Potsdam, 31.05.2023

WASA - WATER SECURITY IN AFRICA (WASA)

WaMiNa

- Nachhaltiges und klimaangepasstes Wassermanagement im Bergbau Namibias und angrenzender Länder-

Schlussbericht

nach NKBF 2017

Zuwendungsempfänger: Universität Potsdam Mathematisch-Naturwissenschaftliche Fakultät Institut für Umweltwissenschaften und Geographie Arbeitsgruppe Bodenkunde und Geoökologie	Förderkennzeichen: 01DG21061
Vorhabenbezeichnung: WaMiNa - Nachhaltiges und klimaangepasstes Wassermanagement im Bergbau Namibias und angrenzender Länder	
Laufzeit des Vorhabens: 01.12.2021 - 28.02.2023 (verlängert bis 31.05.2023)	Berichtszeitraum 01.12.2021 – 31.05.2023
Bearbeiterin: Dr. Flavia Digiacomo (Universität Potsdam & Karlsruher Institute für Technologie) *unterstützt durch*: Prof. Dr. Stefan Norra (Universität Potsdam)	

GEFÖRDERT VOM

Bundesministerium
für Bildung
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Inhalt

I. Teil 1: Kurze Darstellung

1. Aufgabenstellung

Das Projekt "Nachhaltiges und klimaangepasstes Wassermanagement im Bergbau Namibias und angrenzender Länder" (WaMiNa) wurde am 30.11.2021 genehmigt und begann am 01.12.2021. Dieser Endbericht bezieht sich daher auf den gesamten Projektzeitraum vom 01.12.2021 (Beginn des Projektes) bis zum 31.05.2023 (Ende des Projektes einschließlich der 3-monatigen Verlängerung).

Ziel des WaMiNa-Projektes ist es, Managementstrategien für die nachhaltige Wiederverwendung von Grubenwasser und für den Schutz der umliegenden Grund- und Oberflächenwasserressourcen in Namibia und den Nachbarländern zu definieren und umzusetzen. Schwerpunkte der Projektarbeit sind daher die Überwachung und der Schutz von Gewässern, die Wiederverwendung von Grubenwasser (z.B. Bewässerung von Phytosanierungsmaßnahmen), die Folgen des Klimawandels und die entsprechend notwendige Klimaanpassung, Wassermanagement nach dem Bergbau, Biodiversität und Boden- und Grundwassersanierung sowie Schutz von Oberflächengewässern. Darüber hinaus werden auch Themen wie Wasserverteilung, Wassermanagement und Wassergerechtigkeit betrachtet.

Um das Verbundvorhaben „WaMiSAR“ zielorientiert auszurichten und vorzubereiten, wurden für das Definitionsprojekt „WaMiNa“ folgende vier Arbeitspakete (AP) definiert, die im Zuge der Projektlaufzeit erfolgreich bearbeitet und umgesetzt wurden:

- AP 0 Koordination des Gesamtprojektes
- AP 1 Aufbau eines Ausbildungsnetzwerkes
- AP 2 Etablierung des Mine Water Management Network (MiWaNet)
- AP 3 Wissenschaftliche Vorarbeiten zur Erarbeitung eines fokussierten Arbeitsprogrammes für die Hauptphase
- AP 4 Formulierung des Antrages für die Hauptphase.

2. Voraussetzungen, unter denen das Vorhaben durchgeführt wurde

Bereits vor dem Projekt WaMiNa gab es eine langjährige und enge Zusammenarbeit zwischen der Arbeitsgruppe des Projektkoordinators Prof. Norra und der Mehrzahl der assoziierten deutschen Projektpartner (z.B. **TZW, KIT-IMK-TRO, KIT-IWG, KIT-EGG, SEBA Hydrometrie**

GmbH & Co. KG, HYDROISOTOP GmbH, AQUANTEC GmbH - alle Akronyme sind im Anhang ausführlich aufgeführt) in ähnlichen Forschungs- und Themenbereichen. Ihre Expertise umfasst alle Aspekte vom Klimawandel über Wasserhaushalt, Sensorik, Monitoringkonzepte, Sanierung, Hydrogeologie und Hydrologie bis hin zu Wasserpolitik und Ökonomie, die für die Entwicklung nachhaltiger und klimaangepasster Lösungen für das Grubenwassermanagement entscheidend sind. Kooperationen bestanden u.a. im Rahmen früherer BMBF-geförderter Projekte.

Auf afrikanischer Seite wurden bereits vor der Definitionsphase des WaMiNa-Projektes erste Kontakte zu den namibischen Partnern geknüpft. Durch die Kooperation zwischen **KIT-EGG** und der Namibia University of Science and Technology (**NUST**) wurden die anderen Projektpartner in Namibia, d.h. **SASSCAL**, **ASEC** und **DRFN**, kontaktiert und nach mehreren Koordinationssitzungen ausgewählt, um als Projektkoordinatoren in Namibia am ursprünglichen WaMiNa-Projekt teilzunehmen. Darüber hinaus waren die folgenden in Namibia tätigen Bergbauunternehmen seit der Anfangsphase des Projektes beteiligt: **Gratomic** (Abbau von Graphit), Trevali (heute **Appian**, Abbau von Zink und Blei), **B2Gold** (Abbau von Gold) und **Shali** (Abbau von Kupfer und Seltenen Erden) sowie die zentrale Wasserversorgung in Namibia, **NamWater**.

In Südafrika wurden Kontakte zur Water Research Commision (**WRC)** geknüpft, das auf lokaler und regionaler Ebene eine Schlüsselrolle in der Forschung, Entwicklung und Innovation im Bereich der Wasser- und Sanitärversorgung spielt und stark in die Bergbaufolgebewirtschaftung in der Region Mpumalanga und am Orange River involviert ist, sowie zu **delta h** und **AquaMatters**, die über spezielles Fachwissen im Bereich der Grundwasserbewirtschaftung und der In-situ-Sanierung von kontaminiertem Boden und Grundwasser verfügen. Außerdem arbeitet AquaMatters eng mit dem deutschen Unternehmen **Sensatec** zusammen. Als Bergbauunternehmen hat die **Anglo American Thermal Coal** (heute **Thungela**) Interesse an dem Projekt gezeigt. Während der Umsetzungsphase spielte **Impact Catalyst** eine zentrale Rolle bei der Suche nach Kofinanzierungslösungen und der Vermittlung zwischen den südafrikanischen Bergbauunternehmen und der örtlichen Gemeinde. Der soziale Aspekt ist für ein erfolgreiches Projekt in einem Land wie Südafrika, wo das Verständnis der lokalen Gemeinschaft, ihrer Bedürfnisse und wirtschaftliche Rahmenbedingungen von größter Bedeutung ist, noch wichtiger.

3. Planung und Ablauf des Vorhabens

Um die Ziele des Projektes zu erreichen, hat die Projektkoordination mit verschiedenen - bekannten und neuen - namibischen, südafrikanischen, botswanischen und sambischen Universitäten, Institutionen, Bergbauunternehmen und Firmen, sowie zu deutschen Hochschulen und Firmen zusammengearbeitet. In diesem Zusammenhang erfolgten u.a. folgende koordinative und administrative Tätigkeiten:

- Finanzverwaltung
- Öffentlichkeitsarbeit
- Organisation von Projekttreffen, Reisen, Workshops, Vorlesungen Vor-Ort und online (Teil 2: Tabellen 1 bis 5).
- Evaluierung, Dokumentation und Protokollierung der Projektreffen (online sowie Vor-Ort).
- Vorbereitung und Durchführung mehrerer Vor-Ort-Treffen und Besichtigungen von potentiellen Standorten für Felduntersuchungen (Teil 2: Tabellen 2 and 3).
- Kontaktaufnahme und Vorstellung des Projektes bei verschiedenen Regierungsstellen und Ministerien, Forschungszentren und Universitäten, Beratungsunternehmen und Bergbauunternehmen, die in den Ländern des südlichen Afrikas tätig sind.
- Kontaktaufnahme mit mehreren Bergbauunternehmen und Organisation von Vor-Ort-Treffen in Namibia und Südafrika.
- Organisation und Durchführung von drei Reisen in südafrikanische Länder, an denen auch potenzielle deutsche Projektpartner beteiligt waren (Teil 2: Tabellen 2 and 3).
- Organisation und Durchführung des Kick-Off-Treffens (März 2022), des Stakeholder Workshops (Mai 2022) und des Workshops in Deutschland (Dezember 2022, Teil 2: Tabelle 4), bei denen Partnerorganisationen aus Deutschland, Namibia, Südafrika, Sambia und Botswana sich getroffen und gemeinsam Ideen für die Hauptphase des Projektes entwickelt haben (Teil 2: Tabellen 1 bis 5). In diesem Zusammenhang wurde die Organisation der Reisen für die assoziierten Projektpartner in jeglicher Hinsicht von der Koordination des Projektes übernommen.
- Aufbau eines Ausbildungsnetzwerkes und gemeinsame internationale Lehreinheit (Tabelle 6)
- Teilnahme an den BMBF-Info-Veranstaltung „Water Security in Africa - Stakeholder Information Event" (10.10.2022 und 05.04.2023).

Auf der Grundlage der Ergebnisse dieser Kooperationen und der ersten Voruntersuchungen werden nun zwei Anträge für die Hauptphase ausgearbeitet. Zum einen der Antrag „Sustainable and climate adapted Water Management in Mining of Southern African Region (WaMiSAR)“ unter Federführung des Lehrstuhls für Bodenkunde und Geoökologie der Universität Potsdam und zum anderen der Antrag „Assessing and improving water quality of Namibian drinking water dams (NamDam)“ unter Federführung des Technologie Zentrums Wasser (TZW) in Karlsruhe.

4. Wissenschaftlicher und technischer Stand, an den angeknüpft wurde

Die Bergbauunternehmen im südlichen Afrika haben große Fortschritte beim Wasser- und Gewässerschutz gemacht und versuchen höchsten Standards gerecht zu werden. Die Aktivitäten in der Definitionsphase haben allerdings gezeigt, dass es hier länderspezifische Unterschiede gibt und wirtschaftliche und soziale Randbedingungen die Umsetzung von Schutzmaßnahmen und Best-Practice Konzepten und Technologien erschweren. Gerade die Nutzung von in-situ und online messenden Sensorsystemen ist so gut wie nicht vorhanden. Zudem existieren Herausforderungen bei der Revitalisierung von Bergehalden und der Nutzung von Grubenwässern. Größte Schwierigkeiten ergeben sich, wenn ungesicherte Bergehalden nicht mehr von Unternehmen gemanagt werden. Daher stellt die Bergbauindustrie aufgrund von Umweltverschmutzung und Kontaminationen eine potentielle Gefahr für die Wasserressourcen dar. Um sicherzustellen, dass das verwendete Wasser den geltenden Wasserqualitätsnormen entspricht, sind eine komplexe Wasseraufbereitung und eine ständige Überwachung der Wasserqualität erforderlich. Der Bergbau wird häufig in abgelegenen Gebieten betrieben, was im Hinblick auf Umweltschutz und -überwachung berücksichtigt werden muss, beispielsweise in vergleichbaren Regionen wie Australien (Prosser et al. 2011)[1]. Befindet sich der Bergbau zudem in der Nähe von Menschen, müssen die daraus resultierenden Mensch-Umwelt-Beziehungen eruiert werden, wie Ukpai et al. (2021)[2] beispielsweise für das Anambra-Becken in Nigeria feststellen.

Viele internationale Unternehmen, die im Bergbausektor tätig sind, wie z. B. Trevali Mining (CAN), Gratomic (CAN) oder Anglo American (UK), sind derzeit auf dem neuesten Stand der Wissenschaft und Technik. Aufgrund des Klimawandels und des Bevölkerungswachstums werden jedoch dringend neue weiterführende Ansätze und Technologien benötigt, da davon auszugehen ist, dass die Länder des südlichen Afrikas in den kommenden Jahrzehnten unter einem Rückgang der verfügbaren Wasservorräte leiden werden ("TREVALI-Sustainability report 2021)[3]. Vor allem der rasant steigende Wasserbedarf der Landwirtschaft hat bereits zu verschiedenen Versuchen geführt, saures, durch Minen kontaminiertes Grubenwasser für Bewässerungszwecke zu nutzen; trotz der damit verbundenen Risiken in Form von Versalzung der genutzten Böden und einem Anstieg der Schwermetallgehalte im Boden und in landwirtschaftlichen Produkten (Jovanovic et

1 Prosser I P, Wolf L, Littleboy A 2011: Water in mining and industry. In I P Prosser: Water - science and solutions for Australia. CSIRO Publishing, Collingwood, Australia.
2 Ukpai SN, Ojobor RG, Okogbue CO, Nnabo PN, Oha AI, Ekwe AC, Nweke MO 2021: Socio-economic influence of hydrogeology in regions adjoining coal bearing formation: water policy in Anambra Basin. Water Policy 23 (3), 654-683.
3 TREVALI "Sustainability report 2021" report (https://trevali.com/site/assets/files/7310/trevali_mining_sustainability_report_2021.pdf)

al 1998, Garrido et al 2009)[4,5]. In diesem Zusammenhang ist es von entscheidender Bedeutung, eine sichere und nachhaltige Wiederverwendung von Grubenwasser in der Landwirtschaft zu ermöglichen und gleichzeitig eine zunehmende Konkurrenz um Wasser zwischen dem Bergbau und der Landwirtschaft zu vermeiden. Die Bewirtschaftung von Grubenwasser ist ein komplexer Prozess, bei dem die Bedürfnisse aller Akteure und Interessengruppen berücksichtigt werden müssen, einschließlich des Schutzes bestehender Wasserressourcen, der Vermeidung von Verschmutzung, der Erhaltung der Natur mit ihrer biologischen Vielfalt und der Ökosystemleistungen. Darüber hinaus wird die Wasserbewirtschaftung im Bergbau als industrielles Thema behandelt und unterliegt den Standards der Umwelt- und Sozialverträglichkeitsprüfung (ESIA). Daher ist die Gewährleistung einer nachhaltigen und klimaangepassten Wassersicherheit im Bergbausektor ein komplexes Unterfangen, das Wassermenge, Wasserqualität, Wasserinfrastruktur und hydraulische Aspekte mit ihren jeweiligen Auswirkungen auf Menschen und Umwelt umfasst (Abb. 1).

