Programme and Abstract Book

4th SADC GROUNDWATER CONFERENCE
10th - 12th of November 2021
VIRTUAL CONFERENCE

THEME: Towards a Water Resilient SADC-Groundwater Systems Thinking.
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WELCOME NOTE:

Eng. James Sauramba
Executive Director: SADC-GMI
SADC Groundwater Conferences were debuted in 2018 and since then, this premier groundwater event in the SADC region has grown from strength to strength. The past three conferences have demonstrated great impetus in aiding the SADC region addressing water security issues and challenges as well as forge the way forward for a water secure and resilient SADC. The 4th SADC Groundwater conference is no exception to the norm.

Colleagues, Partners and Stakeholders, on behalf of the Organizing partners, I wish to welcome you all to the 4th SADC Groundwater Conference, hosted under the theme “Towards a Water Resilient SADC - Groundwater Systems Thinking”. This theme is of utmost importance if we aspire to have a SADC region that is resilient to the impacts of climate change through a holistic and innovative approach.

If there is one thing the Covid-19 pandemic taught us is to embrace technology that we have at our disposal and how we have adapted to allow it to serve us during times such as these. Consequently, the use of technology has enabled us to effectively connect and have meaningful discussions amidst a pandemic of such magnitude. We have a New Normal that we have gladly acclimatised to.

As the SADC region, and globe at large continue to navigate through the Covid-19 pandemic and the impacts of climate change, it becomes pivotal that, as the Groundwater Community of Practice, we continue to engage and find innovative solutions to water challenges confronted by the approximately 280 million people living in the SADC region. This conference provides us with another opportunity to pause and take stock of milestones and strides we have achieved and find solutions to exacerbating water challenges faced by our people. We all know that as the result of climate change, the dependency on groundwater is escalating, and that puts pressure on this finite resource.

As much as we will be meeting virtually, we still anticipate that this conference will provide a great networking opportunity for our stakeholders and partners. We also hope that it will allow stakeholders to share emerging issues and innovations currently utilized in the groundwater and surface water fraternity to combat the growing impacts of climate change.

This year’s conference brings to prominence groundwater Systems thinking as one of the key approaches in achieving a water resilient SADC. Discussions will revolve on how the systems thinking approach could innovatively contribute to a water-secure SADC region and how to mitigate the worsening impacts of Climate Change.

Through esteemed keynote speakers and presenters, we have assembled a diverse conference programme which will provide insights to the systems approach and ignite discussions that will accelerate the region towards a water – secure zone. Utilizing streamlined presentations and panel discussions, the conference will highlight how systems thinking could contribute to water security. This conference comes at the time when Africa is preparing for the Africa Water and Sanitation week and the Groundwater Summit to be held in 2022, and resolutions of this conference will play a critical role in contributing to the discourses of these events.
The 4th SADC Groundwater conference coincides with the start of our 2nd Phase of the Sustainable Groundwater Management in SADC Member States project, funded by the Cooperation in International Waters in Africa (CIWA). As we embark on a new project, we are looking forward to your continued support to fulfil our mandate of serving the region once again.

As a regional Centre of Excellence, we are cognisant of the importance of partnerships and strategic collaborations that help us to fulfil our mandate. We are therefore grateful for your presence and participation as it will promote the sharing of experiences and knowledge to elevate our responses to groundwater challenges.

We would like to thank all sponsors who continue to support us in making this event a reality. Finally, I thank you all for taking time to be part of this premier event and I wish you all fruitful deliberations.

A Warm Welcome!

Chers collègues, partenaires et parties prenantes

Je vous souhaite, au nom du comité organisateur, la bienvenue à la 4e conférence de la SADC sur les eaux souterraines sous le thème **Pour la sécurité de l’eau dans la région de la SADC — Réflexion systémique autour des eaux souterraines**. Ce thème d’une importance capitale témoigne de notre volonté de matérialiser la vision d’une SADC résiliente au dérèglement climatique à travers une approche globale et innovante.

L’expérience de la Covid-19 nous amène à comprendre que la technologie est un moyen d’adaptation utile en temps d’épidémie. En effet, la technologie nous a permis de rester connectés et d’entreprendre des discussions pertinentes. Nous nous sommes bien adaptés à la nouvelle norme que nous impose cette pandémie.

Alors que la SADC et le reste du monde s’imprègnent des effets de la Covid-19 et de l’évolution du climat, il devient impératif que les spécialistes des eaux souterraines poursuivent leurs efforts de collaboration pour trouver des solutions innovantes aux défis de l’eau auxquels 280 millions de personnes sont confrontées dans la région. Cette conférence est l’occasion renouvelée de prendre la mesure de nos réalisations à ce jour et de trouver des solutions à ces défis exerçant sur l’eau. Comme nous le savons, le changement climatique augmente notre dépendance aux eaux souterraines, ce qui accroît la pression sur ces ressources tarissables.

Malgré son mode virtuel, nous espérons que cet évènement soit l’occasion d’approfondir le réseautage entre les parties prenantes et nos partenaires. Nous souhaitons également que les parties prenantes saisissent l’occasion pour présenter les défis émergents et les innovations actuellement adoptées dans le monde des eaux souterraines et de surface en réponse au dérèglement climatique.


Grâce à d’éminents orateurs et présentateurs, nous avons élaboré un programme de conférence diversifié qui donnera un aperçu de l’approche systémique et suscitera des discussions qui permettront d’accélérer la sécurisation de l’eau dans la région.

Cette 4ᵉ conférence de la SADC sur les eaux souterraines coïncide avec le début de la 2ᵉ phase de notre projet de gestion durable des eaux souterraines dans les États membres de la SADC, financé par la Coopération internationale sur les eaux en Afrique (CIWA). Ce nouveau projet nous offre l’occasion de saluer votre soutien continu à l’exécution de notre mandat qui consiste à servir la région une fois de plus.

Nul besoin de rappeler à notre centre d’excellence l’importance des partenariats et des collaborations stratégiques pour remplir notre mandat. Ainsi, nous avons l’honneur de vous compter parmi nous pour partager des expériences et des connaissances afin de mieux répondre aux défis relatifs aux eaux souterraines.

Nous tenons à remercier tous les sponsors qui ont contribué à l’organisation de cet événement. Pour conclure, permettez-moi de vous remercier une nouvelle fois pour votre participation à cet événement de premier plan. Je vous souhaite un grand succès lors de vos délibérations.

*Accueil chaleureux!*
NOTA DE BOAS VINDAS
DIRECTOR EXECUTIVO DA SADC-GMI (JAMES SAURAMBA)

As Conferências da SADC sobre Águas Subterrâneas foram lançadas em 2018 e, desde então, este evento principal sobre águas subterrâneas na região da SADC tem crescido de força em força. As três últimas conferências demonstraram um grande ímpeto na ajuda à região da SADC na abordagem das questões e desafios da segurança da água, bem como no estabelecimento de um caminho para uma SADC segura e resiliente no que respeita a água. A 4ª conferência da SADC sobre Águas Subterrâneas não é exceção à regra.

Colegas, Parceiros e Partes Interessadas, em nome dos parceiros organizadores, desejo dar as boas-vindas a todos na 4ª Conferência da Água Subterrânea da SADC, organizada sob o tema “Rumo a uma Água Segura da SADC - Pensamento sobre Sistemas de Água Subterrânea. Este tema é da maior importância se aspirarmos a ter uma região da SADC que resista aos impactos das alterações climáticas através de uma abordagem holística e inovadora.

Se há uma coisa que a pandemia da Covid-19 nos ensinou é abraçar a tecnologia que temos à nossa disposição e como nos adaptamos para permitir que ela nos sirva em épocas como esta. Consequentemente, a utilização da tecnologia permitiu-nos estabelecer uma ligação eficaz e ter discussões significativas no meio de uma pandemia de tal magnitude. Temos um Novo Normal a que nos aclimatámos de bom grado.

À medida que a região da SADC e o mundo em geral continuam a navegar através da pandemia da Covid-19 e dos impactos das alterações climáticas, torna-se fundamental que, como Comunidade de Prática de Águas Subterrâneas, continuemos a envolver-nos e a encontrar soluções inovadoras para os desafios hídricos enfrentados por cerca de 280 milhões de pessoas que vivem na região da SADC. Esta conferência oferece-nos outra oportunidade para fazer uma pausa e um balanço dos marcos e passos que alcançámos e encontrar soluções para exacerbar os desafios da água enfrentados pelo nosso povo. Todos sabemos que, como resultado das alterações climáticas, a dependência das águas subterrâneas está a aumentar, o que exerce pressão sobre este recurso finito.

Por mais que nos encontremos virtualmente, continuamos a prever que esta conferência proporcionará uma grande oportunidade de networking para as nossas partes interessadas e parceiros. Esperamos também que permita às partes interessadas partilhar questões emergentes e inovações actualmente utilizadas na fraternidade das águas subterrâneas e superficiais para combater os impactos crescentes das alterações climáticas.

A conferência deste ano destaca o pensamento dos Sistemas de águas subterrâneas como uma das abordagens fundamentais para alcançar uma SADC resiliente à água. As discussões vão girar em torno de como a abordagem de pensamento dos sistemas poderia contribuir de forma inovadora para uma região da SADC de água-segura e como mitigar o agravamento dos impactos das Alterações Climáticas.
Através de oradores e apresentadores conceituados, reunimos um programa de conferências diversificado que fornecerá uma visão da abordagem dos sistemas e acenderá discussões que irão acelerar a região rumo a uma zona de água - segura. Utilizando apresentações simplificadas e painéis de discussão, a conferência destacará como o pensamento sobre sistemas poderá contribuir para a segurança hídrica. Esta conferência surge no momento em que a África se prepara para a Semana Africana da Água e do Saneamento e para a Cimeira das Águas Subterrâneas a realizar em 2022, e as resoluções desta conferência desempenharão um papel fundamental na contribuição para os discursos destes eventos.

A 4ª Conferência da SADC sobre Águas Subterrâneas coincide com o início da 2ª Fase do nosso projecto de Gestão Sustentável das Águas Subterrâneas nos Estados Membros da SADC, financiado pela Cooperação em Águas Internacionais em África (CIWA). Ao embarcarmos em um novo projecto, aguardamos com expectativa o vosso apoio contínuo para cumprir o nosso mandato de servir a região mais uma vez.

Como Centro de Excelência regional, estamos cientes da importância de parcerias e colaborações estratégicas que nos ajudam a cumprir o nosso mandato. Estamos, portanto, gratos pela vossa presença e participação, pois irá promover a partilha de experiências e conhecimentos para elevar as nossas respostas aos desafios das águas subterrâneas.

Gostaríamos de agradecer a todos os patrocinadores que continuam a apoiar-nos para tornar este evento uma realidade. Finalmente, agradeço a todos vós por tomarem tempo para participar neste evento principal e desejo a todos deliberações proveitosas.

Uma Calorosa Recepção!
Keynote Speakers’ Biographies

Professor Seifu Kebede Gurmesssa has a BSc in Geology obtained in 1994 and MSc in Hydrogeology obtained 1999 both from Addis Ababa University, and a PhD from the University of Avignon, France obtained 2005 in Isotope (tracer) hydrogeology. He was a research assistant and junior lecturer at the School of Earth Sciences, Addis Ababa University, Ethiopia between 1994-1999 and a Junior Professional Officer at the International Atomic Energy Agency from 2005 to 2006. He became Assistant Professor of Hydrogeology at Addis Ababa University in 200) and Associate Professor of Hydrogeology in 2013. He joined the School of Agricultural Earth and Environmental Sciences and Centre of Water Resources Research, University of KwaZulu Natal in September 2019.

His main interests are tracer hydrology and geochemistry for water resources management, surface water – groundwater interaction and water quality. His multifaceted research includes rural water supply, groundwater irrigation, and human health. He has authored more than 50 peer reviewed articles and a Springer Nature book on groundwater in Ethiopia. Prof. Gurmesssa is VP for the International Association of Hydrogeologists Sub Sahara Africa Chapter.

