Rapid Groundwater Resource Mapping for IWRM in Ethiopia – 2024-2029

Key results:

- New and improved data on the location, extent, and estimated volume of groundwater resources in selected pilot areas through the use of modern rapid geophysical mapping technologies.
- Improved water supply through better information on groundwater resources increasing local climate resilience.
- 240 students undertaken courses in modern geophysical mapping methods.
- 100 water professionals trained in new hydrogeophysical mapping methods at the Ethiopian Water Technology Institute.
- 1 TEM and 1 ERT system in place and operational at each of the three partner institutions: MOWE/EWTI, Hawassa University and Haramaya University.
- A critical mass of Ethiopian operational and analytical capacity in the application of TEM (transient electromagnetics) as well as ERT (electrical resistivity tomography) established.
- Draft guidelines and standard operating procedures for best geophysical groundwater mapping practices in Ethiopia.
- Design of a geophysical data-base add-on to the national groundwater database enabling easy and public access to geophysical data and maps together with SSC Water.
- Improved success rates for borehole drillings in selected areas.
- Efficiency increases for MAR projects supported by geophysical surveys in selected pilot areas.

Justification for support:

- Supporting national water sector strategies, plans and targets in Ethiopian/Danish development priorities and policies, and including the SSC Water, WASH activities/ groundwater mapping activities, and Grundfos solarization projects.
- Supporting the GoE's pursuit of equitable water access for all, as outlined in the 2030 "Pathway to Prosperity", the National Integrated Water Resource Management Programme (NIWRMP) and the Climate-Resilient Green Economy strategies.
- Address recognized data gaps and data sparsity on groundwater resources, which partly limit NIWRMP implementation.
- Close links to outcomes and partners in the ongoing SSC Water.

Major risks and challenges:

- Stakeholder unwillingness to upgrade geophysical technologies and/or integrate these technologies into on-going IWRM projects.
- Sustainability of university-based and EWTI-based geophysics education programs.
- Retention of hydrogeological mapping capacity by stakeholders.

File No.	24/50649					
Country	Ethiopia					
Responsible Unit	Royal Danish Embassy, Addis Ababa					
Sector	Water and climate change					
Partners	Ministry of Water and Energy, EWTI Hawassa and Haramaya Universities,					
DKK million	2024	2025	2026	2027	2028	I alt
Commitment	20					20
Disbursement	10			4	6	20
Duration	2024-2029					
Previous grants						
Finance Act code	06.34.01.70					
Head of unit	Sune Krogstrup					
Desk officer	Henrik Hagen Olesen /Kristine Sorgenfri Hansen					
Reviewed by CFO	YES, Mister Yirdaw					

Relevant SDGs

No Poverty	No Hunger	Good Health, Well-being	Quality Education	Gender Equality	Clean Water, sanitation
Affordable Clean Energy	Decent Jobs, Econ. Growth	Industry, Innovation, Infrastructure	Reduced Inequalities	Sustainable Cities, Communities	Responsible Consumption & Production
Climate Action	Life below Water	Life on Land	Peace & Justice, strong Inst.	Partnerships for Goals	

Objectives:

To support integrated water resource management in Ethiopia through cost effective identification and management of groundwater resources for climate-resilient rural and urban water supplies using modern geophysical technologies.

Environment and climate targeting – Principal objective (100%); Significant objective (50%)

	Climate adaptation	Climate mitigation	Biodiversity	Other green/environment
Indicate 0, 50% or 100%	50%			50%
Total green budget	10.4m			9.6m

Justification for choice of partner:

The Ministry of Water and Energy (MoWE) is the national governmental organization with the mandate to set standards for water resource management in Ethiopia. As such, they are well positioned to champion the use of modern hydrogeophysical groundwater mapping across the water sector. Haramaya and Hawassa Universities, and EWTI have expertise in climate-resilient water resource management, research, and education and are thus well positioned to implement the pilot studies and capacity development efforts central to the project.

Summary:

The groundwater resource mapping project will introduce modern rapid geophysical groundwater mapping technologies to the Ethiopian water sector and enable establishment of standards that will allow modern hydrogeophysical mapping tools to contribute to meeting the NIWRMP. Key objectives include development of a critical mass of human, organizational, and institutional capacity with Ethiopian stakeholders in the use of modern groundwater mapping tools for enhanced water supply and Integrated Water Resource Management.

Budget (engagement as defined in FMI)**:**

Outcome 1 - Developing human, organizational, and institutional geophysical capacities	MDKK 9.63
Outcome 2 - Pilot-studies highlighting geophysical benefits to climate-resilient WRM in Ethiopia	MDKK 10.37
Total	MDKK 20.00

Ministry of Foreign Affairs of Denmark

Project Document

Rapid Groundwater Resource Mapping Programme
for
Integrated Water Resource Management in Ethiopia
– a capacity development programme for new and faster
hydrogeophysical groundwater assessment technologies
2024 - 2029

November 2024

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List of acronyms

AFD	Agence Française de Développement (French Development Agency)
ATV	All-Terrain Vehicle
AU	Aarhus University
BCM	Billion Cubic Meters
CIA	Central Intelligence Agency
DEPA	Danish Environmental Protection Agency
DK	Denmark
DKK	Danish Kroner
ENGDA	Ethiopian National Ground-water Database
ENGWIS	Ethiopian National Groundwater Information System
ERT	Electrical Resistivity Tomography
ETH	Ethiopia
EWTI	Ethiopian Water Technology Institute
GERD	Grand Ethiopian Renaissance Dam
GW-MATE	Groundwater Management Advisory Team is a component of the Bank-Netherlands Water Partnership Program (BNWPP) using trust funds from the Dutch and British governments.
HU	Haramaya University
HWU	Hawassa University
IGSSA	Institute of Geophysics, Space Science and Astronomy
IWRM	Integrated Water Resource Management
JMP	Joint Monitoring Program
km	kilometer
m	meter
M	million
MAR	Managed Aquifer Recharge
MFA	Ministry of Foreign Affairs of Denmark
MoV	Means of Verification
MoWE	Ministry of Water and Energy
MoWR	Ministry of Water Resources
NGO	Non-Governmental Organization
NIWRMP	National Integrated Water Resources Management Program
PI	Principal Investigator
Co-PI	Co-Principal Investigator

RGRMP	Rapid Groundwater Resource Mapping for IWRM in Ethiopia Project
R-WASH	Regional Water, Sanitation and Hygiene
SC	Steering Committee
SDG	Sustainable Development Goal
SOP	Standard Operating Procedure
SSC	Strategic Sector Cooperation
SunWASH	Water and sanitation for Gambella Project under Grundfos Foundation
TEM	Transient Electromagnetic Method
TBD	to be decided
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
US	United States
USD	United States Dollar
USGS	United States Geological Survey
VES	Vertical Electrical Soundings
WASH	Water, Sanitation and Hygiene
WR	Water Resource
WRM	Water Resource Management
WHO	World Health Organization

1 Introduction

This project document outlines the background, rationale and justification, objectives and management arrangements for development cooperation concerning geophysical solutions to integrated water resource management (IWRM) in Ethiopia as agreed between the parties: Aarhus University and the Royal Danish Embassy in Addis.

The formulation of this project document is based on the needs articulated in Ethiopia's National Integrated Water Resources Management Program. The objectives set in this project are then rooted in existing programmes and are aligned with the government of Ethiopia's plans and processes for realising the strategic objectives.

2 Context, strategic considerations, rationale and justification

2.1 Brief summary of main issues

A complex array of challenges driven by geopolitical, domestic, and socio-economic factors must be confronted to achieve Ethiopia's water goals. Geopolitically, Ethiopia is highly dependent on the Nile and currently the construction of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile is completed and the dam is now close to being full. The GERD aims to enhance Ethiopia's hydroelectric power and water availability.

Domestically, the sector suffers from significant infrastructure deficiencies, particularly in rural areas. The water supply infrastructure is limited and often poorly maintained, leading to frequent breakdowns. Many rural communities in Ethiopia depend mainly on groundwater for their water supply, or on unimproved water sources, such as ephemeral rivers and unprotected wells, which are prone to contamination and seasonal variability.

Financial constraints further exacerbate these issues, with insufficient funding for new projects and maintenance of existing infrastructure. Developing water infrastructure in remote and sparsely populated areas is especially challenging and costly, worsening the disparities in water access. Institutional weaknesses compound the sector's difficulties. The fragmented institutional framework leads to inefficiencies in water resource management and allocation, with a lack of coordination among various government agencies and stakeholders resulting in inconsistent policies and practices.

Technologically, the sector is outdated, with strong potential for significant advances if modern methods for water extraction and distribution become standardized. Limited adoption of modern water purification and conservation technologies both hinder efforts to improve water quality and efficiency.

Socio-economic conditions add another layer of complexity. High poverty levels significantly impact the ability to afford safe water. The burden of water fetching typically falls on women and children, affecting their education and economic activities; a major contributing factor to gender imbalances related to education and income levels. Poor water quality leads to waterborne diseases such as diarrhoea, particularly in rural areas where healthcare access is limited. These health issues further entrench poverty. There are also stark disparities in water access between urban and rural settings. Urban areas, despite better infrastructure, struggle with rapid population growth and the expansion of informal settlements, which often lack basic water and sanitation services. This leads to over-extraction and increased contamination risks.

Although urban areas have greater access to improved water sources, the supply is often unreliable. Rural areas face more significant challenges due to sparse and scattered settlements, making infrastructure development difficult and costly. Reliance on unimproved water sources in these areas further exacerbates health and socio-economic issues.

Around 90% of the water for domestic and industrial use is drawn from groundwater resources. Groundwater will continue to be the strategic, most climate-resilient water resource in the coming decades, where temperature increases of more than 2 deg. C, and declining rainfall is expected across much of the nation.

This will increase pressure on existing groundwater resources, and underlines the need to improve and expand information on available groundwater resources at a local, regional and national level, as a prerequisite for designing and implementing Integrated Water Resource Management (IWRM) solutions that are resilient towards future climate scenarios.

The need for proactive, integrated water resource management is a key-priority for Ethiopia, and improving IWRM is the central objective of the National Integrated Water Resources Programme[1].

Lack of sufficient and reliable scientific data - especially on groundwater- affects the capability of the mandated institutions to effectively plan and implement water supply development and water resource management. The NIWRMP prioritizes the need for database development to support decisions on water resource management on two strategic issues:

1. Increasing the use of (and reliance on) groundwater resources.
2. Implementing climate-resilient water harvesting, groundwater recharge and other IWRM measures.

Identifying and mapping groundwater resources presents significant challenges to meeting Ethiopia's water needs. The country's varied geology complicates the identification of reliable groundwater sources. Currently, most new groundwater identifications are based on existing data and/or are based on too few measuring points resulting in a relatively high number of drillings with no or limited yields.

Comprehensive hydrogeological surveys are needed, but can be expensive and time-consuming. Limited technical capacity and resources further hinder these efforts. Additionally, the over-reliance on groundwater in some regions leads to over-extraction, depleting aquifers faster than they can be replenished, which exacerbates water scarcity issues. Developing accurate groundwater maps and managing these resources sustainably, requires a substantial investment in technology, expertise, and infrastructure.

Efforts to address these challenges must be multifaceted and integrated. Infrastructure development, efficient resource management, institutional strengthening, and the adoption of modern technologies are crucial. Addressing socio-economic disparities through poverty reduction, improved education, and healthcare can enhance water access and quality. Tailored approaches for different regions are necessary, focusing on e.g. irrigation in water-rich areas and resilience-building in arid regions. By leveraging these strategies, Ethiopia can improve water access and quality, promoting socio-economic development and poverty alleviation.

[1] (NIWRMP, MoWE 2023)

3 Project Rationale

The intervention logic is:

If modern geophysical technologies are embedded in the Ethiopian Water Sector, a key-step towards ensuring cost-effective identification and management of water resources for climate-resilient rural and urban water supply will be realized. Two key objectives to achieve this goal are:

1) Development of human, organizational, and institutional capacity for the integration and application of modern geophysical technologies within key Ethiopian institutions and stakeholders.
2) Documentation of the benefits of geophysical technologies for climate resilient water management in the Ethiopian context.

The objectives are designed with a focus on addressing key data gaps hindering realization of the climate-resilient water goals outlined in the National Integrated Water Resources Management Plan (NIWRMP). These objectives will be pursued through a highly collaborative framework requiring buy-in and active participation from numerous Ethiopian stakeholders, with key partners and stakeholders elaborated in section 3.2. The work plans to achieve each outcome are elaborated further in sections 3.3.1 and 3.3.2, respectively.

Briefly, RGRMP strives to realize a critical mass of Ethiopian expertise in modern geophysical technologies for groundwater exploration through two parallel efforts. The first centers around geophysical capacity development at key stakeholders throughout the Ethiopian water sector, realized through professional development modules and augmentation of water-management relevant undergraduate/graduate programs at Ethiopian universities with expanded hands-on geophysical training. In parallel to these educational pursuits, on-going geophysical support will be provided to high-priority Ethiopian IWRM projects in order to build a portfolio of successful case studies. The goal is to enable a quantitative cost-benefit analysis of modern geophysical technologies for IWRM relevant to the Ethiopian context to motivate legislators to standardize high-level geophysical practices nationally.

The geophysical strategy balances two technologies, transient electromagnetics (TEM) and electrical resistivity tomography (ERT). The two-technology approach aims to exploit the complementary benefits of the two methods and to ensure an adaptable geophysical suite suitable for a wide range of applications. A focus on TEM systems ensures production of high data densities in rural or semi-urban settings, where the method can deliver unparalleled mapping capabilities. Multiple TEM modalities balancing mapping speeds and depth of investigation will be included to ensure suitability for shallow focused applications, such as managed aquifer recharge projects, and for deep-oriented studies, such as exploration for deep aquifers at 200-400 meter depth intervals as is a common goal in many Ethiopian settings. ERT methodologies offer less spatial coverage compared to TEM but are better suited to semi-urban/urban settings with human infrastructure and for scenarios where high 2D resolution is critical, such as understanding surface/groundwater exchange along river channels. As such, the combined platform enables rapid scouting in both rural and semi-urban settings, where the decision to employ TEM or ERT can be taken on a project-by-project basis to ensure the production of the most relevant geophysical data sets. Technical discussions related to each of these methods is given in Annexes 3 and 4.

3.1 Justification

The project is formulated in strong alignment with both Ethiopian and Danish government priorities, ensured through fostering robust buy-in from key actors within the Ethiopian Water Sector, including the Ministry of Water and Energy, the Ethiopian Water Technology Institute, Hawassa University, and Haramaya University. With regards to the sustainable development goals, the project is informed by and will contribute to SDG 6: Ensure clean water and sanitation for all. Specifically addressed targets include:

6.1) By 2030, to achieve universal and equitable access to safe and affordable drinking water for all,

6.4) By 2030, to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity, and

6.5) By 2030, to implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

The Rio Marker for RGRMP is listed as 50% climate adaptation and 50% other green/environment. The project balances support for real-world climate adaptation initiatives through augmentation IWRM projects with supporting geophysical data, with the aim of enhancing decision-making and sustainable management. These efforts occur during outcome 2, which is elaborated later. The 50% "other green" tag arises from the intensive capacity building focuses within the project, which aim to broadly elevate geophysical expertise within the Ethiopian water sector in order to advance future climate resilient IWRM initiatives.

3.1.1 Alignment with Ethiopian Government Priorities

The project goals aim to support three key Ethiopian initiatives focused on sustainable water access: 1) the National Integrated Water Resource Management Plan (MoWE, 2023), 2) the Climate-Resilient Green Economy Strategy (CRGE, 2015), and 3) the "Pathway to Prosperity" Ethiopia 2030 program (Planning and Development Commission, 2021). These initiatives strive to realize basic water services for all Ethiopian citizens through expansion of potable water resources, enhanced use of groundwater resources, and by fostering rural decentralized management. But realizing these goals will require that suitable water resources can be first located and then managed in a sustainable manner; a serious challenge if the data underlying critical decisions is insufficient to make accurate predictions of how water systems will respond under future scenarios. Prioritization of rural, decentralized water solutions within these programs also pushes management responsibilities into often extremely data sparse regions, where issues will only become compounded by a lack of knowledge of local water systems.