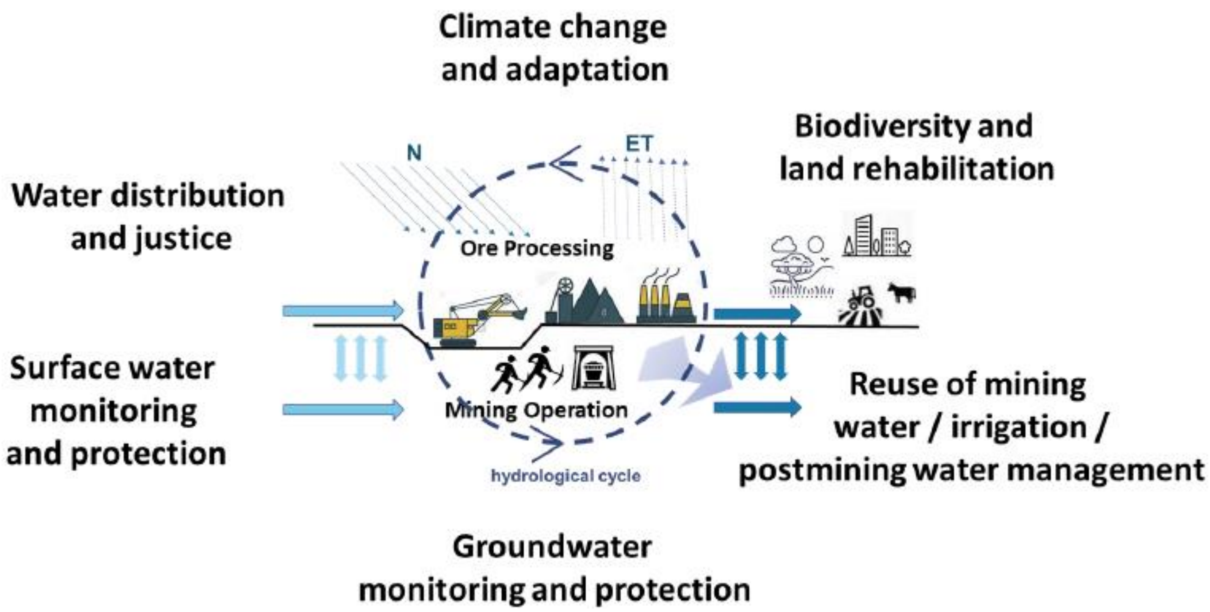


Abbildung 1 Wichtige Bereiche für den Aufbau einer nachhaltigen und klimaangepassten Wasserwirtschaft im Bergbausektor.

4 Jovanovic, N.Z., R.O.. Barnard, N.F.G. Rethman, and J.G. Annandale (1998). Crops can be irrigated with lime-treated acid mine drainage. Water SA, 24/2, 113-122
5 Garrido, A.E., Strosnider, W.H.J. and Naim, R. (2009). Acid mine drainage impacts on irrigation water resources, agricultural soils, and potatoes in Potosí, Bolivia. DOI: 10.21000/JASMR09010486

Angabe bekannter Konstruktionen, Verfahren und Schutzrechte, die für die Durchführung des Vorhabens benutzt wurden

Für den jetztigen Stand des Projektes musste noch nicht auf bekannte Konstruktionen, Verfahren und Schutzrechten zurückgegriffen werden.

Angabe der verwendeten Fachliteratur sowie der benutzten Informations- und Dokumentationsdienste

Die verwendete Fachliteratur ist den erstellten Berichten zu entnehmen.

5. Zusammenarbeit mit anderen Stellen

Während der Projektlaufzeit fand ein reger interdisziplinärer Austausch zwischen den deutschen und afrikanischen Institutionen aus Wissenschaft, Umwelt- und Sozialwissenschaften, Wirtschaft und Verwaltung statt. Der Fokus lag zunächst auf Namibia und Südafrika, doch im Laufe des Projektes wuchs das Interesse an einem noch stärker länderübergreifenden Ansatz, was zu einem Wissensaustausch mit Experten in anderen Ländern wie Botswana und Sambia und zu Überlegungen führte, einige der dort tätigen Bergbauunternehmen in das Projekt einzubeziehen.
Dennoch hat sich im Verlauf des Projektes gezeigt, auch aufgrund der zur Verfügung in Aussicht gestellten Ressourcen, für die erste vierjährige Phase des kommenden Projektes sich auf Namibia und Südafrika konzentriert werden muss, und konkrete Forschungsaktivitäten in Sambia und Botswana erst in einer möglichen Anschlussphase zum Tragen kommen können.
Alle beteiligten Experten aus Wissenschaft und Praxis wurden eingeladen, an den Treffen der Interessengruppen teilzunehmen und ihre Vorschläge und Beiträge einzubringen (Tables 1 to 5). Darüber hinaus waren sie Teil des Bergbauwassernetzwerks (MiWaNet), einer Plattform, die vor Beginn des WaMiNa-Projektes eingerichtet wurde und während der Projektlaufzeit erheblich wuchs. Die Idee dahinter ist, dass die Mitglieder über diese Plattform Wissen, Ideen, Konzepte und Methoden austauschen, um angepasste Bergbauwassermanagementkonzepte zu entwickeln, die die Wassersicherheit in der südafrikanischen Region gewährleisten. Innerhalb des MiWaNet-Konsortiums wurden während der Projektlaufzeit eine Reihe von Seminaren und Workshops (in Präsenz und hybrid) durchgeführt (Tabelle 6).

II. Part 2: Detailed presentation

1. The use of the grant and the result achieved in detail, with a comparison of the specified objectives

In order to align and prepare the "WaMiSAR" project in a targeted manner, the following four work packages (WP) were defined for the initial application of the "WaMiNa" definition project:

WP 1 Establishment of a training network

WP 2 Developing the platform Mine Water Management Network (MiWaNet) between South African and German partners from mining sector, research institutions, authorities and consultancies

WP 3 Scientific preparatory work for the development of a focused work program for the main phase

WP 4 Formulation of the application for the main phase and its networking in the local structures

The **WP 0** was dedicated to the coordination of the overall project.

The following is a detailed description of the objectives and activities assigned to these work packages as well the results achieved during the running time of the project.

WP 0: Coordination of the overall project

In order to achieve the objectives of the project, the project coordination has worked with various Namibian, South African, Botswana and Zambian universities, institutions, mining companies and firms, as well as with German universities and companies. A series of meetings and activities were organised and carried out during the project period, which are listed in Tables 1 to 5. The main meetings and activities are described in detail below.

The **Kick-Off Meeting** took place on 03.02.2022 and was held online due to the COVID-19 pandemic (Table 1). Nevertheless, the first on-site meetings in Namibia, South Africa and Zambia from 06.03.2022 to 16.03.2022 were of great importance to lay the foundation for a future solid cooperation with the local partners (Table 2). Successful meetings were indeed held with the **SLR Consulting**, the **German Embassy in Windhoek** and visits to the facilities of the desalination plant in Swakopmund, at the **Shali Group holdings** (extracting Copper and Rare Earth Elements), and in **Klein Aub** (extracting Copper). Furthermore, during the mentioned meetings it was possible to discuss in detail the project ideas, the project status and the expectations of the local partners and stakeholders. During this travel, also the coal mine residue deposits at **Mafube** in North-East

South Africa were visited and a comprehensive meeting with representants of mine operation and research was carried out (Table 2).

During the stakeholder workshop, which was held on 30-31.05.2022 in Windhoek and in hybrid form, the project coordination team and all participants were able to present their potential project contributions and express their interest in working with other partners (Table 3). During this visit, the project coordination team together with other representatives of the MiWaNet platform held some lectures for the students of the Namibia University of Science and Technology (**NUST)** (Table 6). In addition to that the mine residue deposits in Klein Aub, the mining complex at the **Rosh Pinah Zinc Corporation** (extracting Zinc and Lead) and the **Copper Hut in Tsumeb** was visited.

The organisation and implementation of the workshop held in Germany from 05.12.2022 to 07.12.2022, (Table 4) was of great importance in order to prepare the contents of the WaMiSAR project in a targeted manner. In addition to the symposium, conference, presentations and networking activities, the representatives of of the MiWaNet had the opportunity to visit on 06.12.2022 the “Groupement d'intérêt scientifique sur les friches industrielles” (GISFI), in Homécourt near Metz in France (Fig. 3). GISFI is a field laboratory that investigates the potentials of brownfield soils for phytoremediation and biomass production, and in recent years has also focused on agromining concepts to reprocess mining residues or to use appropriate plants to extract valuable metals from metal-rich soils and corresponding rocks. This knowledge is of high interest to the WaMiNa project and its stakeholders organized within the MiWaNet to develop concepts for the use of mine discharge water and mine waste materials with respect to optimize water security in the post mining water management. At the end of the German workshop, a visit to the Schauinsland museum mine (Museums-Bergwerk Schauinsland) took place (Fig. 4). This mine complex that was created to yield silver, lead and zinc, is located near Freiburg and is the largest in the Black Forest and the Vosges Mountains whit a mine length of approx. 100 km, spread over 22 floors. This visit was very informative and inspiring, expecially for the representatives of Rosh Pinah mine, who are planning to set up an underground museum in their facilities.

The series of meetings organised as part of the trip to Namibia, South Africa and Botswana from 11.02.2023 to 21.02.2023 (Table 5) facilitated the interest of other mines such as **Dundee** (Tsumeb, Namibia), intensified collaboration with the Water Research Commission (**WRC)** and **Impact Catalyst** in South Africa and allowed a visit to the infrastructure of the Botswana International University of Science and Technology (**BIUST)** in Palapye, Botswana. Representative water samples were also taken at the Van Bach and Goreangab reservoirs in Namibia and at the lake in the Brugspruit area.

Furthermore, during the numerous online meetings it was possible to discuss in detail the project ideas, the project status and the expectations of the local partners and stakeholders (Table 1).
In coordinating activities and meetings in Namibia, as well as in contacting Namibian governments, organisations and foundations, the project partners A. Speiser Environmental Consultants CC (**ASEC**) and Desert Research Foundation of Namibia (**DRFN**) played a key role, i.e. in identifying local co-financing opportunities and establishing contact with various mining companies in order to build up trustful communication with their environmental departments. Southern African Science Service Centre for Climate Change and Adaptive Land Management (**SASSCAL**) and **NUST**, which was involved with two faculties (Department of Agriculture and Natural Resources Sciences (**ANR**), Department of Mining and Process Engineering (**MPE**)" and the Project Services Uni (**PSU**), provided the infrastructure for the organisation of MiWaNet seminars and lectures (Table 6) as well as for the project meetings in Windhoek, and organised, among other things, contact and visits to the abandoned mine "Klein Aub".

The following tables summarise the many activities, meetings, trips and topics, as well as the list of participants:

- Table 1 lists the main meetings (online, hybrid and on-site) and activities that took place during the running time of the project. A large number of other bilateral or multilateral meetings or discussions took place, but they are not all detailed in this report.
- Tables 2 and 3 list the meetings and activities that took place during the trip to Namibia, South Africa and Zambia in March 2022 and the trip to Namibia and South Africa in May 2022, respectively.
- Table 4 lists the meetings with German, Namibian, South African, Botswana and Zambian representatives of authorities, institutions, universities, companies and potential partners as well as activities that took place within the WaMiNa project during the workshop in Karlsruhe in December 2022.
- Table 5 lists the meetings and activities that took place during the the trip to Namibia, South Africa and Botswana in February 2023.

Table 1 List of meetings with representatives of the German, Namibian, South African, Zambian, Botswana authorities institutions, universities, companies and potential partners as well as activities that took place during the WaMiNa project.

No.	Date and place	Description
1.	12.01.2022 (Online Meeting)	**Project meeting with SASSCAL** Topic: Discussion to prepare the draft proposal for the WASA main phase and to prepare the kick-off meeting; exchange on the next missions to Namibia to get to know the local partners. Participants: S. Norra (UP), N. Börsig (KIT-AGW), F. Dörr (KIT-AGW), P. Hamukwaya (SASSCAL), H. Black (SASSCAL), M. Siswapi (SASSCAL)
2.	16-01-2022 (Online Meeting)	**Project meeting** Participants: S. Norra (UP), H. Köthe (ICWRGC)
3.	18-01-2022 (Online Meeting)	**Project meeting** Participants: S. Norra (UP), N. Börsig (KIT-AGW), F. Dörr (KIT-AGW), M. Schneider (DRFN), A- Speiser (ASEC)
4.	03.02.2022 (Online Meeting)	**Inception and Kick-Off Meeting** Topic: Project meeting to present the BMBF WaMiNa project, the project ideas, the project structure and the goals as well as the participating partners; presentation of the proposal for the working structure of the WaMiNa project for the next months; determination of topics for further meetings; agreement on a joint schedule. 32 participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS, UZ, IC, NUST, TZW, Sensatec, AquaMatters, SEBA, Dundee, MAWLR, WRC, UWH-IEEM, Hyd, Piewak & Partner Company
5.	10.02.2022 (Online Meeting)	**Project meeting** Participants: S. Norra (UP), J. Helmschroth (KIT-IMK), A. Fink (KIT-IMK)
6.	25.02.2022 (Online Meeting)	**MiWaNet Meeting** Topic: Introduction of MiWaNet members, introduction of participants to their activities, skills, resources and goals; presentations (including background, project ideas, possible cooperation) by the various partners. 35 participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS, UZ, IC, NUST, TZW, Sensatec, Thugela, AquaMatters, SEBA, Dundee, WRC, UWH-IEEM, Trevali, BGR, Gratomic
7.	04.-17.03.2022	**Trip to Namibia, South Africa and Zambia** Travellers: S. Norra (UP), N. Börsig (KIT-AGW), F. Dörr (KIT-AGW) **Activities and details in Table 2**
8.	24.03.2022 (Online Meeting)	**Meeting with DRFN (MoU)** Participants: S. Norra (UP), M. Schneider (DRFN)
9.	13.04.2022 (Online Meeting)	**Meeting with Sensatec** Participants: S. Norra (UP), S. Hüttmann (Sensatec) ----------------- **Meeting with DRFN (MoU)** Participants: S. Norra (UP), M. Schneider (DRFN)
10.	20.04.2022 (Online Meeting)	**Meeting with Mine Water Education Network (Wa-Edu-Net)**