Prof. Tijani is a Nigerian born Hydrogeologist. At AMCOW, he is charged with driving and coordinating the groundwater agenda for sustainable utilization and management of groundwater resources in the African continent. Prof.Tijani is a two-term DAAD Scholar with a Professional Postgraduate Certificate in Hydrogeology and Engineering Geology from the University of Tuebingen, Germany and a PhD in Hydrogeology and Hydrochemistry from the University of Muenster, Germany.

He is a Professor of Hydrogeology and Environmental Geology at the Department of Geology, University of Ibadan, Nigeria, with 22 years of teaching and research experience in groundwater resources evaluation and quality assessment and over 70 scientific research papers and technical reports to his credit. Over the years, he participated in several international conferences and training workshops in different parts of the world including Germany, USA, Canada, and Japan. He is a member of many national and international professional associations like AGID, IAH, GSAF and IAHS and had received several awards, prizes, and fellowships.

Prof.Tijani served as the Editor-In-Chief of the Journal of Mining and Geology and Journal of Engineering Geology and Environment; professional publications of the Nigerian Mining and Geosciences Society (NMGS) and Nigerian Association for Engineering geology and the Environment (NAEGE) respectively. He is fluent in English and German language and his hobbies are reading, writing, traveling, and sightseeing.
ABSTRACTS:
Keynote Speakers
Socio-economic development imperative of AMCOW groundwater program: Spearheading a vision on groundwater resilience in Africa

Author: Moshood N. TIJANI
AMCOW Groundwater Desk Officer,
AMCOW Secretariat, Abuja - Nigeria

Abstract:

There is no doubt that freshwater and its sustainable development and management, presents one of the most challenging and critical factors in sustainable development in Africa. This is consequently to the fact that many African Member States are facing significant population growth, urbanization, and increasing climate change pressures, such as floods and droughts. Therefore, there are increasing dependence on groundwater use in for socio-economic development among Member States. These development imperatives warrant the need for sustainable development, utilization and management of groundwater resources in Africa in order to accelerate the overall socio-economic development in Africa and fulfilling commitments and development aspirations at national to continental level.

It is on the backdrop of this that the African Ministers' Council on Water’s (AMCOW) within the framework of its mandate and in line with its strategic Plan 2018 - 2030, and by extension Strategic Operational Plan (SOP) 2020 - 2024, AMCOW established in 2019 a Pan-African Groundwater Program’s (APAGroP). The principal aim of APAGroP is to support groundwater policy and practice through leveraging on science and appropriate data base to enhance informed decisions on sustainable development and management of groundwater resources for water security and resilience in Africa.

Therefore, the intent of this keynote presentation is to highlight the socio-economic development imperatives of AMCOW Pan-Africa Groundwater Programme (APAGroP), the need for data-driven decision on groundwater development and the roles of partnership with groundwater networks and institutions in unlocking the potentials of groundwater for socio-economic development in Africa.
Groundwater holds the promise to transform the socio-economic space in Africa. Groundwater resources are linked and determines the outcome of several SDGs. Groundwater serves as source of drinking and serve the WASH sector. Regardless of the potential and the urgent needs, consumptive use of groundwater for food production in Africa is limited. Knowledge, institutional and financial bottlenecks must be overcome to sustainability use groundwater resources for socio-economic transformation (poverty, food security, health, conflict, etc.). The fact that groundwater is hidden from our eyes and that the boundary of aquifers doesn’t always coincide with the surface water divide adds complexity to it management. Over the last decade, knowledge on groundwater resources at continental and region scales is growing, however substantial amount of other existing data and information repositories are not readily accessible to users in Africa. Considering the differences in hydrologic and institutional scales in managing groundwaters and surface waters, conjunctive management of the resources require institutional innovation- on promising arrangement may be the ‘problem-shed’ approach. New innovations for the management of rural water supply coming to light- one such example is the FUNDIFIX model which focuses exclusively on the maintenance of existing water infrastructure for communities by service providers financed by the users, government and investors.

The aim of this talk is to give highlights on the current state of knowledge on groundwater in Africa and discuss information and institutional gaps to be filled so as to convert the promise groundwater holds to a measurable socio-economic outcome.
Technical Committee of the Conference:

Dr. Kevin Pietersen: University of the Western Cape, South Africa
Professor. Piet Kenabatho: University of Botswana
Professor. Modreck Gomo: Institute for Groundwater Studies, University of the Free State, South Africa
Dr. Kirsty Upton: British Geological Survey, the United Kingdom
Mr. Brighton Munyai: SADC- GMI South Africa
Dr. Karen Villholth: International Water Management Institute (IWMI), South Africa
Dr. Kawawa Banda: University of Zambia
Eng. James Sauramba: SADC- GMI South Africa
Mr. Bertram Swartz: Ministry of Agriculture, Water, and Land Reform- Namibia

Conference Rapporteur: Dr. Kevin Pietersen
### Day 1: Wednesday 10 November 2021

**DAY 1 – Programme Manager –** Dr. D. Mndzebele.

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<td>- Dr. Patrice Kabeya - SADC Secretariat (Senior programme officer-</td>
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<td>- Prof. Seifu Kebede Gurmessa-IAH (Sub-Saharan Africa President).</td>
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<td>Abdalkarim Gharbia, Balázs Zákányi and Márton Tóth, Experimental and Numerical Study for the Adsorption Behavior of Cu (II) and Mn (II) in Quartz Sand</td>
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<tr>
<td>12:10 - 12:25</td>
<td>Shipra Tyagi and Kiranmay Sarma, Evaluation of groundwater chemistry with multiple land use spectral indices approach</td>
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<tr>
<td>12:55 – 13:15</td>
<td>QUESTION AND ANSWER SESSION</td>
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### SUB-THEME 2: Communities, Institutions, Capacity, and Local-level Governance.

**Special Session: International Union for Conservation of Nature (IUCN) - BRIDGE**

Promoting the participation in water governance and research

**Session Chair:** Ms Mwanamkuu Mwanyika  
**Session Rapporteur:** Mr Brighton Munyai

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<td>14:00 - 14:10</td>
<td>Welcome remarks, Overview and Objectives of the Special Session- IUCN: Mr Davison Saruchera</td>
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<td>14:10 - 14:25</td>
<td>Opening address to contextualise BRIDGE -IUCN</td>
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<td>14:40 - 14:55</td>
<td>Ifedotun Aina, Djiby Thiam and Ariel Dinar, Regulated and unregulated substitutes in water consumption: the case of residential water in South Africa</td>
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<td>14:55 - 15:10</td>
<td>Josephine Mwafuka, Felistas Vushoma, Nkosinathi Muyambo, Trevor Chikumbu, Francis Muromo and Thomas Matingo, Sustainable groundwater management: A coordinated approach for improved livelihood options</td>
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<tr>
<td>15:25 - 15:40</td>
<td>BRIDGE tools that can be used in further research-IUCN</td>
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### Day 3: Friday 12 November 2021

**DAY 3 – Programme Manager:** Ms Thobile Phungwayo

**SUB-THEME 3:** Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions.

**Session Chair:** Mr Fhedzisani Ramusiya  
**Session Rapporteur:** Dr Kirsty Upton

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<th>Time</th>
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<td>08:45 - 09:00</td>
<td>Gavin Kode, Localised groundwater supply systems to improve water resilience at critical service delivery facilities.</td>
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<td>09:00 - 09:15</td>
<td>Robin Petersen, Fhedzisani Ramusiya and Eddie Riddell. Re-establishing the groundwater reference monitoring network in South African national parks.</td>
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| 09:15 - 09:30 | Christinah Makoae, Tlhoriso Morienyane, Phaelo Leketa and Tsosane Lebina.  
**Expansion of national groundwater monitoring network of Lesotho** |
| 09:30 - 09:45 | Portia Mokoena, Fhedzisani Ramusiya, Malefetsane Pule and Lindelani Lalumbe.  
**Evaluation of monitoring network performance for groundwater resources.** |
| 09:45 - 10:00 | Ndubuisi Igwebuike, Innocent Muchingami, Nebo Jovanovic and Thokozani Kanyerere.  
**Using hydrogeophysics and derivative analysis for improved groundwater security, Western Cape, South Africa.** |
| 10:00 - 10:15 | Goodson Chitsa, Zvikomborero Hoko, Webster Gumindoga and Maideyi Meck.  
**Integrating Scientific methods and indigenous knowledge systems in groundwater exploration. A case of Mudzi District Zimbabwe.** |
| 10:15 - 10:30 | Hugh Bruce and Gys Burger.  
**Managed Aquifer Recharge and its Challenges for Windhoek** |
| 10:30 - 10:45 | Andreas Lindhe, Lars Rosén, Per-Olof Johansson, Kelly Gaboiphiwe, Alfred Petros and Jonatan Strömgren.  
**Evaluating large-scale MAR in Botswana based on water supply security, cost-effectiveness, and sustainability** |
| 10:45 - 11:00 | Chrispen Nyangombe.  
**Investigating sustainability of community-based management of solar piped water supply schemes in rural areas: A case of Mt Darwin District, Zimbabwe.** |
| 11:00 - 11:15 | Bertram Swartz.  
**Developing the hydrogeological map of Namibia.** |
| 11:15 - 11:30 |  
**QUESTION AND ANSWER SESSION** |
| 11:30 - 11:40 |  
**COMFORT BREAK** |
### Special Session:
Reflecting on Capacity Building and Research for Groundwater in SADC

**Session Chair:** Mr Silvanus K Uunona  
**Session Rapporteur:** Dr Christinah Fraser

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<td>Welcome remarks, Overview and objectives of the Special Session- Mr Brighton Munyai (SADC-GMI)</td>
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<td>11:50 - 12:10</td>
<td>Defining the Region's capacity and research interventions - Dr Kevin Pietersen (UWC)</td>
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| 12:10 - 13:00 | Panel Discussion Moderator : SANWATCE (Dr Nico Elema)  
**Panelists:**  
   - Jean-Marie Kileshye Onema (Executive Manager - WaterNet).  
   - Eelco Lukas (Institute for Groundwater Studies – University of the Free State).  
   - Kawawa Banda (UNZA/AgNet).  
   - Piet Kenabatho (UB).  
   - Seifu Kebede Gurmessa (IAH). |
| 13:00 - 13:05 | Eng. James Sauramba: Summary and Concluding Remarks |

**BREAK**
**Special Session: AMCO-W-Groundwater Programme: Maximizing Groundwater Potential for Development and Livelihoods**

**Session Chair:** Dr Kirsty Upton  
**Session Rapporteur:** Dr Muchaneta Munamati

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<td><em>Welcome, Overview and Objectives of the Special Session</em> - Dr Ramon Brentuehr (BGR).</td>
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<td>14:10 - 14:25</td>
<td><em>APAGroP (Background, Objectives and Milestones)</em> - Prof. Moshood Tijani</td>
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<td>14:25 - 14:40</td>
<td><em>Country Support Tool (CST)</em> - Ms Rennie Munyayi</td>
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**PANEL DISCUSSION- MODERATOR:** Dr Ramon Brentuehrer

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<td>14:40 - 14:45</td>
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| 14:45 - 15:45 | Panel Discussion                                                          | James Sauramba – SADC-GMI  
Bertram Swartz – Namibia  
Kevin Pietersen – UWC  
Steve Kumwenda- BASE-FLOW (Malawi)  
Musawenkhosi Mwelase- Kingdom of Eswatini  
Paul Orengoh (AMCOW)  
AfDB (tbc) |

**COMFORT BREAK**

**CLOSURE PROCEEDINGS**

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<td>16:00 - 16:10</td>
<td><em>Award of Price:</em> Best young professionals presentation (Mr Davison Saruchera- IUCN).</td>
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<tr>
<td>16:10 - 16:25</td>
<td>Chief conference rapporteur: Overview of the 4th SADC-GMI Conference.</td>
<td>Mr Muthi Nhlema/Mr Steve Kumwenda/NFG Member.</td>
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<tr>
<td>16:15 - 16:30</td>
<td>Vote of Thanks: SADC- Secretariat.</td>
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Sub-Theme 1: Groundwater an integral part of the hydrological system.
Impact of Climate Change on Groundwater Potential and Recharge of The Drought Prone Areas of Runde Catchment, Zimbabwe

