management Project (LVEMP) II Cleaner Production study. Has pollution loadings visualised as well as a maps of biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), nitrate and total phosphorus (TP) loadings to Lake Victoria and tributaries
- http://apps.rcmrd.org/waterquality/index.php?lake=victoria RCMRD Lake Water Quality Visualization Tool - Lake Victoria. Focus on RS/EO water quality data.
- https://freshwaterbiodiversity.go.ug/ Freshwater Biodiversity Portal for Uganda. Data offered by NaFIRRI and in discussions to access this.
- http://repository.seku.ac.ke/bitstream/handle/123456789/739/Gikuma-Njuru_Lake%20Victoria%20environment%20management%20project%20...PDF?sequence=1&isAllowed=y *LVEMP Lake Victoria Regional Water Quality Synthesis Report*, which has some data
- https://www.ais.unwater.org/ais/aiscm/getprojectdoc.php?docid=3400 UN Water Report with river loadings to Lake Victoria
- World Bank tools such as
    - http://appsolutelydigital.com/LakeVictoria/
    - http://spatialagent.org/Uganda/

Africa/Global

- International Groundwater Resource Assessment Centre (IGRAC) databases, specific to groundwater
- Group on Earth Observation (GEO) Portals (https://www.geoportal.org/)
- AMCOW tools, including Africa Water Sector and Sanitation Monitoring and Reporting (http://www.africawat-sanreports.org)
- RAMSAR database (wetlands)

- http://www.africawat-sanreports.org/IndicatorReporting/home Africa Water Sector and Sanitation Monitoring and Reporting
- https://doi.pangaea.de/10.1594/PANGAEA.871462 Diversity II water quality parameters for 300 lakes worldwide from ENVISAT (2002-2012).
- https://www.bafg.de/GRDC/EN/Home/homepage_node.html Global Runoff Database
- https://www.servirglobal.net/ServiceCatalogue/list SERVIR RS/EO data split into regions and service areas, and data source.
- http://52.54.26.108/ RS/EO data by the Africa Regional Data Cube
- https://www.arcgis.com/apps/Cascade/index.html?appid=414730116a3c4c119b80ec9d1727ab74 GEOGLOWS Global River Forecasting Applications
- World Bank tools such as
    - http://spatialagent.org/HydroInformatics/
    - http://appsolutelydigital.com/MonitoringSystems/hydrology.html
    - http://spatialagent.org/Africa/
    - https://geo.fas.usda.gov/GADAS/index.html USDA - Foreign Agricultural Service Global Agricultural & Disaster Assessment System

2.4. Stakeholder Workshop in Entebbe, Uganda

During November 5-7, 2019, the AGL-ACARE and its in-country hosts, the Lake Victoria Fisheries Organization and the National Fisheries Resources Research Institute held the African Great Lakes Stakeholder Workshop. The workshop's goals were to create lake-specific advisory groups of freshwater experts on each African Great Lake to serve as mechanisms for consistent, regular, and extensive collaboration and communications. Freshwater experts from 18 countries were in attendance, including members from each of the 10 riparian African Great Lakes Countries.

Andrew Gemmell and Tallent Dadi (UFZ) attended the workshop. The objectives of this attendance included:

- Assess water quality challenges in the Lake Victoria Basin, including participation at a day-long workshop focused on developing a Lake Victoria advisory group.
- Understand similarities and differences of Lake Victoria to the other African Great Lakes (Albert, Edward, Kivu, Malawi, Tanganyika, Turkana)
- Discuss the WWQA and Africa Use Cases with attendees
- Develop stakeholder network and assess data sources and types associated with the Lake Victoria Basin

2.4.1. Workshop Objectives

The African Great Lakes are Lake Albert, Edward, Kivu, Malawi/Niassa/Nyasa, Tanganyika, Turkana, and Victoria. The workshop was initiated by AGL-ACARE to address the problem of disparate, parochial, short-term research resulting in a lack of comprehensive, comparable scientific data; lack of long-term, continuous, and constant data sets; country- or project-specific results and a lack of focused resources (financial and research) associated with the Great Lakes. The objective was also to respond to three decades of ongoing calls for increased collaboration and capacity building in Africa and to address freshwater issues. The workshop agenda is in **Annex D**.

Attendees included government leaders, regional and basin authorities, intergovernmental organizations, development and funding agencies, non-governmental organizations, community groups and the private sector. The stated workshop goals were to:

1. Establish a clear need for a collaborative process for the African great lakes, individually and collectively.
2. Develop an initial lake advisory group for each African great lake, each with a set of priorities and a plan to achieve them.
3. Establish the core for an effective network for the African great lakes.
4. Build international relationships and knowledge, across boundaries and lakes.
5. Establish a sustainability plan for the advisory groups.

This was proposed by AGL-ACARE to be accomplished in the following way:

- Through a vast network of freshwater partners, ACARE will enhance global collaboration among freshwater learning institutions, organizations, ministries, and other entities to address the challenges facing the African Great Lakes
- ACARE will coordinate regular communication among African Great Lakes experts, strengthening research efforts on understanding the impacts of biological, physical, chemical, economic, political, social, and technical factors on African freshwater resources.

In addition, AGL-ACARE proposes to assist in the development and administration of the African Great Lakes Information Platform[7].

There were day-long breakaway workshops facilitated by AGL-ACARE, with each focused on a specific lake. This included a workshop specific to Lake Victoria.

The goal of the lake-specific workshops was the creation of a long-term process for consistent and regular collaboration and communications among experts on each African Great Lake so each lake can produce long-term, comparable, and peer reviewed data that can be used to positively influence policy and management.

It was proposed that the lake-specific advisory groups collaboration would result in:

- Increased opportunities for global research collaboration;
- Enhanced accumulation of research resources;
- Creation of consistent, credible, comparable long-term data;
- Increased certainty of research impact.

2.4.2. Lake Victoria Workshop

The key outcomes of the AGL-ACARE Lake Victoria Workshop discussions are summarised below.

2.4.2.1. Objectives, Priorities and Mission Statement:

The AGL-ACARE Lake Victoria workshop was conducted on 6 November 2019. The objectives were to assess and discuss the:

[7] https://www.africangreatlakesinform.org/

- Purpose of the Lake Victoria Advisory Group;
- Advisory Group Structure;
- Advisory Group Roles and Leadership;
- Resources Needed for Advisory Group Success;
- Communications Tools;
- Next Steps and Annual Plan;
- Research and Policy Priorities;
- Policy Engagement Strategy.

The specific priorities of the group were to:

- Collaborate in research and timely dissemination to resource managers for informed management decisions;
- Identify sector weaknesses for capacity building;
- Drive investment opportunities to further research and collaborations;
- Advocacy for resource sustainability;
- Problem identification and prioritization;
- Develop tools for decision making;
- Develop data sharing tools for existing data.

The purpose statement for the group agreed upon was:

> *This Lake Victoria Advisory Group exists to enhance communication and collaboration of entities across borders and sectors that work to research and solve issues that impact the health of the lake and surrounding communities.*

The agreed-upon mission statement was:

> *To provide research-based decision support to policy makers and resource managers for the sustainable management of the Lake Victoria Basin. Develop a harmonized research strategy on Lake Victoria*

2.4.2.2. Participants

The workshop participants are summarized in Table 2-1. This included Andrew Gemmell and Tallent Dadi (UFZ). A photograph of the African Great Lakes Stakeholder Workshop and the Lake Victoria working group is represented in Table 2-1 and Table 2-2 respectively.

Table 2-1: Lake Victoria Advisory Group Workshop Participants

Name	Description
James Barasa	Lecturer and a member of Fish Genetics Division at the Department of Fisheries and Aquatic Sciences, University of Eldoret, Kenya
Dr. Tallent Dadi	UFZ
Dr. Rukuunya Edward	Director of Fisheries in the Uganda Ministry of Agriculture Animal Industry and Fisheries
Andrew Gemmell	UN affiliate, UNEP
Prof. Ken Irvine	Chair of aquatic ecosystems group, IHE Delft

Dr. Robert Kayanda	Tanzania Fisheries Research Institute
Dr. Lily Kisaka	Lake Victoria Basin commission (LVBC)
Mary A Kishe	Research scientist, Tanzania fisheries research institute (TAFIRI)
Prof. Julius Manyala	Associate Professor and a member of Fisheries Management Division at the Department of Fisheries and Aquatic Sciences, University of Eldoret, Kenya.
Stella Mbabazi	Fisheries inspector, Ministry of Agriculture, Animal Industry and Fisheries Uganda
Modesta Medard	Marine Programme Coordinator in WWF - Tanzania country office
Dr. Evans Miriti	University of Nairobi. Also closely involved in the Great Lakes information platform: www.africangreatlakesinform.org
Hillary Mrosso	Ecology fisheries statistics and stock assessment TAFIRI
Christopher Nyamweta	Kenya marine and fisheries research institute
Alfred Otieno	Lecturer and a Member of Aquatic Resource Management and Fisheries Management Division at the Department of Fisheries and Aquatic Sciences, University of Eldoret, Kenya.
Zacharia Shitote	Lecturer, Project planning and Management, School of Business and Management Sciences, University of Eldoret, Kenya
Dr. Anthony Taabu-Munyano	Director at National Fisheries Resource Research Institute. Member of Lake Victoria Fisheries Organization (LVFO)
John. K Walakwa	President-elect WASTA program

Figure 2-1: The African Great Lakes Stakeholder Workshop attendees

Figure 2-2: The Lake Victoria working group

2.4.2.3. Lake Victoria advisory group structure

Lake Victoria advisory group structure agreed was as follows:

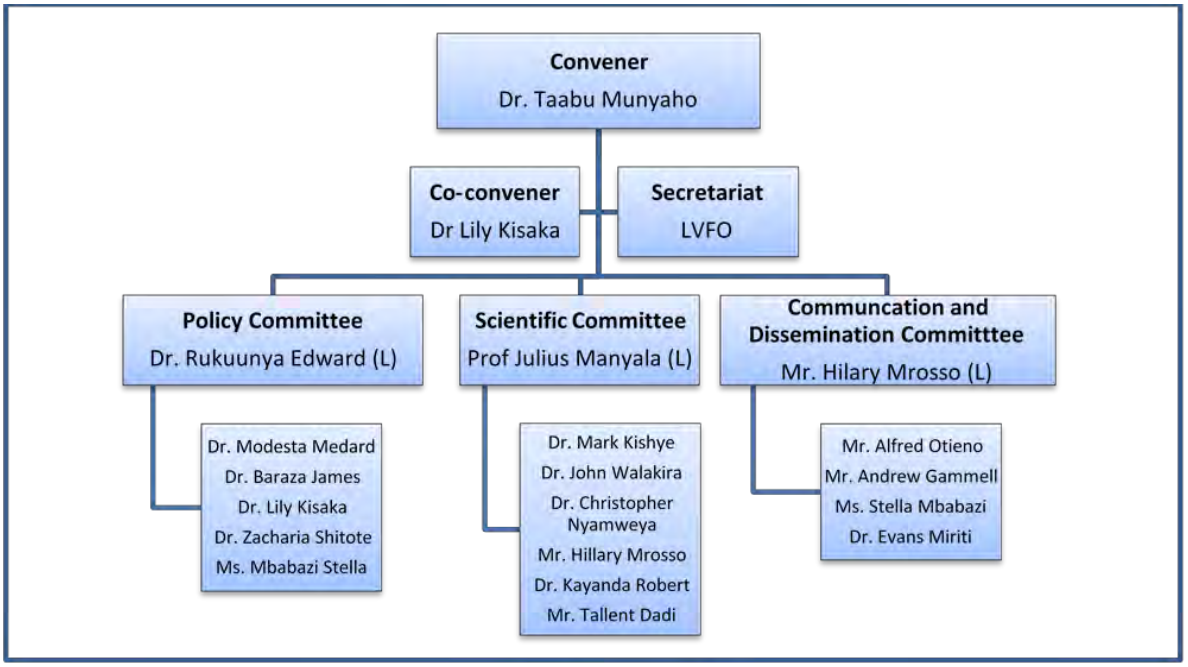


Figure 2-3: Lake Victoria Advisory Group Structure

The Policy committee roles and responsibilities focus on the identification of research and information gaps; receiving and synthesizing policy briefs; engaging with policy makers and

managers.

The scientific committee's roles and responsibilities include the development of a harmonized research strategy on Lake Victoria; synthesis of scientific information and production of periodic report; advice and guidance on producing guidelines and standard operating procedures; Preparing research frameworks/ proposals; identification of research gaps/emerging issues; analysis of existing research agenda in the different research institutions.

The communication and dissemination committee roles and responsibilities include the preparation of policy briefs and the dissemination of scientific findings.

AGL-ACARE was identified as having the role to facilitate the convening of the advisory group members and inter advisory great lakes committees; the development data sharing tools and to mobilize resources from development partners to facilitate research.

It was agreed that there would be only one term for the elected committee members, with elections occurring annually. The convenor is to preside over the voting of the next committee.

Andrew Gemmell and Tallent Dadi volunteered to be members of the Communication and Dissemination Committee so as to be involved in the dissemination of scientific findings and to advance the objectives of the Lake Victoria African Use Case. This engagement continues with:

- Ongoing attendance by Andrew Gemmell and Tallent Dadi at monthly virtual meetings,
- Input by Andrew Gemmell and Tallent Dadi to an article to be submitted to the Journal of Great Lakes Research, paper titled: *Lake Victoria: Overview of Research Needs and the Specific Way Forward.*
- Ongoing (as of 9 June 2021) discussions with AGL-ACARE towards Andrew Gemmell co-authoring a publication named "*Need for a long-term harmonized monitoring of African Great Lakes*" to be submitted to the Journal of Great Lakes Research

2.4.2.4. Advisory Group Discussion Points

The advisory group discussed the level of agreement and development needs to various questions. The outcomes of these discussions are summarized below:

Do group members agree that strengthening science is necessary to positively inform policy and management decisions to ensure the health of this lake's resources?

This was agreed upon. This was proposed to be achieved through:

- Developing a framework for collaboration of different research institutions.
- Profiling of available research capacity with the different research institutions.
- Profiling, harmonizing and standardizing research agendas.
- Planned human resources towards the priority areas.
- Information sharing to aid collaboration.
- Create a forum to transfer the research to policy makers.
- Synergy with policy and political groups to ensure efficient knowledge/ research transfer.
- Scientists should find dissemination mechanisms (e.g. policy briefs, information with economic indicators) availed on platforms that is clear and more readable by the general public/ policy makers. This included a discussion on the need for research to be put into actionable points, including the use of social media experts to improve research dissemination.

- The scattered information should be congregated onto a clear sharing platform in the different research arms of the East African Community (EAC). To create impact, it was discussed that the platform should be utilized by LVFO where there is a council of Ministers.
- Use of indigenous knowledge while undertaking research.
- Scientists should have annual prioritization and review forum.
- Research should involve the private sector.
- Policy makers respond to mainly two drivers – pressure from public-private sector and values associated – so researchers should also prioritize accordingly.

Do riparian country governments support the idea of inter-jurisdictional cooperation?

This was agreed upon. The organisations that were considered for inclusion into inter-jurisdictional at Lake Victoria cooperation were:

- African Ministers Council on Water (AMCOW)
- AGL-ACARE – A neutral body
- Common Market for Eastern and Southern Africa (COMESA) – For trade issues
- EA Legislative Assembly
- Inter University Council of East Africa
- LVBC
- LVFO
- Ministries of Foreign Affairs
- Principle Ministries in EAC

In addition, the Makerere University was noted for potential inclusion. Further, it was noted that indigenous knowledge needs to be enhanced through inclusion of appropriate people, organizations or types of entities.

To strengthen the inter-jurisdictional cooperation, it was discussed that any technical sessions should always include researchers. Further, task/interest groups/advisory groups independent of ministerial attachments should be formed.

The challenges noted are that there is compartmentalization of institutions and they deal with specific line ministries which may not have right stakeholders. Further, administrative bottle necks were noted.

Can a neutral institution facilitate the process of inter-jurisdictional cooperation, like the Advisory Groups?

This was agreed upon. Existing local neutral institutions were identified for consideration included:

- Regional Forum for Research and Training specific to Agriculture and Food production (RUFORUM)
- Inter University council of East Africa
- Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)

However, the nature of a neutral body was discussed, including if it is possible to have a neutral body. Rather, non-governmental/ non- state independent actors such as the UN and its SDGs should be considered.

The role of AGL-ACARE as a non- state independent body was discussed. This included the procedure for legitimization and the need to liaise with AU-IBAR (African Union Interafrican Bureau for Animal Resources), Nairobi Convention and UNEP and cooperation of LVFO.

Would advisory group be able to meet regularly with participation of all members?

This was agreed upon. The advisory group meeting frequency suggested was bi- annual to cater for emerging issues that may arise. There would then be an annual review of what has been done and prioritize what to be researched on the next year; including heads of institutions to better adopt what the technical committees have agreed upon.

Do members have the ability to make decisions for their organization?

It was discussed that members need to consider CEOs or heads of institutions before making decisions.

Do members have the ability to provide input without interference from others within the advisory group (members feel free to express opinions)?

It was agreed that intellectual discretion should be free. CEOs or heads of institutions eventually decide and communicate the agreed-upon points

2.4.2.5. Lake Victoria African Use Case Presentation

Andrew Gemmell presented on the African Use Case initiative, focusing on the Lake Victoria Basin. The presentation included:

- The background to the World Water Quality Alliance.
- The need for collaboration, with relevant examples as stated in the preliminary workshop presentations, including Kevin Obiero (AGL-ACARE/KMFRI) and Robert Kayanda (AGL-ACARE/LVFO).
- The African Use Case Approach and Work Plan.
- A request for collaboration, including
    - Key in-country stakeholders associated with water quality.
    - Water quality data.
    - Input on what limitations exist or are perceived for the sharing data?

Due to time limitations, it was requested for the Advisory Group to share data and stakeholders via email. The discussion on what the limitations to sharing of data identified by the Advisory Group included the following observations by participants on what limits data sharing:

- Lack of data sharing policies.
- Past experiences where collaborators requested for data and went on to use the data without citing or acknowledging the data sources.
- Finding a place of data storage which is acceptable to all.
- Data compatibility problems.
- Scientists working in the public sector limited by country-specific data sharing protocols.
- Data sharing limited or not possible for donor-funded projects.
- Scientists holding data and, in some cases, retiring without making the data available. This is also linked to challenges of data archiving within organisations.
- Limited data processing and analysis capacity by scientists or institutions

- Lack of internal databases to store data.
- Sabotage by data collectors to avoid the release the data.
- Retrieving data from archives sometimes a cumbersome task in addition to one's regular duties.
- Data structuring and formatting problems which can create problems for data analysis.

There was a general consensus that there is need to bring all data into a data-management system that can be accessible to all.

In addition to the presentation to the Lake Victoria Activity Group, a summary of the same presentation was made to the larger workshop on the final day of activities.

2.5. Identification of Water Quality Products and Services

To identify the potential water quality products and services to take forward to co-design, various workshops were held with the identified Lake Victoria Fisheries organisations and institutes. The workshops were undertaken online due to Covid-19 related travel restrictions.

2.5.1. 8 July 2020

An online workshop was conducted on 8 July 2020. This included various representatives (**Table 2-2**) with the following representatives from the Lake Victoria fisheries organisations and institutes:

- Dr. Anthony Taabu-Munyaho: Director at the Uganda National Fisheries Resources Research Institute (NaFIRRI) and Deputy Executive Secretary at Lake Victoria Fisheries Organization (LVFO)
- Dr. Christopher Aura: Assistant Director at Kenya Marine and Fisheries Research Institute (KMFRI) Department of Freshwater Systems Research.
- Dr. Robert Kayanda: Director of Fisheries Resource Monitoring and Research at Lake Victoria Fisheries Organization (LVFO)

The objectives of the meeting were to:

1. Re-introduce the concept of the African Use Case concept as it relates to Lake Victoria and how the WWQA can assist
2. Provide examples of what can be achieved through the WWQA using Lake Victoria as an example
3. Discussion of the priority Lake Victoria water quality concerns and hotspots.
4. Discussion of research and information gaps and to begin discussions on water quality data and information products and services to be co-developed to target hotspots.

Table 2-2: Participants of the online workshop conducted on 8 July 2020

Name	Institution
Andrew Gemmell*	UNEP
Dr. Anthony Taabu-Munyaho	LVFO
Dr. Christian Schmidt	UFZ
Dr. Christopher Aura	KMFRI

Dr. Hans Dürr	RUB
Dr. Hartwig Kremer	UNEP
Dr. Ilona Bärlund	UFZ
Dr. Jaime Rivera	RUB
Dr. Karsten Rinke	UFZ
Prof. Martina Flörke	RUB
Dr. Robert Kayanda	LVFO
Rowena Hay	Umvoto
Dr. Seifeddine Jomaa	UFZ
Dr. Tallent Dadi	UFZ
Dr. Thomas Heege	EOMAP
Wanjiku Githitu Njuguna	UNEP

*Meeting chaired by Andrew Gemmell

To provide an indication of the capabilities and potential support able to be offered by the WWQA, there were presentations from EOMAP, RUB and UFZ.

Ilona Bärlund gave an overview on the UNEP 2013-2016 WWQA pre-study, the triangle approach (combining data from in-situ monitoring, remote sensing, and modelling) and the DPSIR (driver, pressures, state, impact, and response) Framework.

Jaime Rivera demonstrated how modelling can be used to determine nutrient loads at sub-catchment level. He also highlighted the importance of combining modelling with remote sensing data for better management of lakes.

Karsten Rinke showed how an open source, free one-dimension (depth) GLM model can be used to simulate lake temperature and stratification patterns. This model can also be used for linking stratification with phytoplankton dynamics, historical temperature constructions, oxygen dynamics and for climate change studies.

Thomas Heege gave an overview of EOMAP and their services. He also showed how remote sensing data on turbidity can be used for fish studies. He highlighted that remote sensing data for Lake Victoria is available since 1985. EOMAP offered to host a Webinar in the week of 27-31 July 2020 to showcase their products to interested users.

Christian Schmidt gave an overview of the GlobeWQ. He highlighted the pros and cons of the individual approaches of the triangle and emphasized how the integration of these methods is a powerful tool. The GlobeWQ project runs until 2022 and there are plans make it a long-term project.

A round table discussion was then undertaken towards agreement on the priority water quality challenges at Lake Victoria as it relates to fisheries, including Covid-19. In addition, the key research and information gaps associated with the priority water quality concerns were identified and discussed. Lastly, the way forward to assess water quality baseline and hotspots towards pilot product co-creation was workshopped.

Dr Taabu-Munyaho confirmed the lack of in-situ data. LVFO can offer temperature, pH, turbidity, oxygen, and nutrients data from fish surveys. LVFO agreed to the combination of this in-situ data with remote sensing data for the same period to gain more understanding on the lake processes. The key water quality challenges agreed upon were:

- Eutrophication (point/non-point catchment sources, riparian impacts, atmospheric deposition),
- Algal blooms (incl. cyanobacteria),
- Hypoxia,

- Siltation/turbidity affecting fish breeding.

Based on these discussions, the priority research needs as identified by the workshop participants was:

- Hotspot mapping (point/non-point) and ranking
- Land-use change and nutrient linkages
- Water quality budgeting
- Relating science with existing thematic questions (e.g. temperature/climate change)
- Lake-wide studies (spatial and temporal spread) to guide policy/management
- Other: A data sharing policy, capacity building
- ”Low-lying fruits” identified to demonstrate by end of Nov 2020 through pilot activities were:
    - Water quality budget for Lake Victoria, including load calculations (e.g. total phosphorus to the lake) and
    - Harmful Algal Blooms (forecasting and early warning system).

Through the discussions with Dr. Taabu-Munyaho, Dr Kayanda and Dr. Christopher Aura it was agreed that coastal eutrophication, because of the effect on fisheries, are examples of key water quality challenges to address. As a result, based on these identified water quality challenges it was agreed that potential water quality products and services to take forward to a bottom-up co-design process was the calculation of nutrient loads that promote eutrophication (e.g. total phosphorus) to Lake Victoria. This would be done with the aim of ranking the priority catchments contributing to eutrophication at Lake Victoria.

Dr. Christopher Aura, Dr. Anthony Taabu-Munyaho, Dr. Robert Kayanda agreed that the region was ready and interested in “North-South” relationship based on a bottom up, “Local solutions to global problems” approach to address challenges in Lake Victoria. Given the support by the representatives of Lake Victoria fisheries organisations and institutes, formal requests for collaboration were submitted to KMFRI and LVFO. This request included:

- Overview of the Africa Use Case concept and aims,
- Overview of the co-design concept (Calculation of nutrient loads that promote eutrophication (e.g. total phosphorus) to Lake Victoria. This would be done with the aim of ranking the priority catchments contributing to eutrophication at Lake Victoria), and

- Formally requested collaboration in:
    - Identifying key technical staff within your organization interested and available to collaborate with the WWQA and UNEP.
    - The provision of water quality measurements at Lake Victoria and its contributing watercourses (with data ownership retained by the data provider via data-sharing agreements).
    - Sharing key water quality projects developed or in development within the Lake Victoria Basin region.
    - Identifying and facilitating collaboration of key stakeholders associated with the Lake Victoria Basin region.

After the July 2020 workshop, letters requesting collaboration between WWQA and LVFO were sent to Dr Taabu-Munyaho (Deputy Executive Secretary of LVFO). The letters requested assistance in:

- Identifying key technical staff within the organization interested and available to collaborate with the WWQA and UNEP.
- The provision of water quality measurements at Lake Victoria and its contributing watercourses (with data ownership retained by the data provider via data-sharing agreements).
- The sharing of key water quality projects developed or in development within the Lake Victoria Basin region.
- Assistance in identifying and facilitating collaboration of key stakeholders associated with the Lake Victoria Basin region.

The LVFO then reached out to country fisheries research institute Directors at KMFRI, TAFIRI and NaFIRRI to introduce the Africa Use Case initiative. The Directors of KMFRI, NaFIRRI and TAFIRI then nominated fisheries specialists within each of their Institutions to act as focal points.

Dr. Christopher Aura of KMFRI nominated Dr. Chrisphine Nyamweya and Mr. Fredrick Guya. In addition, Dr Anthony Taabu-Munyaho as Deputy Executive Secretary at LVFO reached out to the Directors of KMFRI, NaFIRRI, & TAFIRRI, with the following nominations:

- Dr James Njiru, the Director of KMFRI nominated Dr. Chrisphine Nyamweya (thus seconding the nomination by Dr. Aura).
- Dr Ismael Aaron Kimirei, Director-General at TAFIRI nominated Dr. Baraka Sekadende , and
- Dr Winnie Nkalubo Director of Research at NaFIRRI nominated Dr. William Okello

Once these nominations were finalised on 27 August 2020, a follow-up workshop was conducted on 15 September 2020.

2.5.2. 15 September 2020

This follow-up online workshop served to introduce the WWQA members from EOMAP, RUB and EOMAP to the nominated scientists at KMFRI, NaFIRRI and TAFIRI and to start the process of agreeing on quality products and services to take the co-design process. The attendees are summarised in **Table 2-3.** The workshop objectives were to:

- Introduce the concept of the African Use Case concept as it relates to Lake Victoria
- Provide an overview of key water quality hotspots identified at Lake Victoria
- Provide examples of what can be achieved through this collaboration to address water quality hotspots
- Continue discussions on the current KMFRI, NaFIRRI, TAFIRI research areas
- Discuss how the example water quality products and services be adjusted to meet current KMFRI, NaFIRRI, TAFIRI research areas and
- To agree on the next steps towards a pilot by November 2020

The representatives on the call from the Fisheries organisations included:

- Dr. Baraka Sekadende: A Senior Research Scientist at TAFIRI, with a specialty in nutrient cycling, phytoplankton ecology, wetland ecology, and aquatic pollution.
- Dr. Chrisphine Nyamweya of the Department of Freshwater Systems Research/Limnology at KMFRI. His experience is in simulating ecosystem functioning; looking at hydrography, water circulation patterns and temperature; as well as fish stock assessments.
- Mr Fredrick Guya from the KMFRI Department of Freshwater Systems Research. His research focus in nutrient dynamics and how it effects primary productivity; with work done on pollution sources, especially Nyanza Gulf and select Kenya watercourses (including the Nyando River). Mr Guya's work has also included small water bodies in central and west Kenya (focused on nutrients and how it effects biological processes).
- Dr. William Okello: A Research Officer at NaFIRRI. He is a limnologist with a current research focus on ecological and socio-economic implications of water quality in relation to fisheries productivity in most aquatic environments in Uganda.

Table 2-3: Participants of the online workshop conducted on 15 September 2020

Name	Institution
Mr. Andrew Gemmell*	UNEP
Dr Baraka Sekadende	TAFIRI
Dr Chrisphine Nyamweya	KMFRI
Dr Christian Schmidt	UFZ
Mr Fredrick Guya	KMFRI
Dr Hartwig Kremer	UNEP
Dr Ilona Bärlund	UFZ
Dr Jaime Rivera	RUB
Dr Karsten Rinke	UFZ
Dr Seifeddine Jomaa	UFZ
Dr Thomas Heege	EOMAP
Ms Wanjiku Githitu Njuguna	UNEP
Dr William Okello	NaFIRRI
*Meeting chaired by Andrew Gemmell	

An outcome of the 8 July 2020 workshop was an agreement that the potential water quality products and services to take forward via a co-design process were a coastal eutrophication assessment and the ranking of priority catchment contributors of total phosphorus to Lake Victoria. In addition, at the 8 July 2020 workshop Dr Christopher Aura identified a research need being to relate science with existing thematic questions (e.g. changes in lake temperature linked to climate change based on spatial and temporal data). As a result, water temperature and stratification dynamics modelling was presented as an additional option to take forward to co-design during this workshop. These three examples each rely on remote sensing water quality products due to the spatial and temporal gaps in the Lake Victoria water quality data.

The workshop reiterated that the examples of the water quality products and services provided are examples that can work towards addressing the key water quality challenges and research needs as identified by the Fisheries institutes.

To highlight the capabilities and offerings of the WWQA representatives from EOMAP, RUB presented. Specifically Dr Jaime Rivera of RUB presented on Lake Victoria coastal eutrophication model driven analysis. Dr Karsten Rinke showed how an open source, free one-dimension (vertical gradient) General Lake Model (GLM) model can be used to simulate lake temperature and

stratification patterns, using Lake Victoria as an example. Dr Thomas Heege gave an overview of EOMAP and their satellite-based water quality measurements. Dr Christian Schmidt gave an overview of the GlobeWQ.

There was then a round-table discussion on the current research being undertaken at the Fisheries institutes. This can be summarised as:

1. Dr Okello outlined the ecological and economic implications due to water quality and fish habitat degradation in Lake Victoria and elsewhere in Uganda. Dr Okello continued that while Kenya undertakes routine temperature monitoring, this is not undertaken to the same degree in Uganda due to limited resources. Further, past studies generated data but this is not available/missing. As a result, data is limited to coastal zone measurements from 2008-2010. Dr Okello thus welcomes the use of models, calibrated with Kenya data, to provide indications of the Ugandan temperature trends, as well as eutrophication and algal blooms. Dr Okello continued, stating that anecdotal evidence indicates an improving water quality, and without in situ data there is value in remote sensing and modelled data to verify this improvement.
2. Dr. Chrisphine Nyamweya continued, stating that KMFRI have high temporal resolution (up to weekly for up to 20 years) at select sites. KMFRI also have annual physico-chemical parameters from across the Lake measured during surveys. KMFRI collect water quality data in vicinity of aquaculture cages, serving as a useful indicator of aquaculture impacts.
3. Dr. Baraka Sekadende added that TAFIRI is undertaking water quality monitoring; however, this is not continuous. TAFIRI have some data which can be shared; however, they need to know the modality of sharing as well as the data sharing policies. Regarding the data sharing policies, Andrew Gemmell clarified that the limitations to data sharing were noted as part of past workshops and that these can be addressed using the method as used by GEMStat, where various levels of data sharing can be specified by the data providers (from open sharing, to limited only to this forum) to respect the data providers and data sensitivities.
4. A further question posed by Dr Sekadende was regarding what algorithm was used by EOMAP to differentiate algal blooms and macrophytes. Dr Heege responded that above-water plants have a different signal compared to underwater chlorophyll and phytoplankton; hence, different algorithms are used. Dr Sekadende stated that she expects to see no severe turbidity and total suspended matters at the offshore part of Bukoba and asked what the interpretation of this output may be. Dr Heege responded that turbidity is provided on the portal, but suspended matter is not measured but can be added as a calibrated relationship. Dr Chrisphine Nyamweya added that this might be attributed to inflow from River Kagera. Dr Sekadende asked if there is any means of characterising different kinds and causes of water turbidity. Dr Heege offered a 15-30 minute exercise as part of a separate session to work together to assess the causes of turbidity.