No.	Date and place	Description
		Topic: Project meeting to present the BMBF WaMiNa project, the project ideas, the project structure and objectives as well as the participating partners; introduction to the objectives of the "Education Network" as well as the IWRM courses of SASSCAL and the participating universities. Discussion on the cooperation framework between universities; creation of the seminar series within the MiWaNet platform. 25 participants: UP, KIT-AGW, Aquantec, UASL, BgR, NUST, NUST-PSU, NUST-MPE, BIUST, UFS, IC, ZU, SASSCAL, WRC, MoF
11.	22.04.2022 (Online Meeting)	**Meeting** Subject: Collusion with CoHydrim-SA Participants: S. Norra (UP), H. Köthe (ICWRGC), L. Bharathi
12.	03.05.2022 (Online Meeting)	**Project meeting** Topic: Preparation of the workshop in Namibia Participants: N. Börsig (KIT-AGW), F. Dörr (KIT-AGW), R. Munyayi (NUST-PSU), P. Mabuku (NUST-PSU)
13.	12.05.2022 (Online Meeting)	**Project meeting** Topic: Preparation of the workshop in Namibia Participants: R. Munyayi (NUST-PSU), P. Mabuku (NUST-PSU), A. Speiser (ASEC)
14.	19.05.2022 (Online Meeting)	**Project meeting** Topic: Preparation of the workshop in Namibia Participants: N. Börsig (KIT-AGW), F. Dörr (KIT-AGW), R. Munyayi (NUST-PSU), P. Mabuku (NUST-PSU)
15.	29.05-05.06.2022	**Trip to Namibia and South Africa** Travellers: S. Norra (UP), F- Eichinger (Hyd), P. Rinkel (Aquantec), K. Richter (Aquantec), S. Tirivarombo (BIUST) **Activities and details in Table 3**
16.	01.07.2022 (Online Meeting)	**Meeting with NamWater** Topic: Discussion and exchange about algae problems Participants: S. Norra (UP), F- Eichinger (Hyd), A. Tiehm (TZW), J. Sirunda (NamWater)
17.	06.07.2022	**Meeting with BIUST** Participants: S. Norra (UP), S. Tirivarombo (BIUST), P. Eze (BIUST), T. Binetsi (BIUST). J. Jendow (BIUST)
18.	25.08.2022 (Online Meeting)	**Planning meeting** Topic: Organisation of the series of seminars within the framework of the MiWaNet platform. Discussion of the current project status, the reports to be prepared as well as discussion of the next steps to prepare the draft application for the WASA main phase. Participants: S. Norra (UP), F. Digiacomo (KIT-AGW), R. Munyayi (NUST-PSU); P. Mabuku (NUST)
19.	14.10.2022 (Online Meeting)	**Project meeting**

No.	Date and place	Description
		Topic: Report on the BMBF stakeholder meeting on 10.10.22, organisation of the workshop in Germany in December. Discussion about the project proposal, possible contributions of the individual partners. Participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS, delta h UZ, IC, NUST, TZW, Sensatec, Thugela, AquaMatters, SEBA, Dundee, MAWLR, WRC, UWH-IEEM
20.	05.-09.12.2022	**Workshop in Germany** Travellers: A. Speiser (ASEC), D. Saymann (Rosh Pinah ZC), K. Witthüser (delta h), S. Tirivarombo (BIUST), P. Eze (BIUST), C. Harding (Impact Catalyst), I. Nyambe (ZU) M. Schneider (DRGN), G. Schneider (NUI) 35 participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS/Delta h, UZ, IC, DRFN, NUST, NUI, JIG, TZW, Hyd, UASL, Sensatec, Thugela, AquaMatters, UWH-IEEM, SLR-EC, Trevali, SEBA **Activities and details in Table 4**
21.	11.03-21.03.2023	**Trip to Namibia and South Africa** Travellers: S. Norra (UP), F.Digiacomo (UP & KIT-AGW), F. Eichinger (Hyd) **Activities and details in Table 5**
22.	20.04.2023 (Online meeting)	**Project meeting** Topic: Discussion about the application structure, the evaluation criteria, the WP and the partners. Participants: S. Norra (UP), F. Digiacomo (UP, KIT-AGW), E. Eiche (KIT-AGW), T. Gil-Diaz (KIT-AGW), K. U. Rudolph (UWH-IEEM), A. Tiehm (TZW), C. Richter (Aquantec), F. Eichinger (Hyd), S. Hütmann (Sensatec), C. Külls (UASL), K. Witthüser (Delta h, UFS)
23.	03.05.2023 (Online meeting)	**Coordination meeting** Topic: Exchange on the final report and outline as well as contributions to the main phase of the project, discussion on the WP and the distribution of activities. Participants: S. Norra (UP), F. Digiacomo (UP, KIT-AGW), A. Speiser (ASEC), M. Schneider (DRFN), G. Schneider (NUI)
24.	08.05.2023 (Online meeting)	**Coordination meeting** Topic: Exchange on the final report and outline as well as contributions to the main phase of the project, discussion on the WP and the distribution of activities. Participants: S. Norra (UP), F. Digiacomo (UP, KIT-AGW), A. Speiser (ASEC), M. Schneider (DRFN), K. Richter (Aquantec), K. U. Rudolph (UWH-IEEM), A. Tiehm (TZW), F. Eichinger (Hyd), S. Hütmann (Sensatec), C. Külls (UASL), K. Witthüser (Delta h, UFS)
25.	09.05.2023 (Online meeting)	**Coordination meeting** Topic: Exchange on the status of the reports, exchange on the outline for the main phase of the project, the contributions to the main phase of the project and the WP and distribution of activities. Participants S. Norra (UP), F. Digiacomo (UP, KIT-AGW), H. Musiyarira (NUST), R. Munyayi (NUST)
26.	09.05.2023 (Online meeting)	**Coordination meeting**

No.	Date and place	Description
		Topic: Exchange on the outline for the main phase of the project, the contributions to the main phase of the project and the WP and the distribution of funds and activities. Participants S. Norra (UP), T. Wassenaar (NUST)
27.	10.05.2023 (Online meeting)	**Meeting with Impact Catalyst** Topic: Exchange on the outline for the main phase of the project, the contributions (including WP 4.2, Brugspruit, Isibonelo, field investigations, exchange of students, scientists, technicians and trainees, gender aspects and social inclusion) to the main phase of the project, and the WP and distribution of activities. Participants S. Norra (UP), Rory Baker, N. Greyling (IC), C. Harding (IC), S. Hüttmann (Sensatec), L.S. Kuhr (Sensatec), M. Romijn (IC)
28.	12.05.2023 (Online meeting)	**Meeting with Rosh Pinah ZC** Topic: Exchange on the outline for the main phase of the project, the contributions (including pytoremediation, use of mine water for revegetation, sensor system for groundwater monitoring, in-kind contribution) to the main phase of the project and the WP and distribution of activities. Participants S. Norra (UP), D. Saymann (Rosh Pinah ZC), A. Speiser (ASEC), K. Richter (Aquantec)
29.	15.05.2023 (Online meeting)	**Meeting with Impact Catalyst** Topic: Exchange on the outline for the main phase of the project (WP 4.2) Participants: S. Norra (UP), Rory Baker, N. Greyling (IC), C. Harding (IC), K.U. Rudolph (UWH-IEEM)
30.	16.05.2023 (Online meeting)	**Meeting with Dundee** Topic: Presentation of the plan for the main phase of the project, exchange on the contributions (pytoremediation, groundwater remediation (prevention of as-leaching), laboratory analyses (including mineralogical and chemical analyses), identification of historical mining waste, in-kind contribution) to the main phase of the project and the WP and distribution of activities. LoI. Participants S. Norra (UP), F. Digiacomo (UP & KIT/AGW), S. Hüttmann (Sensatec), A. Tiehm (TZW), L. Stelmaszyk (TZW), H. Ylikangas (Aquamatters), V. Kavindjima (Dundee) C Sililo (Dundee), I. Iyambo (Dundee), K. Kamundu (Dundee)
31.	16.05.2023 (Online meeting)	**Coordination meeting** Topic: Sharing the distribution of funds, activities and possible field work. Participants: S. Norra (UP), F. Digiacomo (UP & KIT/AGW), S. Hüttmann (Sensatec), A. Tiehm (TZW), L. Stelmaszyk (TZW), H. Ylikangas (Aquamatters)
32.	17.05.2023 (Online meeting)	**Meeting with B2Gold** Topic: Presentation of the plan for the main phase of the project, exchange on the contributions (i.e. groundwater 'monitoring, water balance model, laboratory analyses (i.e. mineralogical and chemical analyses), in-kind contribution) to the main phase of the project as well as the WP and the distribution of activities. LoI. Participants S. Norra (UP), F. Digiacomo (UP & KIT/AGW), A. Akanandjembo (B2Gold)
33.	19-05-2023 (Online meeting)	**MiWaNet Meeting** Topic: Exchange on the outline for the main phase of the project, the contributions to the main phase of the project and the WP and the distribution of activities 25 Participants

No.	Date and place	Description
34.	22.05.2023 (Online meeting)	**Meeting with Impact Catalyst and South African Partners** Topic: Exchange on the work for the application for the main phase of the project, the contributions to the main phase of the project and the WP and the distribution of activities (WP 4.2, work at Brugspruit, Isibonelo); LoI, in-kind contribution, tandem PhD students co-funding possibilities. Participants S. Norra (UP), F. Digiacomo (KIT-AGW 6 UP), C.Harding (IC), L. S. Kuhr (Sensatec); N. Greyling (IC), R. Baker (IC), K. Witthüser (delta h), M. Romijn (IC)

Table 2 *List of meetings with representatives of Namibian, South African and Zambian authorities, institutions, universities, companies and potential partners as well as activities that took place within the framework of the WaMiNa project during the trip to Namibia, South Africa and Zambia in March 2022.*

No.	Date and place	Description
1.	06.03.2022 (Swakopmund, NA)	**Arrival in Windhoek and meeting with ASEC** Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), A. Speiser (ASEC),
2.	06.03.2022 (Swakopmund, NA)	**Project meeting** Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), A. Speiser (ASEC), M. Schneider (DRFN), G. Schneider (NUI)
3.	07.03.2022 (Swakopmund, NA)	**Project meeting** Topic: DRFN mission, role of Uranium Institute, mining in Namibia ----------------- **Visit to the Orano desalination plant near Swakopmund** (Fig. 1) Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), A. Speiser (ASEC), M. Schneider (DRFN), G. Schneider (NUI).
4.	08.03.2022 (Windhoek, NA)	**Project meeting** Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), M. Schneider (DRFN), G. Schneider (NUI)
5.	07.03.2022 (NUST, Windhoek, NA)	**Project meeting** Topic: Presentation of the BMBF WaMiNa project, the project ideas of the NUST participants and about project ideas applicable in NA. Organisation of the next workshop and lectures in Namibia in May/June. Exchange about possibilities for research, training (including "sandwisch PhDs") and exchange within the framework of the main project. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), M. Schneider (DRFN), G. Schneider (NUI), A. Speiser (ASEC)
6.	09.03.2022 (NUST, Windhoek, NA)	**Meeting with NUST** Topic: Presentation of the BMBF WaMiNa project, the project ideas of the NUST participants and about project ideas applicable in NA. Organisation of the next workshop and lectures in Namibia in May/June. Exchange about possibilities for research, training (including "sandwisch PhDs") and exchange within the framework of the main project.

No.	Date and place	Description
		Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), A. Matro-Gorese (NUST-PSU), M. Pillalamarry (NUST-MPE), T. Wassenaar (NUST-ANR), R. Munyayi (NUST-PSU), B. Mapani (NUST-PSU) ----------------- **Meeting with Shali Group (exploration company)** Topic: Presentation of the BMBF WaMiNa project and the project ideas, exchange about concepts and possible pilot sites with an exploration company. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), W. Shali, K. Nambala
7.	10.03.2022 (Windhoek, NA)	**Meeting with the Ministry of Agriculture** Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), Mrs. Amakali (Ministry of Agriculture) ----------------- **Field Visit to Klein Aub Mining** Visit to a disused mine and its current water management concept. Test installation of the water content sensor system brought from Germany. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), M. Pillalamarry (NUST-MPE), T. Wassenaar (NUST-ANR) ----------------- **Meeting with SLR-EC** Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), A. Bittner (SLR-EC) Topic: Presentation of the BMBF WaMiNa project and the project ideas,
8.	11.03.2022 (Windhoek, NA)	**Meeting at the German Embassy** Topic: Presentation of the BMBF WaMiNa project, exchange about current projects in Namibia that are funded by the German side. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), H. Beck (German Ambassador in Namibia) ----------------- **Meeting with Rosh Pinah ZC** Topic: Presentation of the BMBF WaMiNa project, discussion on current water management concepts and water quality monitoring at Rosh Pinah mines. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), D. Saymann (Rosh Pinah ZC)
9.	12.03.2022 (Pretoria,SA)	**Working meeting** Topic: Presentation of the BMBF WaMiNa project, discussion on remediation concepts in mines and mining. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), K. Witthüser (UFS, Delta h), H. Yilikangas (AquaMatters)
10.	13.03.2022 (Pretoria,SA)	**Project meeting** Topic: Presentation of the BMBF WaMiNa project and exchange on the inclusion of socio-economic aspects as well as project ideas applicable in SA. Idea to create a list of mine water irrigation projects.