Authors: Liberty S. Gona, Webster Gumindoga, Donald T. Rwasoka, Richard J. Stuart. Owen

Department of Civil Engineering, University of Zimbabwe, Box 167, Mt Pleasant, Zimbabwe
Upper Manyame Sub-Catchment Council, Box 1892, Harare, Zimbabwe
Department of Geology, University of Zimbabwe, Mt Pleasant, Zimbabwe

Correspondence: gonalibertys79@gmail.com wgumindoga@gmail.com drwasoka@gmail.com richardjsowen@gmail.com

Abstract

Groundwater provides critical freshwater supplies for most rural communities living in semi-arid and arid regions. In these regions, rainfall is erratic. Water resource is vulnerable to climatic changes. The above problems are also experienced in Runde catchment of Zimbabwe, largely a semi-arid catchment with significant surface water development and groundwater use by rural communities. Unfortunately, the catchment has inadequate information on its groundwater resources, development and management. The main objective of this study is to assess the impact of climate change on groundwater potential and recharge (GWPR) in the drought prone areas. Current groundwater potential and recharge were determined by GIS and remote sensing. The projected precipitation, temperature and ET were statistically downscaled using data from HadCM3 and CanESM2 Global Circulation Model from 1980 to 2080. Results show decline in precipitation and an increase in temperature. The present Groundwater Potential (GWP) was mapped by spatial weighted overlay analysis method with inputs: soil type, geology, land use, precipitation, topographic wetness index and elevation. The GWP mapping showed that 62.4% of Runde Catchment has very high to moderate and 37.6% low to very low. The estimated groundwater potential zones were validated with field determined borehole yields within the catchment. The validation data showed that 13.33% and 33.33% of the total boreholes were under very high (>7l/s) and high (4-7l/s) while 20% and 33.33% were accounted for the moderate (2-4l/s), low (1-2l/s) and very low (<1l/s) potential zone respectively. The GWP map shows decline in high potential zones by 17% since 1980 to 2020 due to climate change. To achieve sustainable groundwater management, this research articulates the insights to inform adaptation policies like mechanical conservation works enhancing recharge.

Keywords: GIS; Precipitation; Wetness index; Validation
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Sub-Surface Characteristics and Evaluation of Groundwater Potential Zones of Idi-Ayunre Southwest, Nigeria.

Authors: 1 Adetoyinbo, Adedeji Adegoke, 2 Bello, Adekunle Kazeem and 1 Fredrick Fiyebolu Magi

Department of Physics, University of Ibadan, Ibadan, Nigeria
Department of Physical Sciences, Bells University of Technology, Ota, Nigeria

Correspondence: Bello, Adekunle Kazeemakbellokazeem@yahoo.com ; akbellokazeem@gmail.com

Abstract

The dynamic techniques and the complex nature of earth sciences is a serious cause for worry for geoscientists. In this work vertical electrical sounding (VES) was integrated with geographic information system (GIS) to delineate subsurface characteristics and evaluate groundwater potential zones in Idi Ayunre, Ibadan, Oyo State. The survey was done using VES with twenty one points to estimate the groundwater prospective. The results of the analysis are presented in form of curves, tables, and maps. The analyses and interpretation of the vertical electrical sounding (VES) results were processed using WINRESIT and ARCGIS10.0. There is fracture zone at 7.8 m depth in VES 10 with resistivity of 21.2 Ωm which indicate the existence of groundwater at that point. When considering the whole VES point on the average, the analyses show that the groundwater prospective in this study area is low. The main aquifer units suited for groundwater exploration in the study area as indicated in the results are the vertical electrical soundings: VES 1 and VES 16 respectively.

Keywords: Groundwater Potential, Crystalline Basement, Fracture Zone, Weathered Layer
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

RAINFALL RECHARGE FROM SHALLOW AQUIFERS OF ONDJIVA AND SURROUNDINGS (CUNENE, ANGOLA)

Authors: Marco Carlos; Gabriel Luís Miguel

Natural Science Faculty. Agostinho Neto University.

Correspondence: marco.paulo.carlos@gmail.com, gabrielmiuel71@gmail.com

Abstract

The deficient hydrogeological knowledge of Ondjiva and its surroundings conditions the effective characterization of its aquifers and the elaboration of a strategic plan for induced groundwater recharge through surface water available during floods. With 300,000 inhabitants and located in the semi-arid south of Angola, Ondjiva and Surroundings (Angolan part of Cuvelai-Etosha) experienced in 1999/2000 one of the worst drought episodes in the last 37 hydrological years, with an average precipitation of 465 mm, compared to the wettest year - 2010/2011-, with an average value of 1182.24mm. The National Water Plan of Angola (2017), defines for the Cuvelai Unit a recharge value of 18.5mm based on precipitation, without referring to the series of balanced hydrological years. Given the semi-arid region, where precipitation is irregular, with intra-annual variations and typical pronounced deviations, we proposed to integrate innovative methodologies, combining hydrological data from 37 years (1983/1984-2019/2020) from the satellites "Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks" and "The Tropical Rainfall Measuring Mission", provided by the databases of the Hydrometeorological Center of the University of California and NASA; the geological field work, the inventory of 162 water points in an extension of 15,112.583 Km2, from which 66 corresponds to shallow groundwater catchments; "Daily Sequential Water Balance-BALSEQ" and "Thornthwaite", "Curve Number" and laboratory test results that made it possible to calculate permo-porosity parameters, based on the 15 Kalahari soil samples, to better quantify the rainfall recharge of the suspended and shallow aquifers of Ondjiva and Surroundings. This study will also facilitate the design of piezometer networks for the area, and the implementation of the "EFUNDJA - Flood Control" Project, a Geographic Information System, which integrates essentially climatic and geospatial data, that allows monitoring and early warning of flood events.

Keywords: Rainfall Recharge, Shallow Aquifers, Ondjiva and Surroundings, Droughts and Floods.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

An evaluation of tracer hydrology combined with integrated water resource management as tools to site and monitor groundwater recharge.

Authors: Tafadzwa Samantha Mutanga\textsuperscript{1}, Shepherd Nimrod Misi\textsuperscript{2} and Farai Mapanda\textsuperscript{3}

\textsuperscript{2} Department of Construction and Civil Engineering, University of Zimbabwe, Zimbabwe
\textsuperscript{3} Department of Soil Science and Environment, University of Zimbabwe, Zimbabwe

Correspondence: fadziemutanga@gmail.com

Abstract

With the current serious shortages of drinking water in Harare, most residential areas are now relying on groundwater sources. The reoccurrences of waterborne diseases and increase in the rate of illnesses associated with drinking contaminated water has raised serious concerns. It is thus critical to monitor these pollutants regularly. It is possible to apply tracer hydrology technology to track nitrate and sulfate contamination to groundwater sources. Studies have shown that chemical tracers and isotopic tracers can be used to monitor sulfate sources. The current study seeks to evaluate the applicability of implementing tracer hydrology combined with integrated groundwater management sources in selected sites in Harare, Zimbabwe. Each site will be monitored by conducting water quality tests of the groundwater sources and testing the water from the groundwater for biological and chemical parameters. It is expected that the results will show that most groundwater sources at each sampled site biological and chemical water quality parameters have exceeded the recommended water potable quality standards. It can be concluded that tracer hydrology technology combined with integrated groundwater management approaches can be used as tools to site and monitor groundwater recharge.

Keywords: Contamination, Environmental tracers, Tracer hydrology, Water pollution, Groundwater sources.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Assessment of the transboundary Tuli Karoo groundwater resources in Basin.

Authors: P. Tinonetsana\textsuperscript{a}, W. Gumindoga\textsuperscript{a}, R. Owen\textsuperscript{b} and D.T. Rwasoka\textsuperscript{c}

\textsuperscript{a} Department of Civil Engineering, University of Zimbabwe, Box MP 167 Mt Pleasant, Harare, Zimbabwe

\textsuperscript{b} Department of Geology, University of Zimbabwe, Box MP 167 Mt Pleasant, Harare, Zimbabwe

\textsuperscript{c} Upper Manyame Subcatchment Council, Box 1892, Harare, Zimbabwe

Correspondance: primtino@gmail.com

Abstract

Quantitative estimates of amount and quality of groundwater resources are required in the transboundary Tuli Karoo Basin as groundwater is the biggest and most widely distributed store of liquid fresh water available for human use. Such quantitative data is required by the Basin member states, that is, Zimbabwe, Botswana and South Africa to better manage and promote sustainable conjunctive use of the resource. Unfortunately, such important data and information is lacking. Therefore the aim of this study was to map groundwater potential zones and model groundwater recharge as well as groundwater flow in the Tuli Karoo basin. Geographic Information Systems (GIS) and Remote Sensing were used to delineate groundwater potential zones. Nine thematic maps, which are, lineament density, slope, drainage density, topographic wetness index, landuse/landcover, geology, soils and precipitation, were created and weighted using Saaty’s Analytical Hierarchy Process (AHP). Groundwater recharge and groundwater flow were estimated using Soil Water Balance model (SWB) and British Geological Survey (BGS) Groundwater tool respectively in a GIS environment. Results for groundwater potential mapping showed that about 50.7 % of the basin is covered by areas of high groundwater potential, followed by areas of moderate groundwater potential (47.8 %) with areas of very high groundwater potential covering about 1.4 % of the study area. Estimated annual groundwater recharge for the Tuli Karoo Basin ranges from 6.95 mm to 19.93 mm per year. The model for Groundwater flow showed that flow occurs from regions of higher hydraulic head to regions of lower hydraulic head until a steady state is reached. GIS and Remote Sensing as well as modeling tools are recommended for assessment and quantification of groundwater resource since they have the ability to provide spatial and temporal variation of groundwater recharge, potential as well as flow.

Key words: Groundwater, recharge, groundwater potential, Tuli Karoo Basin.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

BASIN CHARACTERISTICS AND BASEFLOW ESTIMATION: CASE OF ODZANI RIVER CATCHMENT

Authors: Eneas Nhidza\textsuperscript{1, 3}, Richard Owen\textsuperscript{2}, Hodson Makurira\textsuperscript{3}, Michael James Tumbare\textsuperscript{3}

\textsuperscript{1}Zimbabwe National Water Authority, \textsuperscript{2}Africa Groundwater Network, \textsuperscript{3}University of Zimbabwe

Correspondence: nhidzaeneas@gmail.com

Abstract

The basin characteristics were characterized using Geographical Information System tools and hydrological data analysis. Baseflow indices on both monthly and annual time steps were determined using the smoothed minima technique. Pearson Correlation Coefficients between basin characteristics and baseflow indices were determined. Correlations between lineaments density, drainage density, permeability, elevation, elevation difference (basin slope proxy), average percentage exotic forestry area, basin area and annual baseflow indices were 0.56, -0.85, 0.84, -0.24, 0.28, 0.16, -0.19, 0.17 respectively. Significant positive correlations of lineaments density and permeability imply significant subsurface structures that promote infiltration, recharge and groundwater flow transmission. Drainage density increases drainage surface area that possibly compromises infiltration and recharge. Basin slope degree classes of 0-5, 5-10, 10-15, 15-20 and 20-25 derived using Geographical Information System tools had correlations with baseflow indices of -0.10, -0.09, 0, 0.05 and 0.16 respectively implying that steeper slopes enhance groundwater discharge to river channels. Correlation of monthly precipitation with monthly baseflow index was -0.61, whereas that of annual precipitation with annual baseflow index was 0.21. The negative correlation of -0.61 is attributed to the possible fact that baseflow contribution of precipitation received in a particular month is significantly experienced in the following months. Correlations of lithologies of granites, gneiss, andesitic/basaltic and dolerite dykes with annual baseflow indices were 0, 0.06, 0.59 and -0.34 respectively. Granites and gneiss have low porosity and permeability hence insignificant correlations, and dolerite dykes possibly block groundwater flow to river channels. Baseflow dynamics needs continuous monitoring to ensure sustainable water supply for water users and the environment in the catchment and downstream.