With regards to the NIWRMP, RGRMP aims to address a critical issue related to the need for developing human and institutional capacity in modern technologies that advance IWRM at the national, regional, and basin scales. In parallel, pilot-activities offer a means to address data sparsity issues hindering implementation of IWRM practices across a range of Ethiopian projects. More specifically, the planned capacity building and pilot studies are in direct support of the following NIWRMP thematic components:

Thematic component 1. National IWRM Capacity, specifically Major Interventions 1.2 (Building planning, coordination, monitoring, and evaluation capacity), 1.3 (Modernization of water resources management systems), and 1.6 (resource assessment and evaluation). Geophysical capacity building in RGRMP offers an opportunity to advance MoWE water resource monitoring, assessment, and evaluation using modern ERT and TEM geophysical technologies.

Thematic component 2. Basin and Hydro-Met Information system, specifically Major Interventions 2.2 (Develop data protocol regulatory framework), 2.4 (Support for the recalibration of hydro monitoring stations and update with new technologies) through development of geophysical guidelines and SOPs and the enhanced geophysical characterization of aquifers for more accurate groundwater model construction and forecasting, respectively.

Thematic component 3. Water resources development, use, and management, specifically Major Intervention 3.2 (Support mainstreaming IWRM in water resources development) by elevating geophysical capacity across the water sector to enhance data-support for water management decisions.

Thematic component 8. Stakeholder engagement, communication, and knowledge management, specifically Major Intervention 8.4 (Support research and innovation in areas of IWRM), where development of human and institutional capacity at partner universities in Ethiopia will elevate research and innovation in IWRM. It will also provide key supplementary data to support groundwater/surface water research, as well as diversify future research opportunities. Taken together, these activities will help cultivate centers of excellence in these geophysical technologies at both Ethiopian universities and the Ethiopian Water Technology Institute.

With regards to the Ethiopian Government's Climate-Resilient Green Economy Strategy (CRGE, 2015), which advocates for local-scale water retention programs and the use of local water resources (strategic priorities 4.2 and 3.2, respectively), both the education and pilot study tracks in this project support these objectives. By empowering a broader pool of Ethiopian stakeholders to utilize modern geophysical technologies, the number of local-scale water management initiatives can be greatly scaled, and their likelihood for long-term sustainability elevated through enhanced understanding of local groundwater systems afforded through inclusion of modern geophysical techniques. Example local-scale solutions that will be supported in this project include managed aquifer recharge projects, where surface runoff is captured or diverted to enhance recharge of groundwater systems, and which are currently being investigated by AFD, World Bank, WRI, and others. Nature-based solutions are also an attractive solution, where ecohydrological approaches to channel overland flow via check-dams to slow runoff gradients (Belete, 2021), thus promoting infiltration, or to channel water towards retention ponds (Hancock, et al., 2010) can enhance water retention/availability. Sand dams, where impediments to sediment and water flow through dry river channels are constructed, also offer means of supplementing the natural storage capacity of local alluvial aquifers (Lassage et al., 2008). RGRMP may help enhance efficiency for each of these approaches by identifying regions where surface waters can be optimally infiltrated in order to replenish local groundwater systems.

The Pathway to Prosperity program seeks to make basic economic and social services, with clean water identified explicitly, accessible to all Ethiopians regardless of economic status. Emphasis is placed on accessing climate-resilient potable water sources in rural settings, eliminating dependence on fluoride rich water sources, and expanding efficient irrigation schemes. Underlining these goals is again the need for a more comprehensive understanding of local surface and groundwater systems, which RGRMP aims to help achieve by empowering a larger pool of Ethiopian water sector professionals in modern geophysical tools able to provide this much needed information.

3.1.2 Alignment with Danish Government Priorities in Ethiopia

The project formulation is strongly informed by the Danish government's long-term strategy for climate work, a key aspect of which is clean water. More specifically, Danish policy documents including the Danish Strategy for Development Cooperation and Humanitarian Action, *The World We Share* (2022-2025) and the *Danish Global Climate Action Strategy* (2020). By increasing the capacity and means of identifying new groundwater sources, predicting the long-term viability of these systems and thereby improving the sustainable use of water resources in Ethiopia, this project contributes to the Danish priority of enhancing access to climate-proof, clean drinking water for households in Africa. These goals are also strongly echoed in both the upcoming strategy for Danish engagement in Africa on promoting equal green partnerships, as well as in the Ministry of Foreign Affairs how to note for Climate adaptation, Nature and Environment.

The RGRMP also has strong synergies with Danish water initiatives in Ethiopia, including the Denmark-Ethiopia SSC Water, Danish support of UNICEF's Ethiopia WASH program, and Grundfos' support for a borehole solarization project called SunWASH (PDJF, 2023). The geophysical imaging focus in RGRMP will augment these efforts with supporting data that will better define local groundwater systems and improve data-support for management and design-decisions in these projects. Key stakeholders within those projects, including the Ministry of Water and Energy and UNICEF's Ethiopia WASH group will also be critical partners in this work.

With regards to the on-going Denmark-Ethiopia Water SSC, the SSC and RGRMP have overlapping regional focuses in the Hawassa and Dire Dawa regions. This will ensure strong synergies, as Ethiopian academic partners active in the SSC in both Dire Dawa (Haramaya University) and Hawassa (Hawassa University) will also serve as strategic collaborators in this work. These partners will play critical roles in RGRMP's capacity building efforts through partnership on university-based geophysical education programs, pilot geophysical studies, as well as in project dissemination. RGRMP instrumentation will be based at these universities and made available to support SSC activities in the region. Water utilities based in Hawassa and Dire Dawa are also key stakeholders within SSC Water. A strong connection to these partners will be forged in RGRMP, as both Haramaya and Hawassa Universities have strong local ties with these organizations. Partnership with the utilities may be realized via collaborative geophysical pilots, where priority projects for these utilities can be augmented with geophysical survey inputs to aid in subsequent water system design or management. RGRMP will also benefit greatly from SSC activities developing repositories of hydrogeological and hydrological data, while helping to augment these efforts beyond traditional hydrogeological data, to include geophysical data. The project management structure within RGRMP (discussed further in section 7.1) also includes the SSC project manager at DEPA within the steering committee, ensuring that strategic implementation of RGRMP is strongly aligned with SSC activities. In summary, the common stakeholders and regions of interest between RGRMP and the SSC Water, where all compiled hydrological data and networking opportunities forged in RGRMP are to be shared with SSC colleagues, ensure that close ties and strong synergies will exist between the two strategic programs.

3.1.3. Alignment with Danish Government Cross-Cutting Issues

This project aligns closely with Danish cross-cutting priorities on gender and youth empowerment outlined in "The World We Share - Denmark's Strategy for Development Cooperation". While primarily technical, the project integrates Denmark's commitment to gender equality as a catalyst for societal advancement, emphasizing equal access to education, economic resources, and leadership opportunities for women. A gender specialist will be supported by project funds to ensure that gender sensitivity is adequately considered in all project implementation phases. Particular emphasis will be placed on gender sensitive recruiting practices for planned education modules to help better balance gender statistics within the Geosciences, as well as in stakeholder engagement and dissemination of all project outcomes. These commitments reflect Denmark's vision for long-term, meaningful change, aligning with Sustainable Development Goals on gender equality, decent work, and reduced inequalities.

Youth empowerment is similarly prioritized by the project, with focused initiatives in education and training to unlock young people's potential. University partnerships within RGRMP's are also strongly aligned with the new MFA Africa strategy that emphasizes youth development[2]. This collaboration will provide ample opportunities to integrate Ethiopian undergraduate and graduate students into RGRMP activities (Via Ritzau, 2024). Students will have the chance to develop research projects that culminate in Bachelor's, Master's, or PhD theses related to RGRMP objectives, while also gaining valuable hands-on experience with advanced geophysical technologies, enhancing their skills and attractiveness to future employers.

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[2] https://amg.um.dk/tools/youth-in-development/youth-and-social-sectors-guidance-note

3.1.4. Alignment with other Water initiatives in Ethiopia

RGRMP aims to build a national resource base which can be applied to groundwater surveys and water resource management initiatives countrywide. The project aim to promote collaboration between project partners and to offer expanded geophysical surveys and data support for water resource management in other initiatives. Annex 8 lists examples of parallel water initiatives where such collaboration could be relevant.

3.2 Project Partners and Key Stakeholders

The success of RGRMP hinges upon cultivating strong buy-in from key stakeholders within the Ethiopian water sector. RGRMP will seek to build partnerships through alignment of its education and pilot study goals with priority water initiatives with key government agencies at the federal, regional, and woreda levels, NGOs, universities, and other development agencies. The proposed network of collaborators is highlighted in Figure 1, where relevant stakeholders are denoted within each bubble and their potential role in the project briefly stated in purple.

To establish robust buy-in from a wide spectrum of collaborators we aim to cultivate joint endeavors wherein RGRMP can build capacity within their organizations and/or augment data support for their IWRM activities through geophysical surveys and interpretations. The expenses associated with geophysical activities will be covered by RGRMP funds, thus coming at no cost to the collaborators. In return, RGRMP seeks a commitment from partners to actively engage their water sector professionals, e.g. project hydrogeologists or water engineers, in joint planning and interpretation of the geophysical data, as well as the sharing of all hydrogeologically relevant data (e.g. borehole reports, hydrogeological assessments, etc.). This collaboration framework is imperative to ensure that the geophysical findings directly inform the final design or management decisions of the projects.

The strategy to offer geophysical contributions at no cost to collaborators is designed to leverage infrastructure funds already allocated within collaborator's budgets in order to scale the number of completed water systems where geophysics has contributed in some way to their design, siting, and or management. For example, this will enable RGRMP to contribute to a large number of borehole drilling projects by helping to site boreholes, but without having to pay the drilling expenses and coordinate the drilling logistics. As such, the number of drilled boreholes, MAR systems constructed, nature-based solutions built, and other water management projects supported within the project timeline can be greatly increased because RGRMP will not be required to cover the infrastructure costs. These completed water systems are key to ensuring that an accurate cost-benefit analysis of the value of modern geophysical approaches in the Ethiopian context can be produced by project end.

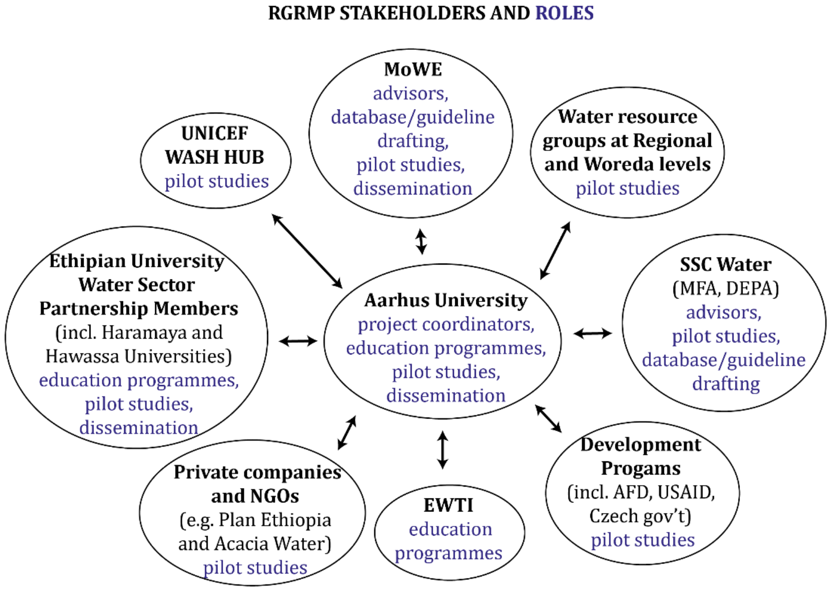

Figure 1: Web outlining the stakeholders within the RGRMP (bubbles), as well as their role (purple text).

The direct Danish and Ethiopian partners in RGRMP, i.e. those that receive project funds and have project staff employed at their institutes, include Aarhus University, MoWE, Haramaya University, Hawassa University, and EWTI.

Aarhus University (AU) is a world-renowned leader in hydrogeophysics, having developed paradigm shifting geophysical tools for groundwater exploration the past three decades. AU will be the project-lead in RGRMP, and support all project activities, including on-the-ground support for education-modules and pilot studies. AU has extensive experience in field applications of geophysics for IWRM, including in East Africa, and has a strong capacity building record having trained academic, governmental, and industry partners in geophysical methods for many years.

MoWE will be a critical project partner, where building a strong collaboration between MoWE and RGRMP will be key to this program's success. Their mandate includes formulation of policy, strategy, and the establishment of nationwide standards. They coordinate and oversee water supply projects financed by federal government budgets, as well as conduct capacity building efforts within the water sector. At the regional level, regional water bureaus are responsible for implementation of federal policies, adaptation to the specific needs of the regions, as well as the planning, implementation, and monitoring of water supply projects. Woreda Water Offices are also mandated to plan, implement, and monitor small water supply schemes. As such, MoWE has the reach necessary to elevate geophysical practices broadly across the water sector. To motivate buy-in from MoWE, RGRMP will align its objectives closely with the National Integrated Water Resource Management plan. A MoWE staffer will be supported via project funds to act as liaison between RGRMP and MoWE, and to play an active role in guideline/SOP formulation, data-base development, and in geophysical pilot-studies in support of MoWE projects.

A second group of stakeholders key to the programme are academic partners within the Ethiopian University Water Sector Partnership, which includes eight Ethiopian universities[3] with specialization in water-related educations. Haramaya and Hawassa University are identified as strategic partners, given their on-going collaboration with the SSC Water and their specialization in IWRM education programs, and will be key points of

[3] The eight Ethiopian Universities within the University Water Sector Partnership include Haramaya, Hawassa, Arba Minch, Jimma, Bahir Dar, Mekelle, Addis Ababa, and Dilla Universities.

contact, where RGRMP staff and equipment will be hosted within research groups at these institutes. Their research programs specialize in groundwater/surface water studies and nature-based solutions for watershed management, respectively. These two universities will also be key partners in the university-focused education activities, where the project will prepare course materials and assist in geophysics education modules that will be integrated into the curriculum at their institutes (as well as at a further 2 institutes in project years 3-5). By building institutional capacity, both human and instrumentation, the project aims to motivate additional Ethiopian universities to partner in the educational objectives in RGRMP to offer students hands-on experience in modern TEM and ERT technologies.

Beyond University partners, the Ethiopian Water Technology Institute (EWTI) is identified as a key partner for educational objectives focused on capacity building for water sector professionals already employed in governmental or industry roles. RGRMP aims to cultivate support from MoWE and EWTI to develop professional development short-courses in ERT and TEM as a means to support the NIWRMP's Thematic component 8.5, which emphasizes IWRM in water education. The target audience of participants would be water sector professionals within both the public and private sectors that could be nominated from MoWE's extensive network. An EWTI staffer will be supported by project funds to aid in the development and teaching of the geophysical short-courses. EWTI will also host geophysical equipment purchased in support of RGRMP activities; this equipment is to be available for use by both's use by EWTI and MoWE.

Beyond the direct project partners, RGRMP plans to pursue broad collaboration with a wide range of water sector stakeholders. In terms of international donors, relevant parties include the Agence Francaise de Developpement (AFD), the United States Aid program (US-Aid), World Bank, UNICEF, and the Czech Republic Embassy. Each of these donors are actively engaged in water-resource projects throughout Ethiopia. The project seeks to establish collaborations with each of these development partners to support their water initiatives with geophysical campaigns to diversify the projects contributed to in this work and to establish key relationships with these foreign agencies.

Additional stakeholders include non-governmental organizations or private companies in Ethiopia. Two key partners identified include Plan Ethiopia (NGO) and Acacia Water (private company). Plan Ethiopia is a large NGO, active in various water projects across Ethiopia, including a large borehole solarization projects supported by the Grundfos foundation. A critical step in these projects is selection of suitable borehole sites, a challenging endeavor given that these decisions are generally made in rural settings lacking significant characterization of local groundwater systems. As such, augmenting these projects with geophysical surveys may help in the identification of suitable borehole locations, key to maximizing the benefits of subsequent solarized borehole installations. Acacia Water is also a key actor in UNICEF's Ethiopia WASH activities, where they have conducted large scale groundwater assessments in several regions of Ethiopia. RGRMP is well-positioned to augment their assessment workflows, which include remote sensing data amongst other factors, with the inclusion of geophysical surveys to collectively deliver enhanced understandings of local water systems. A survey of active geophysical consultants will also be conducted to identify additional potential collaborators, ensuring up-to-date insights about state-of-practice in Ethiopia, and to recruit them as participants in the training programs.