No.	Date and place	Description
		Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW) Y. van Wyk (WRC) R. Muhlbauer (Thungela), C. Harding (IC), K. Witthüser (UFS, Delta h), E. Lukas (UFS),
11.	14.03.2022 (Mafube, Pretoria,SA)	**Excursion to the Mafube Coal Mine** **Guided tour of the mining areas and facilities of the Mafube coal mine** ----------------- **Project meeting** Topic: Exchange of project ideas applicable in SA and possible cooperation. Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW), R. Muhlbauer (Thungela)
12.	16.03.2022 (IP, Lusaka, SA+hybrid)	**Meeting at the University of Zambia** (Fig. 2) Topic: Presentation of the BMBF WaMiNa project and exchange of project ideas applicable in Zambia, Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW) I. Nyambe (UZ) and about 25 other persons. **Meeting at the German Embassy** Topic: Presentation of the BMBF WaMiNa project, exchange on current projects in Zambia with German funding, together with representatives of GIZ Participants: S. Norra (UP), F. Dörr (KIT-AGW), N. Börsig (KIT-AGW) I. Nyambe (UZ), GIZ,

Table 3 *List of meetings with representatives of Namibian and South African authorities, institutions, universities, companies and potential partners as well as activities that took place within the framework of the WaMiNa project during the trip to Namibia and South Africa in May-June 2022.*

No.	Date and place	Description
1.	30.05.2022 (Windhoek, NA+hybrid)	**Stakeholder workshop** Topic: Exchange on the state of science, adoption of cooperation agreements, presentation of the BMBF WaMiNa project. Project status report and discussion of the status report, presentation of the potential project contributions of each institution/company. Exchange about possibilities for research, training and exchange within the main project. Participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS, Delta h, UZ, IC, DRFN, NUST, TZW, Hyd., UASL, Sensatec, Thugela, AquaMatters, UWH-IEEM, SLR-EC, Trevali, SEBA, Dundee, MAWLR, Gratomic, NUI **Lectures for WRM** Speakers: S. Norra (UP), F. Eichinger (Hyd), K. Richter (Aquantec)
2.	31.05.2022 (Windhoek, NA+hybrid)	**Stakeholder workshop** Topic: Presentation of the potential project contributions of each institution/company, involvement of potential funders, exchange of opportunities for research, training and exchange within the framework of the main project as well as possible cooperation partners. Participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS, Delta h, UZ, IC, DRFN, NUST, TZW, Hyd, UASL, Sensatec, Thugela, AquaMatters, UWH-IEEM, SLR-EC, Trevali, SEBA, Dundee, MAWLR, Gratomic, NUI
3.	01.06.2022 (NA) (Tsumeb, NA)	**Tour of Klein Aub** Participants: S. Norra (UP), F. Eichinger (Hyd), K. Richter (Aquantec), A. Speiser (ASEC), S. Tirivarombo (BIUST), M. Pillalamarry (NUST-MPE), B. Mapani (NUST-PSU) ----------------- **Visit to Dundee** Participants: G. Christelis, P. Rinkel, (Aquantec) K. Richter (Aquantec)
4.	03.06.2022 (Rosh Pinah, NA)	**Visit Rosh Pinah ZC Mine & Namwater** Participants: S. Norra (UP), A. Speiser (ASEC) D. Saymann (Rosh Pinah ZC), Richter (Aquantec), B. Mapani (NUST-PSU)

Figure 1 *Visit to the Orano desalination plant near Swakopmund, March 2022 (top left and right and bottom left). Group picture after the visit to the Namibian Uranium Institute (NUI), March 2022 (bottom right).*

Figure 2 *Meeting at the University of Lusaka, Zambia, March 2022.*

Table 4 *List of meetings with German, Namibian, South African, Botswana and Zambian representatives of authorities, institutions, universities, companies and potential partners as well as activities that took place within the WaMiNa project during the workshop in Karlsruhe in December 2022.*

No.	Date and place	Description
1.	05.12.2022 (Karlsruhe, DE+hybrid)	**Workshop** (Fig. 3) Topic: Project status report, presentations by the participants and discussion of the status report; presentation of the potential project contributions of each institution/company. Exchange on the current focus of project development, mines in Southern African countries that can be included in the project; exchange on opportunities for research, training and exchange within the main project. Participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS/Delta h, UZ, IC, DRFN, NUST, NUI, JIG, TZW, Hyd, UASL, Sensatec, Thugela, AquaMatters, UWH-IEEM, SLR-EC, Trevali, SEBA.
2.	06.12.2022 (GISFI, FR)	**Visit to GISFI, Home-court, Lorraine, France** (Fig. 3) Participants: UP, KIT-AGW, ASEC, BIUST, UFS/Delta h, UZ, DRFN, NUST, NUI, JIG, Sensatec, Trevali.
3.	07.12.2022 (Karlsruhe, DE+hybrid)	**Visit to the LURA laboratory (KIT) and TZW laboratory + workshop** Topic: Discussion of the ongoing work and the next steps in preparing the draft proposal for the main WASA phase (including MiWaNet, and Education and Training Network). Preparation of the draft proposal for the WASA main phase, definition of work packages and tasks. Participants: UP, KIT-AGW, KIT-IMK, ASEC, BIUST, UFS/Delta h, UZ, IC, DRFN, NUST, NUI, JIG, TZW, AU Lübeck, Sensatec, Thugela, AquaMatters, UWH-IEEM, SLR-EC, Trevali, SEBA, WRC
4.	09.12.2022 (Freiburg, DE)	**Tour of the Schauinsland Museum Mine** (Fig. 4) Participants: UP, KIT-AGW, ASEC, BIUST, UZ, IC, NUST, Trevali

Figure 3 *Group picture of MiWaNet members during the workshop in Karlsruhe (Karlsruhe Institute of Technology, KIT), Germany (left) and visit to GISFI, Home-court, Lorraine, France, December 2022 (right).*

Figure 4: Highlights of the visit to the Schauinsland Museum Mine, Germany, December 2022.

Table 5 List of meetings with German, Namibian, South African and Botswana representatives of authorities, institutions, universities, companies and potential partners as well as activities that took place in the framework of the WaMiNa project during the trip to Namibia, South Africa and Botswana in February 2023.

No.	Date and place	Description
1.	12.02.2023 (Windhoek, NA)	**Project meeting** Topic: Discussion of the current project status, the reports to be prepared as well as discussion of the next steps to prepare the draft application for the WASA main phase. Participants: B. Mapani (NUST), S. Norra (UP), F. Digiacomo (UP), A. Speiser (ASEC)
2.	13.02.2023 (Windhoek, NA+hybrid)	**Meeting with NamWater** Topic: Presentation of the BMBF WaMiNa project, exchange about possibilities for research, training and exchange within the main project. Presentation of a second project idea (i.e. NamDam) and exchange on the preparation of the draft application for the WASA main phase. Participants: S. Norra (UP), F. Digiacomo (UP & KIT-AGW), P), F. Eichinger (Hyd.), A. Tiehm (TZW), J. Sirunda (NamWater), B. Swartz (MAWLR)
3.	14.02.2023 (Dundee, Tsumeb, NA)	**Meeting with Dundee (Fig. 5)** Topic: Presentation of the BMBF WaMiNa project, exchange about possibilities for research, training and exchange within the main project. Participants: S. Norra (UP), F. Digiacomo (UP & KIT-AGW), A. Speiser (ASEC), F. Eichinger (Hyd), G. Christelis (AquaMatters), S. Hüttmann (Sensatec), H. Yilikangas (AquaMatters), DPMT Key Executives Dundee
4.	14.02.2023 (Windhoek, NA)	**Visit to the Van Bach dam + Water sampling** Participants: S. Norra (UP), F. Digiacomo (UP), A. Speiser (ASEC), F. Eichinger (Hyd.).
5.	15.02.2023 (Windhoek, NA)	**Meeting with the Head of the Environmental Geology Department at the Geological Survey in Namibia** Topic: Presentation of the BMBF WaMiNa project, exchange about possibilities for research, training and exchange within the main project.

No.	Date and place	Description
		Participants: I. Hasheela, S. Norra (UP), F. Digiacomo (UP & KIT-AGW), A. Speiser (ASEC), G. Schneider (NUI)
6.	15.02.2023 (Windhoek, NA)	**Visit to the Goreangab reservoir + Water sampling** Participants: S. Norra (UP), F. Digiacomo (UP & KIT-AGW)
7.	15.02.2023 (Windhoek, NA)	**Project meeting** Topic: Exchange on the preliminary results of the definition phase of the project and the reports to be prepared as well as discussion of the next steps to prepare the draft application for the main WASA phase. Participants: T. Wassenaar (NUST), S. Norra (UP), F. Digiacomo (UP & KIT-AGW), A. Speiser (ASEC), F. Eichinger (Hyd), A. Bittner (SLR).
8.	16.02.2023 (Brugspruit, SA)	**Visit to: Brugspruit (SA) + Water sampling (Fig. 5 and 12)** Participants: C. Harding (IC), S. Norra (UP), F. Digiacomo (UP & KIT-AGW), F. Eichinger (Hyd), S. Hüttmann (Sensatec), H. Yilikangas (AquaMatters).
9.	17.02.2023 (CSIR, Pretoria, SA+hybrid)	**Workshop (Fig. 5)** Topic: Presentation of the BMBF WaMiNa project, discussion of the current project status, exchange on opportunities for research, training and exchange within the framework of the main project as well as discussion of the next steps to prepare the draft application for the WASA main phase (including exchange on BMBF and WRC announcements, work packages, socio-economic toolbox). Participants: C. Harding (IC), N. Greyling (IC), S. Norra (UP), F. Digiacomo (UP & KIT-AGW), F. Eichinger (Hyd), S. Hüttmann (Sensatec), H. Yilikangas (AquaMatters), R. Muhlbauer (Thungela), Y. von Wyk (WRC), K. Witthüser (USF)
10.	18.02.2023 (Pretoria, SA)	**Project meeting** Topic: Discussion of the current project status and discussion of the next steps Preparation of the draft application for the WASA main phase. Participants: S. Norra (UP), F. Digiacomo (UP & KIT-AGW), F. Eichinger (Hyd.)
11.	20.02.2023 (CSIR, Pretoria, SA)	**Visit to the CSIR laboratories** Participants: C. Harding (IC), S. Norra (UP), F. Digiacomo (UP & KIT-AGW).
12.	21.02.2023 (BIUST, Palapye, BO)	**Meeting with the Department of Water and Sanitation Affairs + Visit to the waste water semi purification plant (Fig. 6)** Topic: Presentation of the BMBF WaMiNa project, exchange about possibilities for research, training and exchange within the main project. Visit pilot test using semi-purified water for farm irrigation. Participants: S. Norra (UP), F. Digiacomo (UP & KIT-AGW), S. Tirivarombo (BIUST), J. Jendow (BIUST), 2 staff members of "Department of Water and Sanitation Affairs".

Figure 5 *Group picture at Dundee, Tsumeb, Namibia (top left) and at CSIR, Pretoria, South Africa (top right) after the respective meetings. Field visit at Brugspruit, South Africa (bottom left and right). February 2023.*

Figure 6 *Field visit at the waste water semi purification plant, region of Palapye, Botswana, February 2023.*

WP 1: Establishment of a training network

Eight universities were involved in the WaMiNa project. In addition, locally SASSCAL acted in a supportive capacity for the development of study programs, such as that of Integrated Water Resource Management (IWRM) at NUST. In this context, the following key topics were pursued:

- Networking of the universities through a lecture series on the topic of mine water management
- Survey of training needs in the participating countries. This was done by consulting the representatives of the respective universities during the coordination meetings.
- Development of a concept for the continuation of the cooperation between the participating universities, like for example international tandem programs between students of the participating countries and a joint virtual lecture series.

The main activity in this WP was the organisation and implementation of five online lectures/ seminars as part of the the IWRM course at NUST by MiWaNet members, which is also open to the other participating universities. Table 6 lists the topic and the lecturers.

Table 6 List of seminars and lectures that took place within the WaMiNa project.

No.	Date and place	Description
1.	16.03.2022 (IP, Lusaka)	**Seminar on element fluxes** Prof. Stefan Norra (UP)
2.	31.05.2022 (NUST, Windhoek, NA+hybrid)	**Seminar on the topic: "Challenges in Mine Water"** Prof. Stefan Norra (UP): "Geogenic Arsenic Contamination of Groundwater and the Food-Chain Dr. Karl-Gerd Richter (Aquantec): "Environmental Modelling of Hydrogeological Processes". Dr Florian Eichinger (Hyd.): Isotope Studies in the Environment
3.	11.11.2022 (NUST, Windhoek, NA+hybrid)	**Seminar on the topic: "Challenges in Mine Water"** Prof Mallikarjun Pillalamarry (NUST): "Water Problems in Mining Industries" Prof Dr Kai Witthüser (UFS/Delta h): "Geochemistry of Mine Water"
4.	10.03.2023 (NUST, Windhoek, NA+hybrid)	**Seminar on the topic: "Challenges in Mine Water"** Prof Theo Wassenaar (NUST): "Challenges and opportunities with ecological rehabilitation in the arid zone" Felix Dörr (KIT-AGW): "Soil Moisture Monitoring and Modelling for the example of Vietnam's southern Mekong Delta and its Implication on Land Subsidence Dynamics"
5.	19.05.2023 (NUST, Windhoek, NA+hybrid)	**Seminar on the topic: "Challenges in Mine Water"** Dr. Eelco Lukas (UFS): "Flooding of South African Collieries"

➔ The milestone "First joint international teaching unit" was reached according to plan.

WP 2: Establishment of the Mine Water Management Network (MiWaNet)

MiWaNet is a platform that enables members to discuss the challenges in sustainable and climate-adapted water management in the mining sector across national boundaries and interests and to develop solutions (Fig. 7). The members of this platform have expressed their interest in a written letter of intent (LoI) and have met regularly during the reporting period (WP 2.1).

Figure 7 *MiWaNet structure as round table format to discuss the most urgent challenges for water security in the mining sector and to develop key work priorities in the main project phase.*

Platform members met for two hybrid face-to-face workshops, among others: One in Namibia (May-June 2022), one in Germany (December 2022) (WP 2.2) and regularly online (WP 2.3, Tabelle 1). The aims of these workshops and meetings were:

- Exchange on the state of the science
- Adoption of cooperation agreements
- Involvement of potential funders

At the other regular meetings, the following goals were achieved:

- Exchange of experience
- Deepening networking between the partners
- Elaboration of the main objectives of the main goal of the main application
- Identification of the network partners of the main application
- Support for the development of the training network
- Development of a concept for the continuation of MiWaNet.

In addition, the seven essential goals that had already been formulated for the main phase were deepened and discussed in detail at the MiWaNet meetings. The MiWaNet platform will remain active after the end of the project and all members are invited to stay in touch and share knowledge even if they are not participating in the main project phase.

➔ The milestone "First Virtual Workshop" was reached on schedule.

WP 3: Scientific preparatory work for the development of a focused work program for the main phase

Scientific reports

The WP 3.1 was mainly carried out by DRFN, NUST and SASSCAL within the framework of contracts. DRFN, together with ASEC, conducted baseline studies, which are summarised in the following four baseline studies (see Annex):

- "Surface and groundwater management and monitoring in the mining sector in Namibia", by Arnold Bittner, M. Schneider & A. Speiser
- "Private mining sector in Namibia", by M. Schneider & A. Speiser
- "Water Management in Namibia", by P. Heyns
- “Report on mining methods – Equipment and beneficiation processes: Klein Aub Copper Mine, Otjikoto Gold Mine (B2Gold), Rosh Pinah Zinc Corporation, Tsumeb smelter (Dundee Precious Metals)”, by M. Schneider & A. Speiser.