Keywords: Baseflow, integrated impact, correlation, catchment, basin characteristics, water supply
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Estimation Borehole sustainable yield in a typical confined porous aquifer

Author: M Gomo

Institute for Groundwater Studies, Faculty of Natural and Agricultural Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, South Africa.

Correspondence: modgomo@yahoo.co.uk

Abstract

Estimation of borehole sustainable yield is important in order to operate a borehole in a manner which can maintain the aquifer productivity. Other terms which are used interchangeably with borehole sustainable yield are safe and reliable yield. For the purposes of this study and proposed application, borehole sustainable yield is defined as the constant discharge rate at which a borehole can be pumped during its operating life with without causing aquifer dewatering. In a typical porous confined aquifer, dewatering occurs when water level drop below the top of the aquifer. This dewatering due to pumping can empty the aquifer causing the borehole to dry. Even in cases where the dewatering does not necessarily cause immediate drying of aquifers, the phenomenon can result in aquifer deformation which can negatively affect the future productivity. It is therefore important to ensure that borehole operational pumping rates that does not result in aquifer dewatering are used for borehole operation purposes. In principle, this can be achieved when borehole operational yield does not cause the water level to drop below the top of the confined aquifer. This principle has been used in the Flow Characteristics (FC) method for estimating borehole sustainable yield in fractured-rock aquifers. The applicability of this approach in porous and confined aquifers is investigated in this study. The first component of the paper present the principle basis for applying the FC method approach in porous confined aquifer. Thereafter MODFLOW numerical modelling is used to illustrate how this approach can be applied.

Keywords: Aquifer pumping test; Borehole sustainable yield; Confined porous aquifer; Flow Characteristic (FC) method and MODFLOW
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Characterisation of hydro-geochemical processes influencing groundwater quality in rural areas: A case study of Soutpansberg region, Limpopo Province, South Africa

Authors: ¹Lindelani Lalumbe*, ²Thokozani Kanyerere

¹Department of Water and Sanitation, Private Bag X313, Pretoria 0001, South Africa. ²Department of Earth Sciences, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa

Correspondence: lindelanilalumbe@ymail.com

Abstract

Groundwater is often the main or only source of fresh water supply in arid to semi-arid rural areas owing to decreasing rainfall patterns, reduced availability of surface water and socio-economic activities. It is important to understand the hydro-geochemical processes influencing groundwater quality for improved management and sustainability of the resources. In order to understand the hydro-geochemical process influencing hydro-geochemistry of the Soutpansberg region, this study assessed mean groundwater quality data from 12 boreholes and 2 geothermal springs collected between 1995 and 2017. This study indicated that majority of the samples were classified as fresh groundwater dominated by Ca-HCO₃ and mixed Ca-Mg-Cl type. Gibbs diagram, Pearson correlation, bivariate plots and Saturation Index suggested that rock dominance processes such as weathering of silicates, dissolution of carbonates and halite minerals and ion exchange processes are the main hydro-geochemical processes influencing groundwater quality in the Soutpansberg region. High concentration of F⁻ in the geothermal spring was attributed to dissolution of Fluorite mineral. Point source anthropogenic inputs from fertilisers were attributed to the high concentration of NO₃⁻ in groundwater. The discussion in this study suggested that there is a gap between monitoring data, research outputs and groundwater resource protection policies. Research outputs on groundwater quality are not being used to improve or support groundwater quality management and protection policies or strategies. This study recommended that research outputs should be used to influence and support policy change in arid to semi-arid rural environment.

Keywords: Hydro-geochemical processes, Groundwater protection policy, Remediation
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Hydrochemical assessment and GIS approach of groundwater quality of the Grootfontein aquifer, North West province, South Africa

Authors: Ely Leburu¹*, L.G. Palamuleni¹

¹ Faculty of Natural and Agricultural Sciences, North-West University (Mafikeng campus), P/Bag 2046, Mmabatho 2735, South Africa

Correspondence: EE Leburu: leburueliazare@gmail.com.

Abstract

The main objective of the study was to assess the hydro-chemistry of groundwater quality of the Grootfontein aquifer in North West province, South Africa. Seventeen groundwater samples were collected from boreholes within the aquifer during September 2020. The groundwater samples collected were tested on site for pH, TDS, EC and temperature while other ionic concentrations for major cations (Ca²⁺, Mg²⁺, Na⁺, K⁺) and major anions (SO₄²⁻, Cl⁻, NO₃⁻, HCO₃⁻) as well as TH were analysed in the laboratory. The comparison was made between WHO (2011) and SAWQG (2004) drinking water standard and these analytical results. The physical concentration of major ions around the aquifer showed TDS and calcium higher than the permissible limit beyond 50% of the boreholes. The chemical concentrations of major ions within the study followed the order Ca²⁺ > Mg²⁺ > Na⁺ > K⁺ for cations and SO₄²⁻ > Cl⁻ > NO₃⁻ > HCO₃⁻ for anions. For spatial variation of hydrochemical parameters of the study, the parameter distribution maps were prepared by GIS applying the Ordinary Kriging using semi-Variogram models to assess the best fit model for each parameter. To understand distribution of major ions in the study area, the Piper trilinear diagram, Gibbs diagram and the statistical t-test were employed. The Piper diagram pointed out that the water within the aquifer is dominated by Ca-Cl type. The Gibbs diagrams revealed that the rock-water interaction is a dominant mechanism, which controls water chemistry of the area and the student t-test indicated that the water within the aquifer reveals no statistical significance to contamination. In general, the lithology of the study area and anthropogenic activities such as irrigation agriculture are among many other factors that govern groundwater chemistry of study area.

Keywords: Hydro-chemistry, Grootfontein aquifer, Piper diagram, Gibbs diagram, t-test
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Approaches and considerations for evaluating and managing the impacts of groundwater abstractions on GDEs. A review of literature.

Authors: ¹Brighton Munyai & ²Modreck Gomo:

¹SADC-GMI, Institute for Groundwater Studies, Faculty of Natural and Agricultural Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, South Africa.

²Institute for Groundwater Studies, Faculty of Natural and Agricultural Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, South Africa

Correspondence: brighton@sadc-gmi.org.

Abstract

GDEs are of particular interest from a socio-economic perspective by providing ecosystem goods and services, e.g. production of fishes and service, e.g. through flood controls and grazing fodder during dry periods and prolonged periods of droughts. In addition, they also support biodiversity, providing baseflow to rivers, water purification, pollinator habitat, water supply and recreational opportunities. Despite these enormous benefits GDEs are under threat globally due to increasing human pressures on groundwater and climate change. Transboundary Aquifers are increasingly being relied upon for water supply, especially in Sub-Saharan Africa; however, the impact of the resultant abstraction on GDEs is not fully understood. Understanding this relationship calls for combining methodologies of assessing the state of GDEs and the groundwater quantity spatial and temporal variations.

Studies focusing on the impacts of groundwater use on GDEs and the recommended management approaches have been on the increase in, e.g. Australia, Europe, and North America. This review of literature focuses on tools and approaches to inform the management of groundwater to maintain the integrity of GDEs. It also evaluates the applicability of the approaches considering the paucity of data in the region. The literature review observes that the protection of GDEs is not straightforward due to the existing gaps in knowledge of the characteristics and dynamics of the interaction between groundwater and ecology and the diversity of GDEs. The discourse on GDEs within Transboundary Aquifers is also lacking, in particular for the SADC region.

We discuss the conceptual framework for GDE management, which is centred around managing groundwater levels at limits that provide sufficient flows and access to groundwater in the GDE. Approaches to implementing the conceptual framework from a groundwater management perspective include the volumetric approach, the water level trigger approach, or the buffer zone approach and the possible role of numerical models.

Keywords: GDEs, water levels limits, conceptual framework, numerical models, transboundary aquifer.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Evaluation of the performance of point dilution tracer test to estimate groundwater discharge.

Authors: ¹T Ngobe and ²M Gomo

Institute for Groundwater Studies, Faculty of Natural and Agricultural Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, South Africa.

Correspondence: mthee.ngobe@gmail.com

Abstract

The point dilution tracer test method indirectly estimates the groundwater discharge (Q) from the Darcy's flux (q). Despite the wide application of the method, the accuracy of the use of the point dilution tracer test to estimate groundwater discharge has not been evaluated under a laboratory-controlled environment. This study is therefore aimed to fill this research gap by using a laboratory controlled experiment to evaluate the accuracy of the point dilution tracer test to estimate groundwater discharge. The experiment was repeated four times in the laboratory, and the results of the direct and indirect discharge were evaluated. Initial findings suggest that the indirect discharge estimated from the point dilution tracer test is consistently smaller by a magnitude of 10 than the direct discharge measured during the Darcy's experiment. Additional experiments will be conducted to ascertain the initial findings.

Keywords: Darcy's law; Darcy's velocity; Groundwater discharge; Point dilution tracer test.
Progress in the remote sensing of Groundwater-Dependent Ecosystems in arid and semi-arid environments

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Abstract

Remote sensing of Groundwater-Dependent Ecosystems (GDEs) has increased substantially in recent years. Of significant prominence is the delineation and mapping of groundwater-dependent vegetation, species diversity, and water quality in these ecosystems. The recent technological advancements and the free access to new imagery with improved sensing characteristics has resulted in a numerous application on GDEs assessment and monitoring at varying scales, essentially in the light of global climate change. In this study, we describe the scientific research progress in the use of remote sensing of GDEs. We then present the key trends in the remote sensing of GDEs that underpin many of the recent scientific research strides and application developments. In addition, this work has observed considerable shift towards the use of advanced spatial explicit modelling techniques, high resolution remotely-sensed data to further improve on the characterization and understanding of GDEs. Literature shows the use of freely available broadband remotely-sensed data in delineation and mapping GDEs. Although remarkable progress has been made, this review has revealed the need to further remote sensing and geospatial analysis studies to map and characterize the seasonal variability, as well as long-term changes in GDEs, in the face of climate change and variability as well as water security particularly in data limited environments.

Keywords: climate variability; groundwater; remote sensing; semi-arid environments
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Finding the needle in a haystack: Satellite remote sensing and priority conservation areas in Groundwater Dependent Ecosystems (GDEs).

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Abstract

Groundwater dependent ecosystems (GDEs) are under threat from poorly managed groundwater abstraction, which significantly impacts their conservation and effective management. One of the reasons for the neglect is that there exists no information on their ecosystem services or ecological significance (e.g., biodiversity hotspots). Therefore, pursuant to Sustainable Development Goal (SDG) 15, characterising or identifying biodiversity hotspots in GDEs improves their management and conservation. In this study, we present the first attempt towards spatially characterizing vegetation diversity in GDEs within the Khakea-Bray Transboundary Aquifer located between Botswana and South Africa. Specifically, we used the Spectral Variation Hypothesis (SVH), and remotely sensed data (i.e., Sentinel-2 MSI) to characterize the vegetation diversity of GDEs. Vegetation diversity was used as a proxy for identifying priority conservation areas and biodiversity hotspots. The Rao’s Q was used to measure spectral diversity from several measures of spectral using remote sensed data. We validated the Rao’s Q using field measured data on species diversity (effective number of species) and we tested the performance of all the measures of variation used to derive the Rao’s Q. Our results show that the SVH can be used to spatially characterise GDEs in the Khakea-Bray Transboundary Aquifer. Specifically, we found out that the Rao’s Q was related to field-measured species diversity (R² = 0.61 and P = 0.0003) and the coefficient of variation (CV) was the best measure to derive Rao’s Q. Our observations showed that species diversity was more concentrated around natural pans, along roads, fence lines, and rivers. However, species diversity was observed to decrease with increasing distance (>35m) from natural water pans and simulated an inverse piosphere. Results from this study, provide baseline information necessary for identifying priority areas that need to be conserved within the Khakea-Bray Transboundary Aquifer. Our results can also be used to inform on areas for further monitoring. Overall, the findings of the study are imperative for natural resource managers in advancing the conservation programs of the Khakea-Bray Transboundary Aquifer.