Andrew Gemmell asked how the example water quality products and services presented tie in with the current research being undertaken at KMFRI, NaFIRRI and TAFIRI. Fredrick Guya stated that the Lake Victoria residence time is about 23 years and that beside pollution loading from exogenous sources, nutrients are also remobilized from the bottom sediments. Mr Guya asked how long these nutrients can impact the water quality. Dr Karsten Rinke answered that based on his speculation, the internal loading at the lake is important and that the remobilisation of nutrients from these sediments is an important source, adding that sedimentation is an important process of nutrient removal, and that he speculates that this is low but needs in situ verification. Mr Guya added that stratification is broken between June and August, where nutrients are re-mobilised into the column and that this needs further research to confirm the residence time. Dr Heege answered that EOMAP can look at past turbidity and eutrophication data and how these change over the last one to two decades. Dr Rinke elaborated that the mixing of the lake should bring a pulse of

nutrients up into the productive zone; however, this process is not easily observed and that his opinion the eutrophication is driven more from the coastal zone of Lake Victoria rather than the central water body. Dr Rinke stated that analysis of sediments obtained from the lake by UFZ is underway and offered a linkage to a post-doctorate student looking at the results.

Andrew Gemmell asked what in situ data related to water quality and temperature is available, including nutrients from the contributing catchments. Dr Nyamweya stated that KMFRI has survey data (sometimes profile, sometimes surface water quality data). The sharing of this data depends on the institution, but from KMFRI this should not be a problem due to permissions granted by Dr Christopher Aura. Dr Sekadende stated that from TAFIRI, they have oxygen, temperature, conductivity, turbidity data and some nutrient data that can be shared. However, as stated previously, before this can be done TAFIRI needs to be informed of the mechanism of sharing and the data sharing policy.

Based on the discussions, it was agreed that the examples of Lake Victoria water quality products and services to take forward to a co-design process were:

- A coastal eutrophication assessment;
- Ranking priority catchment contributors of total phosphorus to Lake Victoria;
- Water temperature and stratification dynamics modelling
- All of which are supported by remote sensing water quality products

Andrew Gemmell repeated the objectives of this process, a bottom-up co-design process at scale to find local solutions to global problems and that key is the in-country input in this process, building on the examples of water quality products and services presented.

2.6. Co-Design of Water Quality Products and Services

The water quality data and information products and services agreed to be co-developed by the riparian fisheries organisations (KMFRI, TAFIRI, NaFIRRI) and WWQA (primarily EOMAP, RUB, UFZ) were a coastal eutrophication assessment; water temperature and stratification dynamics; and sediment chemistry. This co-design process was undertaken between September 2020 and April 2021 (end of contract).

2.6.1. Coastal Eutrophication

Available data sources are being assessed to indicate the potential of coastal eutrophication, including the identification of hot spots and potential seasonal patterns. This demand-driven tool is being co-developed by the riparian fisheries organisations and WWQA representatives to characterise the potential of algal blooms to impact fisheries or to identify potential links between aquaculture and coastal eutrophication. This includes the joint use of:

- Remote sensed earth observation (provided by EOMAP), incl. turbidity and chlorophyll-a values for the Lake.
- Water quality modelling to determine total phosphorus inputs into the lake from identified sources such as the domestic sector, agriculture, background loadings etc. (provided by Ruhr-University Bochum, Germany).
- In-situ measurements provided to date (river/lake measurements of nutrients such as nitrate, phosphate etc.) via GEMStat and in-country partners. This information is being used to validate the model and RS/EO data.
- Outcomes envisioned include the identification of nutrient hotspots, their drivers, and their temporal and spatial dynamics (Figure 2-4 and Figure 2-5) so that priorities can be defined, and potential management strategies can be efficiently directed. Further, scenario

modelling can be used to evaluate the effectiveness of a wide range of management alternatives.

- Preliminary Results:
  - Mayor total phosphorus contributors are organic and inorganic fertilizers. Background loads and the domestic sector are more relevant in the sub-basins on the east side.
  - Considering the dominant sources, i.e. organic and inorganic fertilizers, erosion becomes a key pathway. Total phosphorus hotspots are defined by the interplay between nutrient input, runoff, and erodibility.
  - Drivers of eutrophication vary within the lake depending on several morphological, hydrodynamic, hydrological, and anthropogenic factors.
  - The triangle approach exploits complementary information from remote sensing, modelling, and in-situ data for modelling validation and identification of pollution hotspots, its drivers, and potential management strategies.

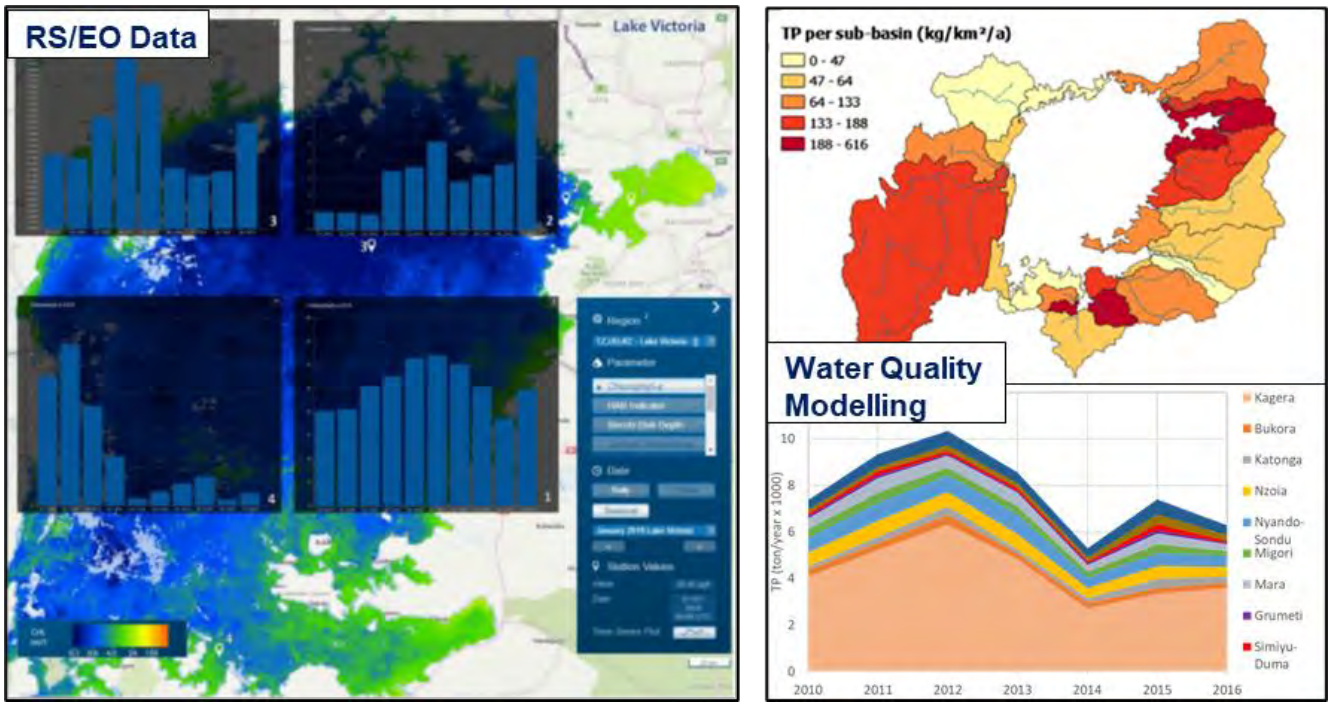
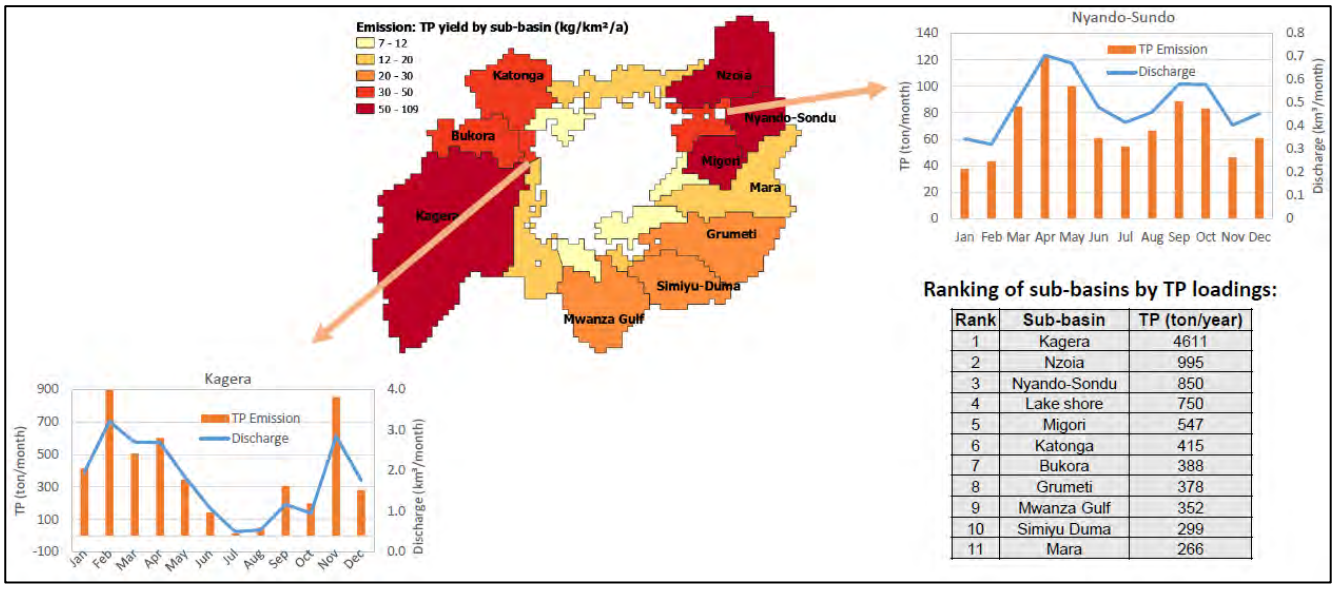


Figure 2-4: Examples of available data sources to complement in-situ data, showing time-series of chlorophyll-a (used with permission of Heege 2020, Lake Victoria time series (http://sdg6-hydrology-tep.eu, data available up to daily from September 2020 onwards) and total phosphorus loadings modelled from main sources (industrial fertilizers, manure, geogenic background, and the domestic sewered sector) per lake sub-basin (used with permission of the Chair of Engineering Hydrology and Water Resources Management at Ruhr University Bochum).



Rank	Sub-basin	TP (ton/year)
1	Kagera	4611
2	Nzoia	995
3	Nyando-Sondu	850
4	Lake shore	750
5	Migori	547
6	Katonga	415
7	Bukora	388
8	Grumeti	378
9	Mwanza Gulf	352
10	Simiyu Duma	299
11	Mara	266

Figure 2-5: Total Phosphorus contributions per Lake Victoria sub-basin (used with permission of the Chair of Engineering Hydrology and Water Resources Management at Ruhr University Bochum)

2.6.2. **Water temperature and stratification dynamics**

Monitoring activities by different research institutions of the adjacent countries generated a valuable record of water temperatures in Lake Victoria over the past years; including data jointly collected by TAFIRI, NaFIRRI and KMFRI under the coordination of LVFO which has been shared with the WWQA. The aim is to use a freely available lake model (GLM 3.1, General Lake Model, **Figure 2-6**) to simulate temperature dynamics in Lake Victoria to inform the extent of stratification and vertical mixing in the water column (an example for Lake Victoria shown in **Figure 2-7**).

At the same time, this initiative brings together monitoring results from different countries and institutions and generates not only the required data for the modelling but also provides data for many other applications in research and development.

The GLM has the following model inputs:

- Lake bathymetry
- Starting temperature profile
- Meteorological input data (taken from ERA5 reanalysis)
    - Air temperature
    - Wind speed
    - Humidity
    - Cloud cover
    - Solar radiation
- Inflows/Outflows (here assumed as zero)

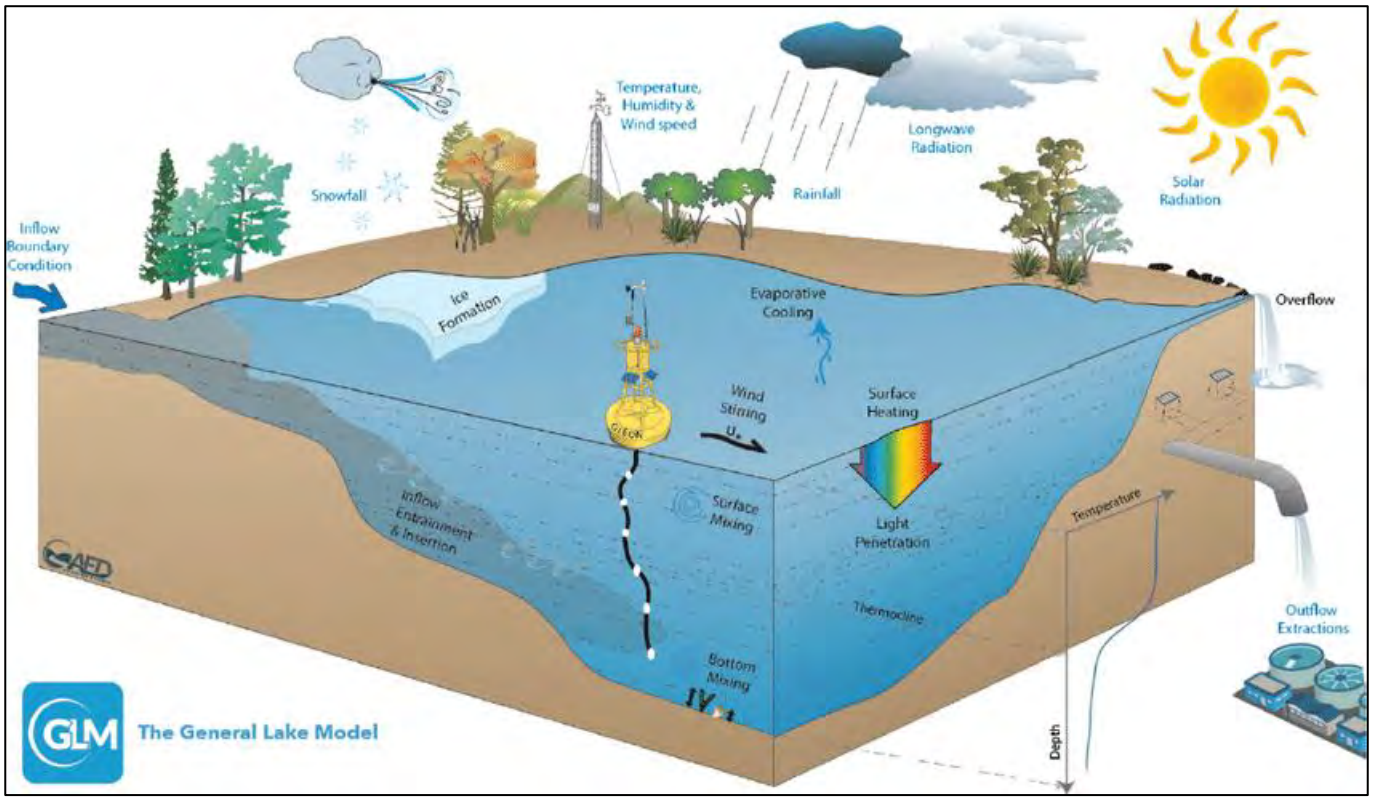


Figure 2-6: Conceptual model of the General Lake Model (adapted from Hipsey et al., 2014), illustrating the effects of exogenous drivers on lake physical processes

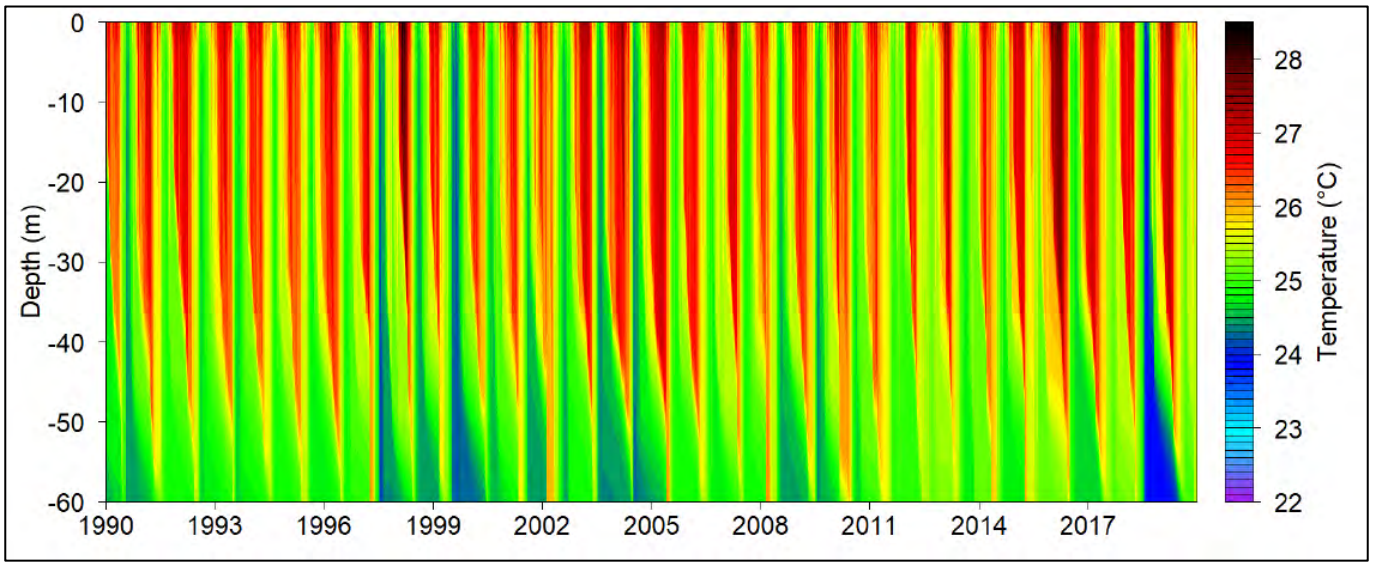


Figure 2-7: The contour graph shows water temperatures (coloured contour, scale see right hand side) over depth (y-axis) and time (x-axis) simulated by Dr Chenxi Mi of UFZ using the one-dimensional lake model GLM (Hipsey *et al* 2019). The model is driven by meteorological data taken from the EWEMBI-dataset (Lange, 2019) and model outputs represent the temperature dynamics at the deepest point of the lake.

The following research topics are being targeted by the Helmholtz Centre for Environmental Research (UFZ) and LVFO:

- Model-based reconstruction of water temperatures of Lake Victoria over the past 30-years at daily resolution
- Water temperature projections for Lake Victoria until 2100 based on different climate scenarios (Representative Concentration Pathway (RCP) 2.6, RCP 6.0, RCP 8.5)
- Potential effects of water temperature dynamics and mixing events on phytoplankton dynamics (derived from satellite-based remote sensing provided by EOMAP)

2.6.3. **Sediment chemistry**

UFZ has offered to collaborate with KMFRI on collected sediment chemistry, water profile physico-chemical quality parameters in the Nyanza Gulf (Kenya) and sediment and water samples near Kampala, Uganda. There is a potential for the joint assessment of sediment release of nutrients, turnover, and indication through algae blooms obtained from remote sensing (EOMAP). Discussions are on-going.

3. VOLTA RIVER BASIN

This section provides a summary of the literature review on the Volta Basin water quality challenges, outcomes of the stakeholder identification process, a summary of data availability associated with water quality, a summary of the stakeholder engagements, the identification of water quality products and services to potentially take forward to co-design between WWQA representatives and in-country partners.

3.1. Literature Review

3.1.1. Current Water quality challenges

3.1.1.1. Poor sanitation

Access to adequate sanitation is a problem for many populations within the Lake Victoria basin. Rural households mainly depend on individual or communal latrines or defecate openly in nearby bushes or riverbanks. Untreated sewage is discharged directly into the environment in larger cities such as Ouagadougou, Bobo Dioulasso, and Abidjan. In Ghana, national assessments identified 70 decentralised wastewater and faecal sludge treatment plants serving less than 10% of the urban wastewater volume, and of these, only 13% were still operating (UNEP, 2016).

This problem is exacerbated by extensive livestock production, which is a major economic activity in various parts of the basin. This results in bacteriological contamination in the watercourses (Abdul-Razak, 2009; Samah, 2012) increasing the risk of acquiring decreases such as diarrhoea. Waterborne diseases are a threat to the rural communities, with a significant contribution to the 2012 mortality rates of children aged less than 5 years in Benin (10%), Burkina Faso (11%), Ghana (7%), Côte d'Ivoire (10%), Mali (12%), and Togo (9%) (UNEP, 2016).

The faecal contamination of water in the Volta basin has important implications for urban and rural water supply. The Volta Lake, for example, is a water reservoir for large cities such as Akosombo; and rural communities depend directly on the surface water as they tend to have less access than urban communities to potable water from boreholes, pumps, or piped water taps. Burkina Faso and Ghana have a largely rural population. As a result, only 37% (in Burkina Faso) to 62% (Ghana) of households have access to safe drinking water. Even where there is access, many still prefer and continue to use untreated water from the river due to quality perceptions and opportunity costs (UNEP, 2016).

Faecal coliform levels are consistently above WHO guidelines for drinking water with levels in the Asukawkaw River for March-June 2012 contributing about 40 % to the total volume of the Volta Lake. In Mali and Burkina Faso, surface water quality is poor with numerous coliform and bacillus bacteria. Further, in the Sourou Valley in north Burkino Faso shallow wells that are a preferred source of drinking water are highly polluted with coliforms (UNEP, 2016).

Contaminated water also has implications for aquatic organisms such as clams, a common and inexpensive source of protein and livelihood for the communities at the Volta estuary. This is due to a clam's capacity to accumulate up to five times the bacterial load in the surrounding water, through its filter feeding activities. The evidence of high microbial contamination of fish caught in polluted waters, making it unsafe or undesirable to eat (UNEP, 2016).

The concentration of faecal coliforms can be influenced by seasonal changes, with high contamination levels at the onset of heavy rains where runoff carries raw sewage and leachate from waste dumping sites into the water bodies (UNEP, 2016).

3.1.1.2. Mining

Small scale gold mining in Ghana (locally called 'galamsey') has become a major contributor to the economy since its legalization in 1989. However, chemicals, especially mercury, from the mining process impacts surface water resulting in water bodies that were once main sources for drinking water now being heavily polluted (Owusu, 2016).

Gbogbo et al., (2016) reported mercury levels in Volta River Basin waters are higher than the WHO drinking water limit of 0.006ug/ml (World Health Organization, 2005). This results in fish, crustaceans and molluscs with mercury levels exceeding the limit set by the Commission Regulation-European Commission for fishery products, muscle meat of fish, and crustaceans.

3.1.1.3. Industrial effluent

One of the major sources of pollution in the Volta basin is industrial waste. A survey of manufacturing industries in the Greater Accra Region showed that the metal industry creates 16% of the total industrial waste, garment and textiles 30%, chemicals and cosmetics 20%, electricals and electronics 1% and mineral products 0.7% (Boadi and Kuitunen, 2002). Examples of waste include detergents and other cleaners – which contain phosphorus, thus promoting algal growth; chemicals and compounds from asbestos sludge; dyes, spent fuel from garages, etc.

3.1.1.4. Agricultural runoff

Farming is one of the main livelihoods within the Volta basin. However, intensive agriculture and the use of pesticides and fertilizers increases these potential pollutants within the Volta basin (Bobobe et al., 2012). High nutrient loads from agricultural sources occur in specific locations such as cotton, sugar cane, or commercial oil palm plantations (UNEP, 2016).

3.1.1.5. Aquatic Alien Plants

Over the last few decades, pervasive water weeds have been a problem for rivers and lakes within the basin. In Ghana, this is a problem which has also been exacerbated by the building of dams, which lead to a proliferation of weeds in the lakes created from the damming process, as well as the rivers up-stream and downstream of these lakes (Gordon and Amatekpor, 1999).The Black and White Volta Rivers have been reported to be infested by the water hyacinth, which also threatens infestation of the Lake Volta in Ghana.

The weeds negatively impact water transport; hydro-power generation; water flow; crop irrigation; aquatic life and can increase in diseases such as malaria and bilharzia (Aloo et al., 2013)

3.1.2. Potential future water quality challenges identified

As in many other countries across the globe, climate change has had negative impacts on Ghana, with research showing increased evaporation, decreased and highly variable rainfall pattern, and frequent pronounced flood and drought situations. This rainfall pattern is regarded as the main cause for declining lake levels in the Volta basin above the Akosombo Dam for example (Owusu, 2008).

In a 2009 review paper, Delpha *et al*. discussed the impacts of climate change on surface water quality in relation to drinking water production. Some of the impacts of climate change related temperature increases on water quality parameters discussed were:

- Increases in pH
- Lower dissolved oxygen

- Increase in mineralization and release of nitrogen, carbon and phosphorus from soil
- Increased rate of pollutant uptake due to an increased metabolic rate and decrease in oxygen solubility, etc.

These changes will lead to problems such as the fuelling of phytoplankton growth and subsequent algal blooms and a deterioration in water quality. It has also been shown that micropollutants, dissolved organic matter and pathogens are susceptible to rise because of temperature increases, thus adversely affecting the quality of drinking water. Rainstorm events will also lead to elevated levels of turbidity and organic matter found in river waters which cause deterioration in treatment performance.

Population increase and urbanization pose a threat to the water resources within the base. Growing demand for water means that supplies will be severely stretched, and pollution problems and environmental degradation are likely to increase. This situation will worsen as the population continues to grow, urbanization increases, standard of living rises, mining becomes widespread and human activities are diversified (Andah et al., 2003).

In the White Volta Basin, many farmers are converting their croplands (especially yam) to cassava production. Although these kinds of landscape changes are unavoidable due to population increases and industrialization, they will affect the hydrology and water quality in a watershed. This is because the types of ground cover and surface debris, evapotranspiration, infiltration, erosion, and sedimentation will be changed, thereby affecting not only the total quantities of pollutant loads but also the transport pathways of pollutant inputs (Awotwi et al., 2016).

3.2. Stakeholder Identification

. Requests for stakeholders and/or data for the Use Cases were sent to WWQA members. Using the contact details received, these stakeholders identified by WWQA members were then in turn also contacted requesting both data and any additional stakeholders, which continued as an iterative process. In addition, a thorough literature review of stakeholders and data was conducted. Through this process, available data (in-situ, modelled, RS/EO) for the Use Cases was collected and shared with the WWQA triangle partners (EOMAP, Helmholtz Centre for Environmental Research, and Ruhr University Bochum). In addition, a database of stakeholders and their interest in collaboration was developed, shared between WWQA members, and enhanced throughout the project.

Stakeholders identified through feedback from the WWQA, as well as through the stakeholder engagement process (both online and in-country) are summarized in **Annex A**. This includes the stakeholder details (name and contact details) as well as a summary of their proposed input to the Use Case. Stakeholders are divided into research, government, and non-governmental/inter-governmental organization. The key in-country stakeholder engagement undertaken is summarized below.

3.2.1. Conference on Climate Resilience and Waste Management for Sustainable Development (CReWAS), Accra, Ghana

Andrew Gemmell and Kornelius Riemann attended the Conference on Climate Resilience and Waste Management for Sustainable Development (CReWAS), organized by the University of Ghana Institute for Environment and Sanitation Studies (IESS), in collaboration with Worldwide Universities Network (WUN) on 16 – 17 October 2019 at the University of Ghana in Accra.

Key outcomes where an improved understanding of the water quality challenges in the Volta River Basin, especially related to solid and liquid waste management in Ghana.

Potential solutions to the solid and liquid waste impacts discussed included better adoption of a circular economy, better waste handling (e.g. segregation), improved solid waste recycling/re-use and associated education and incentives, improved local traditional knowledge and practices, as well as better government support towards waste collection and recycling.

Since individuals from various organizations attended the conference, this was a useful opportunity to discuss the WWQA and Africa Use Cases towards developing a stakeholder network and assessing data sources and types associated with the Volta River Basin (summarized in **Annex C**).

3.2.2. Africa Geospatial Data and Internet Conference (AGDIC), Accra, Ghana

From 22 – 24 October 2019 Andrew Gemmell attended the Africa Geospatial Data and Internet Conference (AGDIC) in Accra, Ghana. Below are the key observations made.

The Ghana Water Company (represented by Maxwell Akosah-Kusi) presented on urban water supply, including automatic water quality monitoring at the production sites. As noted by Andrew Gemmell, there is a high use of bottled and sachet water in Accra due to concerns of reticulated water quality leading to a high level of plastic waste generated. Maxwell stated that the water meets WHO standards, with sachet water often comprising un-treated tap water. This highlighted the need for better education on water quality and home storage solutions to limit contamination of water containers.

Ivy Gladys of the Ghana Ministry of Sanitation and Water Resources presented on sanitation, with mention of BaSIS (Basic Sanitation Information System). This is a decentralized monitoring and evaluation sanitation system developed to aid in the implementation of the Community-Led Total Sanitation (CLTS) at both sub-national and national levels in Ghana. The system is built to populate data collected from approved sources based on some sanitation index in the form of maps, charts and tables.

Since various individuals from various organizations attended the conference, this was a useful opportunity to discuss the WWQA and Africa Use Cases towards developing a stakeholder network and assessing data sources and types associated with the Volta River Basin.

Since the conference was focused on geospatial data, there were numerous opportunities to engage with potential data providers, including SERVIR, the Africa Regional Data Cube, and Digital Earth Africa.

3.2.3. Water Resource Commission, Accra, Ghana

On 24 October 2019 Andrew Gemmell met with Mr. Ben Yaw Ampomah, the Executive Secretary of Water Resources Commission at their offices in Accra, Ghana. The objective was to discuss the WWQA, the Africa Use Cases, and invite collaboration on the Volta Use Case. Mr Ampomah and his colleagues were interested in the initiative and discussions are ongoing towards collaboration.

3.3. Data availability

This section outlines the data that has been identified to data for the Volta Basin. This includes data identified via a literature review, as well as through engagement with the Alliance members and in-country stakeholders. This is tabulated in **Annex C**.

3.3.1. In-situ measurements

3.3.1.1. Literature Review

A 2007 study by Quansah *et al.* applied GIS techniques to map in situ water quality data from the Lower Volta. The collected samples were analysed for temperature, pH, conductivity, turbidity, hardness, total dissolved solids, nitrate, ammonia, phosphates, iron and faecal coliforms. These were digitally mapped to show spatial variability of water quality along the sampling locations.

3.3.1.2. Engagement with Stakeholders

The Institute for Environmental and Sanitation Studies (IESS) at the University of Ghana (as provided by Mr. Peter K. Osei-Fosu of IESS) has undertaken various studies within the Volta Basin. Information is available for transboundary environmental, governance and climate change issues in the Volta Basin. In addition, data is available for:

- Nutrient loading of the sediment and water column in the lower Volta;
- Land-use impacts on water quality in the Volta Basin;
- Environmental quality for aquaculture production, including nutrient inputs, nano-level concentrations of harmful substances such as bacteria, biocides and antimicrobials in sediment, water column and effluent samples.

Prof. Christopher Gordon of the IESS at the University of Ghana advised of the GLOWA Volta Project. This was a project which aimed to develop a framework for water resources decision-making and scientific capacity building in a transnational West African Basin (Van de Giesen et al., 2007). The project had three phases:

- Phase I: the collection of basin data
- Phase II: modelling activities
- Phase III: integration of Phase I and II outputs.

The collection of data associated with the GLOWA Volta Project included climatic, hydrologic, environmental and socioeconomic data, which are scarce within the Volta Basin. Focused studies, many conducted by Ph.D. trainees from the Volta region, attempted to bridge gaps in spatial and temporal scales as solutions to the problems of data scarcity.

The NASA GLOBE[8] program serves as a potential source of useful citizen science data.

3.3.2. Water quality modelling

3.3.2.1. Literature Review

Limited water quality modelling data is available across the Volta basin. Awotwi et al., 2016 published a study on the water quality changes associated with Cassava production in the White Volta basin using an interface between ArcGIS and SWAT (soil and water analysis tool). The tool was used to assess the likely hydrologic and water-quality response of increasing cassava production, with reference to nutrient (total nitrogen, total phosphorus) and sediment levels.

[8] https://www.globe.gov/

3.3.2.2. Engagement with Stakeholders

Phase II of the GLOWA Volta Project focused on modelling activities. Mesoscale climate models were successfully linked with physical hydrology models (WaSIM-ETH) at catchment, tributary and full basin scales. Numerous anthropologic and socioeconomic studies were successfully completed, creating databases from which a range of household models of socioeconomic behaviour were identified (Van de Giesen et al., 2007).