The Danish Environmental Protection Agency (DEPA) will also be a key stakeholder. DEPA is coordinator for the SSC Water program in Ethiopia together with the MFA and will be actively involved in the steering committee overseeing management of RGRMP to ensure strong alignment of this work with the SSC Water.

3.3 Project Outcomes

3.3.1 Outcome 1: Developing human, organizational, and institutional geophysical capacities

A crucial aspect for the long-term sustainability of RGRMP 's objectives is to empower stakeholders within the Ethiopian water sectors with proficiency in modern geophysical technologies. This goal aims to address the lack of widespread expertise in electromagnetic and electrical methods within the current geophysical landscape in Ethiopia. These project activities are related to outcome 1 in the logframe in section 5.

A critical component of these efforts is to elevate geophysical capacity and awareness across the Ethiopian water sector. Two key target-groups are identified: 1) current water-sector professionals working in industry, government, NGOs, and academic roles and 2) the next-generation of water sector professionals currently studying at Ethiopian universities. The project's ambition is to have more than 100 water sector professionals and 240 students participate in the educational modules. To reach each target group within RGRMP 's timeline, two parallel education tracks are required:

1. The first involves establishment of a short-course, targeting current water sector professionals who stand to benefit from the integration of geophysical technologies into their work. RGRMP plans to collaborate with the Ethiopian Water Technology Institute (EWTI), a capacity building institute within MoWE, to host this program. The courses are to be taught jointly by EWTI and AU staff, with a handover of the main teaching responsibility to EWTI towards project end. MoWE and EWTI will be key partners in recruiting participants for the course, as their extensive network of water sector professionals encompasses the target audience.
2. To reach the next-generation of water sector professionals will require partnering with Ethiopian universities to augment their geoscience/water-resource programs with geophysical lecture materials and field coursework. This collaborative effort will be facilitated by the AU team, with a transition plan where initial teaching will be conducted by AU staff in-person via intensive 2-week programs, with a gradual hand-over to Ethiopian professors for teaching in the later stages of RGRMP. AU-support will reduce to remote involvement including curriculum planning, exercise development, and online lectures/software support in later project years, with teaching responsibilities being overtaken by university staff. The goal is to integrate modern geophysical technologies into the curriculum of water-related courses at the undergraduate level. By doing so, the project aims to significantly enhance the students' exposure to these technologies prior to their entry into the professional ranks of the water sector.

The field component of the geophysical modules will be conducted at sites of relevance to SSC Water stakeholders to strengthen synergies between RGRMP and the SSC, where the teaching activities can serve the dual purpose of giving hands-on experience to students, while also producing data sets of value for IWRM projects affiliated with the SSC Water.

To support these education goals, RGRMP will overcome software barriers to broader TEM adoption. ERT technologies, being a much more mature methodology, have numerous free-wares where data processing, imaging, and interpretation are readily accessible given moderate levels of training. However, TEM software generally requires expensive licenses or a high level of programming skills rendering these solutions unattractive to many potential practitioners. A free-ware based on open-source TEM modelling codes will be developed to address the need for user-friendly free software for TEM. Software development will take place in project years 1 and 2, where all subsequent training activities will teach students in the use of this free-ware. The need for an open-access easy-to-use software has been echoed by numerous African partners, and establishing the long-term sustainability of TEM technologies in Ethiopia will require a significant reduction in the access barriers (both programming skills and financial investment).

Our activities will also institutionalize geophysical research capacities at the two strategic university partners, Hawassa University and Haramaya University. These partners are selected given expertise in water resource management education tracks, strong research capacities related to climate-resilient water strategies, and prominent roles within the SSC Water program. This will involve the hiring of four Ethiopian research geophysicists, two at each university and the procurement of geophysical instrumentation for these institutes. The hired staff geophysicists will be recruited from Ethiopian industry/academia or recruited as talented recent graduates in the field of geoscience and will be employed at the relevant university but supported by RGRMP funds. Although employed formally by an Ethiopian university, these research geophysicists will support RGRMP activities as their primary responsibilities. These staff will undergo formal training under close supervision from AU during a two-month visit to Aarhus, Denmark. The training will prioritize robust field acquisition techniques and rigorous data quality control measures. Throughout RGRMP, further emphasis will be placed on developing data processing and interpretation skills of these geophysicists. The aim is for them to evolve into fully independent experts in TEM and ERT technologies, and to augment research capacities within these institutes bringing a powerful set of geophysical technologies relevant for a broad range of research activities. Continuous guidance and oversight from AU personnel will ensure that the crew consistently produces high-quality research. By embedding project staff at strategic Ethiopian university partners, it will ensure strong buy-in from these institutes, as well as enhance likelihood of the long-term sustainability of geophysical capacity by integrating these staff directly into these institutes. These staff will also support teaching and field-exercises for the geophysics modules taught at the universities, as well as provide support for field-exercises during professional development training with the EWTI. Institutionalizing geophysical expertise within these universities will also provide an academic pillar upon which MoWE and EWTI can rely for geophysical advice/support in their future water initiatives. Note that university staff often support supplementary IWRM projects outside of the university, indicating that geophysics capacity embedded at the university partners is also likely to have trickle-down benefits for other local water actors – e.g. support for water utilities in the siting of boreholes. Note that these staff will also be tasked with supporting SSC Water activities in Dire Dawa and Hawassa with geophysical surveys to improve groundwater identification, mapping, and monitoring for other SSC-affiliated stakeholders.

To further institutionalize these geophysical technologies within the Ethiopian water sector, guidelines outlining best practices for the integration of geophysics into various water management frameworks will be drafted together with MoWE. This activity reflects the goals of the NIWRMP Thematic component 7, which aims to prepare, review, and ratify processes of policies, regulations, protocols, guidelines, and manuals. Although these guidelines are not anticipated to become policy prior to project end, the goal is to support MoWE's mandate to set standards and procedures, as these draft guidelines can inform the path forward to standardizing geophysical practices across Ethiopia. These draft guidelines can also be used informally to advise federal, regional, and woreda officials to promote and elevate geophysical surveys within their groundwater development and monitoring projects. Access to concise draft guidelines will also allow officials writing tenders to ensure that contracted geophysicists are held to the required standards and that delivered data and interpretations are in-line with accepted scientific practices.

3.3.2 Outcome 2: Pilot-studies highlighting geophysical benefits to climate-resilient IWRM

A critical component in advancing modern geophysical groundwater assessment technologies in the Ethiopian water sector relies on collaborative partnerships with key stakeholders. RGRMP aims to enhance IWRM projects through the inclusion of improved geophysical data and characterizations of water systems. The goal is to establish a suite of successful pilot studies serving as evidence for the benefits of geophysics for climate-resilient water resource management in the Ethiopian context. By engaging directly with key stakeholders on these projects, Ethiopian partners will get direct exposure to the benefits of modern geophysical methods and technologies through inclusion of these tools in their on-going water resource management initiatives.

The geophysical data sets and characterizations will be offered in-kind to partners in exchange for project partnership, as well as data sharing and collaborative dissemination. The objective is twofold: firstly, to bolster these initiatives by providing robust groundwater data support for informed decision-making, and secondly, to demonstrate the utility of modern geophysical assessment methods through its seamless integration into their projects. Partnerships built on agreements for geophysical data integration into subsequent decision making will maximize RGRMP's outputs in that the mapping focuses can be augmented by parallel infrastructure development programs, where the outcomes of geophysical investigations can be evaluated based on the performance of constructed systems or water management frameworks. These project activities are related to outcome 2 in the logframe in section 5.

In cooperation with the project steering committee (MOWE, AU, MFA, DEPA) a prioritized selection of water initiatives and sites to be supported by hydrogeological mapping will be formulated. This prioritization will focus on programs and projects dedicated to aquifer recharge, sustainable groundwater management, assessment of local groundwater resources, groundwater modelling, and borehole drilling endeavours in areas of relevance for the partners. These decisions will also prioritize high-visibility projects and geographical overlap with SSC Water priorities, but may include projects in other regions of Ethiopia beyond the SSC programme. Prior to the decision to launch each pilot study, a preliminary document outlining the pilot studies key stakeholders, geophysical activities, location, and potential outcomes will be compiled and shared with the steering committee. The steering committee will take the final decision over whether a particular pilot study is to be undertaken by RGRMP. Inclusion of DEPA and MOWE in this pilot selection process will ensure strong synergies between RGRMP, the SSC Water, and MOWE.

Geophysical campaigns will be planned, executed, and interpreted in close collaboration with relevant stakeholders, in order to ensure a strong buy-in from Ethiopian partners and subsequent integration of the data into follow-up decision-making. Geophysical pilot studies are covered by output 2.1 in the logframe in section 5.

To ensure data availability and lasting impact beyond the project, all geophysical outputs in RGRMP will be uploaded to MoWE national databases. Together with MoWE officials overseeing the national database management, and with SSC members involved in database construction activities, a format for the upload of geophysical data will be designed and implemented. All collected data will be uploaded compliant with the required data and report formats. Inspiration will be drawn from the Danish National Geophysical Database, GERDA, where robust templates for data formats of TEM and ERT data have previously been established and followed for more than 10 years in Denmark. The value of publicly available geophysical data is that it helps form a foundation upon which future surveys benefit, as it enables local calibration of the geophysics to geology transforms required during the interpretation steps.

A cost-benefit analysis (CBA) will be conducted in project years 3, 4, and 5 to assess scalability of geophysical pilots by quantifying the actual costs and benefits of the RGRMP pilot projects in both financial and qualitative terms. The CBA will define clear objectives and identify all associated costs, including direct expenses like materials and labour, indirect costs such as time and opportunity costs, and any recurring costs if the pilot were expanded. Benefits are quantified by calculating financial gains—such as increased revenue and cost savings—and non-financial impacts, including improvements in efficiency, environmental outcomes, health, and/or social well-being. The CBA spans a specific time frame, discounting future costs and benefits to their present values, allowing for calculations of key indicators such as Net Present Value and the Internal Rate of Return. Another critical measure, the Benefit-Cost Ratio, is calculated by dividing total benefits by total costs; a BCR above 1 indicates that benefits exceed costs, making the project economically viable. Sensitivity analysis is performed to understand how changes in assumptions impact results, enhancing the reliability of the CBA. This approach provides a comprehensive evaluation, integrating quantitative metrics and qualitative insights, allowing decision-makers to assess the pilot's scalability in terms of economic feasibility and alignment with broader strategic and stakeholder goals. The project will attempt to utilise the resources at the universities to undertake the CBA.

Parallel to these geophysical campaigns will be dissemination efforts focused on documenting and raising awareness of benefits derived from geophysical data for climate-resilient water management. To achieve this, geophysical reports discussing all collected data, providing interpretations, and recommendations will be provided to relevant partners. Note that these reports and interpretations will be prepared with direct input from hydrogeologists, engineers, and other relevant Ethiopian professionals in the project. This will ensure that geophysical data is not simply collected and a report delivered, but rather that decision-makers on the implementer side of the project are fully-informed regarding the geophysical data and include it in follow-up decision-making. Beyond maximizing geophysical data's value to each particular project, this collaborative interpretation approach is also key to building capacity within partner institutes, as relevant staff will gain hands-on experience to geophysical data workflows and subsequent interpretations in settings of importance to their work. The project will document the added-value to the various water initiatives by remaining informed of all downstream developments and project performance. The goal is to compile a robust portfolio of pilot and/or case studies in Ethiopia that underscore the pivotal role geophysics can play in building climate-resilient water solutions and to motivate MoWE partners to institutionalize these geophysical technologies within their national standards.

Dissemination efforts will target a range of relevant water sector stakeholders at both national and international levels, as well as targeting technical and non-technical audiences. Technical dissemination will include the publication of RGRMP outcomes as open-source peer-reviewed journal articles targeting broad water audiences, as well as the presentation of project outcomes at international water conferences each year. Both AU and Ethiopian researchers will lead the various publications. Target conferences will have diverse water sector audiences, ranging from technical academic water conferences to diverse water-sector conferences such as the International Water Association or World Water Congress. At the national-level dissemination will be focused on non-technical outputs presented at Ethiopian water sector conferences, and as well as the publication of white-papers highlighting a range of successful case-studies showing concrete evidence for the value of modern geophysical technologies in Ethiopia. Public-focused outreach will also be pursued through partnerships with news media outlets, both in Denmark and Ethiopia. Connecting with media outlets will leverage the project's diverse network and public relations teams at both Danish and Ethiopian partner institutes. For example, Danish news media will be reached via the public relations group at the Natural Sciences faculty at Aarhus University. It is anticipated that the AU and Ethiopian staff will spend approximately 3 months per year (cumulative contribution of all project staff) on dissemination activities. These activities are related to output 2.1 in the logframe.

4 Theory of change and key assumptions

RGRMP's intervention logic is that broad adoption of modern geophysical technologies by the Ethiopian water sector will address critical issues related to data sparsity or poorly characterized water systems. These missing data are necessary to ensure climate-resilient management of these resources, and their continued absence will present significant challenges in the Ethiopian government's pursuit of its water and climate goals outlined in the Climate Resilient Green Economy Strategy. If these data gaps can be addressed via cost-efficient geophysical technologies, it will enable informed management decisions built upon an enhanced understanding of local water systems. Without such knowledge, water managers are forced to make decisions based on insufficient data-support, thus endangering the long-term viability of water resources. A schematic illustrating the theory of change is shown below in Figure 2.

How will change happen in the specific context?

We expect that change will occur through continued exposure of key stakeholders to the benefits of geophysics for IWRM. A significant effort is made in RGRMP to ensure continued geophysical campaigns throughout the full project period. This will help to scale the number of supported water initiatives and to broaden the pool of RGRMP partners exposed to the benefits of geophysics. The compilation of a large portfolio of Ethiopian cases and quantification of geophysical contributions to IWRM through cost-benefit analyses, in combination with draft guidelines to elevate geophysical standards, will serve as strong motivation to MoWE partners to ensure that future water initiatives benefit from a more comprehensive understanding of local water systems that can be attained through geophysics.

Our strategy is based on strong partner buy-in ensuring intimate exposure to the benefits/limitations of geophysical methods. This hands-on collaborative approach is critical to building expertise within partner institutes, while also ensuring that the role of geophysics is not minimized when it comes to decision-making.

Establishing sustainable education programs, targeting both existing water sector professionals and the next generation of professionals (current students), is also essential to cementing these geophysical technologies in Ethiopia. It is imperative that the pool of trained users grow to ensure that a critical mass of expertise can be embedded at Ethiopian institutes. The strategy of empowering Ethiopian university partners and the EWTI to continue geophysics coursework post project will be key to sustainability of RGRMP outcomes.