Keywords: Khakea-Bray, Transboundary, Aquifer Rao’s Q, vegetation diversity, GDE
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Microbial dynamics in freshwater pans of Khakea-Bray Transboundary Aquifer quantified using metagenomics techniques

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Abstract

Over-exploitation of groundwater from the Khakea-Bray transboundary aquifer system for agriculture and domestic use has reduced the amount of water available to support biodiversity in the region, with implications for primary productivity dynamics. There is no knowledge on how loss of microbial diversity will impact ecosystem functioning. The study aims to conduct a baseline ecological assessment of microbial diversity of the freshwater pans in Khakea-Bray TBA, its role in the diet of major secondary producers and contribution to extracellular polymeric substance (i.e., carbohydrate and protein) production. Sediment cores will be collected from 20 pans and within each pan, samples collected along a transect from the centre to the outer edge. The study will be conducted during the wet and dry season. Illumina-MiSeq high-throughput sequencing will be used for analysis using meta-barcoding approaches, the 16S rRNA gene for bacteria and 23S rRNA and ITS genes for eukaryotes. To determine extracellular polymeric substance production associated with microbial activities, carbohydrate concentration in sediment samples will be measured using the phenol-sulfuric acid assay, whereas the total protein (PRT) analysis will be conducted using the modified Lowry procedure. Patterns in microbial community composition and associated Extracellular polymeric substance are expected to differ within and across the testing pans, with a high diversity expected in wet season compared to dry season. The results from this study will provide insight into microbial dynamics and associated extracellular polymeric substance production in relation to productivity dynamics, with implications for change in climatic conditions and land use in the region.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Plankton diversity in the Khakhea Bray Aquifer Pan Systems

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Abstract

Temporary wetlands are characterized by regular and often complete drying. The duration, timing and frequency of the wet and dry phases are factors driving the structure of dynamic ecological communities in temporary wetlands. These communities are typically characterised by highly specialized assemblages of plant and animal species. These wetlands are important in the provision of various ecosystem services in arid regions, where they often the dominant aquatic ecosystem type. Among the key constituents of these temporary wetlands are plankton, which play important roles in the productivity dynamics in these ecosystems. Plankton from temporary wetland ecosystems in Africa, however, have remained poorly understood. Diversity studies in these wetlands are therefore essential as they can contribute information vital to maintain sustainable biodiversity as well as provide useful biological indicators of the ecosystem health. This research is aimed at contributing towards the understanding of processes that shape plankton diversity in the temporary pan systems of the Khakhea-Bray Trans boundary Aquifer in South Africa and Botswana. It also aims to describe the functional characteristics and species composition of plankton assemblages, and to characterise the planktonic food-web dynamics in these pan systems. The expected results will contribute to a deeper understanding of plankton diversity in temporary wetlands and to the effective management of temporary pan wetland ecosystems in the vulnerable Khakhea-Bray Trans boundary Aquifer region.

Keywords: plankton diversity, temporary pan wetland ecosystems, planktonic food-web dynamics
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Investigating groundwater contamination in St. Mary's Suburb of Chitungwiza, Zimbabwe.

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Abstract

Groundwater contamination from anthropogenic activities causes deterioration in groundwater quality and poses health risks. This is the case with Chitungwiza, where the management of sanitation, sewerage systems and solid waste has deteriorated over time. This study investigated groundwater contamination from sewage and latrines, assessed the spatial variation and vulnerability of groundwater in St. Mary's suburb of Chitungwiza. Parameters selected in this study included pH, temperature, Electrical Conductivity (EC), Turbidity, Chloride, Total Dissolved Solids, Total Suspended Solids, Dissolved Oxygen, NH₄⁺, Alkalinity, Iron, Zinc, Lead, Nitrate, Nitrite, Sulphate, Phosphate, Total Hardness, Magnesium Hardness, Calcium Hardness, Total Coliform (TC) and Faecal Coliforms (FC). Grab samples were collected in 4 campaigns from December 2020 to May 2021 from 5 boreholes and 5 wells in St. Mary’s, close to potential sources of pollution. The samples were analysed using APHA standard methods and were compared to the Standards Association of Zimbabwe (SAZ) and WHO limits to assess suitability for drinking. Repeated Measures ANOVA (RMA) and Principal Component Analysis (PCA) were used to determine spatial and temporal variations in groundwater quality and to identify key parameters, respectively. The groundwater vulnerability assessment was done using the GOD model. Results show 26 % and 48 % of the samples exceeded the WHO and SAZ limits for drinking water quality respectively. Nitrates (145.70±91.66 mg/L), turbidity (11.83±29.37 NTU), EC (948.10±325.65 μS/cm), Iron (1.59±2.04 mg/L), ammonium (127.17±37.50 mg/L), and coliforms (53.20±27.50 cfu/100 mL TC and 24.00±18.50 cfu/100 mL FC) were the key parameters (n=40) in groundwater contamination determined using PCA. Key parameter concentrations in St. Mary’s increased with a reduction in elevation. The study shows that 73 % of the study area had moderate groundwater vulnerability. The presence of coliform in groundwater infers contamination by overflowing sewers prevalent in the area. Treatment at point-of-use is recommended for all groundwater in Saint Mary's suburb of Chitungwiza.

Keywords: Chitungwiza, contamination, groundwater quality, sewage, spatial variation, vulnerability.
In recent times, water shortages have been prevalent in Lilongwe City when supply levels of two reservoirs become too low hence do not meet the city’s demand. Future water shortages have been predicted to worsen during years of dry spell due to effects of climate change. It is against this background that Lilongwe Water Board undertook an assessment and mapping of groundwater resources within a radius of 50km of the City to ascertain potential for conjunctive use and vulnerability of groundwater, which would provide basis for future investments in groundwater development. The study methodology included data collection, identification of potential aquifers, geophysical surveys and drilling, data interpretation, and reporting. The project established groundwater occurrence within both the weathered and fractured basement aquifer. High groundwater potential occurred in the west, under superficial cover, which promotes groundwater recharge as runoff is limited, while low groundwater potential occurs in the east. The fractured basement aquifer has higher groundwater potential than the weathered aquifer. Groundwater recharge estimated from water level hydrographs and chloride mass balance method showed recharge rates of 20mm/yr to 120mm/yr. Aquifer transmissivity varied from <1m²/d to 60m²/d, with the highest transmissivity found within the fractured aquifer. Groundwater quality is good, with all parameters falling within recommended limits for Malawi drinking water standards for boreholes and shallow wells, MS733:2005. Groundwater chemistry data did not show any evidence of pollution. The groundwater type showed dominance of CaHCO₃, indicating fresh and recently recharged groundwater system. The study estimated the available groundwater volume in the project area to be approximately 1,818MCM/yr, which was reduced by 50% to cater for environmental flow requirements. Individual borehole yields were found to limit the full exploitation of the available sustainable groundwater volume. The zone to the west of the project area, which has boreholes with yields more than 2.5l/s, was marked as a potential wellfield for future groundwater development. Recommendations include setting up groundwater monitoring systems to inform effective management and utilisation of groundwater resources from the developed groundwater supply schemes.

Keywords: conjunctive use, groundwater occurrence, groundwater potential, groundwater vulnerability, groundwater quality.
Floodplains are among the most dynamic, productive, diverse, and threatened ecosystems in the world. Their interactions between ground and surface water are a key element in understanding the resilience of floodplains to hydrological changes, especially with the advent of climate change and variability that has affected many aquatic ecosystems. Conjunctive evaluation of ground and surface water in floodplains is critical for integrated water resources management. The main objective of this study was to evaluate groundwater-surface water interactions in the Barotse floodplain. To achieve this objective, remote sensing was employed to identify perennial green vegetated areas with shallow depth to groundwater table in the floodplain. Normalized Difference Vegetation Index (NDVI) using Sentinel-2 imagery from 2015 and 2020 in Google Earth Engine (GEE) were used to identify riverine perennially green vegetation. Digital filtering using “EcoHydRology Library” in R statistical package was used to extract base flow from discharge data collected from the three main gauging stations along the Zambezi River in the study area to estimate the contribution of groundwater to surface flows in the Floodplain.

Hydrochemistry was employed to determine the composition of the different water sources and identify the genetic link between the local and regional flow of groundwater and interactions with the Zambezi River. Water samples collected from various water sources were analyzed for stable isotope [deuterium ($^2$H) and oxygen ($^{18}$O)] to determine the origin of the water and the nature of the interaction. Statistics were applied to determine the significance of the correlation between remotely sensed data and ground-based measurements. The average base flow in 5 hydrological years from October 2004 to September 2009 shows a 44.8 % contribution upstream at Lukulu gauging station and a 48.2 % contribution downstream at Senanga gauging station. The hydrochemistry signature shows a similar signature between groundwater and the Zambezi River indicating connectivity between river water and groundwater. From the stable isotopes, the data shows deuterium ($^2$D) and oxygen ($^{18}$O) were depleted in groundwater and river water but enriched was in surface pools. The stable isotopes show high local infiltration of rainwater. The stable isotopes show that the interaction is such that groundwater discharges to the river system. Statistical analysis indicates an inverse relationship between the baseflow index and NDVI of 0.74 using the spearman correlation in a 95% confidence interval. The correlation between baseflow and dissolved oxygen shows a similar trend indicating an increase in baseflow also increases the concentration of dissolved oxygen. Therefore the significance of this relationship is such that when there is an increase in baseflow, oxic water to the floodplain increases that help sustain the ecosystem.

**Keywords:** Groundwater; Surface water; Floodplain; Remote sensing; Base flow; Hydrochemistry; Stable isotopes.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Observation based continental-scale groundwater study in Africa: Drilling trends, water level fluctuations, and depletion.

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Abstract:

Much of the rural and urban population in Africa uses groundwater for water supply, industry, and agriculture. Continent-scale groundwater studies in Africa focus on quantifying the amount of recharge, and considerable regional- and local-scale studies focus on exploration, development, and management of groundwater resources. Aside from groundwater recharge studies at African continent scale, current understanding of the potential and sustainability of groundwater resources can be improved. Here we implement groundwater resource studies based on observed groundwater data, such as drilling depth, year of well construction, and water level change in major aquifer systems in Africa. Our results exemplify the critical and growing importance of groundwater as a primary water supply in many sub-Saharan African countries. These countries include Uganda, Malawi, Zambia, South Africa, and Ethiopia. For the case of Ethiopia, examination of groundwater drilling records demonstrates an increase in typical well depths over time, highlighting the importance of deeper groundwater aquifers to meeting present-day and future water supplies.

Keywords: Groundwater, Well depth, Groundwater development, Groundwater sustainability, Climate change.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Experimental and Numerical Study for the Adsorption Behavior of Cu (II) and Mn (II) in Quartz Sand

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Abstract

Heavy metals as Cu (II) and Mn (II) are prevalent in the environment. The effect of heavy metals on the soils environment is based on the ability of soils to mobilize these contaminants. It is indispensable to examine the reaction technique between heavy metals and soil according to soil decontamination perspective. This study carried on a series of experiments to investigate the adsorption behaviour for Cu (II) and Mn (II) in quartz sand. The isothermal adsorption results for Cu (II) and Mn (II) presented that the adsorption capacity reached the peak value when the initial concentration was about 10 mg/L. The Freundlich and Langmuir adsorption isotherm models were applied to investigate the adsorption isotherm of Cu (II) and Mn (II). The study results confirmed that the Freundlich model synchronous the best with the experimental observed data by compared with the Langmuir solution.

Keywords: Heavy metals, Adsorption, Freundlich Isotherm Model, Langmuir Isotherm Model.
Sub-Theme 1: Groundwater an Integral part of the hydrological system.