3.3.3. Earth observation/remote sensing data

3.3.3.1. Literature Review

Ghansah et al., 2016 mapped the spatial changes in Lake Volta using a remote sensing approach. The authors looked at Landsat imagery of the lake for the years 1990, 2000 and 2002, which showed that the area of the lake increased from 1990 to 2000 and decreased from 2000 to 2002. The authors also suggest that this method can be used to demarcate buffer zones around the lake, which would be useful to minimize the influx of solid waste into the lake, as well as maintaining its water quality.

Various sources of remote sensing data exist, including:

- The USGS Global Visualization Viewer (GloVis)
- NOAA (National Oceanic and Atmospheric Administration) Class

3.3.3.2. Engagement with Stakeholders

As discussed in Chapter 2 the ARDC is a tool that harnesses the latest EO data and satellite technology to help various countries, including Ghana address various issues relating to agriculture, food security, deforestation, urbanization, water access, and more. Kenneth would benefit from datasets in-situ datasets to validate EO data, including the NASA Ocean Colour Chlorophyll-A OC3 Algorithm for Lake Volta (Ghana) and Weija Reservoir (Accra).

SERVIR Global has the SERVIR Global Service Catalogue, a searchable collection of demand-driven geospatial services that use Earth observations to support decision making and resilient development, including in Water and Water Related Disasters. This includes the monitoring of galamsay activities in Ghana, with information on the location of illegal mining sites across Ghana and their associated land degradation.

Kerstin Stelzer of Brockmann-Consult advised that Lake Volta has been included int the CGLOPS Data set, with time series and maps available for chlorophyll-a and total suspended matter (TSM). However, it needs some data handling to get the information out of the global products to perform analyses for individual lakes.

Thomas Heege of EOMAP provided feedback that EOMAP can share UNESCO world water quality data[9] over Africa. In addition, EOMAP can share the eoLytics tool which enables countries / organizations to produce for water quality monitoring with selectable time frame, resolution, frequency. Further, EOMAP has other earth observation water quality data as well online and free on other portals which can be shared including two web applications with free data available[10][11]

Steve Greb of the University of Wisconsin-Madison Aquatic Sciences Center and Space Science

[9] www.worldwaterquality.org
[10] https://eoapp2.eomap.com/
[11] https://eoapp.eomap.com/

and Engineering is open to collaborate, especially earth observation data. GEO AquaWatch is building a global WQ monitoring service, merging in situ and remote sensed data.

3.3.4. Others

Josiane Nikiema (IWMI-Ghana) states that IWMI and the other CGIAR organizations are currently working on a platform for data sharing (waterdata.iwmi.org).

BaSIS - Basic Sanitation Information System. This is a decentralised monitoring and evaluation sanitation system developed to aid in the implementation of the Community-Led Total Sanitation (CLTS) at both sub-national and national levels in Ghana. The system is built to populate data collected from approved sources based on some sanitation index in the form of maps, charts and tables.

3.4. Stakeholder Workshop in Accra, Ghana

An Expert Consultation Workshop was organised to take place in Accra, Ghana from 25-27 February 2020. The objective of the workshop was to initiate a long-term collaborative network of stakeholders and WWQA members associated with the water quality of the Volta Basin that work to define in-country water quality hotspots and solutions.

3.4.1. Workshop Organisation

3.4.1.1. Logistics

Workshop logistics were arranged by Andrew Gemmell and Dr Kornelius Riemann, with the help of the Institute for Environment and Sanitation Studies (IESS) at the University of Ghana. The institute is well respected in the region for their research on water resources, including water quality. As a result, their involvement was critical in promoting collaboration on the Africa Use Case concept in the region.

An invitation list was developed by Andrew Gemmell and Dr Kornelius Riemann and IESS. Ghanaian participants were then invited to attend by IESS through telephone calls followed by invitation letters and e-mails. International participants were invited by Andrew Gemmell and Dr Kornelius Riemann via email. The organisation invitation list is summarised in Table 3-1.

Table 3-1: Volta Workshop Organisation Invitation List

• Adventist Development and Relief Agency, Ghana • AMCOW • BUI Power Authority (Ghana) • Bulk Oil Storage and Transportation Limited (Ghana) • Burkina Faso Ministry of Water, Water Resources and Sanitation. Director of Studies and Information on Water. • Burkino Faso Directorate General of Water Resources, Water Quality Service • Coalition of NGOs in Water and Sanitation • Community Water and Sanitation Agency • CSIR Water Research Institute (Ghana) • Danish International Development Agency (DANIDA) • FAO • Forestry Commission • GEMS/Water/BAFG • Ghana Environmental Protection Agency • Ghana Meteorological Agency • Ghana National Development Planning Commission • Ghana National Disaster Management Organization (NADMO) • Ghana Standards Authority • Ghana Statistical Service • Ghana Water Company Limited • Ghana Water Resources Commission	• GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) • Global Partnership for Sustainable Development Data • International Water Management Institute (IWMI) • Kwame Nkrumah University of Science and Technology • Ministry of Sanitation and Water Resources • The Development Institute • United Nations University Institute for Natural Resources in Africa • Université de Ouagadougou. URF Sciences de la Vie et de la Terre (UFR/SVT) • University of Energy and Natural Resources (UENR) • University of Fada N'Gourma (UFDG) • University of Ghana Departments of Chemistry, Earth Science, Marine and Fisheries Sciences • University of Ghana, Institute for Environmental and Sanitation Studies (IESS) • University of Ghana/SERVIR West Africa, Centre for Remote Sensing and Geographic Information Services • Volta Basin Authority • Volta River Authority • World Vision

Prior to the workshop a list of questions was sent to all invited attendees via a Google Sheet survey. This was used to get feedback from invitees who were unable to attend, as well as to get attendees to start thinking of the workshop topics. The questions included:

- What do you consider the biggest water quality concerns are in your area of expertise of the Volta basin?
- What are the water quality issues in the Volta basin that need more research and information so that informed decisions can be made?
- Who/which user groups would benefit from better data availability?
- What sorts of benefit would users derive from better data availability?
- Who are the major holders of water quality data for the Volta Basin (this could include in situ, citizen science, remote sensing, modelling data)?
- What role does citizen science play in data collection?
- List what you think are the major limitations to sharing water quality data for Volta Basin?
- What are the challenges for conducting effective research and implementation within the Volta Basin (e.g. barriers to conducting research, limited data sharing, funding, etc)?
- What are the barriers or challenges which prevent the implementation of effective water quality solutions (like wastewater collection/treatment, pollution prevention, regulation etc.)?

- Are there any opportunities to enhance effective water quality research and solution implementation?
- What water quality data repository options are you aware of to promote data sharing?
- What data and information gaps are there that need further assessment?

3.4.1.2. Attendees

The workshop took place at the Tomreik Hotel, Accra, Ghana from 25-27 February 2020. The Agenda is provided in **Annex D**. The workshop attendees are summarized in Table 3-2. Attendees included representatives from government and academia in Ghana and Burkino Faso, NGO/IGOs, and project partners (GEMS/Water and UFZ). The majority of attendees is captured in **Figure 3-1**. In addition, there was a virtual presentation by EOMAP.

Table 3-2: Attendance List for the WWQA Expert Consultation on Volta Basin Use Case (25-27 February, 2020)

Institutions	Name
AMCOW	Patricie Leumeni
Burkina Faso Directorate General of Water Resources, Water Quality Service	Ouattara Cheick
Community Water and Sanitation	Gustav M. Osiakwan
CSIR, Water Research Institute	Anthony Yaw Karikari
EPA Ghana Environmental Protection Agency	Sam Adu Kumi
GEMS/Water/BAFG	Philip Saile
Ghana Environmental Protection Agency	Helina S. Dodd
Ghana Standard Authority	Francisca Frimpong
Ghana Standard Authority	Fiona Gyamfi
Global Partnership for Sustainable Development Data	Kenneth Mubea
Institute for Environment and Sanitation Studies	Gbedze Bright Yao*
Institute for Environment and Sanitation Studies	Christian Marilyn Ama Adoma*
Institute for Environment and Sanitation Studies	Annan Eugenia Ama Akofua*
Institute for Environment and Sanitation Studies	Dordaa Sampson**
Institute for Environment and Sanitation Studies	Ted Annang
Institute for Environment and Sanitation Studies	Millicent Amekugbe**
Institute for Environment and Sanitation Studies	Dan Nukpezah
IWMI	Boamah Edward Oppong
KNUST	Kwaku Amaning Adjei
National Disaster Management Organisation	Victor Addabor
The Development Institute	Ken Kinney
UFZ	Tallent Dadi
UN RCO	Gifty Tetteh
UNEP	Kornelius Riemann
UNEP	Andrew Gemmell
University of Energy and Natural Resources	Kabobah Amos.
University of Fada N' Gommal, Burkina Faso	Ouedraogo Issoufou
Volta River Authority	Philip Tetteh Padi
Water Resources Commission	Esi Biney

* Graduate Students from IESS
** Support staff for the meeting

Figure 3-1: Workshop Delegate Photograph (Day 1)

3.4.2. Workshop Procedures and Outcomes

3.4.2.1. Objectives

The objectives of the workshop were outlined as follows:

- **Objective 1**: Enhanced understanding of the African Use Case concept. **Outcome:** An understanding of the importance and benefits of the African Use Cases, particularly Volta Basin and how the WWQA can assist
- **Objective 2**: Discuss Volta Basin water quality concerns. **Outcome:** Improved understanding of the water quality hotspots in the Volta Basin
- **Objective 3**: Determine the key water quality datasets available and any limitations to data sharing. **Outcome:** Begin process to enhance data sharing between stakeholders.
- **Objective 4**: Discuss research and information gaps in the Volta Basin. **Outcome:** Begin discussions on water quality data and information products and services to be co-developed to target hotspots.
- **Objective 5**: Initiate a bottom-up social engagement process between in-country stakeholders and WWQA **Outcome:** Supporting local solutions through global experience.

3.4.2.2. Workshop Topics

The workshop agenda is provided in **Annex D**.

- Introduction to the WWQA and the Africa Use Case initiative, Africa Use Case Work Plan and the integration of in-situ data, RS/EO and modelling.
- Discussion of issues related to:
    - Water Quality and Health/Cities
    - Water Quality and Food
    - Water Quality and Ecosystems
- Biggest water quality concerns in the Volta basin
- Issues that need more research and information for more informed decisions
- User groups that would benefit from better data availability
- Water quality data availability – who has what?
- Limitations to data sharing
- Barriers or challenges which prevent the implementation of effective water quality solutions
- Challenges and opportunities for effective research and implementation
- Presentations/overview of:
    - In-situ and citizen science data
    - Water quality modelling
    - Earth observation remote sensing
    - Water quality databases
    - Other data repository options
- Introduction to water quality data and products. Discussion on objectives and requirements for data and information products and services to be developed.
- Discussion on how to promote bottom-up social engagement process between in-country stakeholders and WWQA
- Discussion on best forum to discuss possible products/services
- Discussion on missing role-players to be included going forward

3.4.2.3. Water Quality Concerns

A panel discussion was held to workshop the water quality concerns In the Volta River Basin. To guide the session, the discussions included the interaction of water quality with Health/Cities, food and ecosystems. The discussion was facilitated by Prof. Christopher Gordon of the IESS, University of Ghana. The Panel comprised representatives from the following organisations and institutions:

- Ghana Council for Scientific and Industrial Research (CSIR) Water Research Institute (WRI)
- Water Resources Commission of Ghana
- Volta River Authority

- Ghana Community Water and Sanitation Agency
- Burkino Faso Directorate General of Water Resources
- University of Fada N'Gourma

The water quality concerns are summarised below:

- There is still a reliance on open defecation in Ghana. This results in elevated bacteriological loads to watercourses. Further, in both Burkina Faso and Ghana it was noted that there was impacts to water quality from bacteria due to sewage contributions to watercourses from insufficient or lacking formal sewage systems.
- There are geogenic sources of elevated iron, manganese, arsenic and fluoride (towards the north of the basin) in the environment.
- There is a reliance of the Ghana Community Water and Sanitation Agency on the treatment of groundwater for potable use. Where groundwater is of non-potable quality, they cap boreholes. However, there are options to treat impacts (e.g. elevated iron and manganese) without ceasing well use.
- Water is sometimes stored in open containers at households, leading to water contamination and health impacts.
- Salinisation and salt-water intrusion in coastal zones and in the drier northern portions of the basin.
- Desalination is used in some coastal areas, with it noted that boron levels can be elevated.
- There is a movement of communities into the watercourse buffer zones in Ghana. This includes communities living below the high-water mark of the Volta Dam. This leads to water quality impacts during high-flow periods (e.g. open defecation leading to elevated bacteriological loads). This is compounded by climate change (reduced rainfall) and watercourse siltation.
- Water-side markets were noted to have elevated microbial pollution. In addition, runoff of fish waste leads to decomposition and anoxia. This is especially prevalent in Lake Volta.
- Plastics and micro-plastics, especially in the lower Volta basin.
- Agriculture, leading to nutrification of watercourses through over-fertilisation. This includes farms within river floodplains.
- Burkina Faso noted water quality impacts from tanneries in operation.
- There is an increase in water hyacinth in watercourses which impacts water quality (e.g. decomposition) and aquatic health. There is a need to monitor the spread of invasive aquatic plants.
- Various water quality impacts were noted as a result of informal (galamsey) and formal mining. This includes elevated levels of cyanide, mercury, lead, arsenic. Mining also was noted to result in acid mine drainage, with groundwater and surface water impacts. Surface water impacts such as turbidity due to sand winning.
- There are impacts to water quality from aquaculture, including from over-feeding and from feed containing antibiotics; having impacts to wild fish. In addition, there are impacts to aquaculture from poor water quality. It was noted that improved understanding on eco-toxicity impacts is required.

3.4.2.4. Issues that need more research and information for more informed decisions

Open discussions were held to share what issues the workshop attendees understood to require more research and information to be able to make more informed decisions on water quality. The identified issues are summarised below:

- Security of sampling in high-risk zones
- Mining impacts, including cross-border impacts and the extent of impacts
- Epidemiology, toxicology and eco-toxicology
- Bio-indicators
- Contaminants of Emerging Concern (CECs)
- Micro-plastics and impacts
- Regular water quality monitoring (temporal & spatial)
- How to assess data quality and reliability
- Laboratory accreditation and inter-lab accreditation
- Artificial intelligence and assessment of lab quality
- Standardisation of lab equipment and methods (via a standards authority)
- Lab technician training and capacity building
- Water quality standards specific to country
- Land-use/land-cover change and impacts to aspects such as water quality linkages, and groundwater recharge
- Re-forestation and water quality improvement
- Sedimentation (e.g. reservoirs)
- Changes to water availability for drinking supply. Surface water volume estimations. Assessment of the location and volume of groundwater resources
- Saline intrusion, including impacts due to coastal zone abstraction (e.g. for agriculture use).
- Climate change and water quality
- The Volta Lake trophic state (meso- or eutrophic?)
- Groundwater governance
- Economic valuation of water.
- Affordable water quality testing techniques in-country
- Improvement in the art of data visualization to make science more understandable and engaging.
- Disaster risk, including from early warning to last line of reporting
- Risk assessment: source-pathway-receptor linkages
- Water treatment of natural and anthropogenic impacts using local water supply and materials (as opposed to piped water)
- Impacts of on-site sewage treatment systems on groundwater (e.g. soakaways intercepting the water table)

- Ecological water flow requirements
- Nature based solutions to improve water quality and water quantity.
- Phytoremediation (e.g. of mining impacts)
- Plant based water treatment methods (e.g. Moringa being having anti-microbiological action and assisting in coagulation).
- Desalination as an option for water supply.

3.4.2.5. User groups that would benefit from better data availability

Open discussions were held to share opinions on which user groups would most benefit from an improvement in water quality data availability. These users were identified (in no particular order) as:

- Agriculture extension officers
- Government decision-makers regarding cross-boundary impacts
- Water regulators and researchers
- Developers of water quality standards
- Media to sensitize audience on water quality challenges
- District-level decision makers
- Aquaculture farmers (inland fisheries)
- Ghana Water Company
- Policy makers
- NGO's
- Health centres
- Community Water and Sanitation Agency
- Laboratories
- Borehole drillers
- Gender and the access/selection of water sources
- Global data repositories, local data repositories

3.4.2.6. Volta Basin Water Quality Data Holders and Providers

Through open discussions with the workshop attendees, the primary water quality data holders and providers within the Volta Basin were identified. These are summarised below:

- Burkina Faso:
  - Directorate General of Water Resources
  - Irrigation Development Authority
  - Ministries of Water and Sanitation
  - National agencies of water
  - National Laboratory for Water Analysis

  - West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL)
  - Niger Basin Authority (NBA)
  - National Office for Water and Sanitation
- Ghana:
  - CSIR-Water Research Institute
  - Environmental Protection Agency
  - Hydrological Services Department
  - Ghana Water Company Limited.
  - Community Water and Sanitation Agency
  - Water Research Institute
  - Water Resources Commission
  - Volta River Authority
  - The German Federal Ministry of Education and Research program “Global Change and the Hydrological Cycle” (GLOWA).
  - National Disaster Management Organisation.
- International Institute for Water and Environmental Engineering (2iE)
- Water drilling companies
- NGO’s
- AMCOW, including a data officer (quality)
- Citizen science
- Hydro power generators
- Public and private laboratories
- Universities
- Volta Basin Authority

3.4.2.7. Data Repositories

The available data repositories were discussed and summarised. In addition, based on feedback from stakeholders both before and after the workshop, other available data repositories were identified. These are all summarised as follows:

- Ghana Central Intelligence Agency (CIA)
- International Atomic Energy Agency (i.e. isotopes)
- Data repositories maintained by Ghana Water Resources Commission
- Volta Basin Information Sharing System (VBISS).
- IUCN Central and West Africa Programme (PACO)

VOLTA

- http://gefvolta.iwlearn.org/project-resources/studies-reports/tda-final/regional-tda/volta-

basin-tda-english GEF-Volta Project, with water quality descriptions, as well as tabulated results)

- https://sanitationghana.org/map/ Basic Sanitation Information System – BASIS for Ghana. This includes access to formal sanitation data.
- Volta HYCOS (https://hydrohub.wmo.int/en/projects/Volta-HYCOS). Hydrological Cycle Observing System (HYCOS) specific to the Volta Basin area.

AFRICA/GLOBAL

- International Groundwater Resource Assessment Centre (IGRAC) databases, specific to groundwater
- Group on Earth Observation (GEO) Portals (https://www.geoportal.org/)
- AMCOW tools, including Africa Water Sector and Sanitation Monitoring and Reporting (http://www.africawat-sanreports.org)
- RAMSAR database (wetlands)
- http://www.africawat-sanreports.org/IndicatorReporting/home Africa Water Sector and Sanitation Monitoring and Reporting
- https://doi.pangaea.de/10.1594/PANGAEA.871462 Diversity II water quality parameters for 300 lakes worldwide from ENVISAT (2002-2012).
- https://www.bafg.de/GRDC/EN/Home/homepage_node.html Global Runoff Database
- https://www.servirglobal.net/ServiceCatalogue/list SERVIR RS/EO data split into regions and service areas, and data source.
- http://52.54.26.108/ RS/EO data by the Africa Regional Data Cube
- https://www.arcgis.com/apps/Cascade/index.html?appid=414730116a3c4c119b80ec9d1727ab74 GEOGLOWS Global River Forecasting Applications
- World Bank tools such as
    - http://spatialagent.org/HydroInformatics/
    - http://appsolutelydigital.com/MonitoringSystems/hydrology.html
    - http://spatialagent.org/Africa/
    - https://geo.fas.usda.gov/GADAS/index.html USDA - Foreign Agricultural Service Global Agricultural & Disaster Assessment System

3.4.2.8. Limitations to Sharing Water Quality Data

There were limitations to data sharing that were shared between both the Lake Victoria and Volta Use Cases and these are summarised in **Chapter 4.** In addition ,specific to Ghana, the following were noted:

- The Ghana WRC receives raw data from WRI, thus some raw data comes at cost to external users which can limit water quality information synthesis.
- There is not a consolidated Ghana government department mandated to water quality monitoring, with this role currently split between the EPA and WRC.

3.4.2.9. Challenges for effective research and implementation

- Political will
- Effective communication to policy/decision makers, including improving impact of research
- Funding. This includes insufficient industry funding. A need to prove capabilities to best utilize funding towards success
- Better industry engagement. Industry supporting research
- Sharing data
- Quality of data, including quality control and quality assurance
- More researchers in water resources. Aging human capital
- Maintenance of monitoring stations. Lack of maintenance culture
- Separation of power
- Data-sharing within institutions (e.g. within a university) so not to duplicate efforts
- Monetization of data

3.4.2.10. Opportunities for effective research and implementation

- Industry social responsibility (e.g. off-shore oil companies)
- Funding, including for students towards data collection
- Scholarships to be focused on highlighted issues/hotspots
- Better research into water quality, land use etc.
- Increased water quality monitoring (e.g. by Ghana water company)
- Municipality engagement, including related to illegal dumping
- Lab capacity, standardization, better lab equipment
- Knowledge dissemination
- Capacity building
- Collaboration, including cross-border collaboration; collaboration between industry and research to improve data sharing/availability; students assigned to industry to design solutions
- Industry/research disconnect. Solutions take time to research.
- Science-policy interface
- Improve skills in communicating research to industry with content that is easily digested/understood
- Policy and legislation towards funding of research. Insufficient current provision by government
- Impact stories. Media involvement. Improved influence. Solving real-world problems for real impact.
- International community exposure to Africans (in country and abroad) and collaboration
- University centres of excellence (i.e. EO/RS, modelling etc). Combined capabilities between universities and cross-border. African World Bank centre for excellenc

3.4.2.11. Identification of Participant Water Quality Requirements

To work towards identifying potential water quality products and services, the water quality needs were discussed with the workshop participants. To guide these discussions, the participants were split into three groups: Academic, Government and NGO/IGO role-players. The groups discussed their needs amongst themselves, and then responses were discussed and enhanced through further combined workshops. The water quality requirements as discussed and agreed are as follows:

- Develop a stakeholder engagement plan – including partner organisations in WWQA
- Field trip(s) with stakeholders and partners
- Monitor water quality, including cross-border impacts.
- Mine impacts (e.g. acid mine drainage)
- Methods to assess nutrient loads
- Methods to increase in situ monitoring points: citizen science, cheap meters/methods, apps to assess water quality etc.
- Assessment methods for point and non-point pollution sources
- Techniques/equipment to measure flow and suspended solids to assess sediment load
- Realtime monitoring (water quality and levels/flow)
- Impacts to indigenous fish from aquaculture
- Algae identification methods
- Improved aquatic invasive monitoring
- Longitudinal studies (spatial/temporal e.g. look at a watercourse from source to discharge to ocean to assess impacts)
- Combined impacts of chemical cocktails.
- Migration/pastoralization/land-use impacts (e.g. nutrient loads)
- Groundwater
    - Validation of groundwater data
    - Geogenic issues (e.g. fluoride)
- Lab facilities for primary contaminants in water and wastewater (heavy metals, antibiotics, Contaminants of Emerging Concern (CECs), microplastics, nutrients)
- Gap analysis of lab and equipment. Concern of expired chemicals/reagents. Investigate options to share un-used lab equipment between laboratories
- Validation of water quality results (quality assurance/quality control – QA/QC)
- Water quality database options
- Develop an information platform
- Development of water quality standards (based on data)
- Improved understanding of populations vulnerable to water quality impacts (incl. flooding)
- Understand causal chain between water quality and public health

- Mine rehabilitation
- Improved sanitation technologies
- Wetland encroachment management
- Wetland rehabilitation
- Remote Sensing Earth Observation – provision of:
    - Baseline maps
    - Opensource tools
    - Land use impacts (mining, deforestation, markets; including extent and rate of change)
    - Flood risk (including climate change)
- Modelling – provision of:
    - Opensource tools for modelling
    - Nutrient inputs
    - Flood risk and vulnerability (including climate change)
- Sustainable funding and long-term investment
- Publication of an annual/biannual state of freshwater report in Africa
- Develop impact stories
- Develop sustainability plan
- Communicate results. Publication of at least one research paper from the Africa Use Cases project
- Coordination in water space: Technical expertise not working in harmony, silo's. Understand why harmonization/coordination not occurring (e.g. organizations saving only to personal computers, policy implementation, cross-border impacts, staffing numbers)
- Policy harmonization and the science-policy link.
- Good water governance
- Align with disaster management to assess risks to communities by poor water quality (location of community, population, health, access to water, sanitation status, etc.
- Capacity building:
    - Monitoring
    - Technicians
    - Contaminants of Emerging Concern (CECs)
    - Citizen science
    - Data analysis
    - Remote Sensing Earth Observation
    - Modelling
    - Organize a learning event as a result of the capacity-building
    - Long-term capacity building e.g. scholarships
    - Capacity building rather than cost-saving (e.g. in-country lab analysis)

    - Influence school curriculum on water quality (e.g. integrated science subject)
- Training in the basics of data (metadata, database options, QA/QC etc.)
- International institution for tropical agriculture to capacitate labs (local support to local capacity building

3.4.2.12. Best forum to discuss possible products/services

The Africa Use Case concept includes a process of consultation between Use Case stakeholders and Alliance members to co-design the water quality data and information product(s). As a result, the workshop included a session to agree on the best forum to undertake these discussions.

It was agreed by participants that this forum should be chaired by WRC under the supervision of the Executive Director. It was agreed that this would be formally communicated by UNEP. Thereafter, WRC would invite key organisations for collaboration.

The platform that would provide the most efficient form of communication was discussed, and it was agreed that this should be in the form of email and once the collaborative group is finalised, to include communication via a more informal mobile platform such as WhatsApp

3.4.2.13. Additional role-players to be included going forward

While the workshop aimed to include as many key stakeholders as possible, not all were able to attend due to time and logistical limitations. As a result, the following role-players were proposed by the workshop attendees to be included going forward:

- Ghana Meteorological Agency (GMet)
- Ghana Statistical Services
- Ghana Water Company,
- Centre for Remote Sensing and Geographic Information Services (CERGIS) based in Accra, Ghana
- Ghana Ministries such as Ministry of Education, Ministry of Sanitation and Water Resources, Ministry of Environment, Science, Technology and Innovation, Ministry of Works and Housing Hydrological Services Department . Ministry of Food and Agriculture, Ministry of Health, Ministry of Fisheries and Aquaculture Development; Ministry of Land and Natural Resources
- Ghana Atomic Energy Agency
- Mining via the Ghana Minerals Commission
- Ghana local government,
- SDG solution centre (Accra, Ghana)
- Burkina Faso National Water Agency
- Burkina Faso Universities
- Burkina Faso: 2iE, UNICEF, PlanBurkinaFaso (NGO), Catholic Relief Service (CRS), Red Crescent/Cross, Ministries of Water, Education, Research, Health
- NGO's such as WaterAid, World Vision International, Adventist Development and Relief Agency, SNV

- Drilling contractors (for groundwater information)
- Economic Community of West African States (ECOWAS) as part of political mandate
- Niger Basin Authority (learning shared between basins)
- Volta Basin Authority
- Sustainable development planning via the Ghana National Development Planning Commission

3.4.3. Workshop Survey

A workshop survey was conducted to determine the overall success of the workshop. This included questions on:

- If the workshop objectives were met,
- Meeting contents,
- Logistics
- General comments/suggestions

A survey tool developed by Mentimeter (https://www.mentimeter.com/) was used. This allowed for the survey questions to be shared with attendees at the workshop. Attendees then answer the questions at the same time, at the workshop, using laptops or smart phones. As each question is answered, the survey outcomes a visualised in real-time and projected for all attendees to see. This ensured feedback from the attendees, as well as gave the organisers an opportunity to provide immediate feedback. The survey is provided in **Annex E.**

3.5. Water Quality Products and Services

To assess the Volta water quality challenges and associated impacts, and to assess data sources and types and any limitations to the sharing of such data there was attendance by WWQA members at various conferences in Ghana. In addition, a Stakeholder Engagement Workshop was held in Accra, Ghana to assess the key water quality hotspots and water quality data and information products and services that may be of interest; and the to initiate a bottom-up social engagement process.

The key water quality challenges identified by the Stakeholder Engagement Workshop participants were:

- Poor sanitation (resulting in elevated bacterial contamination, exacerbated in Ghana by community movement into watercourse buffer zones);
- Mining activities (causing heavy metal and turbidity impacts);
- Industrial effluent (variable impacts, including plastics and micro-plastics);
- Agricultural runoff (elevated nutrients and pesticides, leading to increased aquatic alien plants);
- Aquaculture (including impacts to water quality and impacts from poor water quality; and,
- The future challenges identified included climate change, population increase, urbanization, and land use change.

As a result, it was identified that there is an urgent need to understand land use changes and nutrient loadings to watercourses (including watercourse encroachment by communities along the rivers and reservoirs); a need to monitor the spread of invasive aquatic plants; and an assessment of mining impacts.

Further, there is not a consolidated Ghana government department mandated to water quality monitoring, with this role currently split between the Ghana Environmental Protection Agency (EPA) and Water Resources Commission (WRC), highlighting the institutional challenges to optimal water quality management in the region. Formal letters were sent to the WRC and Ghana Ministry of Sanitation and Water Resources introducing the concept of the WWQA-UC projects and requesting collaboration. This included a request for:

- Sharing information on existing water quality databases relevant to the Volta Basin region.
- Assistance identifying and facilitating collaboration of key stakeholders associated with the Volta Basin region.
- A request for collaboration in the development of water quality pilot products and services for local/national application.

All in-country stakeholders identified and shared by Alliance members, as well as those identified through engagement at conferences, workshops and meetings were formally approached via e-mail. The mail included a 1-pager (**Annex B**) specific to the Use Case prepared by Andrew Gemmell, outlining the WWQA, the Africa Use Cases, water quality challenges per Use Case, and the work plan. The objective of this communication was to find out how partners are able to contribute (i.e. existing data, projects and relevant stakeholders in these regions) and would like to see certain aspects of their work featured in these use cases.

Discussions towards potential water quality product and services are ongoing, in part due to ongoing development of in-country partnerships and collaboration. The potential water quality product and services are a poor water quality impact index, and remote-sensed groundwater quality assessment. These are summarised in the following two sections.

3.5.1. Ghana Water Quality Impact

The Ghana National Disaster Management Organization (NADMO) proposed an innovative tool that translates poor water quality severity (measured through a water quality index) into poor water quality impact (expressed in terms of vulnerability of affected populations). The water quality index would be derived in collaboration with the WWQA. The vulnerability profiling would include the Volta Basin baseline household survey (which includes data on households' water sources and poverty status, as well as population data and administrative boundaries). As the data/model fusion monitors and analyse water quality in the Volta Basin in near-real time, poor water quality will be translated into impact estimates on vulnerable populations (Figure 3-2). Required data for vulnerability profiling include:

- Most recent baseline household survey (Volta Basin coverage);
- With data on households' water sources (for drinking etc.);
- With information on each household's poverty status;
- Representative at sub-national level (ideally Admin 2);
- Population data at subnational level;
- Map files corresponding to the level at which the survey is representative (administrative boundaries).

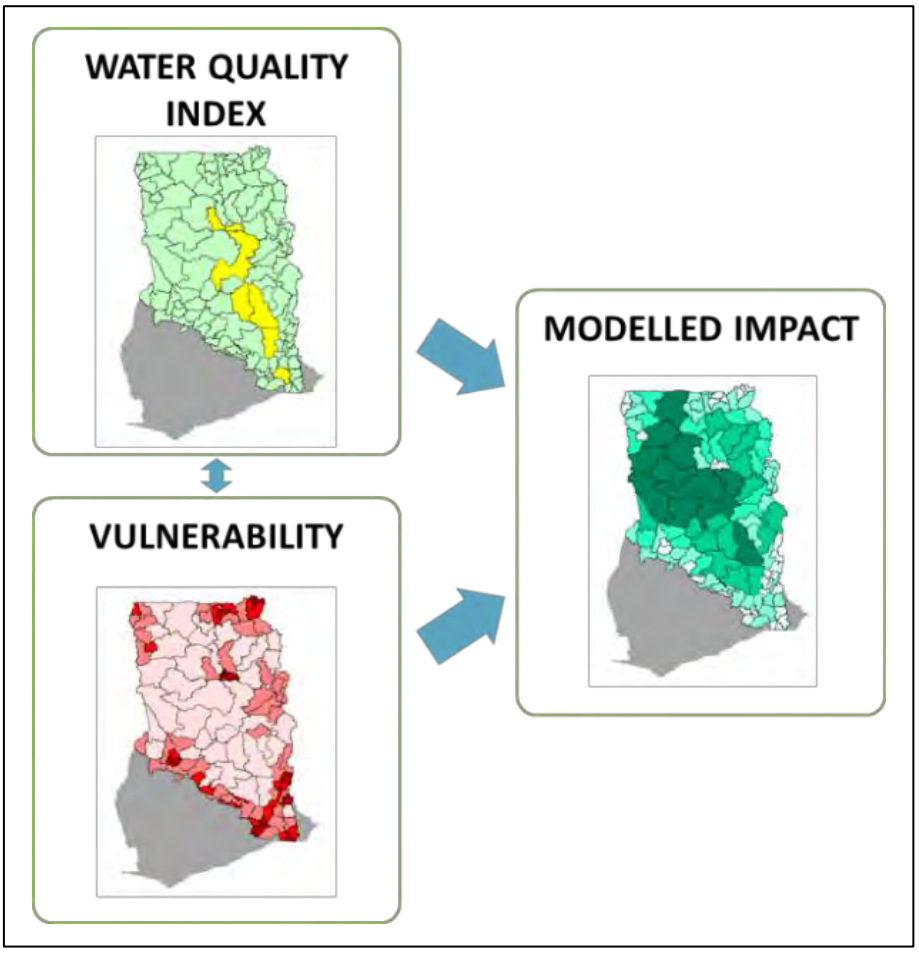


Figure 3-2: NADMO proposal to use a water quality index and vulnerability to calculate a water quality impact.