SASSCAL produced the following report (see Annex):

- “Sustainable and climate adapted water management in mining industry of Namibia”

Prof. H. Musiyarira (NUST-MPE) contributed with the following report (see Annex):

- “Water management practices in Namibia”

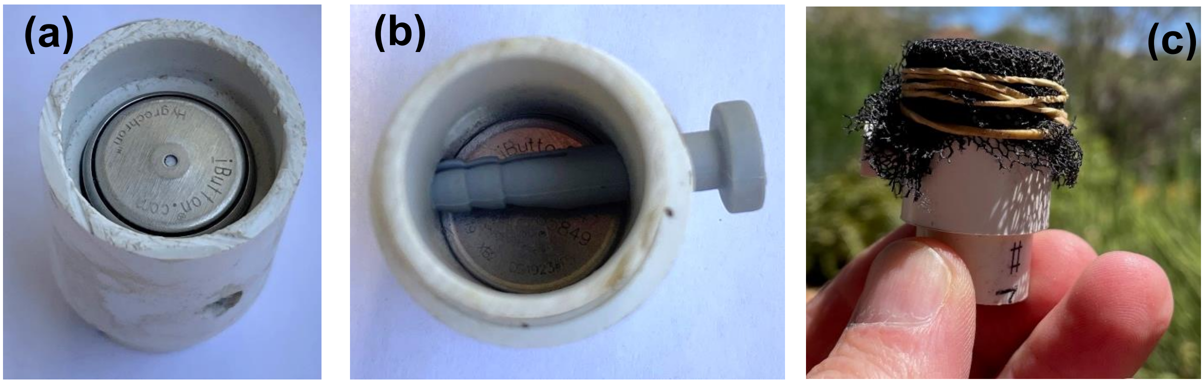
Prof. T. Wassenaar (NUST-ANR) conducted a series of experiments using an alternative approach to soil moisture measurement using a low-cost, easily deployable hygrochron (i.e. iButtons) (Fig. 8). The methods and the results of his experiments are summarised in the following report (see Annex):

- “Successful rehabilitation of dryland mined areas requires soil moisture monitoring to optimize the use of water”

In addition, due to the relevance of the topic and the importance of avoiding redundancies, an extensive literature review was conducted by the student assistant Milena Mensching (see Annex):

- "Overview of raw material distribution, mines, mining activities and the environmental and social problems and impacts of raw material extraction in Namibia, South Africa, Zambia and Botswana" (in German language).

All reports are attached to this final report and will be available online via the University of Potsdam website.



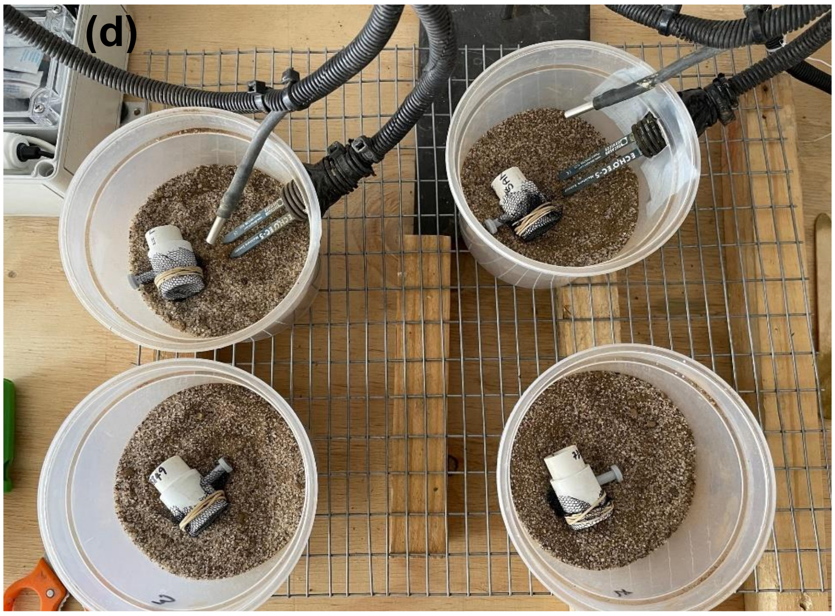


Figure 8. The iButton was placed inside the holder with the iButtons' measuring hole facing up (a) and was "locked" in place on the bottom side using a plastic pin (b). Two layers of a fine nylon mesh was fixed over the upper side, to prevent ingress of soil particles in the open volume in front of the iButton. One iButton plus holder was placed on its side on a bed of ~2cm soil in each soil container and covered with soil (d) to the edge of the container. Two of the soil containers also received a EC5 soil moisture probe (d).

Identification of potential pilot studies for the main project phase

During the definition phase, several meetings were held with representatives of various mining companies and universities involved in the mining sector in Namibia, South Africa, Botswana and Zambia (see Tables 1-5). Based on the results of the discussions, eight sites were identified for potential pilot studies for the main phase of the project (Fig. 9). These sites cover different climates of the regions, different commodities and will host different site studies according to their specific conditions.

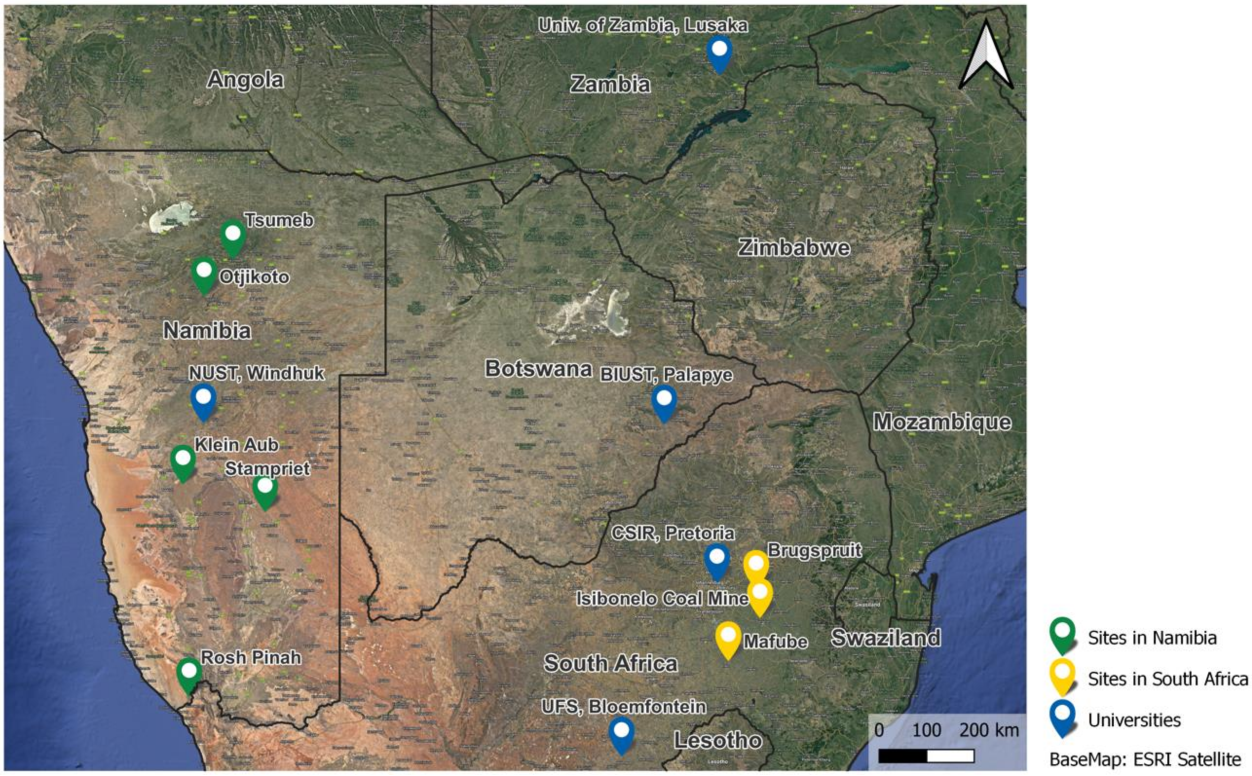


Figure 9 *Sites in the Southern African Region choosen as investigation site for the main project phase.*

First fieldworks

The initial fieldwork had to be adapted to the actual conditions on the ground. The investigations were initiated together with the NUST-ANR working group (Prof. Theo Wassenaar). In the course of identifying possible focal points of work, a first joint field inspection took place (in Klein Aub, Namibia, February 2022). During this visit, the functionality and operation of automated soil moisture sensors were demonstrated (Fig. 10), which can provide relevant data on the water availability of plants used for phytoremediation. Two of these measuring devices were subsequently lent to the NUST-ANR working group and are available for their research activities. Prof. Wassenaar (NUST-ANR) and his working group investigated the possibilities of using so-called iButtons for monitoring soil moisture on heaps and prepared a related report (see Annex).

Figure 10 *Visit to the abandoned mine in Klein Aub, Namibia (left). Test installation of the water content sensor technology brought from Germany (right). (May 2022)*

During the field trip in June 2022, instead of investigations to identify mining-related sources of groundwater contamination in Tsumeb (Namibia), investigations were carried out in the vicinity of the mine in Rosh Pinah. In this context, tailings samples from the local mine (Rosh Pinah Corporation Ltd) as well as water samples from the Orange River, the Nam Water drinking water plant (TWNM) and from the Rosh Pinah mining area were taken and analysed in the "Laboratory for Environmental and Raw Material Analysis" (LERA) at KIT. Chemical analyses of the water samples to determine trace elements, cation and anion content were carried out using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Ion Chromatography (IC).

The salinity (anion concentration) in the water samples from the water plant and the Orange River showed that the limits set by the Namibian Department of Water Affairs were not exceeded[6] .The measured values from Rosh Pinah confirm the challenge of using mine waters due to high salinity (Tables 7 and 8).

[6] "Guidelines for the Evaluation of Drinking Water for Human Consumption with regard to Chemical, Physical and Bacteriological Quality, Department of Water Affairs, Windhoek, Namibia (1988).

Table 7 *Anion concentrations of different water samples: NamWater drinking water plant (TWNM), Orange River and Rosh Pinah and standard values[1] . IC measurements at KIT-LERA.*

Parameter	TWNM	Orange River	Rosh Pinah	Group A*	Group B*	Group C*	Group D*
pH	7,5	7,6	7,1	5,5	9,5	4	11
F^- (mg/l)	0,20	0,21	1,11	1,5	2	3	3
Cl^- (mg/l)	19,9	22,2	1000	250	600	1200	1200
Br^- (mg/l)	0,08	0,15	3,88	-	-	-	-
NO^{3-} (mg/l)	1,79	3,74	92,1	10	20	40	40
SO_4^{2-} (mg/l)	25,1	29,4	1310	200	600	1200	1200

*Guidelines for the Evaluation of Drinking Water for Human Consumption with regard to Chemical, Physical and Bacteriological Quality, Department of Water Affairs, Windhoek, Namibia (1988). Group A: Water of excellent quality. Group B: Water of acceptable quality. Group C: Water with low health risk. Group D: Water with high health risk or water unsuitable for human consumption human consumption.

Table 8 *Trace element and cation concentrations of various water samples: NamWater drinking water plant (TWNM), Orange River and Rosh Pinah and standard values[1] . ICP-OES and ICP-MS measurements at KIT-LERA.*

Element	TWNM	Orange River	Rosh Pinah	Group A*	Group B*	Group C*	Group D*
Ca (mg/l)	26,3	29,9	348	150	200	400	400
Fe (µg/l)	67,4	653	103	-	-	-	-
K (mg/l)	3,73	3,63	32,4	200	400	800	800
Mg (mg/l)	11,1	13,6	187	290	420	840	840
Mn (mg/l)	0,01	0,01	0,57	-	-	-	-
Na (mg/l)	18,0	24,1	571	100	400	800	800
Si (mg/l)	7,50	8,81	8,22	-	-	-	-
Li (µg/l)	2,08	2,43	103	2500	5000	10000	10000
Be (µg/l)	<0,02	<0,02	<0,02	-	-	-	-
B (µg/l)	28,7	33,9	1390	-	-	-	-
Al (µg/l)	52,3	985	35,8	0,15	0,50	1	1
Ti (µg/l)	<0,30	27,3	1,68	2	5	10	10
V (µg/l)	7,95	9,36	0,39	250	500	1000	1000
Cr (µg/l)	0,45	2,47	0,21	100	200	400	400
Mn (µg/l)	9,76	11,3	598	-	-	-	-
Co (µg/l)	0,46	0,44	2,85	250	500	1000	1000
Ni (µg/l)	1,66	2,49	7,14	250	500	1000	1000
Cu (µg/l)	16,3	11,7	13,4	-	-	-	-
Zn (µg/l)	95,0	41,7	3280	-	-	-	-

Element	TWNM	Orange River	Rosh Pinah	Group A*	Group B*	Group C*	Group D*
Ga (µg/l)	0,05	0,33	0,05	-	-	-	-
As (µg/l)	2,57	4,07	7,53	100	300	600	600
Rb (µg/l)	0,77	1,85	127	-	-	-	-
Sr (µg/l)	124	144	4920	-	-	-	-
Mo (µg/l)	0,79	0,95	10,6	500	100	200	200
Sb (µg/l)	<0,20	<0,20	6,12	-	-	-	-
Pb (µg/l)	13,2	9,9	227	-	-	-	-

*Guidelines for the Evaluation of Drinking Water for Human Consumption with regard to Chemical, Physical and Bacteriological Quality, Department of Water Affairs, Windhoek, Namibia (1988).

Four samples (at two different depths at two different locations) were taken from the tailings dam at the local mine in Rosh Pinah (Fig. 11). Table 9 shows the element concentrations determined by X-Ray Fluorescence (XRF), normalised to the reference materials. Further analyses (e.g. chemical dissolution of the solid sample and ICP-MS analyses) are required for a better understanding (e.g. very high concentration).