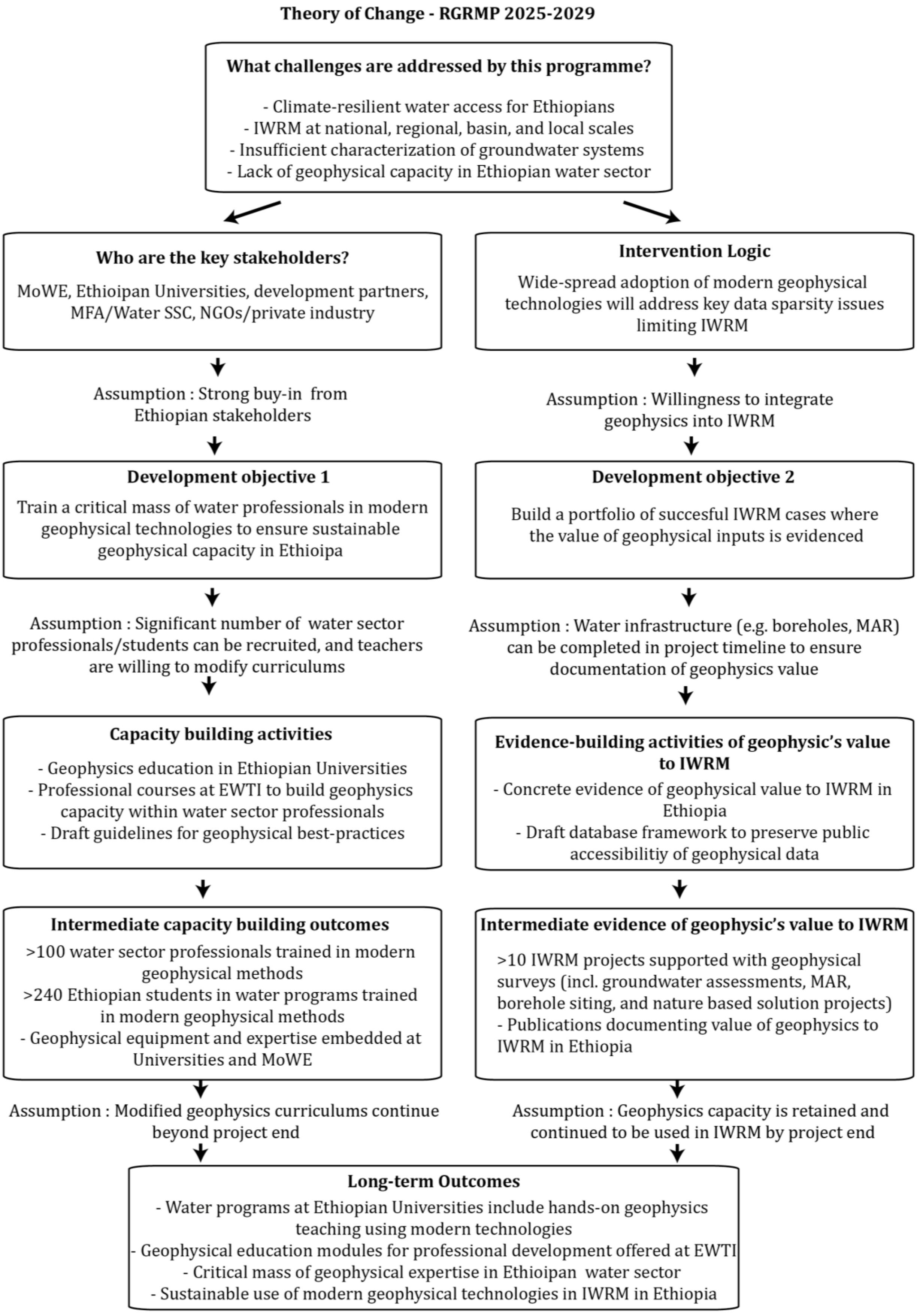

Figure 2: Theory of Change.

5 Summary of the results framework

For results-based management, learning and reporting purposes, MFA will base the actual support on progress attained in the implementation of RGRMP as described in the below results framework. Progress will be measured through Aarhus University's monitoring framework focusing on a limited number of key outcome(s) and corresponding outputs and their associated indicators. A results logframe outlining outputs, output indicators, means of verification (MoV), baselines, and corresponding targets is given below. A detailed workplan outlining the timeline of various activities is also given in the Annex 2.

Table 1: Logframe of RGRMP's outcomes/outputs.

Project/Programme	Climate Resilient Water Programme
Project/Programme Objective	To support integrated water resource management in Ethiopia through cost effective identification and management of groundwater resources for climate-resilient rural and urban water supplies using modern geophysical technologies.
Impact Indicator	1. TEM and ERT geophysical surveys used to support MoWE projects focused on climate resilient groundwater management, monitoring, and exploration. MoV: Inclusion of geophysical data/interpretations in MoWE project reports. 2. MoWE and university partners have capacity to conduct TEM and ERT geophysical surveys independently. MoV: Geophysical surveys conducted and reports written by MoWE and University partner staff. 3. Education programs on the use of TEM and ERT technologies for water resource management integrated into water-programs at Ethiopian universities. MoV: Number of students completing TEM/ERT education modules at university partners. 4. On-going TEM/ERT capacity development within Ethiopian water sector, through education modules at EWTI. MoV : Number of water sector professionals completing certifications in TEM/ERT technologies at EWTI. 5. Embedded TEM/ERT expertise at Ethiopian university partners. MoV : Publications discussing TEM/ERT for water resource management in Ethiopia led by Ethiopian University staff.
Baseline	Water resource management is often based on insufficient data coverage, where geophysical technologies are underutilized. Remote sensing based assessments, and traditional hydrogeological mapping are the current standards. Geophysics is generally limited to several VES soundings per groundwater assessment. IWRM, especially for groundwater, is severely limited by lack of necessary hydrogeological data.

Outcome 1	Developing human, organizational, and institutional geophysical capacities.
Outcome 1 Indicators	1.1 Overview of existing geophysics practitioners in private and public institutions, and summary of their SOPs. MoV : Spreadsheet containing information of geophysics practitioners in Ethiopia and summary of their SOPs. 1.2 Completion of inception phase report, finalization of partner agreements, and approval of implementation strategy by steering committee. MoV: Submission and approval of inception phase report by steering committee. 1.3 Hiring of staff trained in TEM/ERT methodologies at university partners and MoWE. MoV : Employment contracts for staff with TEM/ERT expertise with the university partners and MoWE. 1.4 Number of development partners/donors and projects using TEM/ERT geophysical methods to support IWRM decisions. MoV: The publication of reports containing geophysical assessments in support of IWRM, including the number of different development partners, as well as the number of project reports. 1.5 Number of water sector professionals capable of independent TEM/ERT geophysical surveys. MoV: Number of professionals receiving certification in TEM/ERT methods following completion of education modules at university partners or EWTI.

	1.6 TEM/ERT geophysical surveys conducted by MoWE/university partners using their own equipment. MoV : TEM/ERT instrumentation owned and hosted at MoWE/university partners. 1.7 Draft guidelines and SOPs outlining TEM/ERT best-practices written together with MoWE, and tested in Ethiopian projects. MoV : Presentation of draft guidelines to WR and WASH sub-groups at MoWE. 1.8 Completion of open-source TEM software and open-access TEM textbook free to practitioners. MoV: TEM software/textbook freely downloadable online.	
Baseline	2025	Pool of geophysicists trained in modern TEM/ERT technologies is limited and inclusion of these technologies in water initiatives is lacking.
Target 1.1 (Ind 1.1)	2025	Completion of overview of existing geophysics practitioners in Ethiopia and summary of their SOPs.
Target 1.2 (Ind 1.2)	2025	Completion of inception phase report, signing of partner agreements and approval of implementation strategy by the steering committee.
Target 1.3 (Ind 1.3)	2025	Completion of project staff hiring, including 2 at Hawassa University, 2 at Haramaya University, 1 at MoWE, 1 at EWTI, and 3 at Aarhus University.
Target 1.4 (Ind 1.6)	2025	Completion of TEM/ERT equipment procurement. 1 TEM and 1 ERT system at Hawassa University, 1 TEM and 1 ERT system at Haramaya University, and 1 TEM and 1 ERT system at EWTI.
Target 1.5 (Ind 1.4/1.5)	2025	Plans for delivering TEM/ERT education modules agreed upon between AU, Ethiopian university partners, and EWTI.
Target 1.6 (Ind 1.4/1.5)	2025	Completion of first round of TEM/ERT modules at partner universities and EWTI, training of 30 students and 20 water sector professionals.
Target 1.7 (Ind 1.4/1.5)	2026	Updating of education modules to reflect year 1 feedback, and completion of second round of TEM/ERT modules at partner universities and EWTI, training of 30 students and 20 water sector professionals.
Target 1.8 (Ind 1.7)	2026	Completion of first draft of guidelines and SOPs for TEM/ERT best-practices in Ethiopia.
Target 1.9 (Ind 1.8)	2027	Completion of open-source TEM software for use in education modules, together with an open-access TEM textbook for use in coursework.
Target 1.10 (Ind 1.4/1.5)	2027	Updating of education modules to reflect year 2 feedback, and completion of third round of TEM/ERT modules at partner universities and EWTI, training of 60 students and 20 water sector professionals.
Target 1.11 (Ind 1.4/1.5)	2028	Updating of education modules to reflect year 3 feedback, and completion of fourth round of TEM/ERT modules at partner universities and EWTI, training of 60 students and 20 water sector professionals.
Target 1.12 (Ind 1.7)	2028	Draft guidelines and SOPs tested in 5 geophysical surveys, and an update of the guidelines to reflect lessons learnt.
Target 1.13 (Ind 1.4/1.5)	2029	Completion of fifth round of TEM/ERT modules at partner universities and EWTI, training of 60 students and 20 water sector professionals.
Target 1.14 (Ind 1.7)	2029	Updated draft guidelines and SOPs presented to WR and WASH sub-groups at MoWE.

Output 1.1	Draft guidelines and SOPs written that outline the best practices for the use TEM and ERT technologies in support of IWRM, developed together with MoWE and the SSC.
Output 1.1 Indicators	1.1.1 Draft guidelines and SOPs for TEM/ERT support for IWRM validated in Ethiopian context. MoV : Successful IWRM supported by geophysics, documented in reports (e.g. siting of boreholes or recharge projects via geophysical surveys). 1.1.2 TEM/ERT geophysical campaigns conducted by project partners adopt practices outlined in the draft guidelines/SOPs. MoV : Geophysical reports that comply with the draft guidelines/SOPs. 1.1.3 Discussion of a potential regulatory framework to implement draft guidelines/SOPs together with MoWE and the SSC. MoV : Meetings/documents outlining steps necessary if a regulatory framework built on the draft guidelines is to be implemented.

Baseline	2025	No standardization of geophysical data collection practices and reporting is currently implemented.
Target 1.1.1 (Ind 1.1.1)	2025	Completion of meeting with MoWE/SSC and circulation of document outlining necessary components of initial guidelines/SOPs draft.
Target 1.1.2 (Ind 1.1.1)	2026	Completion of first draft of guidelines and SOPs for TEM/ERT best-practices in Ethiopia.
Target 1.1.3 (Ind 1.1.2)	2027	Testing of draft guidelines/SOPs in 3 projects (cumulative).
Target 1.1.4 (Ind 1.1.2)	2028	Testing of draft guidelines/SOPs in 6 projects (cumulative).
Target 1.1.5 (Ind 1.1.2)	2028	Updated draft guidelines/SOPs to reflect lessons learnt during pilot studies.
Target 1.1.6 (Ind 1.1.1)	2029	Presentation of draft guidelines/SOPs to WR and WASH subgroups at MoWE.
Target 1.1.7 (Ind 1.1.3)	2029	Meeting with MoWE, SSC, and MFA to outline potential regulatory framework if guidelines are to be implemented, and compilation of the discussion into a report.

Output 1.2		Geophysics modules developed, tested and integrated in the curriculums at Universities within the Ethiopian University Water Sector Partnership.
Output 1.2 Indicators		1.2.1 The number of water programs at Ethiopian Universities that have integrated TEM/ERT geophysical modules into their curriculums. MoV : The teaching of geophysical modules by Ethiopian academic staff. 1.2.2 Number of students graduating water programs at Ethiopian universities that have completed geophysical modules. MoV: Number of students passing module exams on TEM/ERT methods.
Baseline	2025	Addis Ababa University, Haramaya University and Hawassa University have water and geological related science curricula limited to basic resistivity methods, such as VES, or focus on alternative geophysical methods (e.g. gravity, magnetics, seismics). Teaching of geophysics is often limited to class-room lectures and limited opportunity for hands-on field experience is available.
Target 1.2.1 (Ind 1.2.1)	2025	Agreements reached with Hawassa and Haramaya Universities to implement geophysics modules in 2025-2029.
Target 1.2.2 (Ind 1.2.2)	2025	Geophysics education modules developed and taught to undergraduate/graduate students in water programs at Hawassa and Haramaya Universities with support from AU staff; 30 students participating.
Target 1.2.3 (Ind 1.2.2)	2026	Geophysics education modules taught to undergraduate/graduate students in water programs at Hawassa and Haramaya Universities with support from AU staff; 30 students participating.
Target 1.2.4 (Ind 1.2.1)	2026	Agreements reached with two additional Ethiopian universities to implement geophysics modules in 2027-2029.
Target 1.2.5 (Ind 1.2.2)	2027	Geophysics education modules taught by Haramaya and Hawassa staff to undergraduate/graduate students in water programs; with 30 students participating.
Target 1.2.6 (Ind 1.2.2)	2027	Geophysics education modules taught to undergraduate/graduate students in water programs at two additional Ethiopian universities (TBD) with support from AU staff; 30 students participating.
Target 1.2.7 (Ind 1.2.2)	2028	Geophysics education modules taught by Haramaya and Hawassa staff to undergraduate/graduate students in water programs; with 30 students participating.
Target 1.2.8 (Ind 1.2.2)	2028	Geophysics education modules taught to undergraduate/graduate students in water programs at two other Ethiopian universities (TBD) with support from AU staff; 30 students participating.
Target 1.2.9 (Ind 1.2.2)	2029	Geophysics education modules taught to undergraduate/graduate students in water programs at four Ethiopian universities (Hawassa, Haramaya, and two others (TBD)); 60 students participating.

Output 1.3	TEM and ERT geophysics short-courses developed, tested and integrated into EWTI program with MoWE support.
Output 1.3 Indicators	1.3.1 Number of geophysical short-courses teaching best practices of TEM/ERT technologies for IWRM, where teaching is led by EWTI staff. MoV : The teaching of geophysical modules by Ethiopian academic staff. 1.3.2 Number of water sector professionals receiving certification in TEM/ERT methods via geophysical modules taught at EWTI. MoV: Number of completion certificates given to short-course participants.

Baseline	2025	No geophysical courses in TEM/ERT for water sector professionals.
Target 1.3.1 (Ind 1.3.1)	2025	Meeting with MoWE and SSC to identify pool of relevant water sector professionals to invite to attend the short courses and the compilation of a corresponding participant list.
Target 1.3.2 (Ind 1.3.2)	2025	Geophysics education modules developed and taught to water sector professionals at EWTI with support from AU staff; 20 professionals participating.
Target 1.3.3 (Ind 1.3.1)	2025	Collection of feedback from year 1 participants and updating of course program/materials.
Target 1.3.4 (Ind 1.3.2)	2026	Geophysics education modules developed and taught to water sector professionals at EWTI with support from AU staff; 20 professionals participating.
Target 1.3.5 (Ind 1.3.2)	2027	Geophysics education modules developed and taught to water sector professionals at EWTI with support from AU staff; 20 professionals participating.
Target 1.3.6 (Ind 1.3.2)	2028	Geophysics education modules developed and taught to water sector professionals at EWTI with support from AU staff; 20 professionals participating.
Target 1.3.7 (Ind 1.3.2)	2029	Geophysics education modules developed and taught to water sector professionals at EWTI with support from AU staff; 20 professionals participating.

Outcome 2		Pilot-studies highlighting geophysical benefits to climate-resilient IWRM in Ethiopia.
Outcome 2 Indicators		2.1 Number of MoWE projects using TEM and ERT geophysical methods to support IWRM decisions. MoV : MoWE project reports containing discussion of geophysical surveys. 2.2 Number of development partners/donors and projects using TEM/ERT geophysical methods to support IWRM decisions. MoV : The number of development partners/donors that publish reports containing geophysical assessments in support of IWRM, as well as the number of project reports. 2.3 Number of publications (including peer-reviewed journal articles, white-papers, news articles, and presentations at international/national conferences) on geophysical contributions to IWRM in Ethiopia. MoV : Copies of the publications. 2.4 Drafting of a framework for the upload of geophysical data into MoWE databases. MoV: A report outlining proposed database structure, data formatting, and information to be included in geophysical database.
Baseline	2025	Geophysical input to IWRM decision-making is generally limited to sparse VES data-sets.
Target 2.1 (Ind 2.1/2.2)	2025	Completion of kick-off meeting with all project partners, and joint selection of 5 water initiatives to support with geophysical surveys.
Target 2.2 (Ind 2.1/2.2)	2025	One pilot study demonstrating contribution of TEM/ERT geophysics to IWRM in Ethiopia.
Target 2.3 (Ind 2.1/2.2)	2026	Two pilot studies demonstrating contribution of TEM/ERT geophysics to IWRM in Ethiopia.
Target 2.4 (Ind 2.3)	2026	Publication of one peer-reviewed journal article, one white-paper targeting Ethiopian water sector professionals, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.5 (Ind 2.2)	2027	Meeting with 3 development partners (beyond MoWE/SSC) to identify water initiatives that will be supported by geophysical surveys. Selection of 3 additional water initiatives to support with geophysical surveys.
Target 2.6 (Ind 2.1/2.2)	2027	Presentation to MoWE WR and WASH sub-groups on geophysical contributions to IWRM, and the joint selection (together with MoWE/SSC) of 2 additional water initiatives to support with geophysical surveys.