As proposed by NADMO, in **Figure 3-3**, each district Vulnerability Profile is determined by calculating the percentage of households in that district that are considered vulnerable to poor water quality. Individual households' water vulnerability is determined based on a combination of two factors: exposure to poor drinking water sources and lack of resilience (poverty).

A range for Water Quality Loss Threshold (WQLT) is defined, (where WQLT corresponds to the threshold loss of water quality at household level (in %) above which households would need assistance to be able to access potable water).

According to NADMO, the proposed Volta Water Risk Tool (V-WiT) will help translate outputs of the innovative data/model fusion approach, proposed by the World Water Quality Alliance, into information decision makers / stakeholders at both local and national level will readily appreciate and act upon.

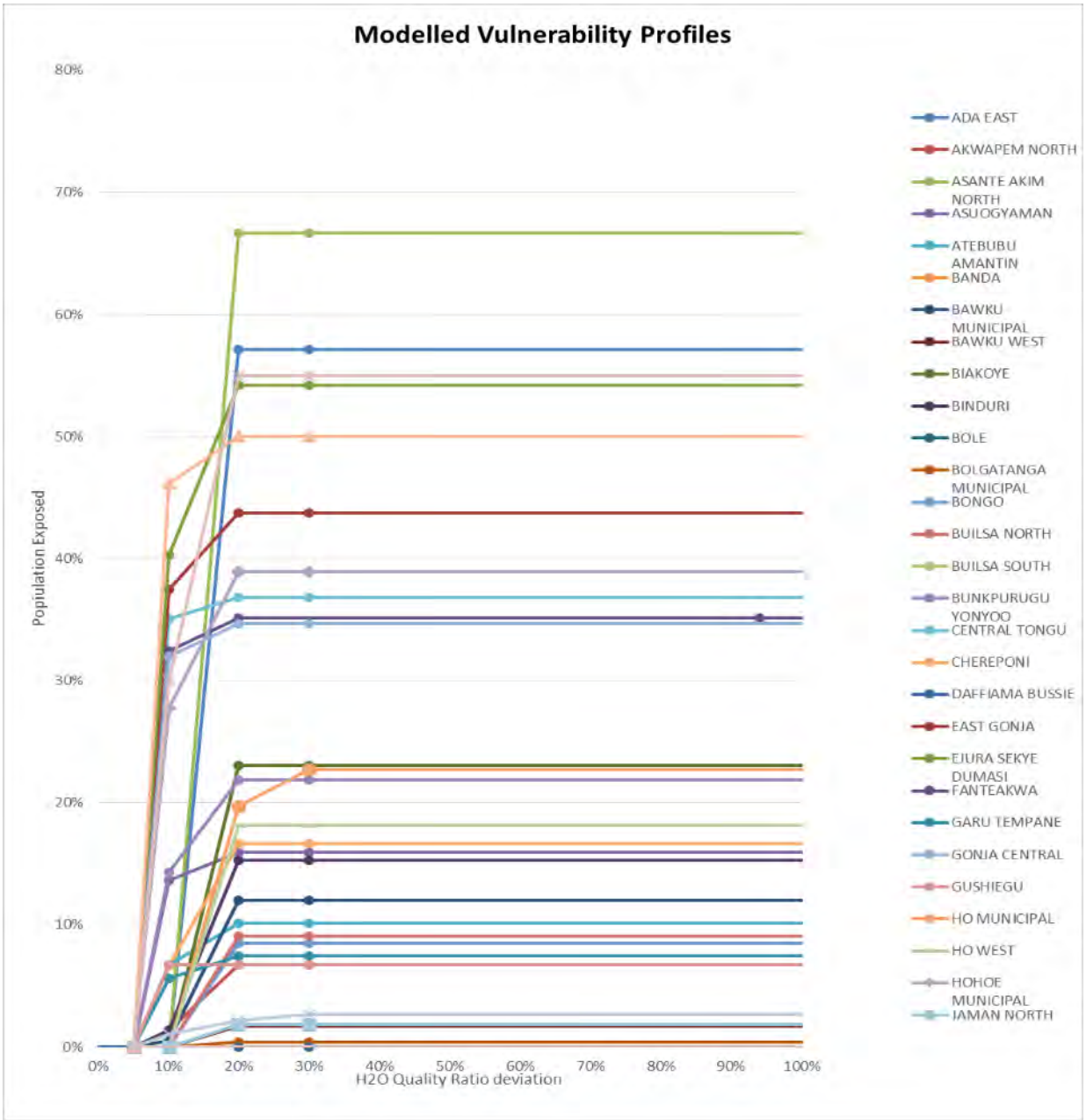


Figure 3-3: NADMO modelled vulnerability profiles determined based on a combination of two factors: exposure to poor drinking water sources and lack of resilience (poverty).

3.5.2. Remote-sensed groundwater quality assessment

The University of Fada N'Gourma, Burkina Faso has proposed a groundwater quality assessment based on remote sensed data, using the DRASTIC (**D**epth to water, net **R**echarge, **A**quifer media, **S**oil media, **T**opography, **I**mpact of vadose zone, and hydraulic **C**onductivity) vulnerability mapping method in conjunction with land use data to assess pollution risk (Ouedraogo *et al*., 2016; Honnungar, 2009; Baghapour et al. 2016; Secunda et al. 1998). Each of DRASTIC index parameters is assigned ratings and a numerical weighting to reflect its relative importance in estimating groundwater pollution potential. This is being pursued with the University of Fada N'Gourma, Burkina Faso. A tentative output for the Volta Basin is provided in Figure 3-4

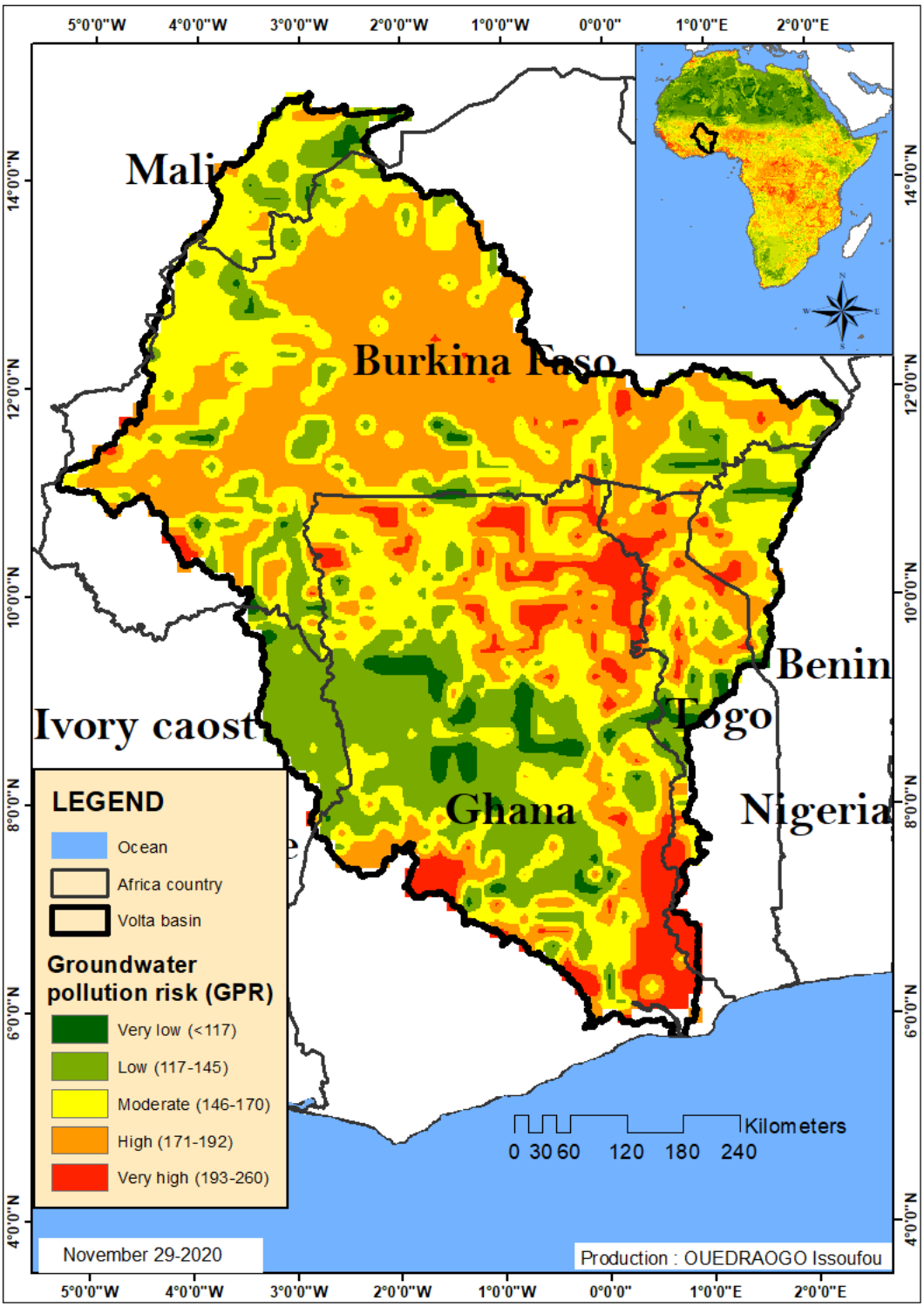


Figure 3-4: Groundwater pollution risk map in Volta Basin area, provided by Issoufou Ouedraogo University of Fada N'Gourma, Burkina Faso

4. Limitations to Data Sharing

Overall, at both the Lake Victoria and Volta Basin Use Cases, there is a reliance on in-situ measurements that leads to limitations in spatial and temporal resolution of water quality. This is exacerbated by concerns around in-situ data sharing by data owners. As a result, there was a need to use alternative options to use alternative data sources such as RS/EO, modelling and citizen science. In addition, there is a need for improved capacity building, including in data analysis, data management, and data sharing policies.

Limitations to data sharing were discussed with in-country stakeholders at each of the Use Cases, with the following feedback:

- A general lack of funding to adequately assess water quality, with a need for sustainable funding and long-term investment. In-country funding by local government was noted to be lacking, with a need for additional contributions (including international funding).
- A need to improve the impact of research through more effective science-policy interface, and to better communicate the science to policy-makers via impact stories (solving real-world problems for real impact).
- A “north-south” divide where data is provided to funded projects, with limited benefit to in-country data providers.
- Past experiences where collaborators requested data who then went on to use the data without citing or acknowledging the data sources. There were also concerns that shared data is used without permissions, impacting planned publications by the data providers.
- Some data providers advised that data cannot be shared without payment, thereby limiting organisations such as GEMStat (The Global Freshwater Quality Database, part of the UNEP GEMS/water programme[12]); obtaining data.
- There is a lack of data sharing policies/protocols, with these sometimes being specific to the country or organisation/institution or limited by clauses in donor-funded projects.
- There is a general lack of internal databases to store data in an easily accessible format, exacerbated when databases are shared between organisations/ institutions/ countries. This includes limitations in the availability of hardware, and training on software. Due to a lack of standard formats, there can be data structuring and formatting problems. As a result, there was a consensus that there is need to agree at the start of a project/initiative on a common data-management system, with agreed data types and formats that allows for better collaboration between organisations/ institutions/ countries. At the Volta Use Case, it was noted that there is a need for enhanced data sharing via a central validated repository; however, it was noted that this is currently not incentivised, and that this would need long-term funding to collect and make data available to the database.
- While databases where developed with useful data, these were noted to be specific to a project with maintenance stopping after the project ended; thereby resulting in a loss of access to data by stakeholders.
- There was a call for in-country capacity building in modelling and RS/EO, as well as data storage, processing and analysis.

The Volta Basin use case did not fully succeed in providing a water quality assessment and co-designing and developing products and services relevant to the local stakeholders, due to several factors including:

[12] https://gemstat.org/

- Fragmented institutional landscape in Ghana regarding water resource management and utilization with responsibility for monitoring, enforcement, resource development split across several national and regional institutions,
- Different institutional landscape and governance structures in neighboring countries with the Volta Basin Authority as transboundary agency apparently not fully functional,
- Lack of involvement of civil society in terms of NGOs, although the Ghanaian Coalition of NGOs in Water and Sanitation was invited, no NGO attended the expert workshop.

5. Summary and Way Forward

The United Nations Environment Programme is cooperating with relevant organizations in the World Water Quality Alliance to develop a Global Water Quality Assessment (GWQA) for consideration by UNEA 6 in 2023.

During the WWQA Inception Workshop held in November 2018 in Geneva, the Alliance decided to pilot and demonstrate current capabilities and future water quality information services through three case studies in Africa (in the following referred to as Use Cases). These Use Cases provide an initial testbed that puts the quality of surface and ground waters into the context of the local 2030 Agenda and its multiple linkages across the Sustainable Development Goals (SDG). Central in these initial test cases is the integration of in-situ and remote sensing-based Earth Observation and water quality modelling data to derive the best possible current state of water quality (baseline) with a multi-stakeholder driven process defining demand for water quality services. The ultimate objective is to provide an evidence base that links water quality hotspots to solutions and investment priorities. The process is stakeholder focussed so that products and solutions can be co-designed and co-created between the WWQA partners and the local stakeholders.

Based on the objective and aim for use cases and the identified criteria, the participants of the 1st WWQA Workshop in Geneva on 28-29 November 2018 selected three Africa Use Cases comprising different water quality challenges, existing data and information, governance aspects and hydrological conditions. The selected African Use Cases comprise:

- Cape Town Main Aquifer Systems: Variety of aquifer systems in and around Cape Town; earmarked for water supply to Cape Town; water quality issues are pollution due to land use activities, geogenic elevated concentrations, impact on surface ecosystems.
- Lake Victoria: Transboundary lake shared between Kenya, Tanzania, Uganda, Rwanda and Burundi; main water quality issue is impact on ecosystem health.
- Volta Basin: Transboundary river basin shared between Burkina Faso, Togo, Mali, Cote D'Ivoire and Ghana; main water quality issue are pathogens.

This report focused on the Lake Victoria and Volta Basin Use Cases. Requests for stakeholders and/or data for the Use Cases were sent to relevant working groups carrying out the global Assessment as case information. Using the contact details received, these stakeholders identified by the World Water Quality Alliance were then in turn also contacted requesting both data and any additional stakeholders (snowball mechanism), which continued as an iterative process. In addition, a thorough literature review of stakeholders and data was conducted. Through this process, available data (in-situ, modelled, RS/EO) for the Use Cases was collected and shared with the expert teams in charge of the triangle approach in the World water Quality Assessment (EOMAP, Helmholtz Centre for Environmental Research, and Ruhr University Bochum). In addition, a database of stakeholders and their interest in collaboration was developed, shared with the Alliance community of practice, and enhanced throughout the project.

The stakeholder engagement process to identify the key water quality concerns and the need for associated water quality products and services took various forms for the Lake Victoria and Volta Basin Use Cases.

5.1. Stakeholder Engagement

5.1.1. Lake Victoria Basin

In respect to the Lake Victoria Use Case, there was attendance at the Global Lakes of the World symposium on "*Emerging frontiers for African Great Lakes: Promoting Blue Economy, food*

security and Conservation" in Kisumu, Kenya in August 2019; as well as the Great Lakes African Center for Aquatic Research and Education (AGL-ACARE) organised stakeholder workshop in November 2019 in Entebbe Uganda titled "*African Great Lakes Stakeholder Network Workshop: Strengthening Capacity in Research, Policy, and Management through Development of a Network of African Great Lakes Basin Stakeholders*". The objective of attendance at these events was to assess water quality challenges and associated impacts at Lake Victoria and its catchment; discuss the WWQA and Africa Use Cases with key Lake Victoria fisheries research institute Directors and Scientists, develop a stakeholder network, and assess data sources and types associated with Lake Victoria, and any limitations to the sharing of such data. This was enhanced with the past needs assessments undertaken by SERVIR-Eastern and Southern Africa (2016a and 2016b). The WWQA and Africa Use Cases were presented at the AGL-ACARE stakeholder workshop. WWQA members Mr Andrew Gemmell (UNEP) and Dr Tallent Dadi (Helmholtz Centre for Environmental Research) were nominated to the Lake Victoria Working Group (who's activities continue to date). Mr Gemmell and Dr Dadi continue engagement with the Working group, attending the monthly virtual meetings, and inputting to two draft publications to be submitted to the Journal of Great Lakes Research.

This was followed by subsequent on-line workshops due to the Covid-19 pandemic. In July 2020 the WWQA met with the Lake Victoria Fisheries Organisation (LVFO). LVFO is a specialized institution of the East African Community (EAC) whose mandate is to coordinate the management and development of fisheries and aquaculture resources in the EAC region. The composition of the LVFO is made of the Fisheries and Aquaculture Management and Research Institutions, including the Kenya Marine & Fisheries Research Institute (KMFRI), National Fisheries Resource Research Institute (NaFIRRI), and Tanzania Fisheries Research Institute (TAFIRI).

After the July 2020 workshop, letters requesting collaboration between WWQA and LVFO were sent to Dr Taabu-Munyaho (Deputy Executive Secretary of LVFO). The LVFO then reached out to country fisheries research institute Directors at KMFRI, TAFIRI and NaFIRRI to introduce the Africa Use Case initiative. The Directors of KMFRI, NaFIRRI and TAFIRI then nominated fisheries specialists within each of their Institutions to act as focal points. Workshops with these individuals were held in August and September 2020 with the aim to re-introduce the concept of the African Use Case concept as it relates to Lake Victoria and how the Alliance can assist; provide examples of what can be achieved through the Alliance; discuss the priority Lake Victoria water quality concerns and hotspots; discuss research and information gaps; and to begin discussions on water quality data and information products and services to be co-developed to target hotspots.

Through the discussions, various limitations to data sharing (both between Fisheries institutions, and between these Institutions and WWQA) and these are summarised in **Section** Error! Reference source not found.. Where water quality databases were available, this had limited spatial and/or temporal extent. As a result, there was a focus on modelled and RS/EO water quality data, validated by in-situ data (i.e. through the WWQA triangle approach) to derive a water quality baseline. Key water quality challenges agreed upon at Lake Victoria were eutrophication; algal blooms (including cyanobacteria); hypoxia, and siltation/turbidity affecting fish breeding.

The water quality data and information products and services agreed to be co-developed by the riparian fisheries organisations (KMFRI, TAFIRI, NaFIRRI) and WWQA (primarily EOMAP, RUB, UFZ) were a coastal eutrophication assessment; water temperature and stratification dynamics; and sediment chemistry. This co-design process was undertaken between September 2020 and April 2021 (end of contract). Additional funding is to be secured to take these products and services forward in a meaningful way to ensure real-world problems are solved for real impact.

- Coastal Eutrophication:
    - Available data sources are being assessed to indicate the potential of coastal eutrophication, including the identification of hot spots and potential seasonal patterns. This demand-driven tool is being co-developed to characterise the potential of algal blooms to

impact fisheries or to identify potential links between aquaculture and coastal eutrophication. This includes the joint use of:

- Remote sensed earth observation (provided by EOMAP), incl. turbidity and chlorophyll-a values for the Lake.
- Water quality modelling to determine total phosphorus inputs into the lake from identified sources such as the domestic sector, agriculture, background loadings etc. (provided by Ruhr-University Bochum, Germany).
- In-situ measurements provided to date (river/lake measurements of nutrients such as nitrate, phosphate etc.) via GEMStat and in-country partners. This information is being used to validate the model and RS/EO data.

o Outcomes envisioned include the identification of nutrient hotspots, their drivers, and their temporal and spatial dynamics so that priorities can be defined, and potential management strategies can be efficiently directed. Further, scenario modelling can be used to evaluate the effectiveness of a wide range of management alternatives.

- Water temperature and stratification dynamics: Monitoring activities by different research institutions of the adjacent countries generated a valuable record of water temperatures in Lake Victoria over the past years; including data jointly collected by TAFIRI, NaFIRRI and KMFRI under the coordination of LVFO which has been shared with the WWQA. The aim is to use a freely available lake model (GLM 3.1, General Lake Model) to simulate temperature dynamics in Lake Victoria to inform the extent of stratification and vertical mixing in the water column. At the same time, this initiative brings together monitoring results from different countries and institutions and generates not only the required data for the modelling but also provides data for many other applications in research and development. The following research topics are being targeted by the Helmholtz Centre for Environmental Research (UFZ) and LVFO:
  - o Model-based reconstruction of water temperatures of Lake Victoria over the past 30-years at daily resolution
  - o Water temperature projections for Lake Victoria until 2100 based on different climate scenarios (Representative Concentration Pathway (RCP) 2.6, RCP 6.0, RCP 8.5)
  - o Potential effects of water temperature dynamics and mixing events on phytoplankton dynamics (derived from satellite-based remote sensing provided by EOMAP)
- Sediment chemistry: UFZ has offered to collaborate with KMFRI on collected sediment chemistry, water profile physico-chemical quality parameters in the Nyanza Gulf (Kenya) and sediment and water samples near Kampala, Uganda. There is a potential for the joint assessment of sediment release of nutrients, turnover, and indication through algae blooms obtained from remote sensing (EOMAP).

5.1.2. Volta Basin

With regards to the Volta Use Case, there was attendance at two conferences in Accra, Ghana in October 2019: The *Conference on Climate Resilience and Waste Management for Sustainable Development*, Accra, Ghana; and the *Africa Geospatial Data and Internet Conference*. The objective of the attendance was to assess the Volta water quality challenges and associated impacts; discuss the WWQA and Africa Use Cases with attendees, develop a stakeholder network, and assess data sources and types and any limitations to the sharing of such data.

In collaboration with the Institute for Environment and Sanitation Studies (IESS) University of Ghana, who are regional experts in the Volta River water quality, a Stakeholder Engagement

Workshop was coordinated in Accra (February, 2020) which was attended by 29 representatives from Burkina Faso and Ghana, including participants from government, academia, NGO/IGOs, the UN RCO, and project partners GEMS/Water and Helmholtz Centre for Environmental Research. The outcomes of the workshop were an enhanced understanding of the key water quality hotspots; the water quality data and information products and services that may be of interest; and the initiation of a bottom-up social engagement process. The key water quality challenges identified by the Stakeholder Engagement Workshop participants were:

- Poor sanitation (resulting in elevated bacterial contamination, exacerbated in Ghana by community movement into watercourse buffer zones);
- Mining activities (causing heavy metal and turbidity impacts);
- Industrial effluent (variable impacts, including plastics and micro-plastics);
- Agricultural runoff (elevated nutrients and pesticides, leading to increased aquatic alien plants);
- Aquaculture (including impacts to water quality and impacts from poor water quality; and,
- The future challenges identified included climate change, population increase, urbanization, and land use change.

As a result, it was identified that there is an urgent need to understand land use changes and nutrient loadings to watercourses (including watercourse encroachment by communities along the rivers and reservoirs); a need to monitor the spread of invasive aquatic plants; and an assessment of mining impacts.

Further, there is not a consolidated Ghana government department mandated to water quality monitoring, with this role currently split between the Ghana Environmental Protection Agency (EPA) and Water Resources Commission (WRC), highlighting the institutional challenges to optimal water quality management in the region. Formal letters were sent to the WRC and Ghana Ministry of Sanitation and Water Resources introducing the concept of the WWQA-UC projects and requesting collaboration.

Discussions towards potential water quality product and services are ongoing, in part due to ongoing development of in-country partnerships and collaboration. The initial products and services being investigated to take forward include:

- The Ghana National Disaster Management Organization (NADMO) proposed an innovative tool that translates poor water quality severity (measured through a water quality index) into poor water quality impact (expressed in terms of vulnerability of affected populations). The water quality index would be derived in collaboration with the WWQA representatives, with initial discussions in this regard undertaken with UFZ.
- University of Fada N'Gourma, Burkina Faso proposed a groundwater quality assessment based on remote sensed data, using the DRASTIC vulnerability mapping method in conjunction with land use data to assess pollution risk (Ouedraogo *et al.*, 2016). This is being pursued with the University of Fada N'Gourma, Burkina Faso.

5.2. Stakeholder Engagement Steps and Lessons Learnt

Knowledge exchange is a powerful way to share, replicate, and scale up what works in development through learning from the practical experience of others who have gone through, or are going through, similar challenges of finding working solutions. The direct results from knowledge exchange can also influence results at the institutional and even systemic levels (World Bank Group, 2016). Knowledge sharing and transfer in the field of Integrated Water Resource Management, on a global scale, can be improved with an understanding of cultural considerations, technical opportunities, and constraints, and the theory underpinning knowledge management.

(Delfau, 2018). The knowledge exchange process followed was as per The World Bank Group (2016), as summarised in Section 1.5.

With regards to the lessons learnt through the Africa Use Cases knowledge exchange, these should be adopted at other Use Case areas through a continued process of knowledge exchange. This should include the following steps:

- To best utilize the existing relationships within the Alliance, the Alliance members should be engaged to request information on relevant stakeholders and existing data within their networks. Using the contact details received, these stakeholders can in turn also be contacted requesting both data and any additional stakeholders (thus a snowball mechanism). The stakeholder database should be formalised for tracking interactions and progress, including:
    - Name and organisation of the stakeholder, including contact details, position, address, and comment section to track engagements and actions.
    - Role of stakeholder (e.g. provides data, provides details of other stakeholders, interested in outcomes, etc.).
    - Type of data the stakeholder may be able to share (raw data, information, RS/EO, modelling, report, etc.).
    - Comments (projects, accessibility of data, hyperlinks etc.)
    - Priority (e.g. low, medium, high) based on Use Case objectives and stakeholder needs.
- The stakeholder network developed can then be engaged to determine:
    - What in-country engagement has been undertaken by these Alliance stakeholders in the past, to leverage these existing connections/relationships with in-country partners.
    - Availability of existing databases (in-situ including citizen science, modelled, RS/EO).
- There needs to be the development of a repository for all received data. This should use existing options (e.g. GEMStat, GlobeWQ) to allow for formal data management procedures.
- The initial engagement with in-country partners should be to introduce the team and the Use Case aims/objectives. If the in-country partners have been identified by the Alliance, an introductory meeting between the stakeholder engagement facilitator, Alliance representative and in-country partner should be undertaken to build on existing relationships .
- Useful is attendance at conferences/symposia/workshops in the assessment countries to meet with a robust collection of stakeholders and introduce the concept face-to-face. Ideally this can include a presentation of the Use Case approach. If there are working groups in existence specific to the study area, facilitator(s) and Alliance representatives should consider participating (including in the publication of journal articles).
- The Covid-19 pandemic meant that in-country and in-person meetings could not be undertaken after February 2021. However, these virtual meetings may have reduced the effectiveness of communication and thus collaboration. As noted by Karl et al. (2021) the human brain has evolved over time to facilitate face-to-face communication and that videoconferencing lacks some of the key communication characteristics (e.g., co-location, body language, and possibly facial expression if the video is turned off or there are several participants on one screen) (Koch, 2004). Consequently, communication between individuals using videoconferencing is less natural and more cognitively demanding; which results in participants having lower motivation to engage both behaviorally and cognitively (Kuzminykh and Rintel, 2020). To assist in engagement, there should be a formal memorandum of understanding (MoU) in place between WWQA and in-country stakeholders. This should be signed by representatives from WWQA/UNEP and in-country partners with sufficient influence to better ensure success. The in-country partner can then identify key staff to be responsible for engaging with WWQA. This engagement should include a brief one- or two-page introduction of both the WWQA, and the

Use Case aims, objectives, methodology and data/stakeholder needs so that the Use Case project can more easily be described to in-country partners.

- Critical are workshops (in country if feasible due to the limitations of virtual meetings) to identify what in-country stakeholders need in terms of water quality products and services.
    - Attendees should include government/public sector, civil society, policy makers IGO's, NGO's, academic institutions, etc, with representatives from junior to executive management levels in each where possible. It is important to invite all key stakeholders, with representatives from the correct management level, to ensure that potential stakeholders do not feel excluded.
    - The workshops are best initiated using in-country partners that have existing relationships and experience in developing workshops with the in-country stakeholders to ensure that needs are met.
    - There should be panel discussions and plenaries that include WWQA and in-country stakeholders to enhance collaboration and a shared outcome.
    - Important workshop considerations include the need for
        - Travel support (for air and land travel), including assistance with visa's for those experts participating from abroad.
        - Workshop days short enough to allow delegates to focus on the workshop and allow time to still meet their day-to-day needs.
    - The workshops should aim to
        - Provide examples of what can be achieved through the Alliance.
        - Discuss water quality data availability, limitations to data sharing, barriers or challenges which prevent the implementation of effective water quality solutions, and research and information gaps. The workshop should aim to understand limitations to data sharing (both between data providers, and between data providers and WWQA). This is so that any concerns can be allayed where possible.
        - Discuss the priority water quality concerns and hotspots as they relate to health/cities, food, and ecosystems
        - Assess data repository options to promote coordinated data sharing and prioritized assessments of identified hotspots.
        - Determine stakeholder assessment capacities pertaining to Enabling Environment (provisions related to freshwater quality monitoring); Institutions and Participation (institutional and human capacity), Management Instruments (existing monitoring programmes and previous assessments, and financial incentives) and Financing (financial resources available).
        - Initiate a process of bottom-up co-design between stakeholders and WWQA members to develop evidence-based products to inform improved global, regional and local water management.
    - Post workshop follow-up should be done to maintain momentum, including e-discussions via video-conference, and reporting to share learning from the workshop with a wider stakeholder group. Ideally this can develop into a community of practice that interacts regularly to learn from one another.
- The engagement described above aims to build collaboration and trust between the Alliance and in-country stakeholders. This process aims to break the north-south divide and show how the Use Case approach can solve real-world problems for real impact, thereby benefiting in-country stakeholders. Once this collaboration and trust is in place, data specific to the water quality

products and services can be requested from the in-country stakeholders.

- Co-design of the products and services can then commence. This process needs continued workshops between the Alliance stakeholder network and in-country stakeholders to maintain relationships and ensure the in-country needs are met. Ideally these should be in-person workshops as often as feasible, followed by online engagements at least monthly.
- It is important that the Alliance stakeholders used have experience and availability relevant to the chosen products and services. This includes the ability to integrate the data types into a consolidated dataset for use in developing the products and services.

5.3. Way forward

Overall, at both the Lake Victoria and Volta Basin Use Cases, there is a reliance on in-situ measurements that leads to limitations in spatial and temporal resolution of water quality. This is exacerbated by concerns around data sharing by data owners. As a result, there was a need to use alternative options to use complementary data sources such as RS/EO, modelling and citizen science. In addition, there is a need for improved capacity building, including in data analysis, data management, and data sharing policies.