Evaluation of groundwater chemistry with multiple land use spectral indices approach

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Abstract

Groundwater chemical variations within sub-surface regimes are better comprehend in relation to land use influences, which are seldomly assessed in the explicit quality control and management strategies of groundwater resources. Therefore, current evaluation of groundwater chemistry, within shallow aquifers, is based upon the set of retrieved land use spectral indices in an urbanized settings of Ghaziabad district of Uttar Pradesh, India. Satellite dataset of multispectral Landsat 8 Imagery for the year 2017 was acquired for necessary spectral information and calibrated images were processed to calculate the Normalized Difference Vegetation Index (NDVI), Normalized Differential Salinity Index (NDSI), Normalized Difference Built-Up Index (NDBI), Modified Normalized Difference Water Index (MNDWI) and Land Use Land Cover (LULC). In order to collate the analytical groundwater chemistry- based parameters with land use indices, a statistical method of Normalized Difference Dispersal Index (NDDI) was also computed as to obtain index values of groundwater quality status at twenty-six (26) sampling locations within the region for pre- and post-monsoon seasons. Furthermore, a correlation coefficient was applied that estimated the interrelationships of spectral and seasonal chemistry in response to LULC changes. The results have shown that areas with high urban density (as per index of NDBI), showed higher variations in the quality of dispersal ranges in terms of NDDI and therefore, concludes that integration of land use spectral indices is one of the crucial techniques which delivers a strategy to monitor groundwater quality variations within the urban settings and predict the impacts arising from urbanization, agrarian and industrial units within the spatial extent of the region.

Keywords: Groundwater Quality, Land Use, Spectral Indices, Dispersal Indices
Averting land subsidence impacts through optimal groundwater management: the case of the Hout River Catchment

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Abstract

Water scarcity has long been one of the most serious threats to human civilization. The freshwater surface is becoming increasingly scarce worldwide as a result of the continuous increase in unfavorable climatic conditions. As a result, groundwater has emerged as the most cost-effective alternative source of water for human survival. Groundwater over-extraction, on the other hand, could result in another environmental externality in the form of land subsidence. Thus, creating negative impacts in the form of damages to infrastructure, and the performance of groundwater-dependent ecosystems. In the long run, these environmental externalities may alter the geological formation of the aquifer. The loss of aquifer storage capacity owing to land subsidence is a negative externality that is seldom discussed. We overcome this limitation and investigate the indirect loss of the aquifer storage capacity due to land subsidence along with the direct land subsidence negative externalities. This is done through the development of an economic optimization model for groundwater utilization. We found that when taxes on land sinking and aquifer storage capacity reduction are in place, the water table level increases, and groundwater extraction and land subsidence decrease. Such taxes have an insignificant effect on both withdrawals and the water table in fractured-rock aquifers. Finally, we demonstrated that, to develop effective and optimal groundwater management policies, a better understanding of the contribution of groundwater pumping to land sinking and inelastic compaction per aquifer is required.

Keywords: land subsidence, groundwater management, Hout River catchment
Identification of Suitable Sites for Smallholder Irrigation in the Drylands of Zimbabwe using Weighted Overlay Model

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Abstract

The use of photovoltaic powered systems to abstract water from alluvial aquifers of ephemeral rivers is being increasingly utilised by smallholder irrigators in Zimbabwe. Due to the increased adoption a quick and effective site selection process is required. Traditionally this has been carried out through physical surveys and transect walks, however this is an arduous and expensive exercise. The research explores the use of GIS based, weighted overlay modelling to remotely identify suitable sites for smallholder irrigation on six sand rivers in the Gwayi catchment that can then be groundtruthed. This significantly reduces the time and difficulty of physical surveys and ensures that no potential sites are missed and only the more promising sites are surveyed, reducing assessment time and costs by guiding physical surveys to delineated areas which show high suitability. The most suitable areas have been delineated based on weights of three parameters; Topographic Wetness Index, Normalised Difference Vegetative Index and Drainage Density. The model showed that the most suitable areas correspond to confluences of tributaries and the model was set with this as the primary weight and the Normalised Difference Vegetation Index as the least sensitive. Community brushwood gardens were digitally mapped and their locations corresponded to the most suitable river sections. The model was found to be good at delineating suitable areas. A Monte Carlo analysis showed that the model is robust to changes in the assigned weights.

Keywords: Alluvial aquifers, Effective water management, Local knowledge systems
Water resource assessment, Remotely identifying suitable sites
Sub-Theme 2: Communities, Institutions, Capacity, and Local-level Governance.

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Abstract

This paper posits the nuanced need for engaging a “Theo-Ancestral Voice” in modelling local groundwater changes in Southern Africa today. From a mixed methods approach, the inquiry explores the expressions from the communities dotted around the Tugwi-Mukosi Dam in rural Masvingo south, Zimbabwe. For these respondents, modelling the local groundwater changes should feature around an indigenised, mandatory, faith-oriented, doctrinal and society-laden obligation that teaches and motivates humanity to live in harmony with the provisions of nature. This ‘created order’ should sprout and develop with the “continued existence of mankind” – as these communities believe that the spirit of the dead or ancestors forever lives and continues to guide and inform groundwater harvesting and usage. This same spirit can continue to “speak and raise signal” around the current and future local groundwater changes. It is an imperative “undying aqua-theological voice” from our ‘indigenous’ ancestors that enables the flow and transmission of learned and shared aqua-ecological data, knowledge, experience and wisdom that can be manipulated in managing the local groundwater changes in Southern Africa today. This voice can boost and strengthen the capacity, response-ability and agency of the local communities and institutions to theologically interpret, speak and innovatively act around the groundwater changes at their disposal. It is a ‘voice of the living-dead’ that which is never silent, it is ever there, and has to occupy its rightful position in Southern Africa today, informing us what we should or should not do as we endeavour to responsibly manage some groundwater changes within and around our locales. It should be a voice particularly “captured and harnessed” from the local communities, “contextualising” how such a powerful voice has helped them face some groundwater changes. Both local communities and institutions should therefore, continue to embrace the value of this “indigenous, infallible and indelible aquatic voice”, as they responsibly think, plan and act around the recurring local groundwater changes, hence ensuring a Contextual Theology of Indigenised Groundwater Management to be ushered in and around Southern Africa today and tomorrow.

Keywords: Theo-Ancestral Voice, Local Groundwater Changes, Contextual Theology of Indigenised Groundwater Management
Regulated and unregulated substitutes in water consumption: the case of residential water in South Africa

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Abstract

The choice of water for use in residential households is usually limited to either the more regulated piped water or less regulated groundwater sources such as boreholes or wellpoints. Many households find it beneficial to secure access and consumption by investing in the less regulated groundwater sources, consequently, putting the groundwater resource at risk of excessive extraction. This paper contributes to the small existing literature on the substitution or complementary threshold of piped and groundwater in developing countries. Our analysis explicitly considers groundwater as an unregulated substitute for piped water. First, we investigate determinants of households’ decision to use piped and groundwater supply. Second, we determine the distributional impact of counterfactual price rebalancing scenarios that influence the fixed charge and variable volumetric charge of piped water. Third, we estimate the elasticities of both piped water and groundwater demand. We use a simple utility maximization model that yields both a water-type choice model and a demand specification whose parameterization allows examining households’ responses to regulated price changes. For our estimation we employ the five waves of the South African National Income Dynamics Study (NIDS) datasets and the water tariff publications of each of the country’s nine provinces. Our analysis shows empirical evidence in favour of certain determinants of households’ choice of water type. Specifically, ownership of dwellings, large household size, participation in agricultural activities, ownership of a vehicle, and number of rooms within household dwellings are factors that explain the reason for high groundwater usage share. Our estimation also shows evidence for the increased household choice of piped water when a counterfactual price rebalancing strategy that influences the fixed charge and variable volumetric charge does exist. Furthermore, we provide insights on the potential effect of the piped water rebalancing strategy on welfare changes.

Keywords: Piped water, groundwater, residential water demand, public utility regulation, South Africa
**Sustainable groundwater management: A coordinated approach for improved livelihood options**

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**Abstract**

Water is a core development issue in semi-arid Zimbabwe with limited water resources. Groundwater is a default water source for the large part of the rural communities as well as during droughts, water scarcity and emergencies. The climate is continuously changing, and the future of the world in all aspects is at risk, emergency and water scarcity situations are continuously increasing. This calls for the need to analyse groundwater sources, uses and management in order to inform on sustainable management practices for improved livelihood activities, especially in semi-arid and arid environments where climate change impacts are expected to be adverse. The study was carried out in Ward 2 of Rushinga District in Mashonaland Central Province, Zimbabwe. Combined qualitative and quantitative research was done in order to establish groundwater sources, uses and management. Remote sensing was used in identification of groundwater sources and establishment of groundwater quality and quantity. Key informant interviews, focus group discussions, observations and semi-structured questionnaires were used to collect data on groundwater sources, uses and management. The study found that main groundwater sources were boreholes and deep wells. Main groundwater livelihood uses were gathered as household use, irrigation and livestock watering. Traditional leadership, water point committees, District Development Fund and Zimbabwe National Water Authority were gathered as the key players in groundwater management. The study found that there was no coordinated approach in the management of groundwater. Each water source was managed independently resulting in unsustainable groundwater management. Therefore the study recommends a coordinated approach in groundwater management to ensure sustainability.

**Keywords:** groundwater; sustainable; management, livelihood
The borderlands of the Horn of Africa experience recurrent environmental, economic and water security shocks. There is increasing reliance on groundwater sources, infrastructure and institutions to overcome drought conditions. A groundwater analysis was conducted to understand the relationship between (i) communities and community institutions, and (ii) the formal national frameworks and institutions for groundwater management. The methodology for the groundwater management analysis was based on a literature review, key informant interviews and Focus Group Discussions in case study areas. The case study areas were chosen in dialogue with local partners and included Tog Wajaale between Ethiopia and Somalia, and Moyale in the borderlands of Ethiopia and Kenya. There was a third case study area selected which was Afar triangle bordering western Djibouti and north-western Ethiopia but could not be visited due to security concerns. In the borderlands regions informal institutions and clan or ethnic affiliations dictate cross-border migrations, transhumance and regional trade flows. Informal institutions carry out functions in managing trade relations, overseeing access to natural resources such as groundwater and conflict resolution in borderland areas. This, particularly, holds for areas where formal institutions have limited reach. Where formal institutions are in place their operations are normally restricted to small towns and settled villages. In this case, the formal institutions and communities collaborate for managing the groundwater source. At community level it is difficult to separate formal and informal institution decision-making as clan leader’s take-up formal leadership positions. Despite the importance of informal institutions it is not recognised in formal policies and legislation. Local adaptations exist in e.g. northern Kenya where a traditional system for water allocation works side by side with water user associations in managing water points. Natural resources issues, such as water and pasture are top priorities for borderland communities providing an opportunity for sustained resilience interventions.

**Keywords:** groundwater management, institutions, borderlands, horn of Africa
ABSTRACTS:

SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions
LOCALISED GROUNDWATER SUPPLY SYSTEMS TO IMPROVE WATER RESILIENCE AT CRITICAL SERVICE DELIVERY FACILITIES

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Abstract

At the point of a disaster and immediately thereafter, there is often a greater need for essential services such as health care services. Without water at these facilities, the resultant unavailability of these essential services will certainly exacerbate the disaster but could also become a disaster of itself. Disaster response plans often rely on the ongoing availability of certain basic but critical services, and the absence of these at the vital time can undermine the effectiveness of the response plans and the ability of disaster managers to navigate through the disaster. During the early part of 2017, the Western Cape Province was confronted by a serious ecological and systemic shock, being an extended drought period with the associated risk of acute water shortages. The Western Cape Government needed to ensure a continued water supply to key facilities and thereby ensure service delivery.

The strategy of establishing localised groundwater supply systems to improve water resilience was considered for implementation at 95 facilities and ultimately established at 61 of them. The effective establishment and sustainable ongoing operation of these localised groundwater supply systems needs to be assessed and evaluated to inform not only the current but also future disaster planners of the determinants of success and the extent of actual water resilience embedded in this manner to mitigate against future disasters that lead to loss of water supplies.

The effectiveness of the strategy of using localised groundwater supply systems in this way is being reviewed by examining decisions made, the surrounding and supporting data, the outcomes and overriding reasons for the outcomes at the various decision stages under four broad categories; namely (1) groundwater sustainability, (2) treatment / water quality and costs sustainability, (3) technical, operational and maintenance capability and (4) regulatory compliance sustainability.