Target 2.7 (Ind 2.1/2.2)	2027	Two pilot studies demonstrating contribution of TEM/ERT geophysics to IWRM in Ethiopia.
Target 2.8 (Ind 2.3)	2027	Publication of one peer-reviewed journal article, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.9 (Ind 2.1/2.2)	2028	Three pilot studies demonstrating contribution of TEM/ERT geophysics to IWRM in Ethiopia.
Target 2.10 (Ind 2.3)	2028	Publication of one peer-reviewed journal articles, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.11 (Ind 2.1/2.2)	2029	Two pilot studies demonstrating contribution of TEM/ERT geophysics to IWRM in Ethiopia.
Target 2.12 (Ind 2.3)	2029	Publication of one peer-reviewed journal articles, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.13 (Ind 2.1/2.2)	2029	Completion of wrap-up meeting, and presentation to MoWE WR and WASH sub-groups on project outcomes quantifying geophysical contributions to IWRM.
Target 2.14 (Ind 2.4)	2029	Completion of report outlining geophysical database for potential augmentation of national groundwater database and the upload of all project data to the data in formats complying with the database.

Output 2.1		Portfolio of Ethiopian pilot studies highlighting the value of geophysics to IWRM in Ethiopia.
Output 2.1 Indicators		2.1.1 Number of water initiatives (including groundwater assessments, managed aquifer recharge, and nature-based solution projects) supported with TEM and ERT geophysical data to improve IWRM decisions in Ethiopia. MoV: IWRM reports containing discussion of geophysical surveys. 2.1.2 Number of development partners/donors and the number of projects supported with geophysical surveys. MoV: Reports published by development partners/donors containing geophysical surveys. 2.1.3 Number of publications (peer-reviewed articles, white-papers, news-articles, conference presentations) on geophysical contributions to IWRM in Ethiopia. MoV: Copies of publications. 2.1.4 Number of cost-benefit analyses quantifying benefits of geophysical data for different IWRM projects. MoV : Copies of cost-benefit analyses reports.
Baseline	2024	Geophysics is underutilized for water resource characterization, with geophysical data sets for groundwater assessments generally limited to sparse VES soundings.
Target 2.1.1(Ind 2.1.1/2.1.2)	2025	One pilot study highlighting geophysical contribution to IWRM.
Target 2.1.2 (Ind 2.1.1/2.1.2)	2026	Two pilot studies highlighting geophysical contribution to IWRM.
Target 2.1.3 (Ind 2.1.3)	2026	Publication of one peer-reviewed journal article, one white-paper targeting Ethiopian water sector professionals, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.1.4 (Ind 2.1.1/2.1.2)	2027	Two pilot studies highlighting geophysical contribution to IWRM.
Target 2.1.5 (Ind 2.1.4)	2027	Cost-benefit analysis showing value of geophysics contributions for pilots completed to date.
Target 2.1.6 (Ind 2.1.3)	2027	Publication of one peer-reviewed journal article, one white-paper targeting Ethiopian water sector professionals, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.1.7 (Ind 2.1.1/2.1.2)	2027	Presentation to MoWE WR and WASH sub-groups on project outcomes quantifying geophysical contributions to IWRM.

Target 2.1.8 (Ind 2.1.1/2.1.2)	2028	Three pilot studies highlighting geophysical contribution to IWRM.
Target 2.1.9 (Ind 2.1.4)	2028	Cost-benefit analysis showing value of geophysics contributions for pilots completed to date.
Target 2.1.10 (Ind 2.1.3)	2028	Publication of one peer-reviewed journal article, one white-paper targeting Ethiopian water sector professionals, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.1.11 (Ind 2.1.1/2.1.2)	2029	Two pilot studies highlighting geophysical contributions to IWRM.
Target 2.1.12 (Ind 2.1.4)	2029	Cost-benefit analysis showing value of geophysics contributions for pilots completed to date.
Target 2.1.13 (Ind 2.1.3)	2029	Publication of one peer-reviewed journal article, one white-paper targeting Ethiopian water sector professionals, one popular news article, and two presentations at international water conferences. The topics will be geophysical contributions to IWRM in Ethiopia.
Target 2.1.14 (Ind 2.1.1/2.1.2)	2029	Presentation to MoWE WR and WASH sub-groups on project outcomes quantifying geophysical contributions to IWRM.

Output 2.2		Draft framework for the inclusion of geophysical data into MoWE's national groundwater database completed together with MoWE/SSC.
Outcome 2.2 Indicator		2.2.1 Collaborative design of geophysical database add-on to national groundwater database, including outline for data formats, description, and reporting requirements. MoV : Presentation of draft framework to MoWE WR group, and completion of report outlining the draft database framework. 2.2.2 Number of geophysical data sets complying with the draft database requirements uploaded to the draft database. MoV : Accessibility of previous geophysical data via the database. 2.2.3 Plans outlined for the augmentation the national groundwater database with the proposed geophysical data add-on. MoV : Report outlining requirements to implement the draft geophysical add-on within the national groundwater data-base. 2.2.4 Number of geophysical data sets complying with the draft database requirements uploaded to the MoWE geophysical database. MoV : Accessibility of previous geophysical data via the MoWE geophysical database.
Baseline	2025	Geophysical data is not incorporated into the current groundwater database and no nationalized compilation of publicly available geophysical data/reports is available.
Target 2.2.1 (Ind 2.2.1/2.2.3)	2025	Meeting with MoWE/SSC staff giving overview of existing national database, and preparation of outline for initial requirements of a geophysical database add-on.
Target 2.2.2 (Ind 2.2.1)	2026	Design of geophysical formats for inclusion in national databases together with MoWE and SSC.
Target 2.2.3 (Ind 2.2.2)	2027	Preparation of all project geophysical data into formats complying with the draft database and upload to a test database.
Target 2.2.4 (Ind 2.2.1)	2028	Meeting with MoWE/SSC staff for overview of test database performance.
Target 2.2.5 (Ind 2.2.2)	2029	Preparation of all project geophysical data into formats complying with the draft database and upload to the test database.
Target 2.2.6 (Ind 2.2.3)	2029	Meeting with MoWE/SSC staff to form plan for potential integration of the draft geophysical database add-on into the national groundwater database.
Target 2.2.7 (Ind 2.2.4)	2029	Preparation of all project geophysical data into formats complying with the draft database and upload to the MoWE database.

6 Inputs/budget

The total budget for RGRMP is DKK 20 million; a budget breakdown can be found in Annex 1. The budget is to be overseen by Aarhus University, with relevant disbursements made to Ethiopian partners (MoWE, EWTI, Haramaya University, and Hawassa University).

The grant is to be disbursed to AU based on written disbursement request detailing the bank account and the amount to be disbursed. The conditions for transfer of funds are, an approved work plan and budget for the period to be financed, satisfactory technical and financial reporting has been submitted for previous periods and satisfactory use of prior transfers. Up on receipt of funds AU need to confirm receipt of funds within 14 days after receipt. Below is the disbursement schedule to AU for the grant:

DKK million	2024	2025	2026	2027	2028	total
Commitment	20					20
Disbursement	10			4	6	20

Aarhus University has a budget of approximately DKK 13.4 million, of which DKK 2.6 million is an investment in geophysical instrumentation for Ethiopian partners.

The Ethiopian partners collective budget is approximately DKK 6.6 million. In terms of human resources, Table 2 outlines the research staff within the project, including their institute and brief responsibilities.

Table 2: Summary of RGRMP research staff, including the corresponding institute and responsibilities.

Institute	Staffer	Responsibility
Aarhus University	Anders Vest Christiansen	Project PI : Project management, partner coordination, supervision of AU staff
	Denys Grombacher	Project Co-PI : Partner coordination, outcome 1 and 2 management, supervision of AU staff
	Line Meldgaard Madsen	Outcome 1 and 2 support of ERT activities
	Research Geophysicist	Outcome 1 and 2 support
	Research Geophysicist	Outcome 1 and 2 support
	Research Hydrogeologist	Outcome 2 support
MoWE	Research Geophysicist	Database, and guidelines/SOP support, liason between MoWE and RGRMP, and outcome 2 support
EWTI	Research Geophysicist	Outcome 1 support
Hawassa University	Coordinator	Hawassa U. Project-lead : Partner coordination, outcome 1 and 2 management, supervision of Hawassa U. staff
	Research Geophysicist	Outcome 1 and 2 support
	Research Geophysicist	Outcome 1 and 2 support
	Research Economist	Cost-benefit analysis support
	Gender specialist	Adherence to gender sensitivity in project implementation
Haramaya University	Coordinator	Haramaya U. Project-lead : Partner coordination, outcome 1 and 2 management, supervision of Haramaya U. staff
	Research Geophysicist	Outcome 1 and 2 support
	Research Geophysicist	Outcome 1 and 2 support

AU funds support the hiring of three full time project staff at AU in support of RGRMP. These staff will coordinate and execute all project outcomes together with the Ethiopian partners. Additional AU support staff include Professor Anders Vest Christiansen, Associate Professor Denys Grombacher, and Assistant Professor Line Madsen, who bring technical expertise in TEM/ERT methodologies, and also have salary allotted to cover project commitments. Funds are allocated for AU staff to conduct two two-week geophysical campaigns per annum in support of output 2.1. Further funds are also earmarked to cover AU staff travel to Ethiopia to lead geophysics training programs at both EWTI and Ethiopian universities in support of outputs 1.2 and 1.3. Beyond these in-country activities for the AU staff, they will also be tasked with the day-to-day responsibilities of supporting all outcome 1 and 2 activities remotely from Aarhus University. Tasks to be completed from Aarhus include all logistics coordination, education materials development, and geophysical data workflows (incl. survey planning, data handling workflows, report writing, partner coordination, and dissemination activities). Dissemination costs related to presentation of project outcomes at international water-sector conferences and as published articles are also included.

The budget for Ethiopian partners will support the hiring of 10 research scientists tasked with supporting outcome 1 and 2 activities. These geophysicists and coordinators have significant time-commitments to the project in order to scale the number and size of supported water initiatives. Staff hired at the university partners and EWTI will support education programs in outcome 1, including support for all hands-on field exercises within the training programs. The university-based staff, together with the MoWE staffer, will also conduct geophysical surveys in support of outcome 2 throughout the full project duration. They will also assume an increasing responsibility for geophysical survey planning, data handling flows, reporting, and dissemination as the project progresses and the number of IWRM projects supported each year increases. The MoWE staffer will also be tasked with liaison responsibilities, serving as point of contact between MoWE and RGRMP, including on-going discussions surrounding the draft guidelines and augmentation of the national groundwater data base. The EWTI staffer will support all education modules at EWTI targeting water sector professionals. Salary is also allocated for a gender specialist and an economist to ensure compliance with gender sensitivity in all aspects of the project implementation, and the completion of cost-benefit analyses, respectively. Funds are also allocated for the procurement of three TEM systems, and three ERT systems; one TEM and ERT system each for Haramaya University, Hawassa University, and MoWE/EWTI. The TEM/ERT systems purchased for MoWE/EWTI are intended to be hosted at EWTI and will be available for use by MoWE for geophysical surveys in support of their water initiatives, as well as by EWTI in support of their training activities. Instrument funds are placed on AU's budget, and have no admin fee applied. A year-by-year breakdown of output expenses is given below in Table 3.

Field work expenses related to fuel, vehicle costs, hotels, and per diems are allocated to support the significant field workload of RGRMP's Ethiopian staff. Funds for training course expenses, such as food, venue costs, participant per diems, and field-expenses are also included. External audit funds are also allocated each year for Ethiopian partners. Ethiopia partners will be supported via quarterly disbursements from AU pending receipt of a financial report from the previous quarter.

Table 3: Summary budget of RGRMP given in thousands of DKK.

		RGRMP Budget Summary in Thousands of DKK					
		2025	2026	2027	2028	2029	Total
Output	1.1	93	58	51	51	51	303
	1.2	1684	834	858	846	347	4570
	1.3	1123	606	606	552	305	3193
	2.1	2668	1856	1897	1890	832	9143

2.2	140	165	225	158	133	820
Contingency	105	130	155	185	170	745
Audit	30	30	30	30	30	150
Admin	215	246	255	245	117	1077
Total	6057	3925	4077	3956	1985	20000

Any reallocations to budget items for salaries, staff and admin costs must be approved by the MFA and any budget change between outputs which is more than 10% of the approved budget needs prior written approval from RDE in Addis Ababa

7 Institutional and management arrangement

To achieve RGRMP's goals, a team comprising sixteen researchers will execute project activities. This team consists of six researchers based at Aarhus University and 10 researchers at Ethiopian partner institutes. Supporting this team will be a management structure led by Professor Anders Vest Christiansen and Asscociate Professor Denys Grombacher, who collectively possess significant project management experience, including involvement in numerous Grand Solution Innovation Fund Denmark projects and European Union projects, as well as in geophysics-centric projects across Africa. At AU, a project secretary and financial controller are also partially salaried by the project (~1 month per project year each) for administrative support. The project secretary will assist in coordination between project partners, planning of research exchanges, and logistical coordination amongst education course participants. The financial controller will coordinate all financial disbursements, auditing, and financial reporting between AU, ETH partners, and MFA-RDE.

The AU team will build collaborations with Ethiopian water sector partners, provide remote support for field activities, coordinate capacity-building efforts, and drive dissemination activities. These tasks will primarily be completed from Aarhus, while AU staff travelling to Ethiopia will be involved in teaching efforts in outcome 1 and field data collection in outcome 2. The Ethiopian team will be tasked with logistics coordination within Ethiopia, conducting field data collection activities, managing partnerships with local stakeholders, and supporting capacity-building efforts. An equitable workload will be implemented, where AU and Ethiopian partners carry equal responsibilities in completing outcomes 1 and 2. All partners will also participate in dissemination.

The AU research staff profiles will include both geophysical and hydrogeological expertise. Three research scientists will be hired at AU to execute project activities, with two specializing in geophysics and the third in hydrogeology. Professor Christiansen, Associate Professor Grombacher, and Assistant Professor Line Madsen, all permanent staff at Aarhus University, will also support project activities, ensuring technical expertise in TEM and ERT methods is present for both pilot studies and educational activities. Ethiopian staff will be recruited from backgrounds in geophysics, hydrogeology, and/or water engineering. Ethiopian geophysical staff members will be employed on a ~1/2 full-time time basis for most duration of the RGRMP. This significant time commitment is essential to scale the number and size of geophysical campaigns undertaken within RGRMP. Gender and economics specialists at Ethiopian institutes will also be hired to ensure gender sensitivities and cost-benefit analyses relevant to the Ethiopian context are conducted.

Note that the research profiles of RGRMP staff are critical for the continued development of geophysical data handling workflows. Pushing geophysical technologies into new settings and geologies will test the limits of existing workflows and require continued adaptation to maximize system performance; a lesson learned through significant past experiences within the project team's research group having used TEM technologies on all seven continents for the past three decades. Strong research profiles will also be key to ensuring that state of art practices are implemented throughout the full project duration.

7.1 Management structure and risk-mitigation

Figure 3 illustrates the management structure and distribution of project staff across partner institutes. The lead of RGRMP will be Professor Anders Vest Christiansen at Aarhus University, supported by Associate Professor Denys Grombacher. Two of the hired AU staff will be appointed lead on daily oversight of human, institutional, and organization capacity building efforts (outcome 1, described in section 3.3.1) and the geophysical-supported hydrogeological assessments (outcome 2, described in section 3.3.2); one staff leading each. All project staff will have biweekly coordination meetings to track progress, identify risks and implement mitigation plans, and to strategize next steps. Responsibilities for dissemination efforts (outcome 2, described in section 3.3.2) will lie with Associate Professor Denys Grombacher, who will coordinate with relevant partners to ensure timely reporting and publication in alignment with the outcome reporting framework.