Limitations to data sharing were discussed with in-country stakeholders at each of the Use Cases (as illustrated in Section 4), with the following solutions proposed:

- Ongoing development of in-country partnerships and trusted collaboration, especially with water resource decision-makers to solve real-world problems for real impact, thereby benefiting in-country stakeholders and data providers to break the north-south divide. This should utilize the existing guidance (e.g. The World Bank Group, 2016), as well as build on the lessons learnt through the Africa Use Cases knowledge exchange process.
- This needs sustainable funding and long-term investment with a need for additional contributions (including international funding to bolster local government contributions). Initial exchange with UN Resident Coordinators are encouraging and suggest, in future, to regularly engage UN Country Teams in this process if possible.
- To formalize engagement letters of collaboration were drafted. These introduced the concept of the World Water Quality Alliance Africa Use Cases and respectfully requested the collaboration with the relevant stakeholder. These were drafted on UNEP letterheads and signed by Andrew Gemmell. However, to better drive collaboration, it is recommended that Memorandums of Understanding are rather drafted and signed by senior UNEP representatives.
- There is a need to investigate options for integrating data derived from the WWQA triangle approach into a single dataset that can be used for water quality decision-making. A need to improve the impact of research through more effective science-policy interface, as well as better communication of the science to policy makers via impact stories.
- A standard protocol for data sharing to ensure data providers retain data ownership and recognition. An example to use is the GEMS/Water Data Policy which allows data providers to select from three different levels of data sharing.
- There is a need to further develop internal databases to store data in a format shared between organisations/ institutions/ countries. This includes limitations in the availability of hardware, and training on software.
- Development of a common data-management system, with agreed data types and formats that allows for better collaboration between organisations/ institutions/ countries. This database option should have ownership by the data providers to ensure maintenance and longevity.

- In-country capacity building in the collection and assessment of data (in-situ data, citizen science, modelling and RS/EO).
- Further development of the Africa Use Case concept to cover various water resource types and scales. This may include linking headwater protection to recharge (Cape Town Use Case); transboundary aquifers, the surface water/groundwater interface (e.g. wetlands).
- There is a need to investigate options for integrating data derived from the Assessment triangle approach into a single dataset that can be used for water quality decision-making. One of the success factors for the Cape Town Aquifer Use Case was the ability of the coordination and assessment team to integrate the three different data types of the triangle approach, i.e. in-situ measurements, remote sensing data and numerical modelling, on a sub-catchment scale. This was achieved through an integration team with overlapping experience in the data types.
- The success of the Cape Town Use Case was also driven by a robust stakeholder engagement process that has developed trust and collaboration over many years and included a local stakeholder (communities and institutions) engagement process. This highlights the need for long-term engagement to ensure real impact.

At Lake Victoria, stakeholder engagement was good and most successful with the riparian Fisheries Institutions. The stakeholder network should be expanded to different sectors and including local contacts of WWQA partners. Further involvement of WWQA partners with existing relationships and projects in the region (e.g. FAO, WMO, World Bank, Women for Water) will strengthen collaborative efforts between in-country parties, and build on existing projects and data. This should include aspects of the Social Engagement Platform workstream aims, such as: using experience in global problems to support local solutions; simple language to describe complex systems; and use data to build knowledge and knowledge to inform action.

The Volta Basin use case did not fully succeed in providing a water quality assessment and co-designing and developing products and services relevant to the local stakeholders. As a result, a follow-on project is needed to adopt a different approach to the social engagement and co-design process with a view to tackle country-specific challenges via adopting a bottom-up approach. Further involvement of WWQA partners with existing relationships and projects in the Volta Basin (e.g. FAO, WMO, World Bank) is needed to strengthen collaborative efforts between in-country parties, and build on existing projects and data. A comprehensive network of stakeholders should be developed, focusing on local role players that are active in the sphere of environmental support or education, and cultural groups and individual artists that include environmental aspects into their art and performance as well as popular sports celebrities (e.g. soccer).

There are obvious synergies between the Africa Use Cases and the UNEP GEMStat and the GlobeWQ workstream. GEMStat and the GlobeWQ platform aim to bridge the global scale water quality assessment and user-tailored water body and river basin scale information needed by regional authorities. However, geospatial platforms such as GlobeWQ are only relevant if they are being used and updated with recent data. The Lake Victoria and Volta Basin Use Cases may act as case studies for GlobeWQ.

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ANNEX A –STAKEHOLDERS

ANNEX A1 – LAKE VICTORIA

Government Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Ms.	Florence Grace	Adongo	Uganda Ministry of Water and Environment. Water Resources Management (DWRM)	Commissioner for Water Quality Management	Plot 12 Mpigi Road, Entebbe, . Uganda	florence.adongo@mwe.go.ug	dwrm@mwe.go.ug, floadongo@gmail.com	ICWRGC/GEMS/Water: GEMS Water NFP
Mr.	Sao	Alima	Kenya Ministry Of Water &Sanitation and Irrigation		Kenya	saoalima@gmail.com		ICWRGC/GEMS/Water: SDG Helpdesk Request
Dr.	Christopher	Aura	KMFRI.	Centre Director (Kisumu)	Kenya	auramulanda@yahoo.com		Andrew Gemmell: Presented on riverine pollution sources contributing to Lake at GLOW9
Mr.	Kassim	Bakari	Tanzania Ministry of Water, Water Quality Services Division.	Regional Water Quality Laboratory	P.O. BOX 431, Dodoma. Tanzania, United Republic of	somwe67@yahoo.com		ICWRGC/GEMS/Water: Performance Evaluation PE-08;GEMS Water Labs
Mr.	John Dominic	Balarin	Kenya National Environment Management Authority		Kenya	Swmtanzania@gmail.com		Andrew Gemmell: Has experience in local governance in the area. Andrew Gemmell met in Kisumu. Provided e-intro to Stephen Katua
Mr.	Philipo	Chandy	Tanzania Ministry of Water and Irrigation		Dar, Tanzania	philipo.chandy@maji.go.tz		
Mr.	Philipo	Chandy	Tanzania Ministry of Water and Irrigation (Maji Ubungo). Water Quality Services Division	Acting Director Divison of Water Quality	Dar Es Salaam. Tanzania, United Republic of	philipo.chandy@maji.go.tz		ICWRGC/GEMS/Water: GEMS Water NFP; SPONGE; GEMS Water NFP Representative Kilian Christ: GEMS/Water NFP Rep
Mr.	Hamidar	Chanzi	Tanzania Ministry of Water, Water Quality Services Division. Central Water Quality Laboratory	Asst. Director Quality Assurance & Water Quality Standards	426 Morogoro Road, P.O. Box 9153, Dar Es Salaam. Tanzania, United Republic of	newchanzihamidar@gmail.com	hamidar.chanzi@mowi.go.tz	ICWRGC/GEMS/Water: SPONGE;Performance Evaluation PE-07;Performance Evaluation PE-06;Performance Evaluation PE-05;GEMS Water Labs;GEMS Water NFP
Mr.	Mteki Heri	Chisute	Tanzania Ministry of Water and Irrigation (Maji Ubungo). Mwanza Zonal Water Quality Laboratory	Senior Chemist	Mwanza. Tanzania, United Republic of	heri.chisute@maji.go.tz	hmteki@gmail.com	ICWRGC/GEMS/Water: GEMS Water NFP; GEMS Water Training Workshop Africa (2017)
Dr.	Rukuunya	Edward	Uganda Ministry of Agriculture Animal Industry and Fisheries.	Director of Fisheries	Uganda	edwardrukuunya@yahoo.com	_	Andrew Gemmell: Policy committee lead in Lake Victoria Working Group
Mr.	Simon	Etimu	Uganda Ministry of Water and Environment. Water Resources Management (DWRM), National Water Quality Laboratory	Principal Analyst	Plot 12 Mpigi Road, Entebbe, . Uganda	simon.etimu@mwe.go.ug	simon.etimu@gmail.com	ICWRGC/GEMS/Water: Performance Evaluation PE-08;Performance Evaluation PE-05;Performance Evaluation PE-06;GEMS Water Labs;GEMS Water NFP
Mr.	Frederick J	Guya	KMFRI. Freshwater Systems Research department		Kenya	freguya@yahoo.com		Andrew Gemmell: Assessed 24 locations in Nyanza Gulf for phosphates and associated contamination. Presented at GLOW9. Research Interests: Environmental and Ecological studies
Ms.	Lillian	Idrakua	Uganda Ministry of Water and Environment.	Commissioner for Water Quality	Uganda	lillian.idrakua@mwe.go.ug	gescca@yahoo.com	ICWRGC/GEMS/Water: AWW Booth visit; GEMS Water NFP; GEMS Water NFP Representative; GEMS Water Scoping Workshop Africa (2016) Kilian Christ: GEMS/Water NFP Rep. IIASA have personal contacts to Directors, Commissioners and a number of professionals.
Mr.	Godfrey	Kahwa	Tanzania Ministry of Water, Water Quality Services Division. Regional Water Quality Laboratory		Iringa. Tanzania, United Republic of	kahwag@yahoo.com		ICWRGC/GEMS/Water: Performance Evaluation PE-07;Performance Evaluation PE-08;GEMS Water Labs
Dr.	Canisius	Kanangire	Nile Basin Initiative (NBI).	Executive Director	Entebbe. Uganda	ckanangire@nilebasin.org		ICWRGC/GEMS/Water: GEMS Water CFP
Mr.	Tom	Kanyike	Uganda Ministry of Water and Environment		Kampala, Uganda	shukar@techie.com		Kilian Christ: Contact provided by Dominique, alternative contact for Nebert Wobusobozi
Mr.	Paul	Kariuki	Lake Victoria Basin commission		Kenya	kariuki@lvbcom.org		Andrew Gemmell: Conversant with a broad spectrum of water issues and in charge of managing water resources affairs at the Lake Victoria Basin Commission

Government Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Mr.	Dismas	Karuranga	Rwanda Water and Forestry Authority		Kigali, Rwanda	karurangadismas@yahoo.fr		Kilian Christ: GEMS/Water NFP Rep
Mr	Stephen	Katua	Kenya NEMA	Head Coastal Marine and Freshwaters	Nairobi, Kenya	SKatua@nema.go.ke	stephenkatua@yahoo.com	Andrew Gemmell: E-intro by John Dominic Balarin (GGEP).
Dr.	Robert	Kayanda	Tanzania fisheries research institute (TAFIRI).		Tanzania	bobkayanda@yahoo.com	-	Andrew Gemmell: Member of Lake Victoria Working Group
Ms.	Nadhifa S.	Kemikimba	Tanzania Ministry of Water and Irrigation (Maji Ubungo). Water Quality Services Division	Director at Divison of Water Quality	Dar Es Salaam. Tanzania, United Republic of	nadhifa.kemikimba@maji.go.tz	siranadhifa@yahoo.com, dwls@mowi.go.tz	ICWRGC/GEMS/Water: GEMS Water NFP; SPONGE; Former GEMS Water NFP Representative
Mr.	Jovitus	Kichumu	Tanzania Ministry of Water, Water Quality Services Division. Regional Water Quality Laboratory		Arusha. Tanzania, United Republic of	kjovitus@yahoo.com		ICWRGC/GEMS/Water: Performance Evaluation PE-08;GEMS Water Labs
Dr.	Lily	Kisaka	Lake Victoria Basin commission		Kenya	kisakaln@gmail.com	kisaka@lvbcom.org	Andrew Gemmell: Co-convenor of Lake Victoria Working Group
Dr.	Mary A	Kishe	Tanzania fisheries research institute (TAFIRI).	Research scientist.	Tanzania	manyalajo@yahoo.com	-	Andrew Gemmell: Member of Lake Victoria Working Group
Mr.	Simintei	Kooke	Kenya Ministry of Water and Irrigation		Nairobi, Kenya	tkooke@gmail.com		Kilian Christ: Contact provided by Dominique, works with WMO Hydrological advisor for Burundi
Mr.	Kenneth	K'oreje	Kenya Water Resources Authority.		Kenya	k.koreje@gmail.com		ICWRGC/GEMS/Water: GEMS Water Scoping Workshop Africa (2016); UNEA Booth visit
Mr.	George	Lugomela	Tanzania Ministry of Water and Irrigation		Dodoma, Tanzania	lugomela@yahoo.com	lugomela@hotmail.com	Kilian Christ: Contact provided by Dominique, works with WMO Hydrological advisor for Burundi
Mr.	Jacob	Majira	Tanzania Ministry of Water, Water Quality Services Division. Zonal Water Quality Laboratory		Mbeya. Tanzania, United Republic of	jacobmajira@yahoo.com		ICWRGC/GEMS/Water: Performance Evaluation PE-08;Performance Evaluation PE-06;GEMS Water Labs
Dr.	Ali Said	Matano	Lake Victoria Basin Commission (LVBC)		Kenya	matano@lvbcom.org		Andrew Gemmell: LVBC Executive Secretary. UN (UNEP, UN Habitat, UNIDO) has been working closely with LVBC on various tasks (climate change). IIASA have strong partnership with Lake Victoria Basin Commission. Collaboration since 2016- One research project ongoing, and one project concluded with two stakeholder workshops organized and run. Working relations with the focal points of all LVBC member countries (usually officials of the Ministries of Water Affairs) from joint research activities and stakeholder consultation workshops.
Ms.	Eudosia	Materu	Tanzania Ministry of Water and Irrigation (Maji Ubungo). Water Laboratory Services Division	Assistant Director Assessment Operations	Tanzania, United Republic of	eudosia.materu@maji.go.tz (retired, address not working anymore)		ICWRGC/GEMS/Water: GEMS Water NFP; GEMS Water Scoping Workshop Africa (2016)
Ms.	Stella	Mbabazi	Uganda Ministry of Agriculture, Animal Industry and Fisheries.	Fisheries inspector	Uganda	mbabazistella@yahoo.com	-	Andrew Gemmell: Member of Lake Victoria Working Group
Mr.	Hillary	Mrosso	Tanzania fisheries research institute (TAFIRI).	Ecology fisheries statistics and stock assessment	Tanzania	hjmrosso@yahoo.com	-	Andrew Gemmell: Communication and dissemination committee lead in Lake Victoria Working Group
Ms.	Safina	Musa	KMFRI. Aquaculture (Freshwater systems) department		Kenya	safeenamusa@yahoo.com	-	Andrew Gemmell: Contact provided by Chris Aura, KMFRI in WWQA feedback. Specialization: Water quality dynamics in aquaculture and Fish nutrition
Ms.	Victoria	Mwaifunga	Tanzania Ministry of Water, Water Quality Services Division. Zonal Water Quality Laboratory		Mwanza. Tanzania, United Republic of	vickymwaifunga@yahoo.com		ICWRGC/GEMS/Water: Performance Evaluation PE-07;Performance Evaluation PE-08;Performance Evaluation PE-06;GEMS Water Labs

Government Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Mr.	John Cornel	Nchimbi	Tanzania Ministry of Water, Water Quality Services Division. Regional Water Quality Laboratory		Mtwara. Tanzania, United Republic of	johncornel18@gmail.com		ICWRGC/GEMS/Water: Performance Evaluation PE-08;GEMS Water Labs
Mr.	Anastase	Niyigaba	Rwanda National Resources Authority		Kigali, Rwanda	niyanastase1@yahoo.fr		Kilian Christ: Contact provided by Dominique, working on IWRM
Ms.	Jeanne-Francine	Nkunzima	Burundi Ministry of Water, Environment, Land and Urban Planning		Bujumbura, Burundi	njeannefrancine@yahoo.com		Kilian Christ: GEMS/Water NFP Rep
Ms.	Jeanne-Francine	Nkunzimana	Burundi Ministry of Water, Environment, Land and Urban Planning.	Director of Sanitation and Water Quality Control	Burundi	njeannefrancine@yahoo.com		Kilian Christ: UNEP should contact persons at national level in Burundi Dr. Ralf Klingbeil (BGR): GEMS/Water contact. Andrew Gemmell: Dr Klingbeil made mention of a groundwater project that Ms Nkunzimana may be able to provide data for (https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Burundi/burundi_fb_en.html)
Mr.	Gerard	Ntungumburanye	Burundi Hydrological Service		Bujumbura, Burundi	ntungagerar@yahoo.fr		Kilian Christ: Contact provided by Dominique, works with WMO Hydrological advisor for Burundi
Ms.	Rose	Nyamori	Kenya Water Resources Authority (WRA).	Assistant Technical Officer	NHIF Building 9th Floor Wing B, Nairobi P. O. Box 45250. Kenya	ranyamori@gmail.com	ranyamori@yahoo.com	ICWRGC/GEMS/Water: GEMS Water NFP; Former GEMS Water NFP Representative
Dr.	Chrispine	Nyamweya	KMFRI Freshwater Systems Research/Limonology department.	Assistant Director Limnology.	Kenya	sanychris@yahoo.com	_	Andrew Gemmell: Member of Lake Victoria Working Group. Specialization: Ecological modelling
Mr.	Fred	Nyongesa	Kenya Water Resources Authority (WRA). Water Quality and Pollution Control	Ag. Deputy Technical Coordination Manager	Nairobi. Kenya	fnyongesa05@yahoo.com		Deputy Technical Coordination Manager. Water Quality & Pollution Control and Laboratory Services. Kilian Christ: GEMS/Water NFP Rep. Offered to meet representatives in Nairobi. Andrew Gemmell: Speaking to Joakim&Peter at GLOW9, apparently WRA hold quite a bit of WQ data for Lake Vic. ICWRGC/GEMS/Water: GEMS Water NFP; GEMS Water NFP Representative
Dr.	Kevin	Obiero	KMFRI. Aquaculture department		Kenya	kevobiero@gmail.com	kevinobiero@yahoo.com	Andrew Gemmell: Focussed on long-term collaboration networks and partnerships for the African Great Lakes. He is a key collaborator with Ted Lawrence from AGL-ACARE. Specialization: Fisheries and Aquaculture Socioeconomic, Community-based Natural Resource Management/Co-management of Fisheries Resources; Aquaculture Technology Adoption
Mr.	Zachary	Ogari	KMFRI Fresh Water Systems	Database manager	Kenya	zach@kenyasdata.com		Andrew Gemmell: Spearheading an data archive facility for all datasets generated under the Fresh Water Systems Division of KMFRI, including water quality. Met at GLOW9
Mr.	John O.	Okungu	Kenya Ministry of Environment, Water and Natural Resources. Provincial Water Office, LVEMP Water Quality Component		Kisumu. Kenya	jonokungu@hotmail.com		ICWRGC/GEMS/Water: Performance Evaluation PE-08;Performance Evaluation PE-07;GEMS Water Labs
Mr.	Mark	Olokotum	Uganda Ministry of Agriculture, Animal Industry and Fisheries		Entebbe, Uganda	markmrc6@gmail.com		Andrew Gemmell: Mark is a PhD Fellow, Makerere Uni., Kampala. Research on Ecotoxicology of Cyanobacteria | Environmental Sciences, Fisheries & Aquatic Sciences. Colleague of Stella Mbabazi. Met at ACARE. Implementing a project called "From the Lab to the World". Mark is mobilizing data for algae, invertebrates and fish.

Government Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Mr.	Philip J.	Olum	Kenya Water Resources Authority.	Former CEO	NHIF Building, 9th Floor Wing B, Off Ngong Road, Nairobi. Kenya	wrma@wrma.or.ke (failed November 2019)		ICWRGC/GEMS/Water: GEMS Water NFP; GEMS Water NFP Data Provider
Mr.	Aloys	Rurantije	Burundi Hydrological Service		Bujumbura, Burundi	arurantije@yahoo.fr		Kilian Christ: Contact provided by Dominique, works with WMO Hydrological advisor for Burundi
Mr.	Melchior	Ryumeko	Burundi Geographical Institute (Institut Géographique du Burundi)		Bujumbura, Burundi	melchioryumeko@gmail.com		Kilian Christ: GEMS/Water NFP Data Provider
Mr.	Mohamed	Shurie	Kenya Water Resources Authority (WRA).	CEO	Nairobi. Kenya	mmshurie@gmail.com		ICWRGC/GEMS/Water: GEMS Water NFP Kilian Christ: GEMS/Water NFP, CEO
Mr.	Robert	Sunday	Tanzania Ministry of Water and Irrigation		Dar, Tanzania	rkituha04@gmail.com	rkituha04@yahoo.com	Kilian Christ: Contact provided by Dominique, to be copied in correspondence with George Lugomela
Dr.	Emmanuel A	Sweke	Tanzania fisheries research institute (TAFIRI)		Tanzania	esweke@yahoo.com	-	Andrew Gemmell: TAFIRI research officer, provided by Chris Aura of KMFRI. His research interests and experience span much of aquatic ecology, resources conservation, assessment and management; aquaculture and environmental sustainability.
Dr.	Anthony	Taabu-Munyano	Uganda National Fisheries Resource Research Institute. Member of Lake Victoria Fisheries Organization.	Director	Uganda	ataabum@yahoo.com	-	Andrew Gemmell: Convenor of Lake Victoria Working Group
Ms.	Rukia	Tuwano	Tanzania Ministry of Water, Water Quality Services Division. Zonal Water Quality Laboratory		Tanga. Tanzania, United Republic of	rukiatuwano@gmail.com		ICWRGC/GEMS/Water: Performance Evaluation PE-07;Performance Evaluation PE-08;GEMS Water Labs
Mr.	Marco	Vitta	Tanzania Ministry of Water, Water Quality Services Division. Zonal Water Quality Laboratory		Bukoba, Kagera. Tanzania, United Republic of	vitta.marco@yahoo.com		ICWRGC/GEMS/Water: Performance Evaluation PE-08;GEMS Water Labs
Mr.	John . K	Walakwa	National Fisheries Resource Research Institute (NAFIRRI)		Uganda	johnwalakwa2003@gmail.com	-	Andrew Gemmell: Member of Lake Victoria Working Group
Mr.	Peter	Wawiye	KMFRI. Freshwater Systems Research department		Kenya	pwawiye@yahoo.com		Andrew Gemmell: Currently involved in water quality bioassessment using macroinvertebrates in freshwater systems at Lake Victoria. Presented at GLOW9. Interests: Water quality bioassessments.
Mr.	Nebert	Wobusobozi	Uganda Ministry of Water and Environment		Entebbe, Uganda	nbazaale65@gmail.com		Kilian Christ: Contact provided by Dominique, WMO Hydrological advisor for Uganda. RETIRED but probably still a useful contact

Research Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Mr	James	Barasa	University of Eldoret, Kenya		Kenya	barkanoti@gmail.com	_	Andrew Gemmell: Member of Lake Victoria Working Group. Lecturer and a member of Fish Genetics Division at the Department of Fisheries and Aquatic Sciences,
Mr	Steve	Greb	University of Wisconsin-Madison. Aquatic Sciences Center and Space Science and Engineering	Associate Fellow	USA	srgreb@wisc.edu.		Andrew Gemmell: Open to collaborate, especially EO data. GEO AquaWatch and the WWQA appear to be on somewhat parallel tracks with some similar objectives (e.g. building a global WQ monitoring service, merging in situ and remote sensed data).
Prof	Ken	Irvine	IHE Deflt	Chair of aquatic ecosystems group	Netherlands	K.irvine@un-ihe.org	_	Andrew Gemmell: Member of Lake Victoria Working Group
Prof	Frank	Kansiime	Makerere University		Uganda	fkansiime@gmail.com		Andrew Gemmell: Provided by Kate Heal (IAHS). Able to provide contacts relevant to water quality data/information of Lake Victoria.
Prof	Chrysi	Laspidou	University of Thessaly. Department of Civil Engineering, Greece		Greece	laspidou@uth.gr		Andrew Gemmell: Met in Ispra. Requested to be informed on dataset with information on Victoria lake. Offered assistance on machine learning or other AI methodologies for either missing data or water quality forecasting.
Mr.	Karl-Erich	Lindenschmidt	University of Saskatchewan (to 2014) now UFZ – PBFS GERMANY.		. Uganda	kel@gm.ufz.de		Provided by ICWRGC/GEMS/Water: GEMS Water CFP
Prof	Julius	Manyala	University of Eldoret, Kenya.		Kenya	manyalajo@yahoo.com	_	Andrew Gemmell: Scientific committee lead in Lake Victoria Working Group. Associate Professor and a member of Fisheries Management Division at the Department of Fisheries and Aquatic Sciences
Dr	Evans	Miriti	University of Nairobi. Also at www.africangreatlakesinform.org		Kenya	eamiriti@uonbi.ac.ke	_	Andrew Gemmell: Member of Lake Victoria Working Group
Prof.	Daniel	Olago	University of Nairobi		Nairobi, Kenya	dolago@uonbi.ac.ke	olagodan@yahoo.co.uk	Kilian Christ: Member of the Scientific Committee of ILEC and would be able to give overview of ILEC activities in Kenya including ESPP
Mr	Alfred	Otieno	University of Eldoret, Kenya		Kenya	achiengalfred@gmail.com	aotieno@uoeld.ac.ke, alfredachieng@yahoo.ocm	Andrew Gemmell: Member of Lake Victoria Working Group. Lecturer and a Member of Aquatic Resource Management and Fisheries Management Division at the Department of Fisheries and Aquatic Sciences
Mr	Nathan	Semwanga	Makerere University		Uganda	Nsemwanga18@yahoo.com		Andrew Gemmell: From the department of Biology. Has contacts related to water quality
Mr	Zacharia	Shitote	University of Eldoret, Kenya		Kenya	Zacharias2002ke@yahoo.com	_	Andrew Gemmell: Member of Lake Victoria Working Group. Lecturer, Project planning and Management, School of Business and Management Sciences,
Mr	Joost	van den Roovaart	Deltares		Netherlands	joost.vandenroovaart@deltares.nl		Andrew Gemmell: Shared information on 3D modelling undertaken in 1999 using Delft3D to simulate water hyacinth. While not yet applied to Lake Victoria, it can be quickly set up to do so

Non-Governmental and Intergovernmental Organisations								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Mr	Davis	Adieno	Global Partnership for Sustainable Development Data			dadieno@data4sdgs.org		Andrew Gemmell: GPSDD Africa Regional Director
Mr.	Colin	Apse	Africa Freshwater Conservation.	Director for The Nature Conservancy Africa Program		capse@tnc.org		Andrew Gemmell: Freshwater ecosystem conservation and sustainable water management. Africa experience: Tanzania, Kenya, Zambia, South Africa, Angola, and Gabon. He may have useful contacts. Name provided by Kilian Christ after Colin hosted webinar in May 2019 (Africa Water Funds Strategy and iconic basins).
Dr.	Ahmed	Eldaw	Global Water Partnership		Plot 17 Mpigi Road, Entebbe, Uganda	Ahmed.K.Eldaw@gwpea.org		Kilian Christ: Responded to call to WWQA members for contacts. Regional Coordinator, GWP Eastern Africa Region
Mr.	Tom	Kanyike	ICPAC		Nairobi, Kenya	shukar@techie.com	tom.kanyike@mwe.go.ug	Kilian Christ: Currently at ICPAC, Nairobi, attached to the SAWIDREA project,
Dr	Ted	Lawrence	AGL-ACARE. African Center for aquatic research and education			ted@agl-acare.org		Andrew Gemmell: Met Martin at GLOW9. Has experience in local governance in the area. Convening the African Great Lakes Platform. They proposed a stakeholder workshop on 5-7 November 2019 in Entebbe Uganda attended by Andrew Gemmell, Tallent Dadi (UFZ)
Ms.	Jacqueline	McGlade	UNEP. Division of Early Warning and Assessment (DEWA)	Special Advisor to the Executive Director of UNEP	Kenya	Jacqueline.McGlade@unep.org		Provided by ICWRGC/GEMS/Water: GEMS Water Steering Committee; UNEP HQ
Dr	Modesta	Medard	WWF.	Marine Programme Coordinator	Tanzania	modesta_medard@yahoo.uk	-	Andrew Gemmell: Member of Lake Victoria Working Group.
Mr	Patrick	Mmayi	UNEP.	Programme Officer	Nairobi Kenya	Patrick.Mmayi@unep.org		Provided by ICWRGC/GEMS/Water: UNEP HQ. Division of Early Warning and Assessment United Nations Environment Programme
Dr	Kenneth	Mubea	Global Partnership for Sustainable Development Data		Nairobi, Kenya	kmubea@data4sdgs.org		Andrew Gemmell: Met in Ispra and Ghana AGDIC: Linked to Africa Regional Data Cube, which uses Water Observations from Space (WOfS) (i.e. EO). ARDC can be used to assess the water quality SDG 6.3.2 and water extent SDG 6.6.1. He requested to use some datasets from GEMS for some validation especially the NASA Ocean Colour Chlorophyll-A OC3 Algorithm for Lake Volta (Ghana) and Weija Reservoir (Accra).
Mr	Geoffrey	Omedo	UNDP	Sustainable development specialist	Nairobi, Kenya	geoffrey.omedo@undp.org		Andrew Gemmell: Info provided by Killian Christ. He works in water in the area
Mr.	Paul	Orengoh	AMCOW		Nairobi, Kenya	paulorengoh.254@gmail.com	porengoh@rti.org	Kilian Christ: When at RTEI, Paul's work mainly focused on developing analytical tools and systems for both the Nile Basin Initiative and the Lake Victoria Basin Commission to support water quality assessments and monitoring.". Offered a skype call to Andrew Gemmell
Dr	Hisham M. S.	Osman	World Bank		USA	hosman1@worldbank.org		Andrew Gemmell: Met in Entebbe at AGL-ACARE w/shop. Has similar objectives to identify stakeholders and data. Launching http://spatialagent.org/
Dr.	Moses	Oyer	OSIENALA (Friends of Lake Victoria)		Kisumu, Kenya	oyierkilli2@yahoo.com		Kilian Christ: Worked on ILEC Ecosystem Service Perceptional Profile (ESPP) study for Lake Victoria
Mr.	Jackson	Raini	FlamingoNet		Nakuru, Kenya	jraini2002@yahoo.com		Kilian Christ: Worked on ILEC Ecosystem Service Perceptional Profile (ESPP) study for Lake Nakuru. Lake Nakuru was more advanced thatn the Lake Victoria ESPP study.
Mr.	Jayakumar	Ramasamy	UNESCO	Programme Specialist	Nairobi, Kenya	r.jayakumar@unesco.org		Andrew Gemmell: Info provided by Killian Christ. He works in water in the area
Mr	L. Roberto	Silva Vara	WMO		Switzerland	LSilvavara@wmo.int		Andrew Gemmell: E-intro via Michael Schwab (WMO) who was in Ispra. HydroSOS Project Officer Climate and Water Department
Mr.	Martin	Van Der Knaap	FAO			martinus.vanderknaap@fao.org		Andrew Gemmell met Martin at GLOW9. Done work at Victoria and Volta. Has database called aquastat
Mr.	Boniface	Waweru Muraya	Kenya Water Institute (KEWI).		Kenya	muraya@kewi.or.ke		Provided by ICWRGC/GEMS/Water: Check/reestablish contact; GEMS Water CFP; Resend invitation
Mr	Jian	Xie	World Bank		USA	jxie@worldbank.org		Andrew Gemmell: Contact provided by William Rex of World Bank after WWQA request for stakeholders. World Bank has supported the LVBC in environmental and natural resources management (including water quality management) through a phased project “Lake Victoria Environmental Management Project” (LVEMP). You may make initial contact with LVBC: Executive Secretary Dr. Ali Said Matano matano@lvbcom.org and LVEMP team leader Dr. Lily Kisaka

Private Organisations								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Ms.	A.	Abira	Charis Ecosmart Solutions Limited.		Kenya	margaret.abira@charis-ecosmart.com (failed April 2019)	mabira59@yahoo.com	Provided by ICWRGC/GEMS/Water: Former GEMS Water NFP Representative; GEMS Water Scoping Workshop Africa (2016); UNEA Booth visit
Ms.	Clarissa	Mulders	WE Consult		Austria	clarissamulders@gmail.com		Andrew Gemmell: Information provided by Sabine Henry (Umvoto). Involved in an AFD funded feasibility study for a large drinking water treatment plant abstracting water from Lake Victoria for National Water and Sewerage Corporation
Mr.	John	Omwenga	Eden Water & Environmental Consultants.	Lead Consultant	Beltop House, Magadi Road, Off Langata Road, Nairobi P.O Box 1067-00517. Kenya	johnomwenga@yahoo.com	jomwenga.omwenga@gmail.com	Provided by ICWRGC/GEMS/Water: GEMS Water CFP