Keywords: water resilience; disaster planning; localised groundwater systems; business continuity planning
SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions


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Abstract

South Africa and the larger Southern Africa region (SADC) is a water stressed region where groundwater is a valuable and finite resource. The fact that the region now experiences droughts of increased severity, limiting surface water availability, groundwater is proving to be a critical buffer in sustaining water for public health, the environment and the economy thereby intensifying the value of the resource.

South African National Parks (SANParks) is the custodian of 22 parks across the country representing 8 biomes. These largely pristine landscapes provide a unique opportunity to understand natural groundwater dynamics. Also, the aquifers in Kruger, Mapungubwe, Kalagadi and Golden Gate Highland national parks form part of the Limpopo Basin, Tuli Karoo, Stampriet and the Karoo Sedimentary Transboundary Aquifer (TBAs) systems respectively. Therefore, in terms of groundwater management, resource protection and early warning systems, SANParks position at the borders with Botswana, Namibia, Mozambique, Lesotho and Zimbabwe provides a unique opportunity for cross-border cooperation for sustainable utilization of shared water resources, including aquifers (SADC Protocol on shared Watercourses), and as sentinels for their status.

As part of a collaborative initiative between SANParks and DWS we aim to continue and re-establish the long-term dataset that is valuable to better understand groundwater trends (on various spatial and temporal scales), impacts of climate change, vegetation, surface water/groundwater interactions and the effects of regional aquifer development. Here we highlight our proposed operational plan and describe the results of available long-term data sets and a recent groundwater hydro-census conducted in multiple parks across South Africa as Phase 1 of the project.
EXPANSION OF NATIONAL GROUNDWATER MONITORING NETWORK OF LESOTHO

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Abstract

The performance in terms of groundwater monitoring in Lesotho has recently declined and as a result poor monitoring data collection which has a negative impact on the annual report on groundwater status of the country has been experienced. This situation results from a combination of external and internal factors, including the difficult access to some of the groundwater monitoring points such as those that are located in remote areas. Other factors include inadequate training on monitoring and inadequate monitoring network. These lead to inefficient groundwater management practices.

This project aims at expanding the existing groundwater monitoring network to form a comprehensive nationwide network for the support and guidance of groundwater management activities in Lesotho. This project will benefit several departments within the Government of Lesotho and the Basotho Nation as well as some other academic institutions and stakeholders within the country and SADC Region. To develop a comprehensive groundwater monitoring network, this project aims at designing a groundwater monitoring network that will encompass all the ten districts of Lesotho. Through this network, relevant stakeholders will benefit directly from the data that will be collected from all the monitoring points existing and on the newly drilled positions.

The existing monitoring boreholes in the country are mostly located within the lowlands of Lesotho, in this study, the scope is wider as the mountainous regions and rural areas are included. Future engagements in this study include among others the capacitation of the stakeholders on groundwater data collection and management, hydrogeological investigations, drilling of the monitoring boreholes on the preferred positions and the initial monitoring.
SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions

Evaluation of Monitoring Network Performance for Groundwater Resources

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Abstract

Good management of groundwater resource requires good hydrogeological understanding and will benefit from a monitoring network detecting changes in aquifer water level due to groundwater abstraction or groundwater quality due to contaminants. A functional groundwater monitoring network can guarantee groundwater retains its beneficial uses and stays potable for future generations. Evaluation of groundwater monitoring network performance is critical for the management of groundwater data influx and groundwater resource management including policy planning for the resource. Often monitoring of network performance is neglected, thus affecting the true reflection of status of the actual groundwater resource in terms of level and quality. Currently the main challenge is that groundwater monitoring data especially from private stakeholders is not well coordinated with the national government. As such, data collected is not systematically stored for future use thus result in monitoring data being lost. Therefore, for a monitoring network to function optimum it requires a collaborative effort between, National Government which is the custodian of the resource, Member States, Water Resource Agencies, abstractors, polluters, researchers and drilling companies. The information collected through these platforms assist in the functionality of the network in addition plays a key role in increasing awareness of water users, enables the introduction of required groundwater demand management measures.

Key words: network performance, groundwater, data quality, monitoring, groundwater
SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions

Using hydrogeophysics and derivative analysis for improved groundwater security, Western Cape, South Africa

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Abstract

The need to improve groundwater security remains critical especially in urban areas where demand for groundwater as an alternative source of water supply increases. Declining trends in availability of surface water because of climate change effects further exacerbates problems of water supply shortage to meet the increasing demand for water, hence the need for groundwater sources. The study argues that if hydrogeophysics data and derivative analysis are not used in aquifer characterization, the knowledge about the aquifer dynamics will be limited. The aim of the study was to improve understanding of the aquifer dynamics using hydrogeophysics and derivative analysis. Geophysics data were collected and analysed using the electrical resistivity tomography and RES2DINV respectively while constant-rate pumping test data were collected over a 72-hour period and analysed using the Flow Characteristic programme. Results from the electrical resistivity tomography survey carried out, showed an extensive layer of fine to medium grain sand with depths of up to 60m in some areas, some coarse grain sand with peat intercalation. The dominate flow regime in the investigated boreholes are wellbore storage and radial flow. The diagnostic plot also showed the presence of various double porosity dips during the pumping cycle, which is indicative of an unconfined aquifer, while aquifer heterogeneity and a no flow boundary were detected in the various boreholes. Double porosity behaviour was portrayed by the stabilization of drawdown during mid-time of pumping, suggesting that the matrix blocks feed the porous opening made by the gravels with water at an increasing rate. Further findings showed that 2 boreholes were drilled in the paleochannels of the Elandsfontein sand and gravel aquifer that runs along the coastline towards the Atlantic Ocean hence the direction of groundwater flow here is Southwest and controlled mainly by the bedrock topography.

KEYWORDS: Derivative analysis, Flow regime, Using hydrogeophysics and derivative analysis, Groundwater modelling, Hydrogeophysical data, West Coast aquifer system
SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions

Investigating a three tier groundwater exploration approach in basement aquifers of Mudzi District, Zimbabwe.

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Abstract

Conventional methods for groundwater exploration that include geophysical surveys, test drilling, and water quality testing have low accuracy and are time-consuming, costly, and lack spatial coverage. This study investigated the potential of integrating Earth Observation (EO) techniques, indigenous knowledge systems (IKS), and geophysics to enhance groundwater potential (GWP) mapping and groundwater quality (GWQ) assessment in Mudzi District, Zimbabwe. Nine (9), GWP influencing themes viz drainage density, geology, rainfall, land-use, topographic wetness index (TWI), slope, soil type, recharge, and elevation were generated using EO techniques. The spatial layers were weighted and aggregated using Saaty s’ Analytical Hierarchy Process (AHP) and Index Overlay respectively. Determination of IKS used to infer GWP and GWQ was derived from Focus Group Discussions (FGDs) and critical field observations. Electromagnetic geophysical profiling of twenty (20) boreholes, including three (3) dry drilling boreholes, with an IKS GWP and GWQ indicating feature(s), was done using a PQWT TC 300 machine. Three (3) water quality campaigns were conducted for 17 of the 20 boreholes from December 2020 to September 2021 to compare IKS findings on GWQ. EO techniques showed that 11.48 % (470.135 km²) of Mudzi District lies in high GWP zones, 35.7 % (1,460.70 km²) in moderate-high, 34.5 % (1,414.401 km²) in moderate, 12.85 % (526.244 km²) in low and 5.5 % (224.320 km²) in very low GWP zones. Geophysical surveys showed that 15 % (3 boreholes) exhibited a high GWP, 15 % (3 boreholes) a moderate-high GWP, 45 % (9 boreholes) a moderate GWP, 10 % (2 boreholes) a low GWP and 15 % (3 boreholes) a very low GWP. IKs based GWP classified 15 % (3 boreholes) to be of high GWP, 15 % (3 boreholes) as moderate-high, 20 % (4 boreholes) as moderate, 30 % (6 boreholes) as low, and 20 % (4 boreholes) as very low. A paired t-test, at p <0.05, showed that dry season water quality parameters: EC, TH, TDS, Mn2+, F-, Cl-, exhibited a significant decrease in concentration during the wet season. Thematic analysis of IKS based water quality analysis from FGDs and household surveys deemed the water quality of 23.5 % (4 boreholes) to be unsatisfactory for the taste and consumption of soap, especially in the dry season. A three (3) tier groundwater potential exploration approach that is EO, IKS, and Geophysics respectively, exhibited the strongest Spearman’s rho correlation coefficient of 0.87 with existing borehole yields at p < 0.01. The value is greater compared to the use of two (2) tier approaches of IKS and geophysics, rho (0.84), EO and geophysics, rho (0.83), EO and IKS, rho (0.80), and a one-tier approach of geophysics, rho (0.81), EO, rho (0.731) and IKS, rho (0.686). Groundwater yield prediction algorithms from integrated EO, geophysics and IKS based groundwater exploration linkages classified the borehole yields in Mudzi District as: very low (Y < 0.35 l/s), low (0.35 ≤ Y < 0.7 l/s), moderate (0.7 ≤ Y < 1.0 l/s), moderate-high (1.0 ≤ Y < 1.4 l/s) and high (Y > 1.4 l/s). A three (3) tier approach has the potential to improve GWP exploration accuracy. IKS can be used to infer GWQ at the borehole pre-siting stage.
Managed Aquifer Recharge in Windhoek

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**Abstract**

The Windhoek Managed Aquifer Recharge Scheme project is a visionary endeavour in integrated water resources management that aims to not only diversify the supply resources of Windhoek, but also to limit surface water evaporation through water banking, whilst also providing a “reserve” resource for periods when surface water supply is limited. Following research and development in the late 1990s, the project concept, consisting of abstraction and managed (artificial) aquifer recharge, was developed in 2004. Unfortunately however, project implementation has been slow, and while aquifer abstraction capacity has been greatly expanded (to 11 Mm$^3$/a and possibly more in future), recharge capacity remains constrained (currently limited to 2 Mm$^3$/a). Over the 2008-2020 period, 41 Mm$^3$ was abstracted from the Windhoek Aquifer while less than 4 Mm$^3$ was recharged through managed aquifer recharge. Managed aquifer recharge can be done using surface water or reclaimed water or a blend of the two, with previous assessments focussing mostly on the volumetric aspects of recharge. Recent drought periods in Windhoek have however highlighted the importance not only of water quantities but the hitherto largely neglected aspects of water quality. Analysis of various water quality parameters of surface and reclaimed water from 2010 to 2019 has for the first time quantified the availability of these two sources and variable blends of the two in terms of suitable quality for managed aquifer recharge. Future plans for the development of the scheme currently hang in the balance, and possibly with it, water security to Windhoek, despite the many obvious benefits thereof. More sophisticated water resource and quality modelling as well as improved management and financial practice are required for managed aquifer recharge to be successful.

**Keywords:** Managed Aquifer Recharge; Integrated Water Resources Management; recharge water quality
Evaluating large-scale MAR in Botswana based on water supply security, cost-effectiveness, and sustainability

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Abstract

Botswana has a water stressed situation due to the climate and a continuously increasing water demand. Managed Aquifer Recharge (MAR) is considered, among other measures, to improve the situation. To evaluate the potential of MAR for improving the water supply security, a probabilistic and dynamic water supply security model (WSSM) was developed. Statistically generated time series of source water availability are used in combination with the dynamic storages in dams and aquifers, and the function and reliability of water treatment facilities and other infrastructure components. The WSSM compares possible supply from the system with the demand to simulate the magnitude and probability of water supply shortages. The model simulates the system and the effects on water supply security from possible mitigation measures (scenarios) for a chosen time-period using one-month time steps. In previous studies, application of the WSSM showed that MAR can substantially increase the water supply security in the regional so-called North-South Carrier water supply system in eastern Botswana. This led to more detailed investigations being carried out in the Palla Road area, located approximately 150 km northeast of the capital Gaborone. The WSSM was updated with respect to new data on aquifer properties from site investigations and hydraulic modelling. Needed modifications in infrastructure for a full-scale MAR operation at Palla Road was also considered. The expected effects on water supply security are compared to the costs for installing and operating MAR over the chosen time-period to evaluate the cost-efficiency for different MAR scenarios. Each scenario is also evaluated with respect to expected social and environmental effects using a multi-criteria analysis approach, addressing the long-term sustainability of the scenarios. This ongoing work will provide decision-support for the design and construction of what will potentially be the first large-scale MAR facility in Botswana.