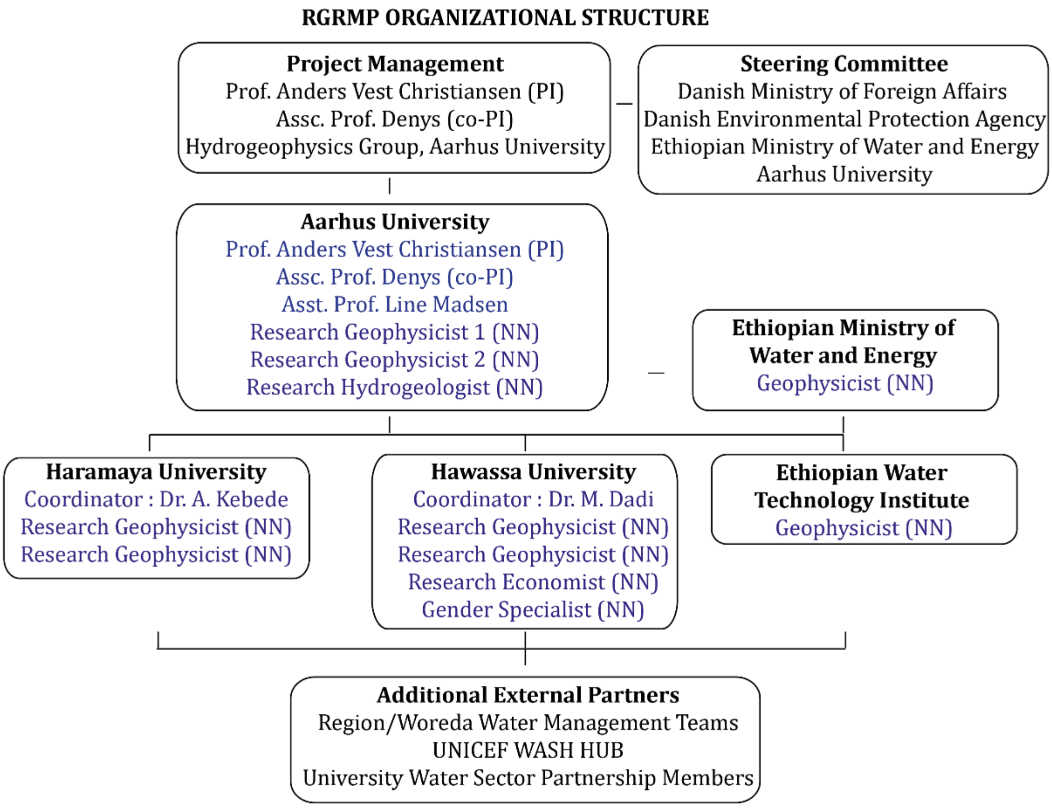

Figure 3: Organizational structure of RGRMP. Blue names have salary supported by RGRMP. (PI: Project lead)

Separate weekly meetings will be held for the teams involved in outcomes 1 and 2. These meetings will involve all relevant AU staff as well as Ethiopian partners. Outcome 1 meetings will include the AU staffer coordinating outcome 1, Associate Professor Denys Grombacher, and the relevant professors/EWTI staff involved in upcoming education modules. Outcome 2 meetings will involve the full project team, as all parties are to be involved in all outcome 2 planning, coordination, and execution. Frequent and regularly scheduled coordination meetings are essential to ensure logistics organization and smooth flow of information between AU/ETH teams. A daily quality control framework will also be implemented for outcome 2 activities, where relevant AU and ETH staff are in daily communication during geophysical campaigns to ensure high-quality data production, identify data issues or errors, and ensure fast turn-around of results to capitalize on partner enthusiasm during field exercises.

A Steering Committee (SC) will also be assembled to advise the project lead. The SC will be composed of representatives from DEPA, MoWE, RDE-ETH, and AU. The mandate for the SC is to take decisions regarding the strategic direction of RGRMP, and to monitor progress towards each output/outcome. The steering committee will also decide upon yearly programs, confirm IWRM pilot projects that will be supported, confirm planned implementation for the education modules, and approve all equipment procurement decisions.

7.2 Reporting and stock-taking schedules

Project reporting, including both progress summaries and financial accounting, will be given bi-annually in alignment with Q2 and Q4 SC meetings. Abbreviated summaries discussing RGRMP progress and target tracking are also to be shared with the SC one week prior to each biannual meeting. Annual narrative progress reports documenting RGRMP outcomes will be prepared and submitted to MFA. Quarterly brief progress reports will be prepared for each steering committee meeting. Work plans are to be agreed upon by relevant parties, with draft plans for each quarter's activities to be included in the reports submitted to the steering committee for discussion at each meeting.

Evaluation of the RGRMP implementation strategy is to be coordinated through on-going feedback exercises. After completion of each geophysical campaign a debriefing will take place, first internally within the project to analyze communication channels and logistics planning, and secondly with the relevant stakeholder to identify ways to optimize integration of geophysical technologies into their workflows. The approach to future campaigns will reflect this feedback to allow practices to iterate and become more streamlined. For the capacity building exercises, following completion of each training program participants will be asked to complete a course evaluation where feedback regarding the course content, teaching approach, and likely long-term retention of learnt skills will be evaluated. The approach to subsequent courses will be adapted to reflect the feedback.

Reporting of geophysical results will involve compilation of geophysical data and outcomes into formats required for integration into national level databases, as well as digestible reports to be given to project partners containing information necessary to inform decision making for each supported water initiative. Reports are to be shared with partners less than 2 months following completion of each campaign to ensure partners have adequate time to allow geophysics insights to inform subsequent decision-making.

The Royal Danish Embassy in Ethiopia will have the right to carry out any technical or financial supervision mission that is considered necessary to monitor the implementation of the RGRMP.

7.3 Project Inception Phase

RGRMP will commence with a 3-month inception phase designed to lay a strong foundation for all subsequent activities. This phase will involve implementation and/or adjustment of the above planned management and financial structures with all project partners. By the end of this period, an updated project executive summary will be formalized to reflect any project refinements, finalized and signed partner agreements with all collaborating entities will be completed, and a consensus on each partner's roles and responsibilities will be reached. This phase will also see the completion of all project hiring processes and the procurement of all geophysical equipment.

Additionally, all partners will establish agreed-upon procedures and timelines for project reporting, financial auditing and disbursements, and a coordination structure for regular project meetings and communication. These outcomes will be described in an inception phase report, which will include an updated partner assessment and context assessment as annexes in the project document. The inception report will then be submitted for approval by the steering committee, ensuring alignment and readiness for project implementation.

8 Financial management, planning and reporting

Project funds are to be handled in agreement with Aarhus University policies defined by Rigsrevisionen. Project funds are to be disbursed to Aarhus University, where Aarhus University will be responsible for disbursements to Ethiopian partners occurring through quarterly payments from AU to the relevant Ethiopian partners. AU will take an admin fee of 7% only on the AU portion of the budget; AU will take no additional admin fee for handling the Ethiopian portion of the budget. AU also ensures the cost of administration at Ethiopian partners' level do exceed 7% of the total budget allocated to each partner.

The disbursement process will involve the submission of a report/invoice outlining planned quarterly activities and expenses by each Ethiopian partner (each partner to prepare their report/invoice separately) to AU prior to each quarter. After receiving and confirming the plan/expenses for the upcoming quarter the disbursement to the relevant Ethiopian partner from AU is made as a pre-payment for upcoming quarterly activities. An additional aspect of this quarterly report will be expenditures from the previous quarter to ensure accurate budget tracking throughout the year. Unspent funds from the previous quarter will be deducted from the following quarters disbursement.

To ensure a smooth transfer of funds between AU and Ethiopian partners, a collaboration agreement between AU and each of the Ethiopian partners will be signed. This partnership agreement will outline the collaborative activities, detail the quarterly disbursement and reporting practices to be implemented, and be negotiated between the AU Technology Transfer Office and the relevant entities at each Ethiopian partner. The collaboration agreement between AU and each of Ethiopian partners covers all of Danish MoFA the requirements to AU.

Account audits for AU budgets, as well as Ethiopian partner budgets are to be submitted each year and reported in detail consistent with the original budget. Ethiopian partner budgets will undergo an external audit annually, to be completed in sync with the end of the Ethiopian financial year. Funds for each Ethiopian partner to complete an annual external audit are included in the budget. AU will provide consolidated annual financial and narrative reports to MFA-RDE, using the results framework reporting format.

Financial reporting by AU to MFA-RDE is to be completed by March 1 of each year. Procedures and timelines for reporting and audits for ETH partners to AU taking account of the difference in fiscal years between DK and ETH will be established before or immediately following project initiation.

Partner budgets are also subject to their Institute policies for auditing and procurement. All geophysical instrumentation purchased in the project is to be owned by the Ethiopian partners. The decision as to which equipment will be purchased will be approved by the steering committee.

9 Risk management

Risk assessments and mitigation measures are informed by the extensive on-the-ground experience, both past and current, of key Ethiopian partners within the projects. These assessments reflect up-to-date knowledge of on-the-ground activities and security situations. These risks are to be constantly monitored throughout the project and implementation strategies to be updated to reflect any risk changes during the project.

The two primary risks for RGRMP include field crew security and robust buy-in of Ethiopian stakeholders. Certain regions of Ethiopia are currently high-security risks due to civil unrest/conflict and as such not suited for field activities in RGRMP. To ensure safety of RGRMP project staff, field activities are to commence only after up-to-date assessments informed by local partners deem local field conditions safe. The term safe here refers to a lack of security issues related to civil unrest, ensuring field access permissions and buy-in from local authorities/communities has been secured, that weather-conditions are conducive to field-work, and that all field safety procedures are known by all staff. To further mitigate these risks, high-security risk regions of the country will be avoided for field work, with prioritization placed on other regions of Ethiopia.

RGRMP also hinges on robust collaborative buy-in from Ethiopian partners, where lack of interest or disengagement from RGRMP during the project period will greatly limit the project impact. To address this risk the program builds a highly collaborative working environment where partners are given opportunity to guide RGRMP field plans to ensure alignment with their project goals/interests. On-going communication and broad existing networks of RGRMP Ethiopian partners will also ensure strong relationships with various stakeholders can be forged. A more comprehensive risk assessment and risk response analysis is detailed in Annex 5.

10 Project closure

The exit strategy for the RGRMP is built upon a slow transition plan where reliance on AU support for geophysical campaigns and training programs will reduce over the project period. Regarding geophysical campaigns, early efforts will require significant AU handling of survey planning, data workflows, and interpretation. But as the RGRMP proceeds, Ethiopian partners will be involved in these procedures repeatedly, creating an environment where they can build the necessary capacity gradually with oversight from AU experts. By RGRMP end the Ethiopian partners will have significant experience in all aspects of the geophysical workflows, and continued access to instrumentation and software beyond the project period. Together, the experience and equipment access will ensure geophysical efforts can be sustained beyond RGRMP. Ethiopian university and MoWE partners will be encouraged to actively pursue supplementary funds to ensure continued maintenance of equipment beyond the project end; examples could include equipment rental or offering geophysical services to local water stakeholders.

To motivate continued implementation of geophysics into Ethiopian water initiatives beyond project end, AU will work closely with MoWE partners to develop draft guidelines of reference to help standardize Ethiopian geophysical practices. Although it is unlikely that these guidelines and SOPs can be made into policy by project end, a path forward to establish a regulatory framework for the implementation of these guidelines will be workshopped together with MoWE by project end. This will ensure that the draft guidelines and the path forward are laid out prior to project end.

For capacity building efforts targeting water sector professionals, the training programs conducted at the Ethiopian Water Technology Institute (EWTI) will gradually transition teaching responsibilities from AU to EWTI staff. This slow transition over the 5-year period ensures EWTI staff adequate time to develop internal capacity, and gain familiarity with the curriculum material. For geophysics modules at university partners, a similar transition plan is envisioned. Modules will initially be led by AU staff, with a gradual hand-off of teaching responsibilities to Ethiopian partners. Curriculum materials, continued instrument access, and the embedding of these modules within broader water-related educations will ensure sustainability of the capacity building efforts beyond project end.

Final reporting will document all RGRMP outcomes with respect to the reporting framework and be concluded 3-months after project end. Final financial reports and audits from all partners will also be submitted together with the final report. Account closure will be done in accordance with each Institute’s internal policies.

Annex 1. Budget specification

	Unit	Unit Cost	Quantity	Budget	Year 1	Year 2	Year 3	Year 4	Year 5
Total Outputs				**19,999,893**	6,056,958	3,925,330	4,076,590	3,955,720	1,985,295
Output 1.1 Guideline/SOP formulation									
Travel cost	Inception/SOP meetings	35,000	1.0	35,000	35,000	-	-	-	-
Salary - Aarhus U.	month	75,500	1.6	119,000	23,800	23,800	23,800	23,800	23,800
Salary - MoWe	month	13,500	6.0	81,000	20,250	20,250	13,500	13,500	13,500
Salary - Hawassa U.	month	13,500	2.5	33,750	6,750	6,750	6,750	6,750	6,750
Salary - Haramaya U.	month	13,500	2.5	33,750	6,750	6,750	6,750	6,750	6,750
Total direct cost output 1.1				**302,500**	92,550	57,550	50,800	50,800	50,800
Share indirect cost output 1.1				21,175	6,479	4,029	3,556	3,556	3,556
Total budget output 1.1				**323,675**	99,029	61,579	3,556	54,356	54,356
Output 1.2 University capacity building									
Activity	Training Module - DK Team	40,000	8.0	320,000	80,000	80,000	80,000	80,000	-
Activity	Training Module -ETH Team	12,000	16.0	192,000	24,000	24,000	48,000	48,000	48,000
Investment	ERT/TEM instrument	440,000	2.0	880,000	880,000	-	-	-	-
Salary - Aarhus U.	month	58,625	40.2	2,356,295	535,775	566,100	566,100	553,300	135,020
Salary - Hawassa U.	month	13,500	30.0	405,000	81,000	81,000	81,000	81,000	81,000
Salary - Haramaya U.	month	13,500	30.9	416,475	83,295	83,295	83,295	83,295	83,295
Total direct cost output 1.2				**4,569,770**	1,684,070	834,395	858,395	845,595	347,315
Share indirect cost output 1.2				258,284	56,285	58,408	60,088	59,192	24,312
Total budget output 1.2				**4,828,054**	1,740,355	892,803	918,483	904,787	371,627
Output 1.3 EWTI capacity building									
Activity	Training module - DK team	42,000	7.0	294,000	84,000	84,000	84,000	42,000	-
Activity	Traing module - ETH team	57,000	10.0	570,000	114,000	114,000	114,000	114,000	114,000
Investment	ERT/TEM instrument	440,000	1.0	440,000	440,000	-	-	-	-
Salary - Aarhus U.	month	58,625	27.4	1,607,295	428,775	352,100	352,100	339,300	135,020
Salary - EWTI	month	13,500	20.0	270,000	54,000	54,000	54,000	54,000	54,000
Salary - Hawassa U.	month	13,500	0.9	11,475	2,295	2,295	2,295	2,295	2,295
Total direct cost output 1.3				**3,192,770**	1,123,070	606,395	606,395	551,595	305,315
Share indirect cost output 1.3				192,694	47,815	42,448	42,448	38,612	21,372
Total budget output 1.3				**3,385,464**	1,170,885	648,843	648,843	590,207	326,687

Output 2.1 Pilot geophysical studies									
Travel cost	Field support - DK team	52,000	9.0	468,000	104,000	104,000	104,000	104,000	52,000
Travel cost	Dissemination - DK team	19,000	4.0	76,000	-	19,000	19,000	19,000	19,000
Travel cost	Field support - ETH team	315,000	4.5	1,417,500	315,000	315,000	315,000	315,000	157,500
Travel cost	Dissemination - ETH team	17,000	5.0	85,000	17,000	17,000	17,000	17,000	17,000
Travel cost	Training in DK of ETH team	50,000	5.0	250,000	250,000	-	-	-	-
Investment	ERT/TEM instrument	440,000	3.0	1,320,000	1,320,000	-	-	-	-
Salary - Aarhus U.	month	58,625	72.4	4,246,910	430,350	1,169,450	1,169,450	1,163,050	314,610
Salary - MoWE	month	13,500	8.0	108,000	13,500	13,500	27,000	27,000	27,000
Salary - Hawassa U.	month	13,500	46.8	631,800	110,160	110,160	137,160	137,160	137,160
Salary - Haramaya U.	month	13,500	40.0	540,000	108,000	108,000	108,000	108,000	108,000
Total direct cost output 2.1				**9,143,210**	2,668,010	1,856,110	1,896,610	1,890,210	832,270
Share indirect cost output 2.1				547,625	94,361	129,928	132,763	132,315	58,259
Total budget output 2.1				**9,690,835**	2,762,371	1,986,038	2,029,373	2,022,525	890,529
Output 2.2 Database formulation									
Travel cost	Kick-off/Wrap-up/Database - DK team	82,000	2.0	164,000	82,000	-	-	-	82,000
Travel cost	Mid-term/Database mtgs - ETH team	67,000	1.0	67,000	-	-	67,000	-	-
Salary - Aarhus U.	month	64,500	6.8	440,000	23,800	130,800	130,800	130,800	23,800
Salary - MoWE	month	13,500	6.0	81,000	20,250	20,250	13,500	13,500	13,500
Salary - Hawassa U.	month	13,500	2.5	33,750	6,750	6,750	6,750	6,750	6,750
Salary - Haramaya U.	month	13,500	2.5	33,750	6,750	6,750	6,750	6,750	6,750
Total direct cost output 2.2				**819,500**	139,550	164,550	224,800	157,800	132,800
Share indirect cost output 2.2				57,365	9,769	11,519	15,736	11,046	9,296
Total budget output 2.2				**876,865**	149,319	176,069	240,536	168,846	142,096
Contingency									
Contingency (max 10% of total direct cost excluding contingency)				745,000	105,000	130,000	155,000	185,000	170,000
Total direct cost				**18,772,750**	**5,812,250**	**3,649,000**	**3,792,000**	**3,681,000**	**1,838,500**
Indirect cost									
Administrative costs (max. 7% of direct cost)				1,077,143	214,708	246,330	254,590	244,720	116,795
Audit	item	10,000	15	150,000	30,000	30,000	30,000	30,000	30,000
Total indirect cost				**1,227,143**	**244,708**	**276,330**	**284,590**	**274,720**	**146,795**
Total budget				**19,999,893**	6,056,958	3,925,330	4,076,590	3,955,720	1,985,295

Annex 2: Workplan breakdown

The below Gantt chart outlines the planned activity timeline for RGRMP outcomes and management activities over the project period. The activities are split into the relevant outputs, as well as in supporting activities (denoted as "other" activities). The number in the cells indicate the relevant targets appearing in the logframe.