Figure 11 *Locations of sampling points in the tailings dam (left). View of the stratified tailings (right).*

Table 9 *Concentration of trace elements in the tailings samples (1 and 2) at two different locations. XRF analysis at KIT-LERA.*

Element	**Location 1 0-5 cm**	**Location 1 5-10 cm**	**Location 2 white layer**	**Location 2 brown layer**
SiO_2 (%)	49,4	49,6	31,2	13,1
K_2O (%)	1,75	1,91	1,66	0,92
CaO (%)	12,3	10,9	16,3	8,15
TiO_2 (%)	0,20	0,23	0,21	0,10
MnO (%)	1,22	0,87	1,91	0,85
Fe_2O_3 (%)	3,36	4,39	6,86	13,7
V (ppm)	146	111	109	54,1
Cr (ppm)	10,4	10,4	124	149
Ni (ppm)	8,0	20,2	11,3	11,2
Cu (ppm)	532	537	238	435
Pb (ppm)	2610	3080	2350	881
Zn (ppm)	11500	15200	13000	23400
Ga (ppm)	33,6	39,6	35,4	43,1
As (ppm)	102	139	125	86,9
Rb (ppm)	73,6	68,5	57,9	34,0
Sr (ppm)	736	979	764	241
Y (ppm)	15,4	13,2	15,7	10,0
Zr (ppm)	85,4	117	48,2	32,6
Nb (ppm)	5,3	5,4	5,2	2,7
Mo (ppm)	8,9	10,4	21,4	32,4
Ag (ppm)	15,4	15,1	4,7	3,6
Cd (ppm)	19,0	22,6	12,0	18,9
Sn (ppm)	2,10	3,40	1,40	1,0
Sb (ppm)	21,3	24,1	16,4	7,1
Ba (ppm)	*30000*	*45900*	*21600*	*8650*
La (ppm)	18,3	43,8	18,6	12,6
Ce (ppm)	37,7	47,0	28,3	8,2
Sn (ppm)	2,10	3,40	1,40	1,0
Sb (ppm)	21,3	24,1	16,4	7,1

During the field trip to Namibia and South Africa in February 2023, water samples were taken at two Namibian dams: Van Bach and Goreangab, at a lake and near a mine in the Brugspruit area (Fig. 12). Water parameters and element concentrations are listed in the Tables 10 and 11.

Figure 12 *Sample collection at the Van Bach dam (top left) and Goreangab dam (top right), Namibia; at a lake (bottom left) and near a mine in the Brugspruit area (bottom right), South Africa. February 2023.*

Table 10 *Parameters measured in the water samples collected at the Von Bach Dam and Goreangab Dam (Namibia).*

	Von Bach Dam	**Von Bach Dam filt.**	**Goreangab Dam**	**Goreangab Dam filt.**
On-site parameter				
Temperature (°C)	28,8		28,6	
pH value	8,98		7,60	
Spec. electr. Conductivity (µS/cm)	282		180	
O^2-conc (mg/l)	9,68		8,69	
Redox (mV)	190		785	
Colour	no colour		yellowish	
Turbidity	clear		low	

	Von Bach Dam	Von Bach Dam filt.	Goreangab Dam	Goreangab Dam filt.
Lab parameter				
Spec. electr. conductivity (25 °C) (µS/cm)	293		795	
pH value	7,57		7,06	
Temperature (°C)	20,0		21,3	
Na^{+} (mg/l)	21,0		94,3	
K^{+} (mg/l)	11,9		21,4	
Ca^{2+} (mg/l)	23,6		37,3	
Mg^{2+} (mg/l)	8,5		11,7	
NH^{4+} (mg/l)	0,06		3,25	
Cl^{-} (mg/l)	15		87,9	
SO_4^{2-} (mg/l)	6,6		53,9	
NO^{3-} (mg/l)	0,4		31,2	
F^{-} (mg/l)	0,18		0,3	
PO_4^{3-} (mg/l)	< 0,03		9,4	
Sr^{2+} (mg/l)	0,13			
Al (mg/l)		0,039		0,044
As (mg/l)		< 0,0025		< 0,0025
Pb (mg/l)				-
Fe^{tot} (mg/l)		0,011		0,067
Cu (mg/l)		< 0,005		0,0053
Mn^{tot} (mg/l)		< 0,01		0,077
Ni (mg/l)		< 0,001		< 0,001
U (mg/l)		-		-
Zn (mg/l)		< 0,0005		0,0028
DOC (mg/l)	12,8		21	
Water hardness calculated (mmol/l)	0,94		1,41	
Water hardness calculated (°dH)	5,26		7,92	
^{18}O CRDS (‰)	0,84		-2,05	
^{2}H CRDS (‰)	-8,0		-15,1	
Deuterium-excess (‰)	-14,7		1,30	

Table 11 Parameters measured in the water samples collected at the Brugspruit lake and mine (South Africa).

Lab parameter	Brugspruit Lake	Brugspruit Mine	Brugspruit Mine filt.
Spec. electr. conductivity (25 °C) (µS/cm)	2430	8250	
pH value	3,28	3,15	
Temperature (°C)	21,7	21,8	
Na^{+} (mg/l)	121	890	
K^{+} (mg/l)	4,3	14,5	
Ca^{2+} (mg/l)	157	454	
Mg^{2+} (mg/l)	90,5	298	
NH^{4+} (mg/l)	< 0,05	52,4	
Cl^{-} (mg/l)	12,1	88,0	
SO_4^{2-} (mg/l)	1430	5700	
NO^{3-} (mg/l)	17,1	3,90	
F^{-} (mg/l)	0,02		0,071
PO_4^{3-} (mg/l)	2,60	7,30	
Sr^{2+} (mg/l)	< 0,03	< 0,03	
Al (mg/l)	46,6		81,4
As (mg/l)	< 0,005		< 0,005
Pb (mg/l)	0,0037		< 0,002
Fe^{tot} (mg/l)	1,1		5,22
Cu (mg/l)	0,09		0,14
Mn^{tot} (mg/l)	15,6		27,4
Ni (mg/l)	0,46		1,41
U (mg/l)	0,006		0,01
Zn (mg/l)	1,49		3,53
DOC (mg/l)		1,1	
^{18}O CRDS (‰)	-1,61	-1,91	
^{2}H CRDS (‰)	-7,70	-9,40	
Deuterium-excess (‰)	5,18	5,88	

➔ The milestone "First investigations in the field" was reached according to plan.

WP 4: Formulation of the application for the main phase and its networking in the local structures

One of the main aims of the project is to formulate and prepare the application for the main phase. To achieve this goal, existing contacts were deepened and new contacts were made (WP 4.1). New local funding organisations were identified and involved (including the **Water Research Commission**, WRC, in South Africa) and further mines were involved (including **B2Gold**) (WP 4.2). To this end, the project was presented to many institutions, companies and also to the German ambassadors in Namibia and Zambia during the trips to Africa (Tables 1-5).
An important role in this WP was played by the MiWaNet platform and its members (WP 1) as well as the partners in Namibia (DRFN, ASEC and NUST). Through the regular meetings and exchange with the experts who are part of this network, it was possible to develop the ideas for the main project.

➔ The milestone "Completion of the main proposal" will be reached by 15.06.2023.

2. The most important items of the numerical evidence

The most important financial items are: Personnel resources, official travel, awarding of contracts and investments.

Personnel resources

The financial resources for personnel costs were necessary to undertake the various tasks within the project, which included both administrative and scientific activities. In this context, the requested cost-neutral prolongation was necessary to guarantee these activities until the completion of the draft proposal for the main phase.
The WaMiNa definition project was accompanied by a large number of administrative and coordinating tasks. These tasks included general project administration (finances, accounting, reporting, representation of the project to third parties, general public relations) as well as numerous tasks related to the organisation and implementation of the WaMiSAR project, which include: the establishment of a research network consisting of national, international and African partners, the organisation and implementation of coordination meetings and workshops, the coordination of WaMiSAR-project application, the transfer of the project into the future.
These administrative activities were accompanied by the scientific work that involved collecting, analysing and interpreting the data collected during the field trips.

Official travel

Work trips within Germany and to Namibia, South Africa, Zambia and Botswana were necessary in order to be able to carry out the diverse project work, coordination meetings and workshops with the national and international partners and/or stakeholders involved in the project initiative. In some cases, costs were also incurred for sponsoring some of the meetings or field campaigns in order to keep the expenses of the hosts to a minimum. For the workshop held in Germany in December 2022, the travelling expenses of the participating partners from Southern Africa and Germany were covered.

Awarding of contracts

DRFN (the central coordinating partner on the Namibian side), ASEC, NUST and SASSCAL were financially supported within the framework of the definition project WaMiNA by awarding subcontracts. The Namibian contractors contributed to identify the most significant challenges for sustainable and climate- adapted mining water management, to design a synergistic research programme to ensure water quality and availability in the mining. The results of their research and review work are summarised in their reports, which cover the issues of water (both surface and groundwater) management practices and monitoring in the mining sector in relation to the actual mining and associated handling processes, as well as legislation, policy, internationally shared water resources, private and public sector mining. All the produced reports are attached to this document and will be available online on the website of the Department of Soil Science and Geoecology at the Institute of Environmental Science and Geography at the University of Potsdam[7].

Furthermore, resources were needed for travel, workshop facilitation and organization.

Investments

Due to the short duration of the project, no relevant investments have been made.

3. The necessity and relevance of the project work carried out

The WaMiNa definition project was originally planned for the period from 01.12.2021 to 28.02.2023 and to be carried out at KIT, where the project coordinator, Prof. Stefan Norra, worked until December 2021. However, since Prof. Stefan Norra has held a professorship at the University of Potsdam since January 2022, the official project management has been transferred from KIT to the University of Potsdam. This shift, combined with the COVID-19 pandemic, the late approval of

[7] https://www.uni-potsdam.de/en/umwelt/research/soil-science-and-geoecology

the project and unexpected administrative delays in staff recruitment, resulted in the project being extended by three months without changing the original budget. Nevertheless, the relevant work to identify and engage national and international project partners through meetings and workshops, as well as the work to develop the Mine Water Management Network (MiWaNet) platform between African and German partners, started in the very early phase of the project and the first field work was carried out.

During the running time, the WaMiNa project established and brought together an international network of German, Namibian, South African, Zambian and Botswana institutions and industry partners whose work resulted in the preparation and submission of the joint WaMiSAR project. The project content and project objectives of the joint initiative were defined together with the African side.

The establishment of the international network and the necessary activities for preparing the application required various trips to the mentioned countries, during which contacts were made and will be later maintained by means of the MiWaNet with the African partners and stakeholders (NUST, SASSCAL, DRFN, ASEC, Impact Catalyst, WRC, BIUST etc.). The same applies to the corresponding trips within Germany, which were necessary for the coordination activities at national level between the WaMiNa project, the industrial partners involved in the joint project, the project management organisations (PTKA and DLR) and the BMBF. All of the domestic and foreign events (coordination meetings, workshops, excursions, etc.) held in the course of these trips were coordinated, organised and financed as part of the WaMiNa project.

Moreover, it was also possible to collect a few water and tailing samples, which allowed amongst others, a first assessment of the water quality in representatives locations near by a mine and of reservoirs in Namibia and South Africa. These findings were subsequently incorporated into the design of the application for the WaMiSAR project.

In conclusion, the work carried out and performed within the framework of the project was necessary and in accordance with the tasks defined at the beginning.

4. The expected benefit, in particular the applicability of the result - including concrete plans for the near future

The utilisation of the results of the WaMiNa definition project consists in the preparation, coordination and structuring of the WaMiSAR joint project. By establishing the research network as well as the MiWaNet and maintaining contacts with the participating partners from science and industry as well as the African partners and stakeholders, a smooth start of the main project, if granted, can be guaranteed. Furthermore, the South African partners are being supported in their applications to the WRC in South African.

In case of approval of the WaMiSAR project and successful completion of the tasks associated with the initiative, the African partners will be able to implement measures and recommendations for water management in both pre- and post- mine phases, water monitoring and protection.

These results will benefit not only the local population in the study area but also the German industrial partners involved, since it is a fact that the governments of the involved African countries will have to invest more in water and environmental technologies in the near future in order to improve the quality of water.

The results of the field investigations will also be integrated into the upcoming work of the main project and will be used for future publications and presentations. The collected, processed and analysed data will be made available to the African partners.

5. The progress in the field of the project with third parties of which the beneficiary has become aware during the implementation of the project

Since the beginning of the project, there has been close contact and exchange with other institutions, that were active or continue to be active in the southern African countries (i.e. Namibia, South Africa, Botswana and Zambia) during the project period. These include, among others, the WRC in South Africa.

For the main project, if granted, this already established cross-project networking with local actors will have the advantage of being able to draw on their experience, knowledge and, in part, their technical implementation, which has the potential to positively influence future scientific and technical prospects for success as well as scientific and economic connectivity.

Furthermore, it is noteworthy that the definition phase of the WaMiNa project provided an opportunity to explore other issues of relevance to African countries and requiring further development, such as the assessment and improvement of water quality in Namibian reservoirs with problems related to frequent algal blooms, high nutrient levels and toxic cyanobacteria. In this context, several parallel meetings were held with selected German and Namibian associated partners and stakeholders to develop innovative project ideas and to finalise them in a separate project: "Assessing and improving water quality of Namibian drinking water dams (NamDam)" under the leadership of the TZW in Karlsruhe,which will be submitted as well by the 15.06.2023 within the WASA-call.

6. The publications of the result that have been made or are planned

Publications

The relevance of the WaMiNa-project was mentioned in the "TREVALI-Sustainability report 2021" (https://trevali.com/site/assets/files/7310/trevali_mining_sustainability_report_2021.pdf, page 70). All reports produced (see below) during the duration of the WaMiNa project will be available online on the website of the Department of Soil Science and Geoecology at the Institute of Environmental Science and Geography at the University of Potsdam. Furthermore, the results achieved within the WaMiNa definition project will flow directly into the WaMiSAR main project and will be used there in the preparation of publications.

Conference contributions

Participation in the BMBF-Event „Water Security in Africa - Stakeholder Information Event" (10.10.2022).

Research studies, bachelor's, master's and doctoral theses

Due to the shortness of the project and the necessary time to organise this work in cooperation with all partners, final papers could not be carried out. Nevertheless, the planned research work was carried out and forms the contents of the following baseline studies and reports (see Annex):

1. "Surface and groundwater management and monitoring in the mining sector in Namibia", by A. Bittner, M. Schneider (DRFN) & A. Speiser (ASEC)
2. "Private mining sector in Namibia", by M. Schneider (DRFN) & A. Speiser (ASEC)
3. "Water Management in Namibia", by P.Heyns (DRFN)
4. "Report on mining methods – Equipment and beneficiation processes: Klein Aub Copper Mine, Otjikoto Gold Mine (B2Gold), Rosh Pinah Zinc Corporation, Tsumeb smelter (Dundee Precious Metals)", by M. Schneider (DRFN) & A. Speiser (ASEC)
5. "Sustainable and climate adapted Water Management in Mining Industry of Namibia", by SASSCAL
6. "Water management practices in Namibia", by Prof. H. Musiyarira (NUST-MPE)
7. "Successful rehabilitation of dryland mined areas requires soil moisture monitoring to optimize the use of water", by Prof. T. Wassenaar (NUST-ANR)
8. "Overview of raw material distribution, mines, mining activities and the environmental and social problems and impacts of raw material extraction in Namibia, South Africa, Zambia and Botswana" (in German language), by M. Mensching (UP).