ANNEX A2 – VOLTA BASIN

Government Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Dr.	Ronald	Abrahams	Water Resources Commission	Basin Officer		ronhams@yahoo.com		Andrew Gemmell: E-intro via Yeneneh Teka (US Embassy Ethiopia)
Mr.	Ebenezer Victor O.	Addabor	Ghana National Disaster Management Organization (NADMO)		Ghana	addabor@gmail.com		Andrew Gemmell: Contacts provided by Kenneth Mubea of data4sdgs
Dr.	Sam	Adu-Kumi	Ghana Environmental Protection Agency (EPA). Environmental Quality		Accra. Ghana	sam.adu-kumi@epa.gov.gh (failed November 2018)	adukumisam@yahoo.com	Provided by ICWRGC/GEMS/Water. GEMS Water NFP; GEMS Water NFP Representative
Mr.	Maxwell	Akosah-Kusi	Ghana Water Company Ltd, Technology & Innovations.		Ghana	akosah.kusi@gmail.com		Andrew Gemmell: At AGDIC conference, Maxwell presented and when I asked a question, he stated Ghana Water Company could share water quality data
Mr.	Michael	Akwei	Ghana Environmental Protection Agency.	Principal Laboratory Technician	C/O EPA Box M 326 Ministries Accra. Ghana	MIK-WEI@HOTMAIL.COM		Provided by ICWRGC/GEMS/Water. GEMS Water NFP; GEMS Water Training Workshop Africa (2017)
Mr.	Ben	Ampomah	Ghana Water Resources Commission		Ghana	byampomah@yahoo.com		Andrew Gemmell: Met in Accra Ghana
Dr.	Frederick	Amu-Mensah	Water Research Institute.	Senior Research Scientist		obeyie@hotmail.com		Andrew Gemmell: E-intro via Yeneneh Teka (US Embassy Ethiopia)
Mr.	Jeremiah	Asumbere	Ghana Environmental Protection Agency.		Accra. Ghana	Jeremiah.Asumbere@epa.gov.gh		Provided by ICWRGC/GEMS/Water. GEMS Water NFP; GEMS Water NFP Data Provider; GEMS Water Scoping Workshop Africa (2016)
Mr.	Mark	Ayertey	Ghana Water Company. Water Quality Department	Water Quality Officer	Accra. Ghana	markayertey@yahoo.com	mayertey@gwcl.com.gh	Provided by ICWRGC/GEMS/Water. UNESCO Regional Expert Meeting on Water Quality in Agenda 2030 SDGs (2016)
Mr.	Charles	Biney	Volta Basin Authority		Ghana	cbiney@gmail.com		Kilian Christ: Former DG, "Mr. Water" of the region
Ms.	Rachel	Bowers	Ghana Statistical Service.	SDG Secretariat	Ghana	rachel.bowers@statsghana.gov.gh		Andrew Gemmell: Contacts provided by Kenneth Mubea of data4sdgs
Mr.	Robert	Dessouassi	Volta basin Agency			dessouassi2003@yahoo.fr		Anderw Gemmell: Provided by Kate Heal (IAHS). Head of the Transboundary basin agency (Volta basin Agency).
Mrs.	Margaret	Macauley	Ghana Water Company Limited	Director, Water Quality Assurance		mnmacauley@yahoo.com		Andrew Gemmell: E-intro via Yeneneh Teka (US Embassy Ethiopia) https://www.gwcl.com.gh/margaret_macauley.html
Mr.	Eric	Muala	Ghana Water Resources Commission		Ghana	ericmuala25@gmail.com		Andrew Gemmell: Contacted to share data and stakeholders. Name received via Ken Mubea.
Mr.	Cheick	Ouattara	Burkino Faso Directorate General of Water Resources, Water Quality Service (Direction Générale des Ressources en Eau. Service Qualité des Eaux)		Ouagadougou. Burkina Faso	o.cheick@gmail.com		Provided by ICWRGC/GEMS/Water. GEMS Water NFP; GEMS Water NFP Representative; GEMS Water Scoping Workshop West Africa (2018)
Ms.	Dorcas Adwoa	Paintsil	Ghana Water Resources Commission		Accra. Ghana	himapaintsil@yahoo.com		Provided by ICWRGC/GEMS/Water. Check/reestablish contact; GEMS Water CFP
Mr	Worlanyo Kwadjo	Siabi	Community Water and Sanitation Agency	CEO		wksiabi@yahoo.com		Andrew Gemmell: E-intro via Yeneneh Teka (US Embassy Ethiopia)
Prof.	Paul L. G.	Vlek	University of Bonn, Center for Development Research (ZEF)	Emeritus professor.	Germany	p.vlek@uni-bonn.de		Andrew Gemmell: According to Prof. Chris Gordon of Uni of Ghana Prof. Vlek involved in GLOWA project. May be able to assist in tracking down data that was on project website (non not online). Founding Executive Director of the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL)
Ms.	Jacqueline	Zoungrana/ Zango	Burkina Faso Ministry of Water, Water Resources and Sanitation. Director of Studies and Information on Water. Ministère de l'Eau, des aménagements hydrauliques et de l'Assainissement. Directrice des Etudes et de l'Information sur l'Eau		3131, avenue de la Liberté B.P. 7025, Ouagadougou. Burkina Faso	zoungjac@yahoo.fr (failed November 2018)		Provided by ICWRGC/GEMS/Water. Former GEMS Water NFP Representative

Research Stakeholders								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Dr.	Samuel	Addo	University of Ghana Marine & Fisheries Sciences Department	Senior Lecturer (Head of Department)	Ghana	samaddo@ug.edu.gh		
Dr.	Felix	Akpabey	CSIR-Water Research Institute	Officer-in-Charge, Tamale.	Ghana	ffelix39@yahoo.co.uk	fakpabey@gmail.com	Andrew Gemmell: Provided by Kate Heal (IAHS). Senior Research Scientist/OIC-Tamale. http://www.csir-water.com/index.php?option=com_content&view=article&id=235:dr-felix-akpabli&catid=34:profile&Itemid=37.
Dr.	Joseph Addo	Ampofo	CSIR Water Research Institute	Director	Accra. Ghana	jaampofo@yahoo.com	jaampofo@csir-water.com	Provided by ICWRGC/GEMS/Water. SPONGE;GEMS Water CFP
Mr.	Kwadwo Ansong	Asante	CSIR Water Research Institute. Environmental Chemistry Division	Research Scientist	Accra. Ghana	kaasante@chemist.com	jaampofo@csir-water.com	Provided by ICWRGC/GEMS/Water. SPONGE;Performance Evaluation PE-08;GEMS Water Labs
Dr.	Emmanuel	Bekoe	CSIR Water Research Institute.	Research Scientist, Surface Water	Accra. Ghana	eobekoe@yahoo.com	eobeng.bekoe@csir-water.com	Provided by ICWRGC/GEMS/Water. GEMS Water CFP
Dr.	Olufunke	Cofie	IWMI		Ghana	o.cofie@cgiar.org		Andrew Germmell: Met at CReWAS conference, Accra, Ghana Oct 2019.
Prof.	Chris	Gordon	University of Ghana, Institute for Environmental and Sanitation Studies (IESS)		Ghana	CGordon@ug.edu.gh	Shared GLOWA CD. Very active in region	Andrew Gemmell: Met at Ghana CReWAS conference. He is involved in the Volta Basin Research Project (VBRP) which is currently part of the IESS has carried out extensive research work on water quality issues in relation to its impacts on fisheries productivity, aquaculture among others and thus has extensive knowledge of the Volta basin.
Dr.	Angela	Lamptey	University of Ghana. Marine & Fisheries Sciences Department.	Lecturer	Ghana	amlamptey@ug.edu.gh		
Mr.	Foster	Mensah	Centre for Remote Sensing and Geographic Information Services. Univerity of Ghana/SERVIR West Africa		Ghana	FMensah@ug.edu.gh		Andrew Gemmell: Contacted to share data and stakeholders. Name received via Ken Mubea.
Dr.	Adelina	Mensah	University of Ghana, Institute for Environmental and Sanitation Studies (IESS)		Ghana	ammensah@staff.ug.edu.gh		Andrew Gemmell: Organiser of CReWAS conference. Open to arranging an in-country stakeholder workshop in early 2020.
Dr.	Josiane	Nikiema	IWMI		Ghana	J.Nikiema@cgiar.org		Andrew Germmell: Met at CReWAS conference, Accra, Ghana Oct 2019.
Dr.	Daniel	Nukpezah	University of Ghana, Institute for Environmental and Sanitation Studies (IESS)		Ghana	dnukpezah@staff.ug.edu.gh		Andrew Gemmell Provided by Kate Heal (IAHS). http://iess.ug.edu.gh/people/faculty/dr-daniel-nukpezah. Research includes: Pollution and pollution control in inland waters; lake and Reservoir limnology and management
Mr.	Kwabena	Nyarko	Kwame Nkrumah University of Science and Technology.	Senior Lecturer	Ghana	nyarko.k.b@gmail.com		Andrew Gemmell: Provided by Kate Heal (IAHS). https://scholar.google.com/citations?user=2ylCnWMAAAAJ&hl=en.
Prof.	Patrick K.	Ofori-Danson	University of Ghana, Marine & Fisheries Sciences Department	Associate Professor (Contract)	Ghana	pofori-danson@ug.edu.gh		Andrew Gemmell: Marine & Fisheries Sciences Department, University of Ghana: Studies on various aquatic ecosystems and fisheries in Ghana. Several projects of the Marine and Fisheries Science Department, including those of MESA, GMES & Africa focus on the marine and coastal environments of Ghana and the West African sub-region. The GMES & Africa project in particular has extensive Earth Observation (EO) capacities that can be adapted for water quality monitoring in the Volta basin and other inland areas.
Dr.	Mwemezi	Rwiza	Nelson Mandela African Institute of Science and Technology. Dept. Water, Environmental Science and Engineering (WESE)	Lecturer	Ghana	mwemezi.rwiza@nm-aist.ac.tz		Andrew Gemmell: Contacted to share data and stakeholders. Name received via Kate Heal.
Prof.	Nindaoua Alain	Savadogo	Université de Ouagadougou. URF Sciences de la Vie et de la Terre (UFR/SVT)		Ouagadougou. Burkina Faso	nindaoua@univ-ouaga.bf	nindaoua@yahoo.fr	Provided by ICWRGC/GEMS/Water. GEMS Water Labs
Prof.	George	Wiafe	University of Ghana. Marine & Fisheries Sciences Department	Associate Professor, MESA & GMES Africa Projects	Ghana	wiafeg@ug.edu.gh		

Non-Governmental and Intergovernmental Organisations								
Title	**Name**	**Surname**	**Organization**	**Position**	**Address / Location**	**e-mail 1**	**e-mail 2**	**Comments**
Mr.	Davis	Adieno	Global Partnership for Sustainable Development Data		Nairobi, Kenya	dadieno@data4sdgs.org		Killian: GPSDD Africa Regional Director
Mr.	Armand	Houanye	Global Water Partnership-Africa Coordination Unit, West Africa		333 Grosvenor Street, Hatfield Gardens, Block A Pretoria, South Africa (but with experience in west Africa)	armand.houanye@gwpao.org	a.houanye@cgiar.org	Killian Christ: GWP Feedback to WWQA request: Technical Advisor for Water, Climate and Development Programme (WACDEP) & Integrated Sanitation and Water Programme for Resilient Cities. Climate risks and water resources management specialist with in depth experience in agricultural water management, integrated water resources management (IWRM), climate change adaptation, climate resilience, water governance and integrity.
Dr.	Ralf	Klingbeil	Federal Institute for Geosciences and Natural Resources (BGR), Germany		Germany	ralf.klingbeil@bgr.de		Andrew Gemmell: Was involved in GLOWA project
Mr.	Bako	Mamane	SERVIR West Africa.	Capacity Development Lead	Ghana	mamanebako01@gmail.com		Andrew Gemmell: Contacted to share data and stakeholders. Name received via Ken Mubea.
Dr.	Kenneth	Mubea	Global Partnership for Sustainable Development Data		Nairobi, Kenya	kmubea@data4sdgs.org		Andrew Gemmell: met in Ispra and AGRIC (Ghana). Linked to Africa Regional Data Cube, which uses Water Observations from Space (WOfS) (i.e. EO). ARDC can be used to assess the water quality SDG 6.3.2 and water extent SDG 6.6.1. He requested to use some datasets from GEMS for some validation especially the NASA Ocean Colour Chlorophyll-A OC3 Algorithm for Lake Volta (Ghana) and Weija Reservoir (Accra).
Mr.	Rameshh	Tripathi	WMO		Switzerland	rtripathi@wmo.int		Andrew Gemmell: E-intro via Michael Schwab (WMO) who was in Ispra. WMO Volta activities are not under HydroSOS, rather under an Adaptation Fund project.
Mr.	Martin	Van Der Knaap	FAO		Accra, Ghana	martinus.vanderknaap@fao.org		Andrew Gemmell: met at GLOW9. Done work at Victoria and Volta. FAO database called aquastat

ANNEX B – ONE-PAGER SUMMARIES OF USE CASES
ANNEX B1 – LAKE VICTORIA

Africa Use Cases Water Quality, Data, Services and Products: Co-Designing Three Pilot Cases in Africa

Mission Statement of World Water Quality Alliance:

The World Water Quality Alliance (WWQA) forms an open, global consortium, pooling expertise on water quality science and technology innovation. It aims at providing a participatory platform for water quality assessments and co-design of tailored and demand-driven services. It addresses priority topics relevant to water governance, scalable water solutions and emerging issues in water management.

Context:

The Use Cases provide an initial testbed that puts the quality of surface water and groundwater into the context of the local 2030 Agenda and its multiple linkages across the Sustainable Development Goals.

The UN Environment Programme is cooperating with relevant organisations including the UN-Water Expert Group on Water Quality and Wastewater in the World Water Quality Alliance to develop a World Water Quality Assessment for consideration by UNEA-5.

Africa Use Cases Aim:

Build the "use case" for a World Water Quality Assessment by means of the piloting and demonstration of current capabilities, future information and services of the World Water Quality Alliance (the "Alliance") through these three case studies.

Central in these initial test cases will be the integration of in-situ, remote sensing-based earth observation and modelling data to derive the best possible current state of water quality (baseline). The objective is to provide an evidence base that links water quality hotspots to solutions and investment priorities. Crucial is a multi-stakeholder in-country driven process defining demand for water quality services (using experience in global problems to support local solutions). Stakeholders include government, academia, civil society and (inter)national organisations (quadruple helix).

Project Phases

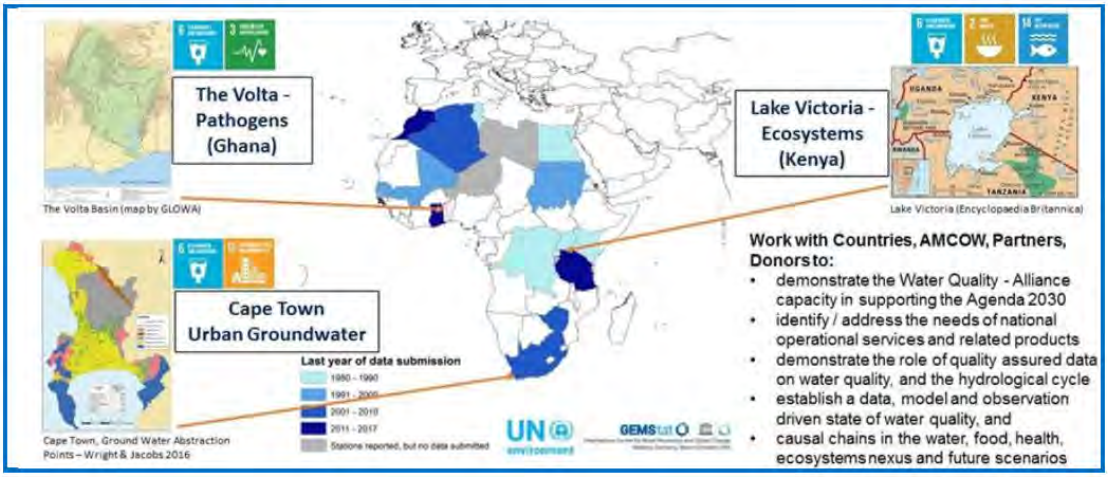
Initiation Phase:

The network of contributing Alliance partners and local Use Case stakeholders is identified, and a rapid assessment of existing monitoring and assessment capacities and availability of data from multiple sources is conducted to determine the current state of knowledge and to set the objectives for the information services to be developed.

Identification Phase:

Existing data and information used to identify, categorise and undertake a preliminary (baseline) assessment of the quality status of the freshwater ecosystems by testing an innovative data/model fusion approach and further data analysis to develop pilot products and services for local/national application.

Use Case Study Areas



Lake Victoria Basin

The Lake Victoria Basin riparian countries are Burundi, Kenya, Rwanda, Tanzania, Uganda

Challenges:

Domestic and industrial wastewater, solid wastes, sediments from soil erosion in the catchment area, agricultural wastes and atmospheric deposition are the major **nutrient sources** that promote algal blooms in the lake.

Parts of Lake Victoria, especially the deeper areas, are now considered dead zones, unable to sustain life due to oxygen deficiency in the water.

The threats facing the lake have caused considerable hardship for the populations dependent on it for their livelihoods and have also reduced the biodiversity of the lake's fauna, most notably fish and phytoplankton.

Reference:
http://catalogue.servirglobal.net/Product?product_id=74

Copyright: World Lake Database International Lake Environment Committee

Work Plan:

1 – Identify Stakeholders and Assess Capacity (Complete by Q4 2019)
- Collate information on existing databases among Alliance members (in situ, remote sensing-based earth observation (RS/EO) and modelling data; water quality products and services)
- Identify and record local Use Case stakeholders
- Assess Use Case capacity and gaps (capacities determined around enabling environment; institutions and participation; management instruments; financing) to assist in developing products and services.

2 – Set Visions and Objectives (Complete by Q1 2020)
- Consult local Use Case stakeholders (incl. inception workshop) to co-design with Alliance members the water quality data and information product(s).
- Compile Use Case databases of existing data for sharing among partners for targeted analysis

3 – Desktop Assessment (Complete by Q2 2020)
- Integrate water quality data in triangular approach (in-situ, RS/EO, modelling)
- Rapid baseline assessment of drivers, pressures & state of water quality to identify hotspots
- Develop co-designed water quality pilot products and services for present and future

4 – Conclusions and Outlook (Complete by Q3 2020)
- Review Results and Compile Outlook

ANNEX B2 – VOLTA BASIN

Africa Use Cases Water Quality, Data, Services and Products: Co-Designing Three Pilot Cases in Africa

Mission Statement of World Water Quality Alliance:

The World Water Quality Alliance (WWQA) forms an open, global consortium, pooling expertise on water quality science and technology innovation. It aims at providing a participatory platform for water quality assessments and co-design of tailored and demand-driven services. It addresses priority topics relevant to water governance, scalable water solutions and emerging issues in water management.

Context:

The Use Cases provide an initial testbed that puts the quality of surface water and groundwater into the context of the local 2030 Agenda and its multiple linkages across the Sustainable Development Goals.

The UN Environment Programme is cooperating with relevant organisations including the UN-Water Expert Group on Water Quality and Wastewater in the World Water Quality Alliance to develop a World Water Quality Assessment for consideration by UNEA-5.

Africa Use Cases Aim:

Build the "use case" for a World Water Quality Assessment by means of the piloting and demonstration of current capabilities, future information and services of the World Water Quality Alliance (the "Alliance") through these three case studies.

Central in these initial test cases will be the integration of in-situ, remote sensing-based earth observation and modelling data to derive the best possible current state of water quality (baseline). The objective is to provide an evidence base that links water quality hotspots to solutions and investment priorities. Crucial is a multi-stakeholder in-country driven process defining demand for water quality services (using experience in global problems to support local solutions). Stakeholders include government, academia, civil society and (inter)national organisations (quadruple helix).

Project Phases

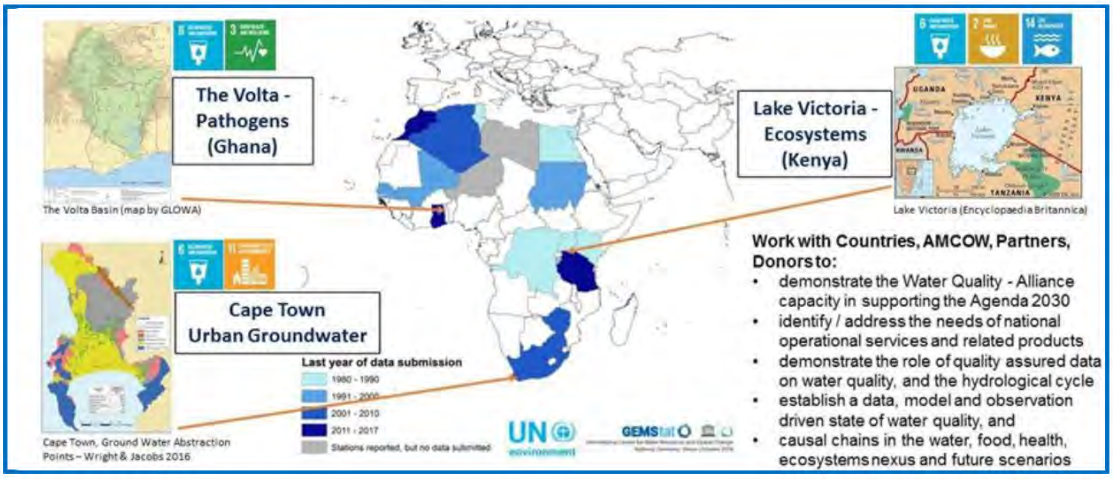
Initiation Phase:

The network of contributing Alliance partners and local Use Case stakeholders is identified, and a rapid assessment of existing monitoring and assessment capacities and availability of data from multiple sources is conducted to determine the current state of knowledge and to set the objectives for the information services to be developed.

Identification Phase:

Existing data and information used to identify, categorise and undertake a preliminary (baseline) assessment of the quality status of the freshwater ecosystems by testing an innovative data/model fusion approach and further data analysis to develop pilot products and services for local/national application.

Use Case Study Areas



Volta River Basin

Includes six countries: Burkina Faso (43%), Ghana (42%), Togo (6%), Benin (3%), Mali (3%), Côte d'Ivoire (2%).

Surface water quality challenges:

- Nutrient load: highly localised from agricultural sources (plantations), markets, industries (beverage and textile), illegal mining activities
- Pathogens: from discharge of domestic waste, untreated sewage, open defecation (humans/animals)
- Sediments from declining natural vegetation

Groundwater quality challenges:

- Localised concerns, incl. fertilizer, sanitation, natural occurrences of heavy metals.

Copyright: GLOWA Volta 2007

Work Plan:

1 – Identify Stakeholders and Assess Capacity (Complete by Q4 2019)

- Collate information on existing databases among Alliance members (in situ, remote sensing-based earth observation (RS/EO) and modelling data; water quality products and services)
- Identify and record local Use Case stakeholders
- Assess Use Case capacity and gaps (capacities determined around enabling environment; institutions and participation; management instruments; financing) to assist in developing products and services.

2 – Set Visions and Objectives (Complete by Q1 2020)

- Consult local Use Case stakeholders (incl. inception workshop) to co-design with Alliance members the water quality data and information product(s).
- Compile Use Case databases of existing data for sharing among partners for targeted analysis

3 – Desktop Assessment (Complete by Q2 2020)

- Integrate water quality data in triangular approach (in-situ, RS/EO, modelling)
- Rapid baseline assessment of drivers, pressures & state of water quality to identify hotspots
- Develop co-designed water quality pilot products and services for present and future

4 – Conclusions and Outlook (Complete by Q3 2020)

- Review Results and Compile Outlook

ANNEX C –DATA SUMMARY

C1 – LAKE VICTORIA

	Type of data (monitoring, modelling, time period etc.)	COMMENTS	Priority
KEY		e.g. A.Gemmell: Comment	1
Reporting			2
Modelling			3
Data			4
EO/RS			
Literature Review:	**Literature Review:** The East African Community and Lake Victoria Basin Commission (LVBC) with the aid of the World Bank have commissioned several studies in the Lake Victoria basin as part of the Lake Victoria Environmental Management Project (LVEMP) Phase I (1995-2005), the majority of the data is detailed in the following reports: · Lake Victoria Environment Report – Uganda Water Quality and Ecosystems Status (Muyodi and Hecky, 2005), · Lake Victoria Environment Report - Kenya National Water Quality Synthesis Report (Aboudha and Hecky, 2005), · Study on Water Quality and Human Health Around Lake Victoria (Lake Victoria Environmental Management Project (LVEMP), 2004) Other similar past studies include: Africa Water Network (1998), Bootsma et al. (1996), Calamari et al. (1995, http://41.89.141.8/kmfri/bitstream/123456789/379/1/Calamari%2c%20D..pdf), Scheren (2005, 2003) and Scheren et al. (2000, 1995). The Center for International Forestry Research worked with citizens in Kenya who contributed valuable water level and water-quality data (Rufino et al., 2018).	S. Jomaa: Can some URL or links be added here? (after each reference) A:Gemmell: All documents requested will be shared in a Google Drive	
Ken Irvine,UN-IHE	Various reports cited to help answer the question: **To what extent has the research and institutional capacity in the Lake Victoria Basin affect the monitoring and management cycle as advocated in this report?**		
Robert Burtscher (lead), Yoshihide Wada, Ting Tang. International Institute for Applied Systems Analysis (IIASA)	Global Lake water quality dataset based on **Remote Sensing** (monthly, 2002-2011): -Lake Surface Water Temperature -Chlorophyll A -Total Suspended Matter -Turbidity -Coloured Dissolved Organic Matter -Immersed And Floating Cyanobacteria (Probability Only) -Floating Vegetation (Probability Only) Readily available, World Bank project/data, intended to be published as open source in 2019.	https://doi.pangaea.de/10.1594/PANGAEA.871462 (this one is also a very interesting database?)	
	District-level **survey data on wastewater** treatment and sanitation (Uganda only, current). Accessible through IIASA collaboration, intended to be published as open source.	O. Büttner: Can be used in the magic triangle (modelling). Open source publication is very good. Parameter must be concretisized: X,Y coordinates; person equivalents served;effluent concentrations or loads for nutrients;	2
	Modelled long-term trends for nutrient export (mainly nitrogen) to Lake Victoria and the basin using global nutrient dataset (fertilizer, nitrogen deposition, manure, nitrogen fixation, nutrient in human waste, etc.), including the influence of global/regional changes and local/regional solution options (10-year interval, current - 2050). IIASA data using internal and external global/regional model inputs. **Readily available, IIASA data using internal and external global/regional model inputs**	(S. Jomaa: Please check the following presentation: Can we download data from the WRIS platform (http://lvbc.wris.info/) https://iiasa.ac.at/web/home/research/3.2_LVBC_WRIS_Water_Resources_Information_System__Eng._Calis.pdf M. Flörke: can be used for magic triangle; I. Bärlund: readily linkable with WorldQual? What does readily available mean, is there a database?	2
	Modelled current and future hydrology and sectoral water demand considering climate change, water and food demands, agricultural management, etc. based on regional development scenarios (daily, current - 2050) **Readily available, IIASA data using internal and external global/regional model inputs**		
Christopher Aura, Assistant Director, Zachary Ogari, Kisumu. Kenya Marine and Fisheries Research Institute (KMFRI)	**Water quality, pesticides, wild major fisheries, cage culture, pond data, riverine and river mouth data** Apparently available at Government of Kenya data (https://kenyasdata.com/), KMFRI website (http://41.89.141.8/kmfri/). Zachary: · Physical chemical data – Water quality surveillance (KMFRI & LVEMP) · Nutrient and Heavy metal levels · Zooplankton and Phytoplankton distribution · Fishing grounds mapping · Water hyacinth hotspots · Cyanotoxins · Fish breeding sites · Cage Culture abundance · Bathymetry of the Lake	O. Büttner: Can be used in the magic triangle (in situ data); I. Bärlund: Could KMFRI/Christopher Aura be a concrete stakeholder for us in June?	1

	· Pesticide contamination · Remote Sensing/ Satellite imagery monitoring **However not immediately available. Andrew in discussion with KMFRI on accessing this data**		
Prof. R.E. Hecky	Prof. Hecky provided **reports** for Lake Victoria •Lake Victoria Environmental Management Project (LVEMP) Water Quality and Ecosystem Status (2005) •Lake Victoria Environmental Management Project (LVEMP), July 2005 •Lake Victoria Regional Water Quality Synthesis Report, 2005. •Various reports specific to Nyanza Gulf (and Napoleon Gulf for mercury).	I. Bärlund: the references / report would be interesting for our final report	
John Dominic, Kenya NEMA	Kenya Environmental Performance Index (KEPI) report 2018. The EPI is a way of quantifying the environmental performance of a state vs SDGs	I. Bärlund: Reference/report would be interesting, would National Environment Management Authority be a stakeholder?	
Mark Olokotum. Uganda Ministry of Agriculture, Animal Industry and Fisheries	Implementing a project called "From the Lab to the World". **Mobilizing data for algae, invertebrates and fish.**	O. Büttner: Sounds like future data; I. Bärlund: Would MAAIF be a stakeholder?	3
AGL-ACARE (African Center for Aquatic Research and Education)	**Lake-specific data** available at www.africangreatlakesinform.org	O. Büttner: Cannot be used: no raw data available.	4
	Evans Miriti: Do not store raw data because of lack of funds/resources to hire a data management expert. **Create links to existing data sources** e.g. http://www.fao.org/geonetwork/srv/en/main.home		
Dr Mwemezi J. Rwiza, The Nelson Mandela African Institution of Science & Technology	**Reports/Papers on:** - Monitoring: monitoring of pollutants e.g. heavy metals; water quality; nutrients; water use; lake level; pollutant sources and fate; influence of climate change - Control: Water hyacinth; water use/abstraction; conservation; lake biodiversity - Management: Stakeholders' involvement; watershed approaches; water use; water quality; land-use; water resources e.g. fishing; human settlement	I. Bärlund: From when are these reports? Maybe interesting for a literature review.	
Joost van den Roovaart, Deltares	**Remote sensing** (1970-now). Remote sensing based on Google Earth engine to track water hyacinth.		
	3D **model** (1999). Model is Delft3D for hydrodynamics. Dedicated water quality model to simulate water hyacinth. Has not been applied to LV but can be quickly set up.	M. Flörke: if data available could be of interest for comparison, maybe magic triangle	2
EOMAP	EO/ RS – *see below*		
John Omwenga, Eden Environmental and Water Consultants 4	**Water Supply & Sanitation Data**		
	1. Rural Drinking Water Supply & Sanitation Program (RDWSSP) of the Ministry of Water (1990 - 1996) – Project covered the Districts within the Lake Victoria Basin; and was supported by the Government of Netherlands and coordinated by DHV and later BKH Consultants. Activities included spring protection, drilling and equipping boreholes, gravity systems community water supply schemes, shallow wells and development of sanitation facilities (VIP Latrines). The Project focused on Malaria prevention and reduction of waterborne diseases.		
	2. Kenya -Finland Rural WS project (KENFICO project). 1985 - 1990. This project was based in Kakamega County and focused in drilling Shallow wells to improve water supplies and reduce waterborne diseases.		
	Comment: Data from both projects may not be readily available or may be in the archives of the Ministry of Water and Ministry of Health		
	Data on status of Rivers draining into L. Victoria, and Lake Victoria **Lake Victoria Environmental Management Program (LVEMP) - Regional program. Data available in regional offices of the project. (Kisumu, Mwanza, Entebbe). 1997- 2004 (LVEMP1)** **- WQ Data available for Sediment Nutrient and Organic Loading** **- Pollution Hotspots also identified (usually downstream of urban settlements , industries and coffee and sugar factories)** **Water quality data is also contained in a project report "The Limnological Study of Lake Victoria". This project was carried out under LVEMP 1.**	O. Büttner: sounds like the data are not compiled and ready to submit. So data are useful but not available at the moment.	3
	- Modelling of Lake attempted		
	· Water quality data is also contained in a project report "The Limnological Study of Lake Victoria". This project was carried out under LVEMP 1.		
	· 2009- 2016 – (LVEMP2)	O. Büttner: sounds like the data are not compiled and ready to submit. So data are useful but not available at the moment.	3
	- Water Quality data available for Sediment, Nutrients and Organic Loading. (However, limited data is available as phase was focused on the implementation of the recommendations of LVEMP1)	S. Jomaa: Please check the following link (Lake Victoria Cleaner Production). Very interesting visualisation tool https://www.arcgis.com/apps/MapJournal/index.html?appid=71137dc4a053423eb01b4612313fd9de#	