Table 4: Gantt chart of RGRMP activities.

RGRMP Work Plans											
Outcome 1 Activities											
Output	Activity	2025		2026		2027		2028		2029	
	Defining/disseminating guidelines/SOPs	1.1.1								1.1.6	1.1.7, 1.4
	Drafting Guidelines/SOPs			1.1.2, 1.8					1.1.5		
1.1	Guideline/SOP testing						1.1.3		1.1.4, 1.12		
	Agreements with Partners	1.2.1, 1.5		1.2.4							
	Harmaya/Hawassa Universities geophysics modules		1.2.2, 1.6		1.2.3		1.2.5		1.2.7		1.2.9, 1.13
1.2	TBD universities - geophysics modules					1.2.6		1.2.8		1.2.9	
	Compile list of course attendees	1.3.1									
1.3	EWTI geophysics modules		1.3.2, 1.6		1.3.4		1.3.5		1.3.6		1.3.7, 1.13
	Geophysical system procurement	1.4									
	Module feedback gathering/course updating		1.3.3		1.7		1.10		1.11		
	Open-source TEM software development					1.9					
Other	Open-access TEM text-book					1.9					
Outcome 2 Activities											
Output	Activity	2025		2026		2027		2028		2029	
	Pilot study - geophysics support for IWRM		2.1.1, 2.2		2.1.2, 2.3		2.1.4, 2.7		2.1.8, 2.9		2.1.11, 2.11
	Dissemination of RGRMP outcomes				2.1.3, 2.4		2.1.6, 2.8		2.1.10, 2.10		2.1.13, 2.12
	Cost-benefit analysis						2.1.5		2.1.9		2.1.12
2.1	Presentation to MoWE donor subgroups					2.1.7, 2.6					2.1.14
	MoWE database coordination		2.2.1					2.2.4		2.2.6	
	Design draft geophysical database				2.2.2						
2.2	Preparation/upload of RGRMP data to database					2.2.3				2.2.5	2.2.7, 2.14
Other	Selection of projects to be supported by RGRMP	2.1				2.5					
General/Management											

Activity	2025		2026		2027		2028		2029	
Inception Phase + Inception Phase report completion	1.1,1.2									
Kick-off (ETH) - Mid-term (AU) - Wrap-up (ETH) meetings	2.1									2.13
Quarterly steering committee meetings										
Outcome-centric weekly meetings										
Annual reporting (financial + narrative report)										
Staff Hiring	1.3									
Training of Ethiopia staff @ AU										

To further illustrate the breakdown of RGRMP activities consider Table 5, which illustrates the number of staff (numbers in each cell) from each institute involved in on-the-ground activities in support of outcome 1, outcome 2, or other activities. The below distribution does not include AU activities that happen remotely in Denmark, but which will occur in continuous support of all Outcome 1, Outcome 2, and other activities.

Table 5: Overview of on-the-ground staff for various RGRMP activities from each institute..

Year	**Institute**	**Outcome 1**				**Outcome 2**			**Inception**	**Kick-off**	**Mid-term**	**Wrap-up**	**Conferences**	
		@ Uni #1	**@ Uni #2**	**#1 @ EWTI**	**#2 @ EWTI**	**Field Work #1**	**Field Work #2**	**Other Pilots**	**Addis**	**Addis**	**AU**	**Addis**	**#1**	**#2**
	AU	2	2	2	2	2	2		2	4				
	HU	2				2		2		3				1
	HWU		2				2	2		3				
2025	MoWE/ EWTI			1	1			1						
	AU	2	2	2	2	2	2						1	
	HU	2				2		2						
	HWU		2				2	2						1
2026	MoWE/ EWTI			1	1			1						
	AU	2	2	2	2	2	2						1	
	HU	2				2		2			1			1
	HWU		2				2	2			1			
2027	MoWE/ EWTI			1	1			1			2			
	AU	2	2	1	1	2	2						1	
	HU	2				2		2						
	HWU		2				2	2						1
2028	MoWE/ EWTI			1	1			1						
	AU					2						4	1	
	HU	2				2		2				3		
	HWU		2				2	2				3		
2029	MoWE/ EWTI			1	1			1						1

Annex 3: Description of transient electromagnetic (TEM) measurements

Transient electromagnetics (TEM) is a non-invasive geophysical imaging technology used for a wide range of near-surface applications, including groundwater assessments, hydrogeological mapping, and constraining surface/groundwater interactions. The measurement involves the use of a pair of coils, where one functions as transmitter and the other as receiver. To generate a response from the earth, a strong current is pulsed in the transmitter coil. This pulsed current is turned off as quickly as possible in order to generate a time-varying magnetic field in the subsurface. This time-varying magnetic field gives rise to an electric field, due to Faraday's law. This electric field in turn leads to the circulation of currents in the subsurface, known as eddy currents, that tend to flow in circular horizontal patterns. The strength and time-dependence of these eddy currents is linked to the electrical properties in the subsurface, in particular the spatial distribution of electrical resistivity at depth. These eddy currents in turn generate their own time-varying magnetic field that can be inductively detected at the surface by measuring the voltage induced in a receiver coil. The observed voltages are then linked to the electrical resistivity present at depth, where different hydrogeological units (e.g. sand versus clay, or weathered zone versus underlying bedrock) can generally be differentiated based on their contrasting electrical properties. As such, the ability to map regions of relatively uniform electrical resistivity in the subsurface or to delineate regions where sharp changes in electrical resistivity occur, reveal powerful insights into the properties at depth. For example, mapping the regional extent or depth intervals of relatively uniform electrical resistivity allows the spatial extent of a unit to be mapped, or its thickness to be estimated, or the depth to the top or base of this layer to be constrained. If this unit corresponds to an aquifer, this is equivalent to mapping the extent of the water bearing layer, offering key insights into the size of an aquifer system, where it can be intercepted by boreholes, and areas at the surface where this system can be recharged.

The measurement can be performed in a range of modalities, from ground-based man-carried systems, to small mobile systems towed by a vehicle such as an ATV, or fully airborne systems flown via helicopter or fixed-wing aircraft. Selection of the relevant modality requires choosing the system appropriate for the scale of the groundwater system to be mapped, the depth range of interest, and the financial constraints of the project.

For ground-based measurements, the standard transmitter has a maximum output current of ~10 A in a large square transmitter loop typically ranging from 40 m to 100 m in dimension. The receiver coil is often smaller, ranging from 2-10 m in side length placed either in the center of the transmitter coil or offset at some distance. The advantage of the large transmit coil is an enhanced depth penetration, where these systems can often image to depths of 250-300 meters depending on local conditions. These measurements require the field crew to lay the loops out by hand, perform a 2-10 minute measurement, and then roll the loops back up. In total, a single measurement takes approximately 15-25 minutes depending on the experience level of the crew, resulting in a single one-dimensional resistivity profile revealing the variation of electrical resistivity with depth. Common production rates are approximately 10-20 sites per day. This form of TEM is the most-readily mobilized, easiest to build capacity, and inexpensive. The trade-off is that it produces the sparsest data sets as it is the slowest of the TEM modalities.

The towed systems are quick to deploy and easily managed by a field crew of two persons. The system consists of an ATV, which carries the instrumentation and tows the transmitter and receiver coils. The transmitter and receiver coils are smaller in this case, typically about 3 m in side length for the transmitter, and less than 1 meter side length for the receiver. The smaller coils result in reduced depth penetration, typically imagining depths of 80-100 meters. However, rapid measurements enable data collection while the system is towed, allowing one-dimensional resistivity depth profiles to be produced every 3-5 meters along the driving direction. The result is thousands of measurements per day allowing tens of kilometers to be mapped each day. The output is a quasi-3D imaging of regional hydrogeology.

Airborne TEM systems represent the best tool for mapping large-scale hydrogeological systems. These systems collect data while the system is either suspended beneath a helicopter or strung around the exterior of a fixed-wing aircraft. The transmitters in these systems are typically in the order of ~20 m side length but generally have many turns and transmit much stronger currents than other systems. The consequence is a large depth penetration reaching hundreds of meters depth, similar to the ground-based systems. These systems can map hundreds of kilometers per day, and typically campaigns often result in the collection of thousands of kilometers of data. The result is a quasi-3D imaging of regional hydrogeology. These systems represent the most expensive TEM modality but can map at scales unachievable by other geophysical imaging technologies.

All TEM data workflows require supplementary software to process, and model collected data in order to image the subsurface. A range of commercial software is available for the processing of ground-based, towed, and airborne data but limited options are available if free-wares are to be used. These free-ware solutions generally require significant programming skills and are restricted in terms of what instrument data can be handled.

The volume of data produced by each TEM modality varies with the number of total measurements, with towed and airborne systems producing on the order of several gigabytes of data per day. Ground-based TEM systems produce lower data volumes, typically with megabytes of data per day.

Annex 4: Description of electrical resistivity tomography (ERT) measurements

Electrical Resistivity Tomography (ERT) is a geophysical technology used for subsurface imaging in various environmental and engineering applications, including groundwater exploration, contaminant plume delineation, and geotechnical investigations. Similar to TEM, ERT is a non-invasive technique that relies on the measurement of electrical properties of the subsurface to infer geological and hydrogeological characteristics.

ERT measurements involve the injection of electrical currents into the ground through a series of electrodes placed on the surface. These electrodes typically form a linear array, with two electrodes acting as current sources and two others as potential electrodes for measuring voltage differences at the surface. The injected electrical currents propagate through the subsurface and form an electrical field depending on the current flow paths. As such, the measured potential differences at the surface reflect the underlying electrical resistivity distributions in the subsurface.

A more common technology called vertical electrical soundings (VES) is based on the same physical principles and core instrumentation as ERT. The VES approach can be considered a simplified version of ERT technologies, which are based on an approach called a Schlumberger sounding. This 4-electrode style measurement results in production of a one-dimensional estimate of the electrical resistivity depth profile at each site. VES is a robust technology, and it is widely implemented across Ethiopia. A limitation of VES is its data acquisition speed. Common production rates allow one to two sites to be imaged per day, resulting in sparse spatial data coverage. The reason for the slow acquisition is that the collection of sounding data requires the injection of currents using many current electrode separations. Current electrodes are placed some distance apart, current injected and the voltage measured between two points. These current electrodes are then moved to a larger separation and the process is repeated many times. A rule of thumb is that the desired depth of investigation is approximately one fourth of the maximum electrode separation. That is, imaging to ~250 meters depth requires current electrodes separated by 1000 meters. As such, this labor intensive process is quite time-consuming.

ERT differs from VES in that many electrodes are placed in the ground, and can be measured simultaneously, up to 64 or 128 channels in certain systems. The advantage is that automated switchboxes can rapidly vary which electrodes function as current injection electrodes and as voltage measuring electrodes. This allows for many potentials to be measured for each current injection, thus reducing the measurement time. In practice, the field operator installs a linear array of electrodes at evenly spaced intervals, and a protocol defined beforehand then collects hundreds to thousands of measurements based on different electrode combinations. The result is a dense data set containing information about the variation of subsurface resistivity both laterally and with depth. This data is then used to produce 2D images of subsurface resistivity, or even 3D images in certain cases. ERT has the benefit that it images 2D variations with high-resolution, enabling detailed imaging of complex hydrogeological settings. A limitation of ERT is its depth penetration and data acquisition speeds. If deep penetration is required, long arrays of electrodes are required – again following the approximate rule where the depth penetration is one fourth of the maximum electrode separation. Typical data production rates are several kilometers of linear imaging per day.

An advantage of ERT systems is that they are robust to human-generated noise sources, such as that generated by powerlines or other electrical infrastructure. As such, the measurements can be performed in urban/semi-urban conditions, as well as in rural settings. The systems are also flexible in the sizes of the electrode separations, allowing easy tailoring of the image resolution to the scale of the problem at hand. This is particularly relevant for high-resolution imaging of small-scale systems, such as sand dams or other small-scale features.

Data processing and inversion require supplementary software, where many commercial or free-ware solutions are available. Data volumes are typically on the order of 10s of megabytes for a kilometer of data, and the storage of resulting geophysical images can readily be saved in various image formats or as moderate sized text files.

Annex 5 : Risk Analysis and Risk Response

The contextual, programmatic, and institutional risks in RGRMP are elaborated in the below tables, together with the planned risk response and corresponding residual risks.

Table 6: Contextual risks.

Contextual Risks					
Risk Factor	**Likelihood**	**Impact**	**Risk Response**	**Residual Risk**	**Background to assessment**
Conflict security issues	Unlikely	Major	Activities in affected areas will cease	Minimal risk remains due to robust security protocols and responsive action plans.	Recent security issues in certain Ethiopian regions
Field crew security	Unlikely	Major	Field work will proceed only after security assessments informed by local partners	Low residual risk as security assessments are continuously updated to reflect current conditions.	Ethiopian partners are actively involved in field work across the country and conduct these assessments routinely
Ethiopia partners buy-in	Unlikely	Major	Active network building and reliance on strong existing connections to strengthen buy-in	Very low risk as proactive engagement with Ethiopian partners is maintained.	Key Ethiopian stakeholders have record of enthusiastic participation in similar projects
Termination of interest or disinterest from project partners	Unlikely	Major	Active engagement throughout survey planning, execution, and interpretation with partners to foster buy-in	Low residual risk; ongoing communication ensures alignment with partner expectations.	Past collaborations with water sector partners
General reluctance to adopt new geophysical technologies from private sector participants	Likely	Major	Education of partners to elevate geophysical standards required during tendering process to motivate adoption of modern technologies	Moderate residual risk; some private sector entities may be slower to adopt new technologies despite educational efforts.	Feedback from private sector collaborators

Table 7: Programmatic risks.