Anhang:

(i) **Abkürzungsverzeichnis / List of abbreviations**

(ii) **Literaturverzeichnis**

(iii) **Berichte / Reports**

Anhang/Annex

(i) Abkürzungsverzeichnis/List of abbreviations

AP	Arbeitspaket
BMBF	Federal Ministry of Education and Research
DLR	Deutsches Zentrum für Luft- und Raumfahrt
IC	Ion Cromatography
ICP-OES	Inductively Coupled Plasma Optical Emission spectroscopy
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
LoI	Letter of Intent
PTKA	Projektträger Karlsruhe
SAR	Southern African Region
TWNM	Nam Water Drinking Water Plant
WaMiNa	Sustainable and climate adapted Water Management in Mining in Namibia and surrounding countries
WaMiSAR	Sustainable and climate adapted Water Management in Mining of Southern African Region
WP	Work Package
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

German partner organisations and institutions

Aquantec AG	Aquantec AG Advanced Quantitative Technology
BfG	Federal Institute of Hydrology
BGR	Federal Institute for Geosciences and Natural Resources
Hyd	Hydroisotope GmbH
JIG	Joswig Engineers GmbH
KIT	Karlsruhe Institute of Technology
KIT-EGG	Geochemistry & Economic Geology
KIT-AGW	Institutes for Applied Geosciences
KIT-IMK	Institute for Meteorology and Climate Research
LERA	Laboratory for Environmental and Raw Materials Analysis
SEBA	SEBA Hydrometry
SLR-EC	SLR Environmental Consulting
Sensatec	Sensatec GmbH
TZW	Technology Centre Water
UASL	University of Applied Science, Hydrology LAB, or University of Lübeck
UP	University of Potsdam
UWH-IEEM	University of Witten/Herdecke - Environmental Engineering and Management

African partner organisations and institutions

Namibia

ASEC	A. Speiser Environmental Consultants CC

DRFN	Desert Research Foundation of Namibia
ICWRGC	International Centre for Water Resources and Global Change
MAWLR	Ministry of Agriculture, Water and Land Reform
MoF	Ministry of Fishery
NamWater	Namibia Water Corporation Ltd
NUI	Namibian Uranium Institute
NUST	Namibia University of Science and Technology
ANR	Department of Agriculture and Natural Resources Sciences
IWRM	Integrated Water Resource Management
MPE	Department of Mining and Process Engineering
PSU	Project Services Uni
Rosh Pinah ZC	Rosh Pinah Zinc Corporation Ltd
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management

Botswana

BIUST Botswana International University of Science and Technology

South Africa

AquaMatters	AquaMatters
delta h	Delta h, Water Systems Modelling
IC	Impact Catalyst
Thungela	Thungela Resources
UFS	University of Free State
WRC	Water Research Commission

CSIR	Council for Scientific and Industrial Research
ICC	International Convention Centre (Pretoria, SA),

Zambia

UZ University of Zambia

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2. "Private mining sector in Namibia", by Martin Schneider (DRFN) & Alexandra Speiser (ASEC)
3. "Water Management in Namibia", by Piet Heyns (DRFN)
4. “Report on mining methods – Equipment and beneficiation processes: Klein Aub Copper Mine, Otjikoto Gold Mine (B2Gold), Rosh Pinah Zinc Corporation, Tsumeb smelter (Dundee Precious Metals)”, by Martin Schneider (DRFN) & Alexandra Speiser (ASEC)
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HIGH-LEVEL BASELINE STUDY

SURFACE AND GROUNDWATER MANAGEMENT AND MONITORING IN THE MINING SECTOR IN NAMIBIA

by

Arnold Bittner, Martin Schneider & Alexandra Speiser

DRFN

Enhancing decision making for sustainable development

HIGH-LEVEL BASELINE STUDY
SURFACE AND GROUNDWATER MANAGEMENT AND MONITORING IN THE MINING SECTOR IN NAMIBIA

Abstract

Namibia is the driest country in Sub-Saharan Africa, with the only perennial rivers lying along the country's borders. Given these circumstances, it is not surprising that most of the country depends heavily on groundwater resources. In addition, and due to the pressure on the limited water resources, a desalination plant was built by a mining company at the coast. Large dams provide the third source of water in Namibia.

The uranium mines are located near the central coast, and are supplied by the desalination plant. Copper is mined in the central northern part, in the area of a large karst-aquifer, from where the water is abstracted. Additional copper mines in central Namibia receive their water from a scheme of interconnected dams. Zinc and diamonds are recovered in the far south of the country, where the mines have access to the perennial Orange River. Namibia has two gold mines, one of which is supplied by a dam, while the second one is able to utilise a strong aquifer. Other commodities produced in Namibia are tin, lithium and iron, all operations are supplied by groundwater bore holes. Given the scarcity and high cost of water in Namibia, all mining operations have stringent water management plans in place and achieve high rates of recycling.

1. General overview groundwater and surface water of Namibia

With a total surface area of 824 269 km^2, Namibia is the second largest country in southern Africa. The country borders the Atlantic Ocean to the west between the 17th and 29th latitudes, Angola and Zambia to the north, Botswana to the east, and South Africa to the south and southeast. A narrow strip about 440 km long, the Zambesi Region, extends eastwards up to the Zambesi River, separating Botswana from Zambia, and touching Zimbabwe.

The subdivision of Namibia into geomorphological units is based on its position on the edge of the African continent und under the influence of the cold Benguela Current. In the west, the Namib Desert is a 80 to 120 m wide belt, which extends along the entire coastline. The Great Escarpment separates the Namib Desert from the mountainous Central Plateau which rises up to 2 000 m above sea level and extends over about half of the country. The lower lying northeastern and southeastern areas of Namibia belong to the semi-arid Kalahari Basin, and the northern bush-covered plans are part of the Owambo Basin.

Namibia has an arid climate and is the driest country in Sub-Saharan Africa. The only perennial rivers lie on the country's borders, namely the Orange River in the south, and the Kunene, Kavango, Kwando and Zambesi in the north. All inland rivers are ephemeral rivers which flow sporadically and only after intense rainfall. After such a flood event, a river course is often dry for many years. Rivers such as the Hoarusib, Uniab, Ugab, Omaruru, Swakop, and Kuiseb usually flow in a good rainy season, however, they may not reach the sea for several years.

The Nossob and Fish Rivers also flow with enough rainfall in their catchments, but they dewater inland into the Orange River.

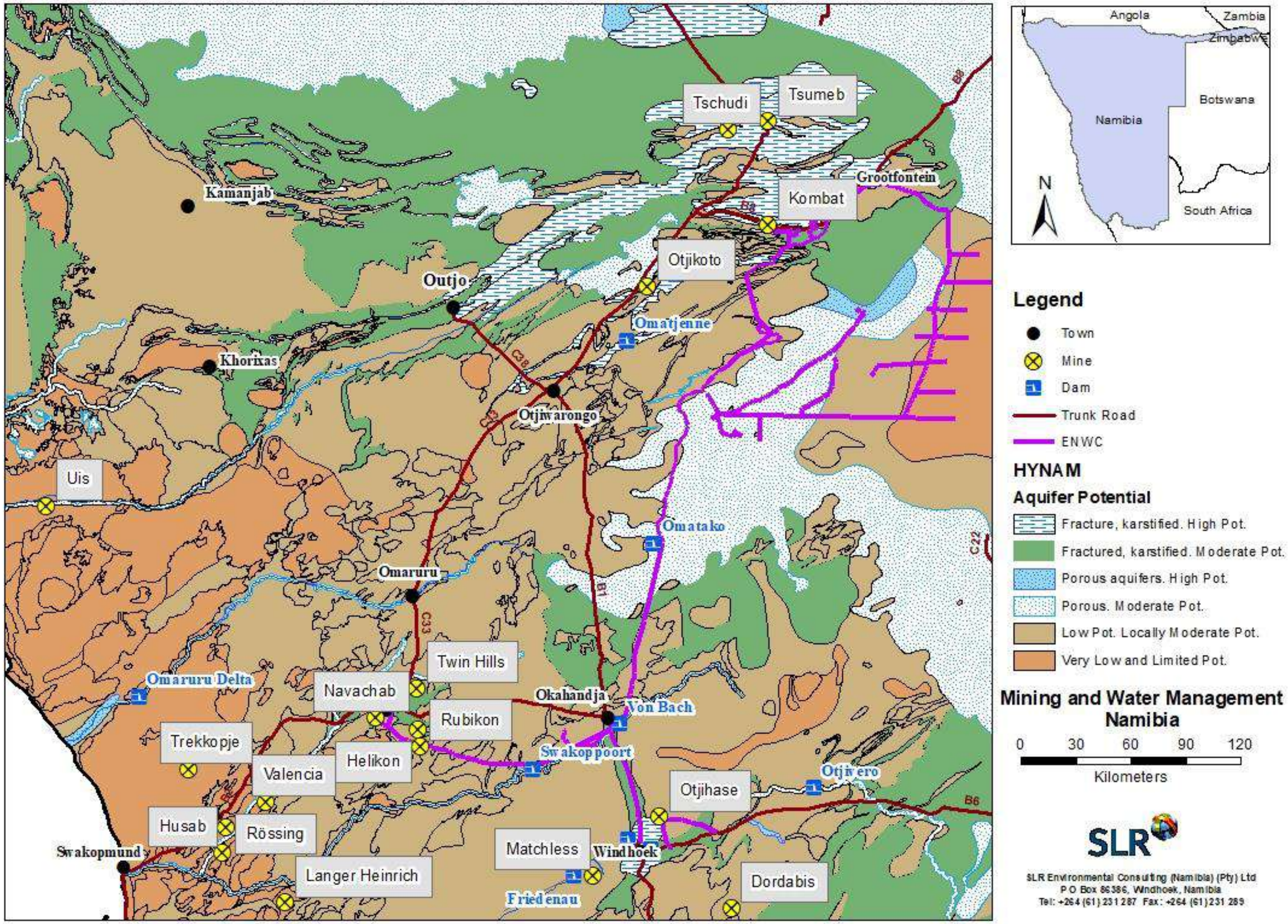
Most of Namibia falls within the summer rainfall region with the main precipitation in the months of January to March. The average precipitation varies between less than 50 mm per year in the southwestern parts and 700 mm in the eastern Zambesi Region, while the mean gross evaporation ranges between 2 500 and 3 800 mm per year.

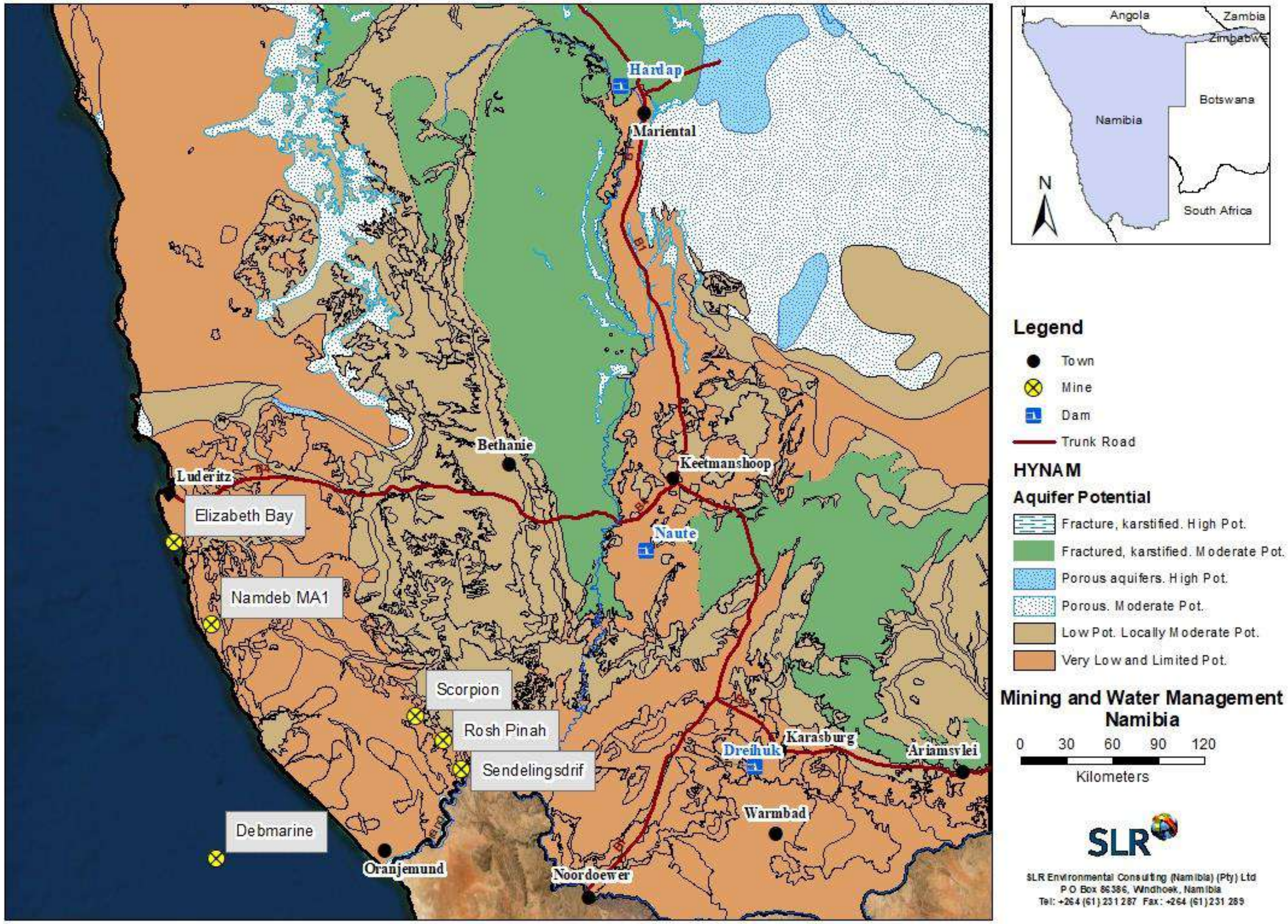
Given these circumstances, it is not surprising that most of the country depends heavily on groundwater resources. There are an estimated 40 000 producing boreholes in Namibia. Numerous small farm dams augment the boreholes, at least for part of the year, and assist in groundwater recharge.