	- LVEMP 2 focused on rehabilitation of Wastewater Treatment Plants for Kisumu, Homabay, and a new WWT plant at Bomet.	S. Jomaa: Another interesting presentation https://iiasa.ac.at/web/home/research/researchPrograms/water/1.4_Lake_Victoria_Basin_Water_Resources_Information_System__.pdf	
	- LVEMP 2 also focused on Wetlands Management and supported the development of Kingwal Wetlands and also some conservation activities around Kundos Wetland.		
	LVEMP 3 (From Aug. 2019 – on-going). The phase started around August 2019 and will focus on amongst other things rehabilitation and automation of Hydromet and water quality monitoring stations.	O. Büttner: sounds like the data are not compiled and ready to submit. So data are useful but not available at the moment. I. Bärlund: Who runs LVEMP 3?	3
	Water Quality monitoring data on Lake Victoria and Rivers draining into it. **WQM data from the WQM stations on the Lake Victoria and rivers draining into it, collected by the Water Resources Authority (WRA). 2006- 2019**	S. Jomaa: Can be used in the magic triangle (in situ data). S: Jomaa: Please check the following link https://iiasa.ac.at/web/home/research/3.2_LVBC_WRIS_Water_Resources_Information_System__Eng._Calis.pdf S. Jomaa: http://lvbc.wris.info/ P.Saile: Quick review: Available as single spreadsheets per station, rather well structured. Most stations seem to have only few measurements for different parameters, time ranges 2009-2014 O. Büttner: Can be used in the magic triangle (in situ data). P. Saile: WRA is GEMS/Water NFP and has been contacted; pending reply; I. Bärlund: if this contact works out, maybe also a stakeholder for the project	1
	Information on status of water quality monitoring available on Transboundary WQM stations at the NBI regional office at Entebbe. Information was collected under the NBI Nile Transboundary Environmental Action Project (NTEAP). Under this project Transboundary Water Quality Monitoring stations were proposed. 2004-2009	O. Büttner: Can be used in the magic triangle (in situ data). A.Gemmell: I have contacted NBI without responses.	1
	Information on Regional Hydro-meteorological Monitoring System Information available on Hydro-meteorological stations at the NBI regional office at Entebbe under the project		
	Data and Information on Water Quality Assessment in the Lake Victoria Basin Area Data and information available in the National Water Quality Assessment Report and Basin Plan for Lake Victoria North (LVNCA) and Lake Victoria South Catchment Area (LVSCA) and the Hydromet Network Report – Data available indicates the established revised WQM stations and Water Pollution Hotspots. This data and information has been collected under the on-going Kenya Water Security and Climate Resilience Project (KWSCRP) – (2017- 2020). Project is being implemented under WRA. Final project Reports to be submitted in May 2020. (2017 - 2020)	O. Büttner: Can be used in the magic triangle (in situ data). Data should be submitted as database or spreadsheet, not only the reports.	1
	Sediment Load Monitoring pilots in micro catchment scale West Kenya Community Driven Development Program (WKCDDP), 2010 - 2016. Focusing on community livelihoods, catchment conservations and sediment monitoring in Lake Victoria North Catchment Area.	SEDIMENT	
	Information on Catchment management activities		
	Sio – Malaba Malakisi Transboundary Project, funded by NBI under NELSAP. Activities included catchment conservation, installations of hydromet stations, and support development of Sub Catchment Management Plans (SCMPs). On- going but currently not active due to lack of funds.		
	Water Quality and Quantity data and Watershed management information		
	Integrated Watershed Management for Kibuon and Tende sub catchments (IWMKT). The project was financed by AfDB through the then Ministry of Regional Development and implemented majorly by WRMA and KARI Kisii, plus other stakeholders. Activities included **water quality and quantity data** in the two sub catchments	O. Büttner: If data are available in useful form it should be used in the magic triangle.	2
	Rehabilitation of water quality and hydromet stations. **Sediment load monitoring** at micro catchment levels where community on-farm conservation measures were being implemented. Support to Water Quality Laboratory in Kisumu- provision of equipment, consumables. Also support given to hydromet data collections by paying Staff gauge readers.2008-2016	SEDIMENT	
	Information and data available at KOSFIP office in Homa Bay and LVSCA offices.		
	Information and data on water safety and security and sustainable development issues		
	MAMASE (Mau Mara Serengeti Project. Purpose is to improve water safety and security in the Mara River Basin (MRB). Also, **Water quality and quantity data generation**, support to Water Resource Units Associations (WRUAs). On-going project	O. Büttner: Sounds like future data	3
Nathan Semwenga Makerere University, Kampala |	**Monitoring** of mostly algal blooms/cyanobactria, trace metals, physico-chemical parameters, macro invertebrates, pathogenic microorganisms, endocrine disrupting substances, other organic residues and macro nutrients. Some local institutions have databases. Projects such as VICRES , LAVEMP , WASO (Monitoring and sustainable management of surface freshwater sources in Africa) have generated data on water quality, and this can be accessed with permission from respective stake holders	O. Büttner: Can be used in the magic triangle (in situ data).; I.Bärlund: potential stakeholder	1
Laban Musinguzi . Uganda National Fisheries Resources	Monitoring (In-situ measurements on defined transects). The data available is between 1999 and 2018 (not continuous though with some gaps for some years). This covers common physical and chemical water quality parameters. The sites covered are both inshore and offshore.	O. Büttner: Can be used in the magic triangle (in situ data); I.Bärlund: potential stakeholder	1
	The data available is collected on transects associated with surveys of biotic components in Lake Victoria.		
	The data is normally archived in **excel spread sheets that have previously been scattered.** At the National fisheries resources research institute, NaFIRRI, there are **deliberate efforts to mobilized the**	O. Büttner: Sounds like future data	3

Research Institute	**data to use to develop biodiversity information and then make it freely accessible on line**. Data use planned involves development of visuals such as water quality maps and trend graphs. Similar mobilization efforts would be required for Kenya and Tanzania to make the data accessible. This may not need a lot of resources as data curation level in these institutions is pretty high. Our collaborations with them makes it easier to access the data		
Godfrey Ogonda. Deputy Director – programs OSIENALA	**Modelling data** Available mostly in publications		
	Monitoring data: Various forms e.g. Water quality, temperature, salinity etc.	O. Büttner: More information is needed	2
Daniel Olago. University of Nairobi	KNATCOM UNESCO, GREAT LAKES UNIVERSITY OF KENYA UNESCO published a monograph focusing on hydrology and limnology of Lake Victoria on its IHP series. **The data seems to be available but upon request.**	O. Büttner: More information is needed	2
	KENYA WATER INSTITUTE KEWI plays its role in ensuring that communities gain access to clean water by conducting groundwater related studies like resources assessments, research, test pumping, borehole rehabilitation, maintenance and test drilling. Andrew Gemmell: **Possibly WQ data available?**	GROUNDWATER	
	MASENO UNIVERSITY Partnered with Nagasaki university and launched the LAVICORD Project. The project commenced on June 2014 to September 2015. Surveys were collected at the Nyanza gulf and to the rivers flowing into the gulf to **monitor water quality and collect** water samples at different locations at the rivers and the lakes where regular sampling was done after every two weeks at the sampling points and regional sampling at every 3 months at the sampling locations.	Can be used in the magic triangle (in situ data).	1
	WATER RESOURCES AUTHORITY WRA undertakes monitoring of ground and surface water resources within Lake Victoria North Basin Area with two monitoring stations in Kitale. Their data is available on their Permit Database (PDB) system which provides data on water use allocation for both surface and ground water abstracted in ach sub catchment area. **The data seems available but on request**. Their current Water Resources Authority Strategic Plan 2018-2022 is available in their website in PDF form	O. Büttner: Can be used in the magic triangle (in situ data). P. Saile: WRA is GEMS/Water NFP and has been contacted; pending reply	1
	KISUMU COUNTY GOVERNMENT Partnered with the Embassy of Russia and UN to control water hyacinth on the lake. The partnership program is dubbed: *Sustainable Management and Utilization of Water Hyacinth in Lake Victoria Basin*. The period of the project is 3 years starting 2019 December	M. Flörke: interesting project that we should follow (triangle?)	
	LAKE VICTORIA BASIN COMMISSION The program and projects done by the commission include:		
	· Lake Victoria Environment Program (LVEMP II) sponsored by World Bank,	S. Jomaa: Please check the following link http://documents.worldbank.org/curated/en/328181540137025874/pdf/Concept-Project-Information-Document-Integrated-Safeguards-Data-Sheet-Lake-Victoria-Environmental-Management-Project-Phase-Three-P165352.pdf	
	· Lake Victoria Water and Sanitation Program Phase two (LVWARSANII) supported by African Development Bank (AfDB),		
	· Population, Health and Environment (PHE) and Planning for Resilience in East Africa through Policy, Adaptation, Research and Economic Development (PREPARED).		
	· UN Habitat also supports Lake Victoria Region Water and Sanitation Initiative (LVWATSAN).		
	Also, Lake Victoria Basin Commission has programs and projects in the pipeline: Lake Victoria Integrated Water Resources Program (LVIWRM), Lake Victoria Multinational Maritime, Transport and Communication Program and Regional Climate Change Adaptation Program. The projects are ongoing.	S. Jomaa: https://www.iwrm-lakevictoria.info/	
	Andrew Gemmell: Project may be able to provide data?	S. Jomaa: Please check this report https://www.slideshare.net/slideshow/embed_code/key/Fb3Rl9rDWNIC8W	3
	EGERTON UNIVERSITY Lake Victoria Basin Commission partnered with Egerton University in a project titled "*Transboundary Water for Biodiversity in Mara River*" aimed at enhancement of efficient and effective use of resources for conservation and livelihood improvement in Mara Basin and its environs and promote jointly the governmental private and non-governmental cooperation through specific activities that enhances partners' capabilities. The project ended 16th Jan 2019. **Andrew Gemmell: Project may be able to provide data?**	O. Büttner: sounds like the data are not compiled and ready to submit. So data are useful but not available at the moment.	3
	EQUATORIAL AFRICA DEPOSITION NETWORK Atmospheric deposition is a major component of nutrient budgets for the African Great Lakes – wet and dry deposition data on HNO3, NO2, NH3, SO2 And O3. 2013 TO DATE. Various stations in study area that may be able to **provide data**	M. Flörke: phosphorous also available?	2
	WSUP-WATER AND SANITATION FOR THE URBAN POOR WSUP's research partners in Kenya are the Ministry of Health, Division of Environmental Health (MOH-DEH) and the Water Services Regulatory Board (WASREB). They conducted a project called: Incentivizing private sector provision of faecal waste emptying services to low income customers in Kisumu aimed at	M. Flörke: maybe of interest for impact on human health?	

	improving the levels of income for low income urban residents. The project took one year from Oct 2018 to Oct 2019.		
	SWAP-SAFE WATER AND AIDS PROGRAMME The Safe Water and AIDS Project (SWAP) trains community health promoters who undertake door to door sales of health and hygiene products and provide health information		
	LAKE VICTORIA SOUTH WATER SERVICES BOARD The Lake Victoria Water and Sanitation Project (LVWATSAN) Kisumu project aims at further improving and expanding the water and sanitation network of the city. This is done in partnership with Agence Francaise De Development AFD to increase water coverage and sanitation to residents in Kisumu as well as increase continuous supply of water. A **water monitoring system** is set to be set up to monitor the quality of the water on Lake Victoria.	O. Büttner: sounds like future data M. Flörke: sanitation data could be helpful P. Saile: contact available?	3
	KISUMU WATER AND SEWERAGE COMPANY (KIWASCO) Routine ions and microbiology for **water quality for portable water supplie**s. Should have a temporally long database for water extracted from the lake.	M. FLörke water abstraction from lake interesting for modelling P. Saile: contact available?	3
	LAKE VICTORIA NORTH WATER SERVICES BOARD Keben Dam Water Supply Project ongoing since April 2018 to solve water shortage in Kapsabet, Nandi Hills and Baraton University.	P. Saile: more information needed.	
Melchior Ryumeko. Burundi Geographical Institute	**Ground water monitoring** in Kagera basin, climatic data, rainfall data, River runoff data. Need to collaborate with the authorities of the IGEBU and the BGR project manager to give permission to share this GPES project data	GROUNDWATER https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Burundi/burundi_fb_en.html?nn=1546392 Groundwater quality data in Rummonge area close to Lake Tanganiyka	4
Robinson Odong. Department of Zoology, Entomology & Fisheries Science, Makerere University	Directorate of Water Resources Management monitoring:		1
	o GWQ (LVB)		1
	o IMB WQ 2010		1
	o WQ 2013 – 2015 various stations	O. Büttner: if available it can be used in the magic triangle (in situ data)	1
	o WQ data 1999 – 2006	O. Büttner: if available it can be used in the magic triangle (in situ data)	1
	· Water Sources for Africa Project: IMB WQ 2017 – 2018 – Monitoring	O. Büttner: if available it can be used in the magic triangle (in situ data)	1
	· Nature, Water & Society project: IMB WQ 2000 – 2004 – Monitoring	O. Büttner: if available it can be used in the magic triangle (in situ data)	1
	· National Water and Sewerage Corporation (NWSC): IMB (23 stations 2016 – 2018) & Katosi – monitoring	WWTP	
	· Uganda National Meteorological Authority: Weather variables (Temp, rainfall, etc).	WEATHER	
	· Department of Chemistry, Makerere University Water Quality/physico-chemical variables	O. Büttner: more information needed.	2
	· Department of Zoology, Entomology and Fisheries Sciences, Makerere University Biological, physico-chemical data	O. Büttner: more information needed.	2
	· The Water Quality Unit, National Fisheries Resources Research Institute (NaFIRRI, Jinja). Biological, Water quality data	O. Büttner: more information needed.	2
	·		
	· LVEMP / DWRM: Pollution loading 2011 – **modelling**	M. Flörke of use for comparison and magic triangle (if validated)	
	· Department of Geomatics and Land Management, Makerere University. **Landsat/Satellite images**		
Greg Silsbe (University of Maryland) in	Work done by Greg Silsbe (University of Maryland) in conjunction with NASA and ESA: Two Decades of **Satellite-Based Water Quality** of Lake Victoria https://tnc.app.box.com/s/72tthbdx3rkqxk3i7e1aurzz8mkp5bxg	S. Jomaa: (other source to consider) http://apps.rcmrd.org/waterquality/index.php?lake=victoria	
Rurantije Aloys, Technical Advisor of Director of Burundi Hydro-meteorological department of Geographic institute of Burundi (IGEBU)	· **Quantity:** In Victoria basin (Ruvubu-Kagera basin), Burundi hydrologic and meteorological service have 21 operational stations on which the measurement of discharge are made regularly. The part of Victoria basin have around 13.000 km2 (area).	O. Büttner: if available it can be used in the magic triangle (in situ data)	1
	· Some **data on quality surface water** are available in National Hydrlogic service (But for some parameters: Ph, conductivity, oxygen, temperature……..).	O. Büttner: if available it can be used in the magic triangle (in situ data)	1
	· Some **data on ground water** exist also for the site located in central of country (others data are collected in Congo basin)	GROUNDWATER	
	PS: The monitoring of the collection data for those parameters is progress		
	· The data can be accessible through the Burundi Hydrological and meteorological service.		
	· Some stations have been installed with through HYCOS/OMM project	O. Büttner: sounds like future data	3
	· Other data are collected with the support of government or the project of the partners	O. Büttner: more information needed	2

	· For the consultants: the accessibility needs a payment of money, for student or government project, the accessibility is free	O. Büttner: sounds like future data	3
Diversity II data set (Odermatt et al. 2018)	Remote sensing data for great lakes including chlorophyll and Cyanobacteria based on ENVISAT 2002-2012	S. Jomaa: https://www.earth-syst-sci-data.net/10/1527/2018/essd-10-1527-2018.pdf https://doi.pangaea.de/10.1594/PANGAEA.871462?format=html#download	1

C2 – LAKE VOLTA

Submitted by	Type of data (monitoring, modelling, time period etc.)	COMMENTS	Priority
KEY		e.g. A.Gemmell: Comment	1
Reporting			2
Modelling			3
Data			4
EO/RS			
Literature Review:	**Literature Review:** A 2007 study by Quansah et al. applied GIS techniques to map **in situ water quality data** from the Lower Volta. The collected samples were analysed for temperature, pH, conductivity, turbidity, hardness, total dissolved solids, nitrate, ammonia, phosphates, iron and faecal coliforms. These were digitally mapped to show spatial variability of water quality along the sampling locations.		
	Awotwi et al., 2016 published a study on the water quality changes associated with Cassava production in the White Volta basin using an interface between ArcGIS and **SWAT** (soil and water analysis tool). The tool was used to assess likely hydrologic and water-quality response of increasing cassava production, with reference to nutrient (total nitrogen, total phosphorus) and sediment levels.		
	Ghansah et al., 2016 mapped the spatial changes in Lake Volta using a **remote sensing** approach. The authors looked at Landsat imagery of the lake for the years 1990, 2000 and 2002, which showed that the area of the lake increased from 1990 to 2000 and decreased from 2000 to 2002. The authors also suggest that this method can be used to demarcate buffer zones around the lake, which would be useful to minimize the influx of solid waste into the lake, as well as maintaining its water quality.		
	• The USGS Global Visualization Viewer (**GloVis**)		
	• NOAA (National Oceanic and Atmospheric Administration) **CLAss**		
The NASA GLOBE program	Citizen Science **Data**		4
	https://www.globe.gov/		
FELIX JERRY AKPABEY. CSIR-Water Research Institute	**Data:**	O. Büttner: Can be used in the magic triangle (in situ data).	1
	· Physico-chemical analyses	I. Bärlund: potential stakeholder	
	· Bacteriological analyses		
	· Pesticide residue analyses		
	Routine analyses of these parameters under several projects		
Prof. Christopher Gordon of the IESS at the University of Ghana	GLOWA Volta Project. This was a project which aimed to develop a framework for water resources decision-making and scientific capacity building in a transnational West African Basin (Van de Giesen et al., 2007). The project had three phases:	O. Büttner: Can be used in the magic triangle (in situ data); potential stakeholder	1
	• Phase I: the collection of **basin data**		
	• Phase II: **modelling** activities		
	• Phase III: integration of Phase I and II outputs.		
	The collection of data associated with the GLOWA Volta Project included climatic, hydrologic, environmental and socioeconomic data, which are scarce within the Volta Basin. Focused studies, many conducted by Ph.D. trainees from the Volta region, attempted to bridge gaps in spatial and temporal scales as solutions to the problems of data scarcity.		
	Phase II of the GLOWA Volta Project focused on **modelling** activities. Mesoscale climate models (MM5) were successfully linked with physical hydrology models (WaSIM-ETH) at catchment, tributary and full basin scales. Numerous anthropologic and socioeconomic studies were successfully completed, creating databases from which a range of household models of socioeconomic behaviour were identified (Van de Giesen et al., 2007).		
Mr. Peter K. Osei-Fosu. Senior Assistant Registrar. University of Ghana	1. Water Quality including **nutrient loading** of sediment & water column	O. Büttner: Can be used in the magic triangle (in situ data).	1
	2**. Land-use impact**s on water quality in the Volta Basin		
	3. Environmental Quality for **aquaculture** production (2018)		
	4. Transboundary environmental, governance & climate change issues in the Volta Basin (2013)		
	Projects:		
	· Volta Basin Research Project (VBRP), University of Ghana: Integrated Management of the Volta Basin. Lower Volta Environmental Impact Studies (1997-2000)		
	· Improving the Sustainability of Aquaculture in Ghana through Environmental Quality Assessment Project (2018), IESS/St. Cloud Aquatic Toxicology Laboratory/ University of Minnesota.		
	· UNEP-GEF Volta Project (2013		

	Data Types:		
	· Sediment nutrient release, internal nutrient loading in the Kpong Headpond etc.	SEDIMENT	
	· Land-use/cover changes & impacts on water resources in the Lower Volta River Basin, Ghana		
	· Nutrient inputs, nano-level concentrations of harmful substances such as bacteria, biocides and antimicrobials in sediment, water column & effluent samples.		
	· Water quantity, degradation of ecosystems & water quality in addition to transboundary governance and climate change issues in the Volta Basin.		
Kate Heal (IAHS)	Documents of interest are:		
	· Volta Basin Transboundary Diagnostic Analysis: https://iwlearn.net/resolveuid/467c3ef0a6ce4f48870594ebf9e20e4b		
	· The Volta river basin – water for food economic growth and environment: https://www.taylorfrancis.com/books/e/9781315707334		
	· IWMI Working Document - Water resources assessment of the Volta basin: http://www.iwmi.cgiar.org/Publications/Working_Papers/working/wor166.pdf		
BaSIS	**BaSIS** - Basic Sanitation Information System (https://sanitationghana.org/about/)		
	BaSIS - Basic Sanitation Information System is a decentralised M & E sanitation system developed to aid in the implementation of the CLTS (Community-Led Total Sanitation) at both sub-national and national levels. The system is basically built to populate data collected from approved sources based on some sanitation index in the form of maps, charts and tables.	WWTP	
Prof. Dr. Chen Sophia Shuang . Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences. Division of Catchment Resources Environment and Regional Development	**Water quality data** by monitoring in Mwanza Gulf of Lake Victoria (March, August of 2016, August of 2019, January of 2020). Lake-Watershed Integrated Management for Sustainable Use of Water in East Africa Great Lakes Basins (2019-2022), under MOST-UNEP joint research program, Funding No. YS2018YFGH000139	O. Büttner: Can be used in the magic triangle (in situ data).	1
	Budget 1.02 million USD. Data access in request		
	Investigation on the **Water Environment Quality** of Major Cities in Tanzania: Rivers, Lakes and Drinking Water Sources (2017). Research Report published in 2017		
Dr. Anthony Karikari, Water Research Institute	WRI is conducting monitoring on behalf of different governmental agencies in Ghana (mostly project based) but access is restricted (payments required)	P. Saile: verbal communication during Accra workshop; I. Bärlund: potential stakeholder?	3
Water Resources Commission ()	WRC is sampling at 41 stations (14 in Volta catchment) three times a year (in collaboration with WRI); data centrally collected i spreadsheets on two computers in WRC headquarters; access limited (payments required)	P. Saile: verbal communication during Accra workshop; Ghana GEMS/Water NFP contacted to discuss provision of data with WRC/WRI	2
EOMAP	EO/ RS – see below		

C3 – Continental/Global Scale

Submitted by	Type of data (monitoring, modelling, time period etc.)	Priority
Reporting		1
Modelling		2
Data		3
EO/RS		4
Hisham Osman, World Bank	The **Spatial Agent** mobile app – download from http://apps.worldbank.org or directly from iOS AppStore(recently updated)/Android Version (much older- being updated)	
	OLC Spatial Agent tutorial/webinar (links to factsheet, webinar, illustrative graphics, interactive tutorial, etc.)	
	Interactive e-Atlas/Dashboard Drafts (Use Chrome Browser):	
	Global HydroInformatics	
	Lake Victoria	
	Uganda	
	Africa	
	Interactive e-books (to package information in new interactive ways - use Chrome browser – navigation on top-right, pls note - many still in draft):	
	· "Disrupting" Development (draft Primer being developed on Disruptive Tech - pls. see the interactive tech explorer)	
	Illegal Wildlife Trade e-book (see interactive charts here)	
	NASA-WB Earth Observations e-book (jointly done with NASA – and on the Bank's Open Learning Campus)	
	In-Situ Monitoring Systems (example of a simple interactive database)	
	External Sites:	
	· USDA GADAS	
	· GEOGLOWS Global Streamflow Estimation	
	The World Bank funded a project in June 1999 for the development and implementation of a framework model for the **simulation of the physical processes** and water quality in Lake Victoria. The model was developed and installed in the three riparian countries.	
Kenneth Mubea, ARDC	Kenneth provided links providing **EO/RS data** on water quality and land cover, as well as links to various literature sources. Andrew Gemmell met Kenneth in Ispra and AGRIC (Ghana). Ken is linked to Africa Regional Data Cube, which uses Water Observations from Space (WOfS) (i.e. EO). ARDC can be used to assess the water quality SDG 6.3.2 and water extent SDG 6.6.1. He requested to use some datasets from GEMS for some validation especially the NASA Ocean Colour Chlorophyll-A OC3 Algorithm for Lake Volta (Ghana) and Weija Reservoir (Accra).	
	http://apps.rcmrd.org/waterquality/index.php	
	http://52.54.26.108/	
	http://www.data4sdgs.org/initiatives/africa-regional-data-cube	
	https://www.opendatacube.org/resources	
	https://www.servirglobal.net/ServiceCatalogue/ (includes data on galamsay in Ghana, and Chl-a in Lake Vic)	
Kerstin Stelzer. Brockmann-consult	Both Lakes are included in the **CGLOPS Data set**, could extract time series and maps from it.	
	· Trophic State Index (TSI) which is a classification of the chlorophyll concentration.	
	· Turbidity	
	· Water colour (water reflectances for different wavelengths)	
	The data is aggregated to 10day-averages.	
	CGLOPS data set is freely available. It needs some data handling to get the information out of the global products to perform analyses for individual lakes.	

Ruhr-University Bochum	**Modelling:** Outcomes from Snapshot report (UNEP, 2016) extracted for the Use cases o Water temperature o BOD loadings, in-stream concentrations o FC loadings, in-stream concentrations o TDS loadings, in-stream concentrations o TP loadings, TP loadings to lakes Outcomes from GlobeWQ project which will be enriched by information and knowledge from regional stakeholders o Focus on FCs and sanitation o Focus on TP intake and seasonality	
SERVIR	SERVIR E&SA conducted **needs assessment** in Tanzania, Kenya, Uganda, and Rwanda to identify and understand existing and emerging needs in the use of Earth Observation and geospatial technologies Water, quality was identified as one of the issues/developmental problem of concern to the four countries.	
	Automated system that **maps water quality** status in Lake Victoria and Lake Malawi was created http://apps.rcmrd.org/waterquality	
	Undertook **stakeholder mapping** in the five countries (Kenya, Uganda, Tanzania, and Rwanda). Water quality focus areas for each country identified.	
	Also offer a toolkit and templates for **stakeholder engagement.** https://www.servirglobal.net/Portals/0/Documents/ServicePlanningToolkit_2017-09-19.pdf	
	Dr. Robinson Mugo has been closely involved in the **satellite-based Water Quality Monitorin**g Service for Lake Victoria	
IWMI	Josiane Nikiema (IWMI-Ghana) states that IWMI and the other CGIAR organizations are currently working on a platform for **data sharing**.	
	www.waterdata.iwmi.org	
FAO	FAO has a GeoNetwork web platform including interactive maps, GIS datasets, satellite imagery and related applications. There is **data available specific to hydrology and water resources**. http://www.fao.org/geonetwork/srv/en/main.home	
EOMAP	**A) Access points to EOMAP WaterQuality data:**	
	Long-term portals for online-access to satellite products for Victoria, Volta, Cape-Town and other regions are available through:	
	1) www.worldwaterquality.org (currently linked to http://sdg6.worldwaterquality.org as ESA-TEP portal)	
	2) http://eoapp.eomap.com (from May 2020 integrates data from http://eoapp2.eomap.com and www.worldwaterquality.org)	
	Furthermore, Victoria, Volta and Cape-Town data should become available through the	
	3) portal of Globe-WQ (www.globe-wq.info) from end of 2020/early 2021	
	B) **Data formats:**	
	1) Raster data from above portals are available as WMS service	
	2) Point data are available at the portal via virtual stations as described in the help section of the portals, format is then .txt data files or PDF (as reporting format	
	3) Raster data hold on the geoservers for the portals are available currently in geotiff format. It might need technical clarification, if you can directly access these geotiff files without our support.	
	C) **Data specs:**	
	1) Products: Turbidity, Chlorophyll, Cyanobacteria Indicator HAB, Temperature. Partly: Secchi Depth, Total absorption)	
	2) Spatial resolutions: 100m, 30m, 10m	
	3) Aggregations: on request, seasonal (see example Victora (already online for year 2019) or spatially for example Volta (available expected in Q2 2020 after clearification with UNEP and UFZ)	
	D) **Enquire mechanisms to access data, time periods, spatial resolutions or aggregations not online available:**	
	1) through UN use-case projects: currently data generation for all Victoria, Volta, Cape-town & time periods between 2000, 2010 and 2020. => Data should be online from by June 2020	

	2) through ESA-TEP platform: users can request for free further data independently (with access and automatic upload to the http://sdg6.worldwaterquality.org portal (as long as ESA funds the TEP portal – clearification requested)	
	3) through the EOMAP eoLytics platform (https://eolytics-wq.eomap.com/): commercial mechanism to generate on-request water quality anywhere in various resolutions and any time periods from 1985 ongoing	
	4) through the GlobeWQ data trigger platform (from year 2021)	
	E) **Data quality assurance mechanisms (e.g. on intercomparability of data from different sensors & algorithms :**	
	1) Data generated from all portals and enquire mechanisms using EOMAP processors are harmonized through their direct link to physical properties, the inherent spectral scattering and absorption characteristics. This insures intercomparability of data over time, independent on sensor (and approach) used. The quality assurance mechanism account the respective highest state-of-the art in physics-based independent water quality mapping, see e.g.:	
	https://www.eomap.com/exchange/pdf/HTEP_Information_Booklet_Water_Quality_Monitoring.pdf	
Junguo Liu School of Nature Conservation, Beijing Forestry University, China	Offers assistance for Activity 3.1 and 3.2. Shared **two papers**: generating water sustainability knowledge with an interdisciplinary "web" model, and another about the threshold of water quality.	
Steve Greb Associate Fellow, University of Wisconsin-Madison. Aquatic Sciences Center and Space Science and Engineering	Open to collaborate, especially **EO data.** GEO AquaWatch and the WWQA appear to be on somewhat parallel tracks with some similar objectives (e.g. building a global WQ monitoring service, merging in situ and remote sensed data).	
Tommaso Abrate. WMO	Global Runoff Data Centre (https://www.bafg.de/GRDC/EN/Home/homepage_node.html) holds some **data on discharge** that have been provided by countries and are accessible for free at some condition concerning their use. Some Volta basin data and information may also be available with the Volta basin Authority (http://abv.int/)	
Other global modelling groups (member of the WWQ Alliance)	**Modelling** · Pathogens (Nynke Hofstra, Wageningen University) · Nutrients (mainly China) and chemicals (Maryna Strokal, Wageningen University) · Nutrients (Arthur Beusen, Lex Bouwman, Utrecht University) · Water temperature (Michelle van Vliet, Utrecht University)	

ANNEX D – VOLTA BASIN WORKSHOP AGENDA

WORKSHOP AGENDA

DAY 1 – 25 February

9:00-10:30: Session 1

- Registration
- Welcome, overview and purpose of workshop
- Round-table introductions
- Background to initiative

10:30 - 11:00: Cocoa Break

11-12:30: Session 2

- Panel Discussion:
  - Presentations/opening remarks by key representatives to discuss the broad water quality challenges
  - Discussion of issues related to:
    1. Water Quality and Health/Cities
    2. Water Quality and Food
    3. Water Quality and Ecosystems

12:30-13:30: Lunch

13:30-15:00: Session 3

- Open Discussion:
  - Biggest water quality concerns in the Volta basin
  - Issues that need more research and information for more informed decisions
  - User groups that would benefit from better data availability

15:00-15:30: Comfort/2nd Cocoa Break

15:30-17:00: Session 4

- Water quality data availability – who has what?
- Limitations to data sharing
- Barriers or challenges which prevent the implementation of effective water quality solutions

DAY 2 – 26 February

9:00-10:30: Session 1

- Summary of Day 1: Outcomes and direction for Day 2
- Challenges and opportunities for effective research and implementation

10:30 - 11:00: Cocoa Break

11-12:30: Session 2

- Presentations/overview of:
  - In-situ and citizen science data
  - Water quality modelling
  - Earth observation remote sensing
  - Water quality databases
  - Other data repository options

12:30-13:30: Lunch

13:30-15:00: Session 3

- Products and services discussion

15:00-15:30: Comfort/2nd Cocoa Break

15:30-17:00: Session 4

- Discuss objectives and requirements for data and information products and services to be developed.
- Discussion on how to promote bottom-up social engagement process between in-country stakeholders and WWQA

DAY 3 – 27 February

9:00-10:30: Session 1

- Summary of Day 1 and 2: Outcomes and direction for Day 3
- Summary of key findings