Programmatic Risks					
Risk Factor	**Likelihood**	**Impact**	**Risk Response**	**Residual Risk**	**Background to assessment**
Geophysical equipment failure	Likely	Minor	Equipment repair can occur on weeks timescale, and redundant equipment exists within RGRMP instrument pool	Minor delays of field activities may occur during equipment repair	Geophysics equipment operates under difficult field conditions and regular maintenance is expected

Recruiting course participants	Unlikely	Moderate	Active/early recruitment using broad Ethiopian network	Low residual risk due to the effectiveness of the recruitment network.	Recruitment for past geophysical trainings has not been an issue
Recruiting project staff	Likely	Moderate	Broad advertisement of positions	Moderate residual risk, as hiring timelines may vary despite wide advertising.	Previous hiring searches for geophysicists
Departure of project staff during project	Likely	Moderate	Broad advertisement of positions	Delay of project activities during rehiring/retraining of new staff	Hiring scientific staff for 5 year durations is difficult
Availability of supporting data insufficient for accurate geophysical interpretations	Likely	Major	Deploy staff to collect additional geophysical data near available geological information to inform local geophysics-to-geology transforms	Uncertainty in geophysical interpretations risk biased hydrogeological characterizations	Past geophysical experiences in data sparse regions

Table 8: Institutional risks.

Institutional risks					
Risk Factor	**Likelihood**	**Impact**	**Risk Response**	**Residual Risk**	**Background to assessment**
Insufficient hydrogeological knowledge within partner organizations	Unlikely	Major	Educate project partners in the utility of geophysical data, and include partners in the planning, execution, and interpretation stages	Low residual risk, as partners gain knowledge through training and involvement in planning and interpretation efforts.	Past collaboration with water sector partners
Project could duplicate parallel activities from other geophysical actors	Unlikely	Minor	Survey similar water sector capacity building programs and water-based donor programs	Minimal residual risk, due to active monitoring of similar programs and efforts to avoid overlap.	Analysis of water sector training activities
Parter organizations could develop negative evaluations of modern geophysical technologies	Unlikely	Major	Educate project partners on capabilities and limitations of geophysical data, and include them in each stage of the survey	Low residual risk, mitigated by education and inclusion, but past misconceptions may still influence partner views.	Overselling by past geophysicists may have tainted partners views on geophysics

Limited instrument pool restricts scaling of project outputs or independence of trained professionals	Likely	Minor	Educate partners to elevate geophysical requirements in their future tenders to motivate the private sector to upgrade practices	Limited capacity for modern geophysical technologies in private sector	Feedback from private sector collaborators
Reluctance or inability to implement developed geophysical guidelines/SOPs within project timeline	Likely	Minor	Collaborative formulation of guidelines/SOPs draft with MoWE to serve as inspiration for future standards	Moderate residual risk, Geophysical guidelines/SOPs are not implemented and standards forcing elevation of geophysical practices are not implemented	Instituting regulations and a related regulatory framework is a slow process
Reluctance or inability to implement developed geophysical database within project timeline	Likely	Minor	Collaborative formulation of geophysical database draft with MoWE to serve as inspiration for future implementation	Moderate residual risk; implementation may delay due to high costs and complexity of national database integration.	Instituting a national database is a slow and expensive process

Annex 6 : Summary of Appraisal Mission Recommendations

The table below (Table 7) lists recommendations raised by the appraisal mission report

Table 9: Summary of appraisal report recommendations.

	Recommendation	Response
1	It is recommended that the Project Document is rearranged according to Aid Management Guidelines as to chapter 2, 3 and 4, as part a finalisation of the Project Document.	Implemented.
2	It is recommended that a minimum of context analysis and partner assessment is included in the revised Project Document and that annex 1 (context analysis) and annex 2 (partner assessment) are prepared as part of the inception phase and included in the inception report.	Implemented.
3	It is recommended to integrate a section specifically focusing on gender imbalance and actions taken by the Hawasa and Haramaya universities to secure as many female students as possible as well as securing their success in the studies.	Implemented.
4	It is recommended that the justification of the project is given a focused presentation in separate chapter or subchapter and that it includes the project's relevance as a mitigation to some of the challenges presented in the National Integrated Water Resource Management Plan.	Implemented.
5	It is recommended that the result framework is updated with the following three outputs indicators: upload of geophysical data to a MoWE database, survey of active geophysical consultants and delivery of open-source TEM modelling codes.	Implemented.
6	It is recommended to include an inception phase at start of the project with a length of 3 months. The inception phase will allow for the finalisation of collaboration agreements between Århus university and the Ethiopian partners, agreeing on job descriptions/requirements, as well as procedures and timelines for reporting on financial reports/audits. The inception phase will be closed with an inception report to be approved by the SC.	Implemented.
7	It is recommended that Risk Tables are adjusted on three aspects; separate between Contextual and Programmatic Risks, revise all risks in the column "Residual Risk" and incorporate an Institutional risk linked to the existence/absence of a Water Resource database within MoWE within a foreseeable future securing that geophysical data can be incorporated.	Implemented.
8	It is recommended that the activities include a comparative cost/benefit analysis that will be used in objectively documenting the relevance of expanding the use of advanced geophysics to the whole country.	Implemented.

Annex 7 : Water Resources in Ethiopia – brief overview

Ethiopia is endowed with a substantial amount of surface and groundwater water resources, but with a high hydrological variability from the more wet areas in the west to the drier areas in the east. The country has twelve major catchments, which form four major drainage systems namely the Nile Basin, Rift Valley Basin, Juba-Shabelle Basin and North-East Coast Basin. All the basins are transboundary in nature. The 12 major river basins represent about 122 billion m^3 of surface water flow and approximately 40 billion m^3 of groundwater (Water Development Commission, 2019). The Nile River, the major river, covers 3,254,853 km^2. The Blue Nile, originating from Lake Tana in Ethiopia, is 1,500 km long and contributes about 80% of the Nile's flow. Lake Tana, the largest freshwater lake, spans 3,600 km^2. The Grand Ethiopian Renaissance Dam (GERD), Africa's largest, is 30 km from Sudan and will produce 6.45 gigawatts, with a reservoir covering 1,874 km^2 and an upstream catchment of 172,250 km^2. Major aquifers include the Ogaden-Juba Basin and Sudd Basin (Umm Ruwaba Aquifer).

Most of the rivers in Ethiopia are highly seasonal, with about 70 percent of the total runoff occurring during the June-September period. Mean annual rainfall distribution is approximately 2,000 mm over the south-western highlands and less than 300 mm over the south-eastern and north-eastern lowlands. All river basins except the Nile Basin face water shortages. Water resources are highest in western Ethiopia (i.e. the Abay Basin) and water scarcity is highest in the east (especially the Awash basin), due to low supply and high demand. Sedimentation has reduced storage capacity in many reservoirs in the Awash basin. Most basins throughout the east are very dry and many locations have only ephemeral surface water.

Groundwater resources in Ethiopia are often poorly understood, with insufficient data on their quantity, quality, and utilization. This knowledge gap hinders effective management and sustainable use of groundwater. Despite this, groundwater is crucial in Ethiopia, providing essential water supply to millions, especially in rural areas. It is vital for poor and marginalized groups who often lack access to surface water sources, ensuring to ensure that their basic needs for drinking, sanitation, and agriculture are met, thereby supporting their livelihoods and well-being.

Ethiopia's aquifers are classified into volcanic, basement, sedimentary rock, and alluvial types. Volcanic aquifers, common in central and western highlands, are thick (500–1,000 meters) and productive, with groundwater depths of 50 to 250 meters. Sedimentary rock aquifers, mainly in eastern lowlands, have low to moderate productivity and recharge rates (30 mm/year) and are deep (200-400 meters). Alluvial and basement aquifers, less common, are found in southern, western, and far northern regions. Alluvial aquifers have the highest groundwater availability, while basement aquifers have the lowest.

Groundwater access varies significantly across Ethiopia. Highland areas with volcanic and alluvial aquifers have higher yields and are crucial drinking water sources. Dire Dawa and Hawassa rely heavily on groundwater, but water tables are decreasing, particularly in Dire Dawa, where borehole depths reached 500 meters eight years ago. In the arid Wabi-Shebelle and Ogaden Basins, groundwater dependency is high despite accessibility challenges. Groundwater is also key to supports livestock and agriculture in these areas.

Groundwater quality is a major concern, particularly due to natural contamination from fluoride and high salinity. Fluoride contamination is prevalent in the Great Rift Valley (Afar-Denakil, Awash, Omo-Gibe, and Rift Valley Basins), with levels often exceeding World Health Organization (WHO) guidelines, posing serious health risks. High salinity affects volcanic aquifers in the Great Rift Valley and sedimentary aquifers in the south, southeast, and northeast.

Microbial contamination is also significant. A national survey found nearly 30% of wells in southern, central, and northern Ethiopia contaminated with E. Coli. In Addis Ababa, only 14% of the population is connected to a sewer system, leading to widespread use of on-site disposal systems that can pollute shallow groundwater. Shallow wells in Addis Ababa are more than twice as likely to be contaminated with E. Coli compared to deep wells.

The lack of accurate data and monitoring systems leads increases risks of unsustainable groundwater use and overexploitation. Insufficient information about groundwater potential and recharge areas hampers effective planning and management. Additionally, watershed and wetland degradation negatively impacts groundwater recharge. Improving data collection, monitoring, and integrated planning is crucial for sustainable groundwater management in Ethiopia.

The status of water supply coverage in the country is poor, although it has been improving over the past two decades. The UNICEF and WHO Joint Monitoring Program[4] (JMP, 2020) places Ethiopia at the second lowest position among 96 countries. Ethiopia has a level of safely managed water supply with of 12.6% (39% in urban and 5.2% in rural areas) of all people have having access to a 'safely managed water supply'. 49.6% of the population (40% in rural areas and 84.4% in urban areas) has 'at least basic drinking water supply'. In 2020, an estimated 57 million people did not have basic drinking water access. 26 million of these are still using unimproved water sources or surface water, which are assumed to be contaminated and dangerous to the health and well-being of the users.

Annex 8 : Collaboration with other IWRM initiatives

RGRMP aim to build a national resource base which can be applied to groundwater surveys and water resource management initiatives countrywide. .The project aim to promote collaboration between project partners, and aims to offer expanded geophysical surveys and data support for water resource management in other initiatives. This annex lists some examples of initiatives where such collaboration could be relevant.

Two examples include the Czech Republic Embassy's and the Agence Francaise de Developpement's (AFD) managed aquifer recharge programs that aim to harvest water to augment water access in drier periods of the year.

The Czech program and RGRMP both in work Dire Dawa, indicating that a strong opportunity exists to help inform local groundwater systems surrounding potential Czech MAR sites using geophysics. Similarly, the AFD-funded program titled "Climate change impact on groundwater in Ethiopia – Managed Aquifer Recharge (MAR) Assessment" aims to understand climate change impacts on groundwater resources and develop climate adaptation solutions. Their project requires comprehensive hydrogeological studies to assess suitability of MAR solutions, and is built upon existing hydrogeological, meteorological, and geological data. One challenge is reliance on hydrogeological and geological maps at coarse resolution – often challenging interpretation at local scales. A strong opportunity exists to augment these MAR assessments with supporting geophysical campaigns where recharge areas demonstrating connection to underlying aquifer systems can be identified.

AU has established robust partnerships with collaborators involved in the initial phases of a US-Aid funded program titled Urban WASH that focuses on ten Ethiopian cities[5], including Dire Dawa and Hawassa, with significant objectives in water infrastructure development. While this program currently lacks geophysical activities in its plans, there is a keen interest in partnering with the RGRMP to enhance their understanding of local water systems before committing to infrastructure investments. RGRMP will leverage the on-going WASH initiatives in the US-Aid project, where background hydrogeological assessments have been compiled in their focus areas, where this project will negotiate access to these key data in exchange for the augmentation of their projects with geophysical surveys. Collaborating with this program not only allows RGRMP to forge connections in additional Ethiopian cities, but also plays a pivotal role in conducting successful pilot studies where the effectiveness of RGRMP's geophysical contributions can be evaluated based on the performance of completed water systems. Contacts created and hydrogeological data attained through partnership with the US-Aid program will also open opportunities to expand to SSC Water networks to additional Ethiopian cities.

World Bank's Horn of Africa – Groundwater for Resilience project also has a strong emphasis on groundwater assessments in Ethiopia, as well as strengthening the enabling environment and institutional capacity for groundwater investigations. RGRMP mirrors these objectives, and as such has strong potential to augment World Bank's groundwater mapping and capacity building efforts, where pilot studies in RGRMP can be conducted in regions of interest to the World Bank project, and key stakeholders in the World Bank project may be invited to participate in geophysical training programs in RGRMP.

A UNICEF program titled R-WASH is focused on augmenting water supplies to refugee camps in the Horn of Africa region, including a number of camps within Ethiopia. This program aims to develop managed aquifer recharge solutions at these sites, and may be supported by RGRMP geophysical pilots during their technical feasibility assessments to suitability of MAR in each context. These surveys can also help optimize MAR designs

[5] The ten cities involved in the Urban WASH program include Harar, Dire Dawa, Dessie, Kombulcha, Bahir Dar, Sheshemane, Hawassa, Mekelle, Adama, and Bishoftu.

and implementation. UNICEF is also involved in deep aquifer exploration in parts of Ethiopia, where borehole sparsity is a major challenge as deep (>300 m) boreholes are extremely expensive (>250,000 USD). Deep looking TEM measurements may help address these data sparsity issues. As such, UNICEF will be approached to cultivate collaborative projects, where geophysical surveys could aid in their WASH activities.

Additional projects focused on groundwater potential mapping, such as those organized by UNICEF and US-Aid in the Sidama and Somali regions, can also be supported by RGRMP pilot studies. These potential mapping activities are informed by geological, hydrogeological maps, socio-economic factors, and remote sensing products and are valuable in identifying regions with increased potential for water resources to guide future water access projects (e.g. drilling, MAR, ect.). Although these programs may include some geophysical activities, RGRMP may help greatly to scale data density and/or the surveyed areas. As such, these programs are also attractive for potential collaborators.

Annex 9: Progress Action Plan

Action/product	Deadlines	Responsible/involved units	Comment/status
Initial actions following the Minister's approval			
LEARNING facilitates that grant proposals are published on Danida Transparency after the Minister's approval	December	LEARNING	
Signing of agreement with Aarhus University	December	RDE Addis	
Register commitment in MFA's financial systems within the planned quarter	December	RDE Addis	
Disbursement of Danish funds to Aarhus University	December	RDE Addis	
Launch of project with government and project partners	February	RDE Addis	

Annex 10: References

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ANNEX 9: QUALITY ASSURANCE CHECKLIST

File number: 24/50649

Programme/Project name: Rapid Groundwater Resource Mapping for IWRM in Ethiopia

Programme/Project period: 2024-2029

Budget: 20.000.000 DKK

This Quality Assurance Checklist should be used by the responsible MFA unit to document the quality assurance process of appropriations, where development specialists from either ELK or other units are not involved in the process; i.e.

- (i) *internal appraisals* of appropriations up to DKK 10 Million where this checklist constitutes the appraisal.
- (ii) *external appraisals* of appropriations between DKK 10 – 43 million and (iii) appraisal in exceptional cases. The checklist aims to help the responsible MFA unit ensure that key questions regarding the quality of the programme/project are asked and that the answers to these questions are properly documented and communicated to the approving authority.

Presentation of quality assurance process:
The programme has been designed in close cooperation with the Danish Environmental Agency to ensure alignment and synergy with the water SSC in Ethiopia. The project has furthermore been appraised by an external consultant and the project was adjusted following the appraisal. Finally, the CFO team of the embassy has gone through the project document

☒ The design of the programme/project has been appraised/appraisal checklist filled out, by someone independent who has not been involved in the development of the programme/project.
Comments: Yes, the project was appraised by Nordic Consulting Group.

☒ The recommendations of the appraisal/comments in the appraisal checklist have been reflected upon in the final design of the programme/project.
Comments: Yes, the appraisal recommendations have been incorporated into the project design.

☒ The programme/project complies with Danida policies and Aid Management Guidelines, including the fundamental principles of Doing Development Differently.
Comments: Yes

☒ The programme/project addresses relevant challenges and provides adequate responses.
Comments: Yes, this is addressed in the project document.

☒ Issues related to HRBA, LNOB, Gender, Youth, Climate Change, Green Growth and Environment have been addressed sufficiently in relation to content of the project/programme.
Comments: Yes, this is addressed in the project document.

☒ Risks involved have been considered and risk management integrated in the programme/project document.
Comments: Yes this is explained in the project document.

In conclusion, the programme/project can be recommended for approval: yes / ~~no~~

Date and signature of Desk Officer:_28.11.24_ ____________________

Date and signature of Management: 28/11-24 ____________________