Keywords: Managed Aquifer Recharge, Water security, Water Supply Security Model, Multi-criteria analysis
SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions.

Investigating sustainability of community-based management of solar piped water supply schemes in rural areas: A case of Mt Darwin District, Zimbabwe.

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Abstract

In Sub-Saharan Africa, lack of access to potable water has been documented as having negative health, environmental and socio-economic outcomes. Some of the outcomes include; increase in diarrheal diseases, contamination of the environment by pathogens that affect both humans and animals (zoonotic), households loose productive populations, and the costs of treating and the losses resulting from absents from productive work. Some of the factors that have negatively affected potable water supply in rural communities of developing countries include unsustainable management of complex water systems, climate change, and lack of financial resources. The three major solar piped water supply schemes (SPWSS) in Mt Darwin District were studied from October 2020 to April 2021. The study sought to investigate the efficiency of communities-based management of SPWSS. The main issues that were studied included functionality, user attitude, and water accessibility issues. The pragmatic approach which meant the merging of positivism and constructivism paradigms guided the study’s data collection methodology. Thus, a mixed methodology approach was used, the following data collecting methods were adopted; household questionnaires, key informant interviews, focus group discussions, and pressure and flow gauges. The Pearson's correlation method was used to analyze the qualitative data and quantitative data. Results showed that the solar-powered pumps were providing water daily in two of the SPWSS. About 82% of the respondents reported adequate water supply whilst those who did not receive adequate water reported high breakdowns and low nodal pressures as major causes in the system. Data from interviews indicated that after implementation, the schemes were handed over to locally elected committees to manage them. The community respondents demonstrated a positive attitude of 2/3 (67%), while 43% had a negative attitude (1/3). About 60% of the respondents were contributing monthly tariffs and 2 out of 3 pump minders were trained but complained about not being paid. In conclusion, the communities have the potential to sustainably manage SPWSS if operation and maintenance issues are prioritized.

Keywords: communities-based management, efficiency, functionality, nodal pressures, potable water.
SUB-THEME 3: Deriving benefits from the groundwater system: Innovative groundwater infrastructure interventions.

Developing the Hydrogeological Map of Namibia.

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Abstract

The purpose of the hydrogeological map of Namibia “The Map” and the explanation book is to provide the public and decision makers with accurate information about the occurrence, quality, utilisation and vulnerability of groundwater resources in Namibia. Ideally, it is a groundwater management tool that is to provide answers to the more pertinent management and governance questions of “where”, “what” and “how much” groundwater resources are available over time. Following the guideline of the preparation of hydrogeological maps published by SADC (SADC, 2010), the project produced “The Map” at a scale of 1:1 000 000. It can assist with the initial planning of environmentally sound new settlements, industrial sites and water abstraction schemes. “The Map” can also be used as a strategic document for national development plans. It can help to identify areas where groundwater knowledge is still rather insufficient and where further investigation studies must be undertaken. This paper/presentation aims at providing SADC Member states with an overview of the projects outcomes and outputs produced in order to assist them with probable replication of this project in their own countries.
The international funders of groundwater projects fall into two main categories: private investors and public investors. Broadly, public investors can be further categorised into: Multi-lateral agencies and funders, notably the development banks, which include the African Development Bank (AfDB), the World Bank, the International Monetary Fund (IMF), the International Finance Corporation (IFC), the European Investment Bank (EIB), etc. Bilateral funders, normally focus on direct country-to-country funding agreement.

These institutions are collectively referred to as International Cooperating Partners (ICPs). While private investors make a significant contribution to groundwater development in the region, their particular investment strategies and criteria vary widely, and are often not easily understood.

**Objective.**
This session seeks to:
- Discuss the funding options available for water/groundwater related projects
- Explore strategies for attracting funding of groundwater projects
- Assist in unlocking some of the hurdles in assessing project preparation funding
Surface water and groundwater systems are connected in most landscapes. Streams gain water from inflow of groundwater through the streambed, and streams lose water by outflow through the streambed. If the water table has large variations during the year, a stream segment could receive water from groundwater for a portion of the year and lose water to groundwater at other times. Consequently, surface water and groundwater are two components of a singular unit, that should be managed holistically. Therefore, effective governance of both surface and groundwater is critical in order to achieve water security, especially in the water scarce region of southern Africa.

The interconnectedness between and among water sources calls for conjunctive management of those sources to encourage their optimal use. Conjunctive management is the simultaneous management of ground and surface water resources, to achieve security of water supply and environmental sustainability. While it is encouraging to see the exponential growth of groundwater research in southern Africa, effective governance of the resource remains a challenge in practice.

To promote innovative research in conjunctive water management, the IUCN’s BRIDGE programme is inviting exciting presentations from young scientists that focus on groundwater management and/or conjunctive water management. The BRIDGE (Building River Dialogue and Governance) initiative aims to build water governance capacities through learning, demonstration, leadership, and consensus-building, in particular in shared water bodies. The objective of BRIDGE is to strengthen capacities of policy makers, NGOs, civil society, local communities and academia to reach effective water agreements.
Special Session: Reflecting on Capacity Building and Research for Groundwater in SADC

Session Overview

In 2017 the SADC-GMI initiated a Capacity Needs Assessment to determine priority challenges for capacity development initiatives in Member States. Key groundwater challenges facing the SADC region were identified as, water supply vulnerability (compounded by climate change, anthropogenic contamination geogenic contamination, land subsidence, seawater intrusion issues to do with long term sustainability, weak institutional frameworks for transboundary aquifer management, general paucity of data and limited data sharing. A roadmap to address these challenges was developed as part of the capacity needs assessment. The roadmap outlined a process of selection of, and design of training initiatives linking transboundary and national aquifer management, research on groundwater challenges and groundwater infrastructure promotion. Over the years capacity development and research initiatives implemented by the SADC-GMI have been guided by the roadmap.

The special session will provide an opportunity to reflect on the region's capacity building and research efforts in the water sector, and to seek ways to create synergies and to make the existing and future initiatives more responsive to groundwater challenges facing the SADC region.

This special session will:

1. Reflect on the Roadmap for groundwater management capacity development in SADC.
2. Discuss the key groundwater challenges facing the region from multiple lenses
3. Explore options to invigorate and refocus the direction of capacity development and groundwater research for the SADC region
4. Forge partnership amongst key stakeholders to address capacity development and the research focus for the SADC region.
The African Ministers' Council on Water (AMCOW) launched the Pan-African Groundwater Program (APAGroP) in 2018. The program is a response to the AMCOW Ministers' request at Gabon to revitalise efforts on groundwater to accelerate impact through Africa's water security. Groundwater networks and institutions across the continent have in turn committed to support the program. One of the core deliverables of the APAGroP is a Groundwater Country Support Tool (CST), aimed at supporting Member States to make the most of their groundwater resources by enhancing sustainable groundwater development and management in line with national development aspirations. There are two dimensions to this support: the CST enables the country to plan, diagnose and to strategize, but equally important, once a country has done that, it mobilizes partners to support the enabling environment and to finance the investments required to move the country towards its desired future state.

This session will:
1. Present an overview of the APAGroP
2. Present the CST and the results emanating from the piloting project in Namibia
3. Discuss ways of rolling out development of the CST in other SADC Member States
4. Explore synergies between the National Policy Legal and Institutional(PLI) Roadmaps and the CST.
We would like to thank the organizing partners and Sponsors for their contribution in making the 4th SADC Groundwater Conference a huge success. Your continued support is highly appreciated.

Sponsors:

SADC - Groundwater Management Institute

SADC-GMI is a subsidiary structure of the SADC Secretariat. SADC-GMI’s core mandate is to promote sustainable groundwater management and provides solutions to groundwater challenges in SADC through creating an enabling policy, legal and regulatory environment; capacity building; advancing research, supporting infrastructure development; and enabling dialogue and accessibility of groundwater information. www.sadc-gmi.org

International Union for Conservation of Nature – IUCN

The IUCN is a membership Union uniquely composed of both government and civil society organisations. It provides public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together. The IUCN Water Programme aims to inspire evidence-based and adaptive change in water resource management that benefits nature and people. In Eastern and Southern Africa, the water programme provides nature-based solutions to unlock water management and governance challenges and opportunities, investments in natural infrastructure and water for development, while mainstreaming knowledge management, climate change, gender and indigenous peoples’ rights in all our solutions. www.iucn.org

BRIDGE- Building River Dialogue and Governance

BRIDGE (Building River Dialogue and Governance) supports the capacities of countries sharing river or lake basins to implement effective water management arrangements through a shared vision, benefit-sharing principles and transparent and coherent institutional frameworks. Its goal is to enhance cooperation among riparian countries by applying water diplomacy at multiple levels.

IWMI - International Water Management Institute

The International Water Management Institute is a non-profit, scientific research organization focusing on the sustainable use of water and land resources in developing countries, IWMI works in partnership with governments, civil society and the private sector to develop scalable agricultural water management solutions that have a real impact on poverty reduction, food security and ecosystem health. www.iwmi.cgiar.org

GRIPP - Groundwater Solution Initiative for Policy and Practice

The GRIPP partnership, led by the International Water Management Institute (IWMI), strengthens, expands and connects current groundwater initiatives. It supports the Global Framework for Action developed by the Groundwater Governance Project funded by GEF and implemented by the UN Food and Agriculture Organization (FAO) together with UNESCO-IHP, International Association of Hydrogeologists (IAH) and the World Bank. https://gripp.iwmi.org/
Organizing Partners:

British Geological Survey (BGS)

The British Geological Survey is a world-leading geological survey and global geoscience organisation, focused on public-good science for government and research to understand earth and environmental processes. BGS is the UK’s premier provider of objective and authoritative geoscientific data, information and knowledge to help society to use its natural resources responsibly, manage environmental change and be resilient to environmental hazards. www.bgs.ac.uk

International Groundwater Resources Assessment Centre (IGRAC)

IGRAC (International Groundwater Resources Assessment Centre) facilitates and promotes international sharing of information and knowledge required for sustainable groundwater resources development and management worldwide. Since 2003, IGRAC provides an independent content and process support, focusing particularly on transboundary aquifer assessment and groundwater monitoring. www.un-igrac.org

Institute for groundwater studies (IGS)

IGS aims to be the preeminent groundwater institution in Africa for academic training and research. IGS is the leading groundwater research group in Africa on aspects related to fractured rock aquifers, industrial and mining contamination, groundwater governance, and groundwater resources. The institute conducts contract research on a wide variety of water-related topics, including mining and industrial sectors in terms of water management, minimisation of pollution, as well as understanding the nature and behaviour of South Africa’s aquifers. https://www.ufs.ac.za/natagri/departments-and-divisions/institute-for-groundwater-studies-(igs)-home

International Association of Hydrogeologists (IAH)

The International Association of Hydrogeologists (IAH/AIH) is a scientific and educational charitable organisation for scientists, engineers, water managers and other professionals working in the fields of groundwater resource planning, management and protection. Founded in 1956. IAH aims to be a leading international society for the science and practice of hydrogeology and to be a globally recognised information source and facilitator for the transfer of groundwater knowledge. www.iah.org

University of Botswana (UB)

The University of Botswana, popularly known as UB, was established in 1982 as the first institution of higher education in Botswana. The university has three campuses: one in the capital city Gaborone, one in Francistown, and another in Maun. The university is divided into six faculties: Business, Education, Engineering, Humanities, Science and Social Sciences and the University of Botswana School of Medicine, a collaboration with the University of Melbourne in Australia. https://www.ub.bw/

University of Zambia

The University of Zambia (UNZA) is a public university located in Lusaka, Zambia. It is Zambia’s largest and oldest learning institution. The university was established in 1965 and officially opened to the public on 12 July 1966. The language of instruction is English. https://www.unza.zm/