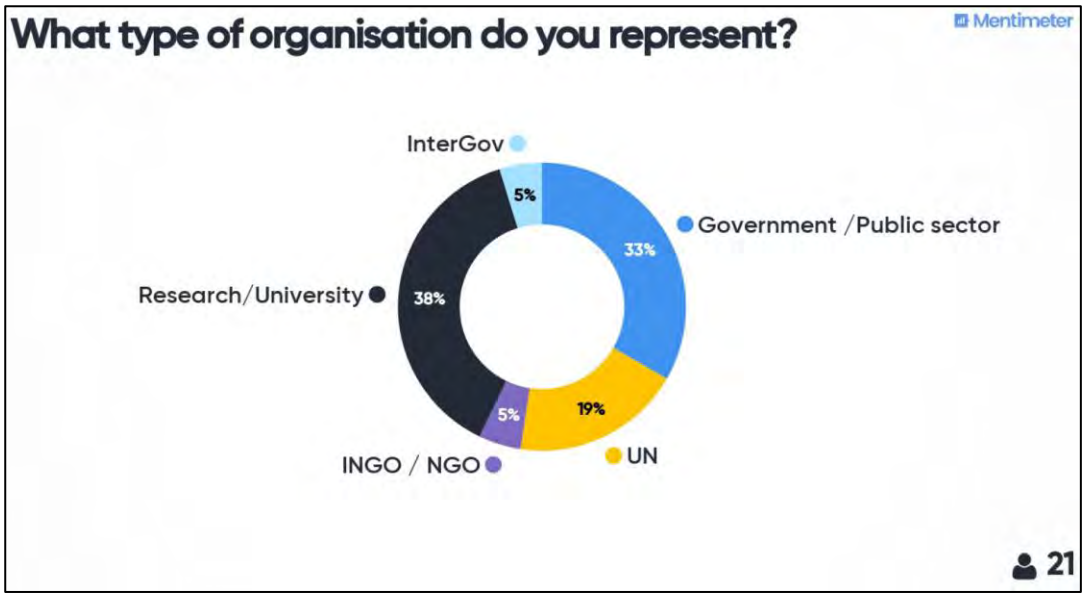
10:30 - 11:00: Cocoa Break

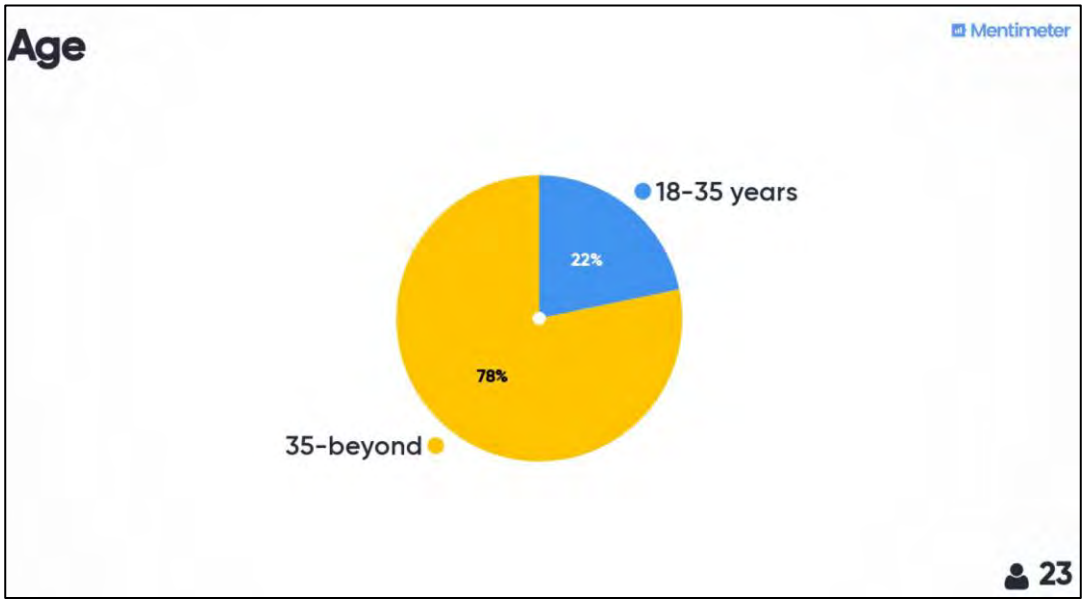
11-12:30: Session 2

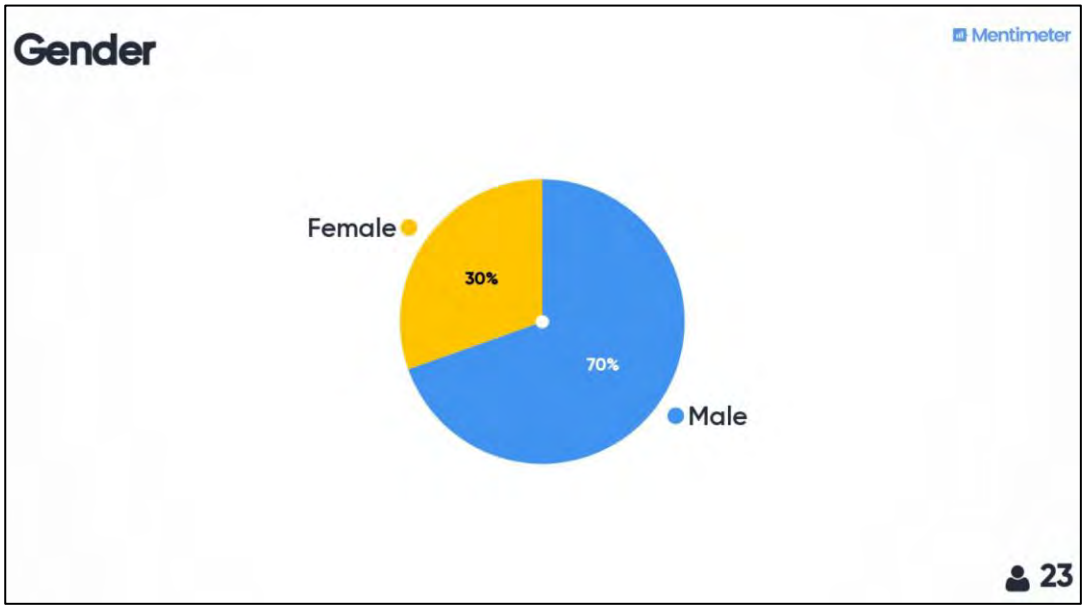
- Discussion on best forum to discuss possible products/services
- Discussion on missing role-players to be included going forward
- Closure and thanks

12:30-13:30: Lunch

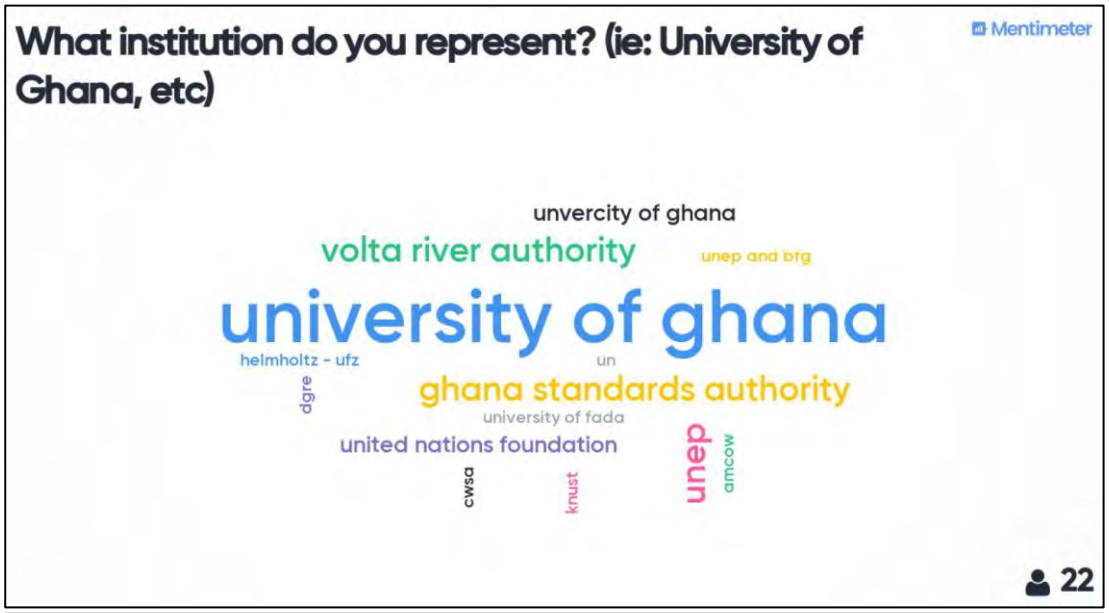
ANNEX E. DELEGATE FEEDBACK





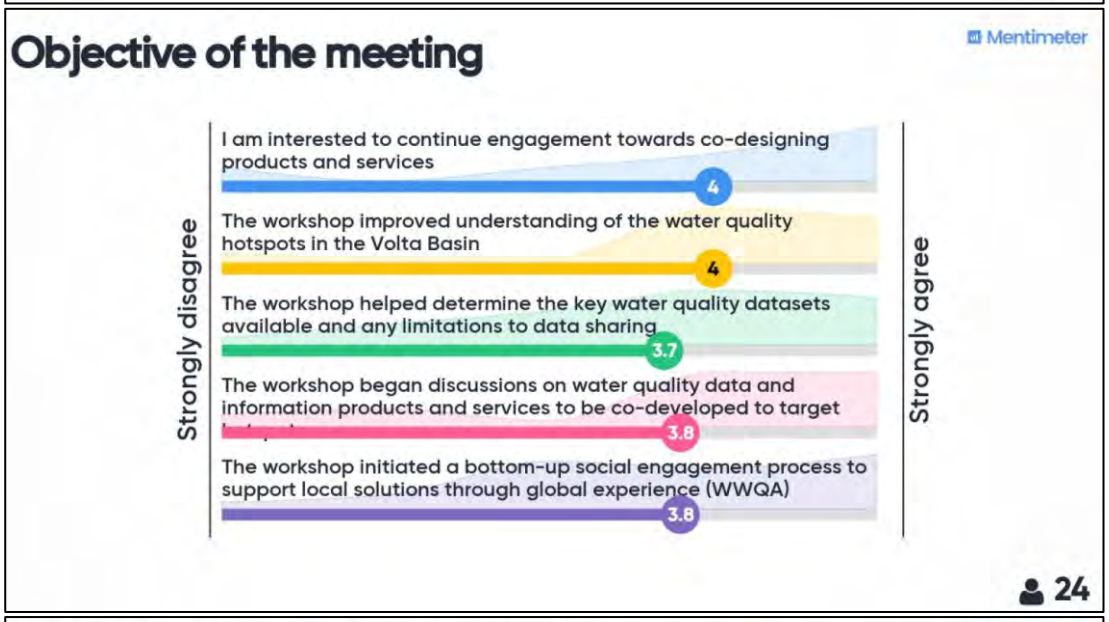

Gender
Mentimeter
Female
30%
70%
Male
23

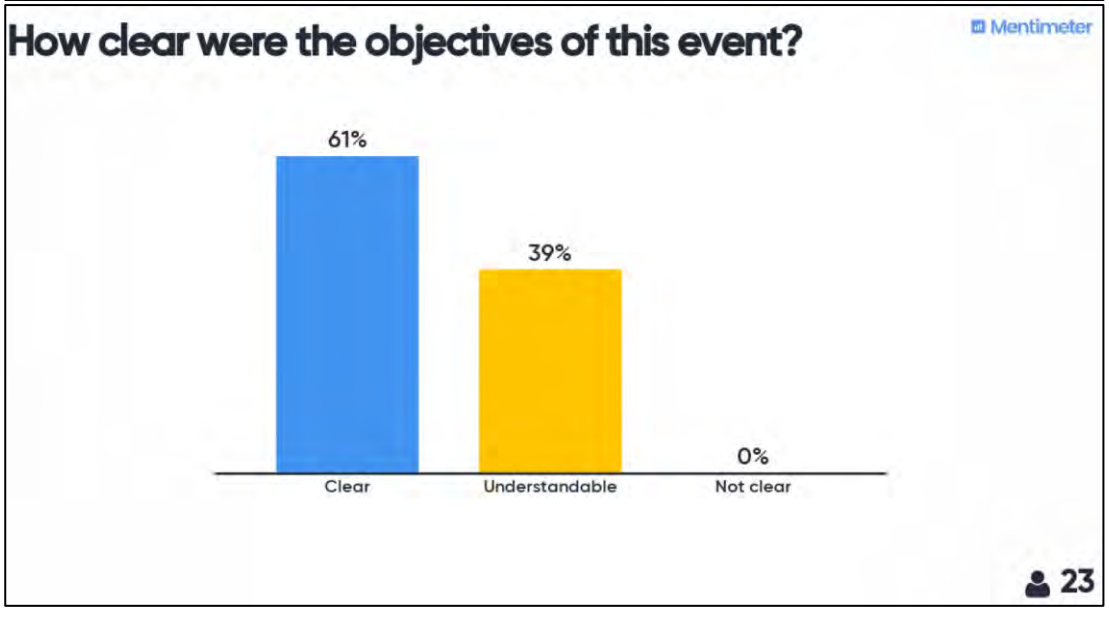

Which country are you most actively engaged in?
Mentimeter
world
africa
ghana
south africa
burkina faso
all african countries
germany
23

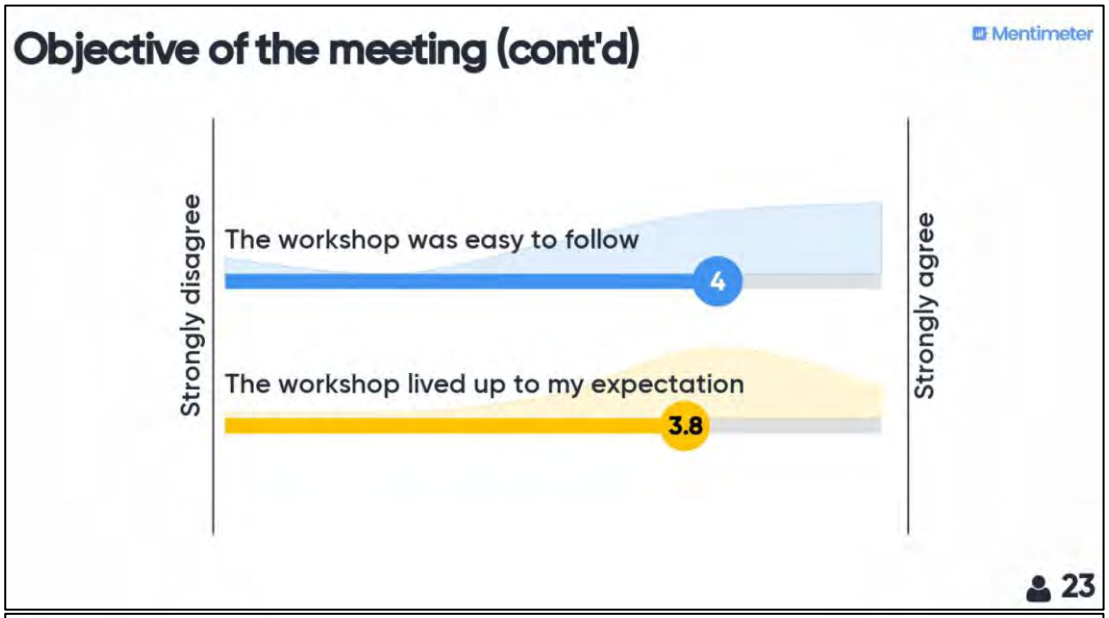

What institution do you represent? (ie: University of Ghana, etc)
Mentimeter
unvercity of ghana
volta river authority
unep and brg
university of ghana
helmholtz - ufz
un
dgre
ghana standards authority
university of fada
united nations foundation
unep
amcow
cwsa
knust
22

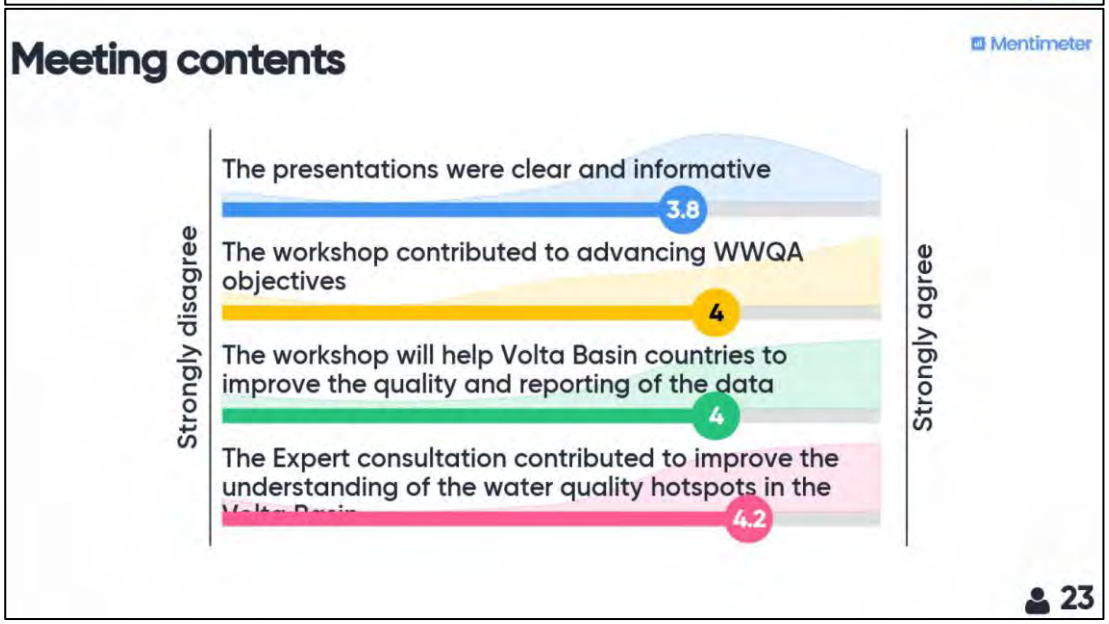

What is your job title?
Mentimeter
geo spatial
lab manager
standards officer
research fellow
postdoc researcher
senior research fellow
senior lecturer
groundwater quality cons
student
senior engineer
hydrogelogist
gis manager
environmental health educ
monitoring evaluation spe
public health manager
affiliate consultant
programme officer
head of unep gwdc
lecturer
biochimiste
22

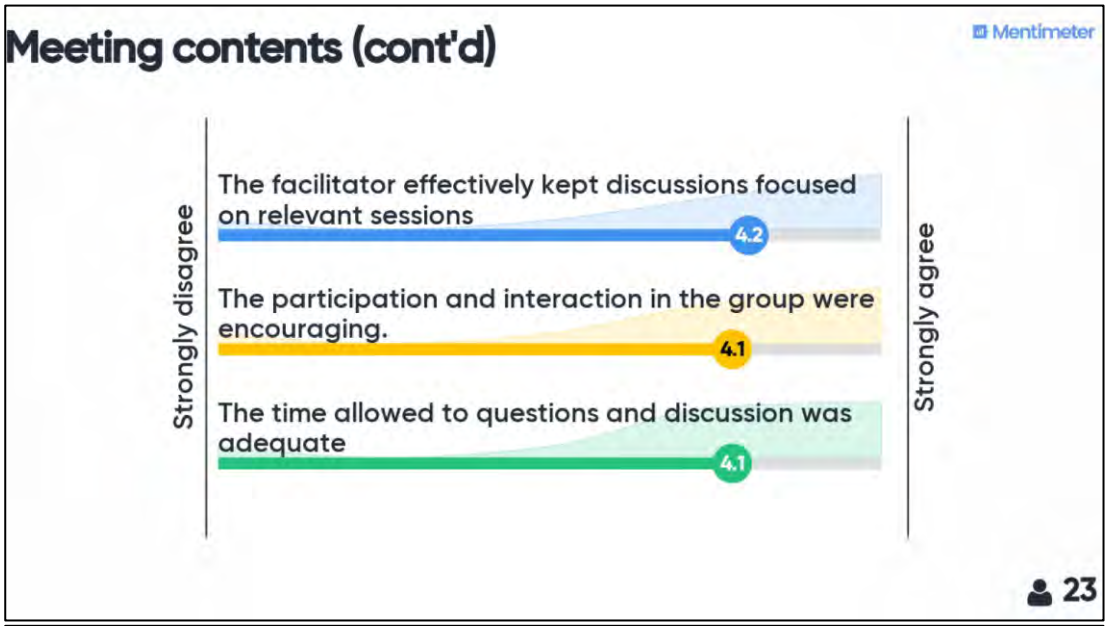

How satisfied are you with the Expert Consultation meeting?
Mentimeter
Very Satisfied
42%
Satisfied
58%
24

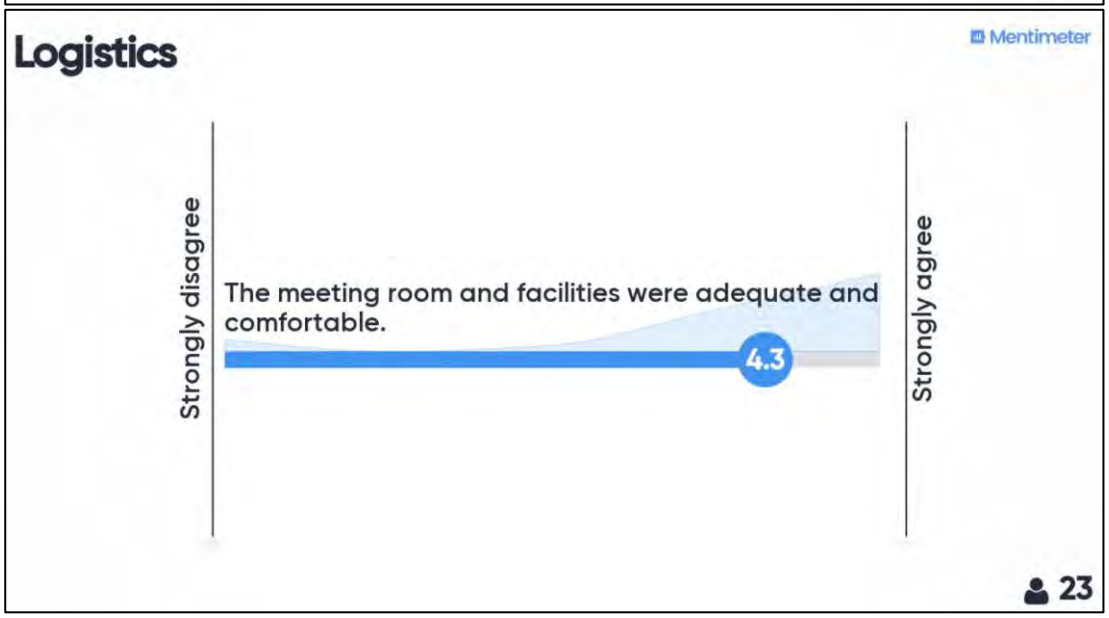

Objective of the meeting
Mentimeter
I am interested to continue engagement towards co-designing products and services
4
The workshop improved understanding of the water quality hotspots in the Volta Basin
4
The workshop helped determine the key water quality datasets available and any limitations to data sharing
3.7
The workshop began discussions on water quality data and information products and services to be co-developed to target
3.8
The workshop initiated a bottom-up social engagement process to support local solutions through global experience (WWQA)
3.8
Strongly disagree
Strongly agree
24

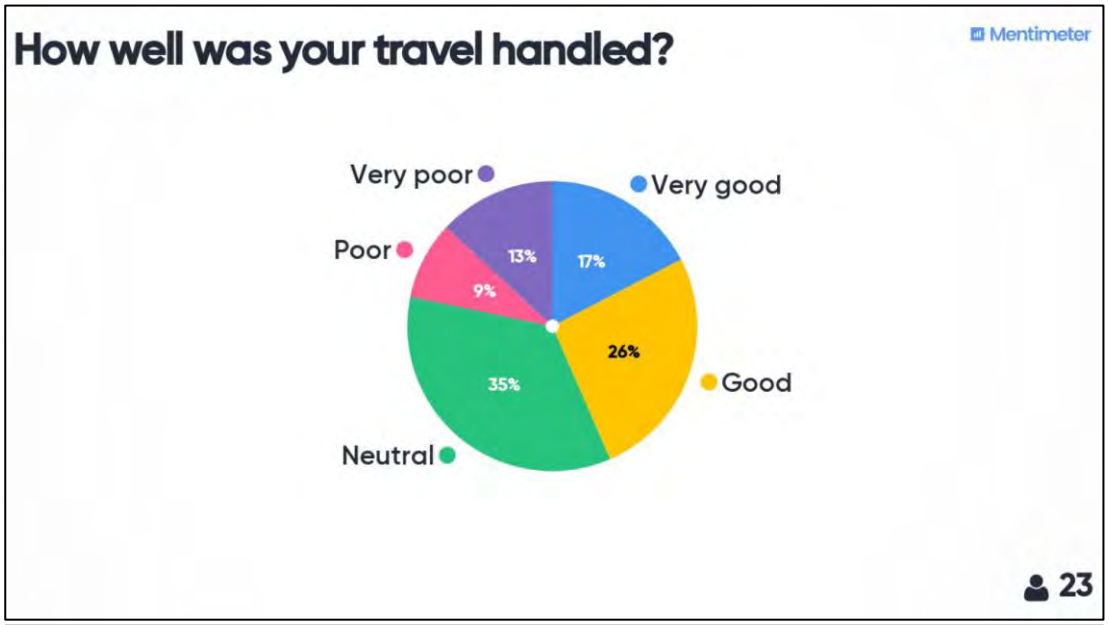

How clear were the objectives of this event?
Mentimeter
61%
39%
0%
Clear
Understandable
Not clear
23

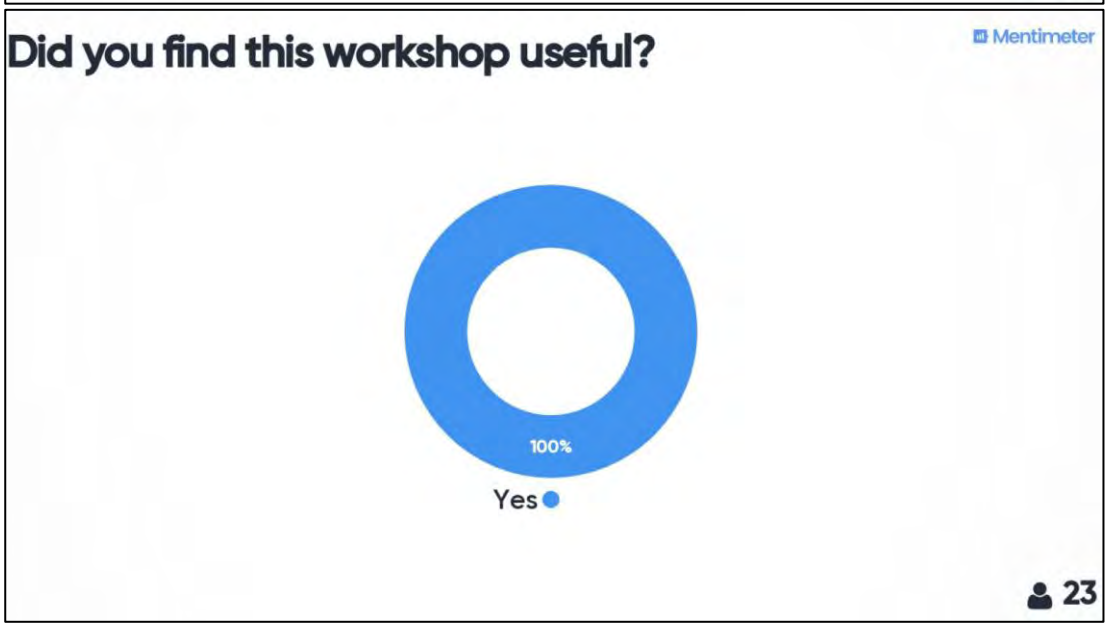

Objective of the meeting (cont'd)
Mentimeter
Strongly disagree
The workshop was easy to follow
4
The workshop lived up to my expectation
3.8
Strongly agree
23


Meeting contents
Mentimeter
Strongly disagree
The presentations were clear and informative
3.8
The workshop contributed to advancing WWQA objectives
4
The workshop will help Volta Basin countries to improve the quality and reporting of the data
4
The Expert consultation contributed to improve the understanding of the water quality hotspots in the
4.2
Strongly agree
23

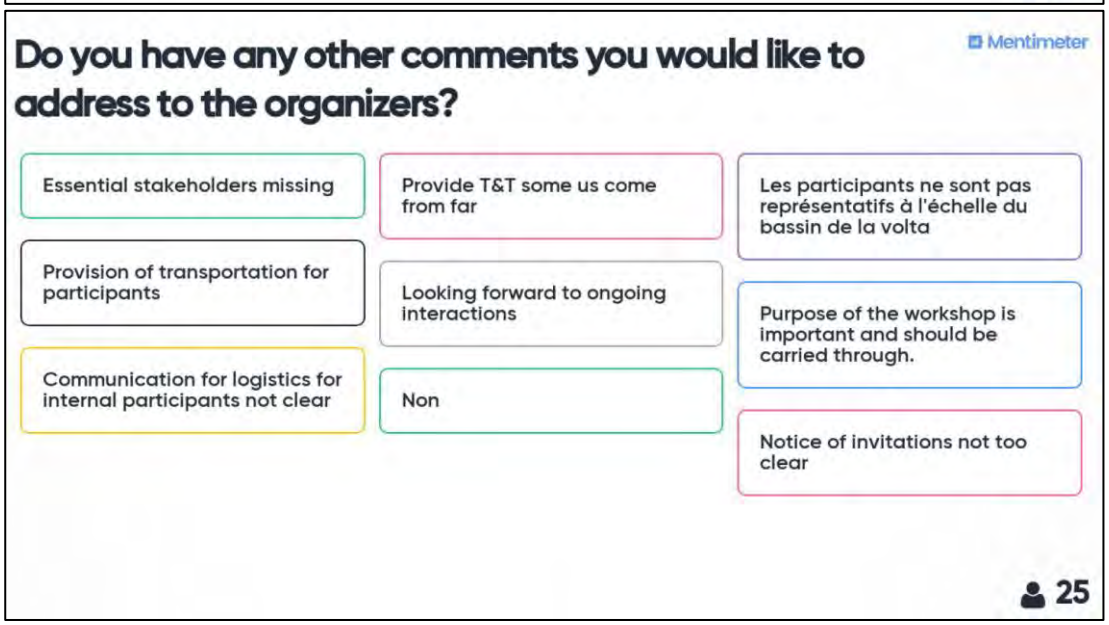

Meeting contents (cont'd)
Mentimeter
Strongly disagree
The facilitator effectively kept discussions focused on relevant sessions
4.2
The participation and interaction in the group were encouraging.
4.1
The time allowed to questions and discussion was adequate
4.1
Strongly agree
23

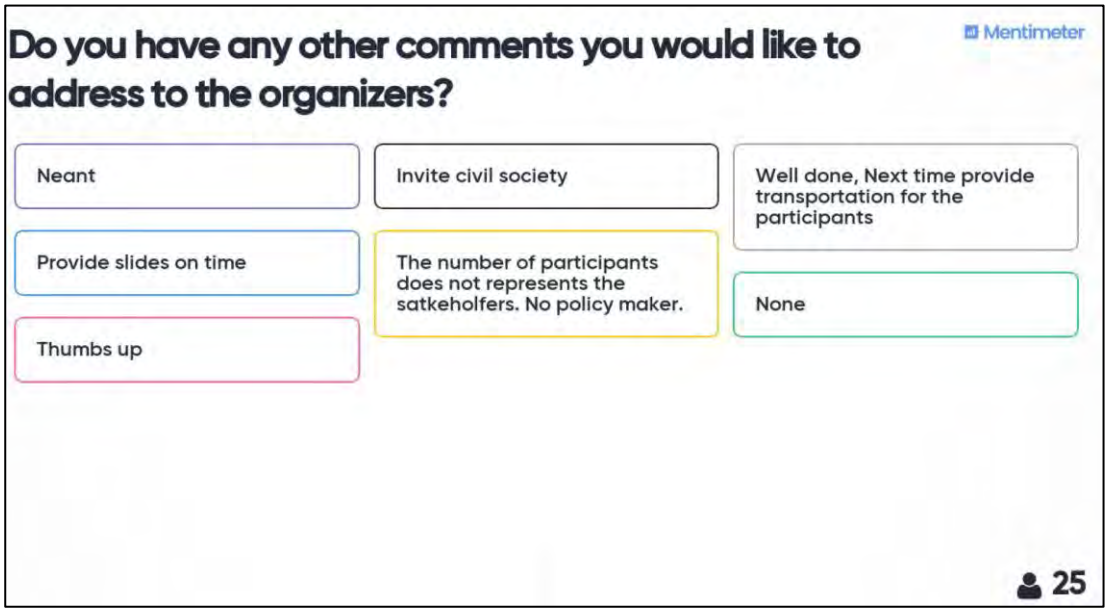

Logistics
Mentimeter
Strongly disagree
The meeting room and facilities were adequate and comfortable.
4.3
Strongly agree
23


How well was your travel handled?
Mentimeter
Very poor
Very good
Poor
Good
Neutral
13%
17%
9%
26%
35%
23


Did you find this workshop useful?
Mentimeter
100%
Yes
23


Mentimeter
Do you have any other comments you would like to address to the organizers?
Keep up the great work!
Good job
None.
Great work!
Keep it up
Time for preparation was quite short
Well done. Keep up the excellent work
Long days
Involve more. Key stakeholders
25


Mentimeter
Do you have any other comments you would like to address to the organizers?
Essential stakeholders missing
Provide T&T some us come from far
Les participants ne sont pas représentatifs à l'échelle du bassin de la volta
Provision of transportation for participants
Looking forward to ongoing interactions
Purpose of the workshop is important and should be carried through.
Communication for logistics for internal participants not clear
Non
Notice of invitations not too clear
25


Do you have any other comments you would like to address to the organizers?
Mentimeter
Neant
Invite civil society
Well done, Next time provide transportation for the participants
Provide slides on time
The number of participants does not represents the satkeholfers. No policy maker.
None
Thumbs up
25