On the basis of geological structure and groundwater flow, Namibia can be subdivided into twelve hydrogeological regions or groundwater basins. These are the Zambesi Basin, the Okavango-Epukiro Basin, the Cuvelai-Etosha Basin, the Otavi Mountainland Karst Aquifer, the northern Namib-Kaokoveld Basin, the Brandberg-Waterberg Area, the Central Namib-Windhoek Area, the Hochfeld-Dordabis-Gobabis Area, the Stampriet Artesian Basin, the Fish River-Aroab Area, the Southern Namib and Naukluft Area, and the Karas Basement.

Grootfontein, Tsumeb, Outjo, Omaruru and Windhoek operate their own water schemes, with Windhoek also being supplied by Namwater from the Von Bach, Swakoppoort and Omatako Dams, as well as via the Eastern National Water Carrier. In addition, Windhoek's water reclamation plant contributes substantial amounts of water to the city's demands. In the other parts of the country, Namwater is responsible for the bulk water supply to schemes such as the Central Namib Water Scheme, which includes a number of large consumers such as the municipalities of Swakopmund, Walvis Bay and Henties Bay, and the mines in the area. This scheme is notably supported by the privately owned Erongo Desalination Plant since 2013.

The maps below show the mine locations in relation to aquifer potential and surface water sources.




Angola
Zambia
Zimbabwe
Botswana
Namibia
South Africa
N
Hardap
Mariental
Bethanie
Luderitz
Keetmanshoop
Naute
Elizabeth Bay
Namdeb MA1
Scorpion
Rosh Pinah
Sendelingsdrif
Karasburg
Dreihuk
Ariamsvlei
Warmbad
Debmarine
Oranjemund
Noordoewer
Legend
Town
Mine
Dam
Trunk Road
HYNAM
Aquifer Potential
Fracture, karstified. High Pot.
Fractured, karstified. Moderate Pot.
Porous aquifers. High Pot.
Porous. Moderate Pot.
Low Pot. Locally Moderate Pot.
Very Low and Limited Pot.
Mining and Water Management Namibia
0 30 60 90 120
Kilometers
SLR
SLR Environmental Consulting (Namibia) (Pty) Ltd
P O Box 86386, Windhoek, Namibia
Tel: +264 (61) 231 287 Fax: +264 (61) 231 289

2. Water management by commodity

2.1 Uranium

2.1.1 Rössing

- The Rössing Uranium Mine is situated some 60 km northeast of Swakopmund and operated by majority shareholder CNNC.
- Rössing requires 3 million m^3 of fresh water annually. Abstraction permit for Khan, but not fully utilized, only used for dust suppression because of salinity. Recycling 55%.
- The mine samples and monitors more than 20 monitoring boreholes in the mining license area and in the Khan River on a regular basis (inhouse). Results are report to the authorities.
- Groundwater samples are analysed by specialist laboratories in Namibia and South Africa for metals (including uranium), major ions and radionuclides.

2.1.2 Swakop Uranium

- Swakop Uranium's Husab Mine is situated in the Namib Naukluft National Park directly southwest of Rössing, and is operated by CGNPC.
- Swakop Uranium's Husab Mine requires 9.6 million m^3 of fresh water annually. Abstraction permit for Swakop River production boreholes, but not utilised because only used during construction phase.
- More than 60 monitoring boreholes within the mining license area and in the Khan and Swakop rivers are regularly monitored, and results reported to the regulators.
- Groundwater samples are analysed by specialist laboratories in Namibia, South Africa, and Germany for metals (including uranium), major ions and radionuclides.

2.1.3 Langer Heinrich

- The Langer Heinrich Mine lies some 80 km east of Walvis Bay in the Namib Naukluft National Park, and is operated by majority shareholder Paladin Resources. It has been under Care and Maintenance since 2018, but a decision to restart the mine has been taken recently.
- Langer Heinrich will require 2.2 million m^3 of fresh water annually, supplied via 80km long pipeline from Swakopmund (desalinated water from ORANO plant), and also from the Swakop River borehole scheme, connected to the mine via a 15 km long HDPE pipeline. The two water sources are blended because of the high salinity of the Swakop River water, and then fed into an on-site desal plant and purified to the processing requirements.
- The abstraction permit for the Swakop River was extended by the DWA in 2020 for the volume of 0.5 Mio m^3/annum. The groundwater is abstracted from two production boreholes tapping the Swakop River alluvium.

- Currently, while under Care and Maintenance, the mine samples 18 monitoring boreholes quarterly and monitors water levels in 33 boreholes monthly on the mine site and in the Swakop River.
- Groundwater samples are analysed by specialist laboratories in Namibia, South Africa, and Germany for metals (including uranium), major ions and radionuclides.

2.1.4 Trekkopje and the Erongo Desalination Plant

- The Trekkopje Mine 70 km northeast of Swakopmund was in operation only from 2012 to 2013, and is currently under care and maintenance.
- During the operational phase water required for the mine was supplied by the purpose built Erongo desalination plant, to which the mine is linked by a dedicated pipeline, and which is an asset belonging to the owner of the mine.
- Should the mine re-open, it will require 8 million m^3 annually, which will once again be supplied by the desalination plant.
- The Erongo Desalination Plant is located 35 km north of Swakopmund, near the settlement of Wlotzkasbaken in the Namib Desert.
- It is the largest reverse osmosis seawater desalination plant in Sothern Africa.
- The desalination plant was originally built to supply water to the Trekkopje Uranium Mine of Orano Mining Namibia, and was inaugurated in 2010. Following the downturn of the uranium market, the mine was placed under care and maintenance, so that the water was no longer required until such time that the mine re-opens.
- An agreement was reached with the Namibian national water utility Namwater to use the potable water produced at the plant to augment the supply to the coastal region.
- Today the desalination plant does not only supply the local municipalities, but also via Namwater other mines, such as Rössing and Husab.
- The seawater desalination process consists of screen filtration, ultrafiltration, reverse osmosis, limestone re-mineralisation, and chloration.
- The first step in the intake of seawater through a pipeline anchored 1 000 m of the coast, at a depth of 10 m. At the intake, a 40 mm diameter screen keeps out aquatic fauna and flora.
- The water is then disinfected and passes through screens that eliminate micro-organisms and particles larger than 60 µm in diameter, followed by ultrafiltration, which removes all remaining particles so that only salt remains in the clear water.
- The next step is reverse osmosis, which separates the water into two streams, namely pure water and a brine stream that is returned to the ocean. The reverse osmosis process forces the water through semi-permeable membranes under high pressure. These membranes allow only water molecules to pass through, thus producing potable fresh water, while the salt remains in the brine.
- After the reverse osmosis step the brine is still at very high pressure. The pressure is exchanged with the fresh incoming seawater, directly recovering 98% of the energy that would otherwise be lost, and reducing the plant’s electricity consumption by approximately 40%.
- In 2021, the Erongo Desalination Plant has set a new record by producing 12.7 million m^3 of fresh water.
- Cumulative production since 2013 has now reached more than 75 million m^3.

2.1.5 Zhonghe Resources

- Zhonghe Resources holds a mining license and a number of exploration licenses to the northeast of Rössing.
- Zhonghe Resources is still in the exploration phase and no future water requirements have been calculated.

2.1.6 Valencia

- Valencia holds a mining licence some 80 km northeast of Swakopmund.
- The Valencia deposit has a JORC compliant ore reserve and is construction ready, once the uranium price has reached the required level.
- Once going into production, Valencia will require 3 million m^3 of fresh water annually.

2.1.7 Bannerman

- Bannerman Resources owns an advanced exploration project 30 km southeast of Swakopmund, with a Definitive Feasibility Study expected to be complete by Q3 of 2022.
- Once going into production, Bannerman will require 2 million m^3 of fresh water annually.

2.1.8 Reptile

- Reptile Mineral Resources and Exploration is an advanced stage exploration company and owns the Tumas project for which a Mining Licence has been applied for.
- Once going into production, the Tumas project will require 2 million m^3 of fresh water annually.

2.1.9 Elevate Uranium

- Elevate Uranium owns large tenements in the Namib Naukluft National Park, and holds the Marenica project to the northeast of Trekkopje Mine under a Mineral Deposit Retention License.
- Elevate Uranium is still in the exploration phase for their tenements in the park, and no future water requirements have been calculated for these.
- Once the Marencia project goes into production, it will require 3 million m^3 of fresh water annually.

2.2 Copper

Namibian copper mines are located in the Otavi Mountainland (OML) of north-central Namibia (Tsumeb, Kombat and others) and in the Khomas Hochland along the Matchless

Belt (MB) (Otjihase and Matchless mines). The OML mines source their water from local groundwater, while the MB mines have to import water via pipeline from surface dams.

2.2.1 Tsumeb (Dundee Precious Metals Smelter)

- The Dundee Precious Metals Copper Smelter is located in the town of Tsumeb.
- The smelter has a water demand of approximately 1.3 Mio m^3/annum.
- A small volume of potable water is also required for drinking and lavatory purposes.
- Groundwater is abstracted from the No. 1 Shaft within the DPMT premises.
- Drinking water is supplied to site via Tsumeb Town reticulation. Tsumeb Town has its own production borehole on the western outskirts, intersecting the Tsumeb Subgroup dolomite aquifer.
- In 2020, SLR Environmental Consulting (Namibia) (Pty) Limited (SLR) was appointed by DPMT to firstly update the existing 3D groundwater flow model to simulate sustainable abstraction from Shaft No. 1 to support permitted groundwater abstraction, and secondly to extend the transport model solution to a reactive transport solution to estimate a more realistic plume extension around the DPMT operations.
- In 2020, a groundwater abstraction permit was issued by the DWA based on the results of the above-mentioned groundwater model by SLR.
- A number of monitoring were drilled by DPMT over the years with the main purpose of monitoring groundwater pollution emanating from various sources within the smelter area.

2.2.2 Tschudi

- Tschudi Copper Mine is located west of Tsumeb in the Otavi Mountainland (Oshikoto Region) and is owned by Weatherly International PLC.
- During operation, make up water is required for processing (heap leach process), mining, domestic purposes, and dust suppression. Water demand is approximately 2 710 m^3/day or approximately 1 Mio m^3/annum.
- The water demand was met from local groundwater inflow into the open cast pit. The mine experienced difficulties due to excessive groundwater inflow from the karstified and fractured Hüttenberg Formation and had to interrupt operations for some months to get the groundwater inflow under control.
- The Department of Water Affairs, Ministry of Agriculture, Water and Land Reform (DWA) issued a groundwater abstraction/discharge permit to the mine for the purpose of dealing with excess water from inflow into the pit. The water was pumped via pipeline to a dam downgradient of the mine and then infiltrated into a karst sink hole outside the groundwater catchment of the mine.
- DWA approved the operation after the mine hydrogeologist could show that stakeholders and the environment were not negatively affected by the dewatering.
- The mine is currently under care and maintenance, and the pit it is filled up with groundwater forming a lake.
- During operation groundwater monitoring was carried out quarterly at four on-site monitoring boreholes and four farm boreholes.

- Samples were taken by a consultant with a sampling pump and analysed by specialist laboratories in Namibia and South Africa for metals and major ions.
- Groundwater monitoring is currently on hold.

2.2.3 Kombat

- The Kombat Mine is located in the Otavi Valley some 37 km east of Otavi, and operated by Trigon Mining.
- Kombat Mine is the only mine in Namibia that has been developed in the early 20th century and that is still operating, albeit intermittently.
- Ownership has changed over the years and mining was interrupted for longer periods due to economic reasons and in connection with water management, such as for example a catastrophic groundwater inflow into the mine workings.
- There is currently only a small open cast mine, and operations have once more been suspended as from 01/08/2022 because of the low copper price.
- The current water demand of approximately 0.5 Mio m^3/annum is met by local groundwater resources.
- NamWater has drilled four production boreholes into the mine working near Shaft No. 1 and abstracts up to 4.5 Mio m^3/annum of groundwater to supply water to the central area of Namibia in times of water shortage due to drought conditions.
- Water for the mine and also for the town of Kombat is drawn from the two shafts in the current mining area.
- The high yielding dolomitic aquifer of the Otavi Mountainland is intersected by the underground mine workings and when the mine was in full operation to mining depths of up to 800m, large volumes (up to 3000 m^3/h) had to be abstracted and discharged to surface dams to be able to keep the mine dry.
- In 2018, SLR Environmental Consulting (Namibia) (Pty) Limited (SLR) was appointed by NamWater to develop a 3D groundwater flow model in FEFLOW to simulate sustainable abstraction from the four production boreholes and to supply groundwater to the CAN via north-eastern water carrier.
- Both, Kombat Mine and NamWater, using the same source, have been granted abstraction permits from DWA, which are to be renewed every two years.
- Groundwater levels and abstraction have to be monitored on quarterly and monthly basis, respectively and the data has to be submitted to DWA for review.
- DWA visits a number of monitoring boreholes on a regular basis and measures water levels manually. The DWA monitoring boreholes were installed prior to independence, installed with recorders, but often not properly maintained.
- NamWater records water levels of their production boreholes and takes water samples on a regular basis but does not have own monitoring bores.
- A groundwater monitoring plan was developed for Kombat Mine as part of an EIA carried put in 2016 and approximately 15 monitoring boreholes on site, but also on surrounding farms, were selected and monitored.

2.2.4 Otjihase

- The Otjihase underground mine is located some 40km northeast of Windhoek and has been in operation intermittently since Independence.
- The Otjihase Mine is currently under Care and Maintenance.
- The underlying meta-sediments of the Kuiseb Formation (Damara Supergroup) have a low to medium groundwater potential and borehole yields are not sufficient to meet the water demand of a larger mine.
- Water is supplied by NamWater via pipeline from the von Sartorius von Bach Dam of the Windhoek water scheme.
- The pipeline to Otjihase extends further east to the international airport and supplies agricultural projects en route (e.g. Neudamm college) as well.
- During Care and Maintenance very little water is consumed and no abstraction permit is required.
- As one of the mines developed prior to independence, groundwater monitoring has been limited.
- There are concerns of stakeholders in the catchment area that groundwater and surface water downstream of the mine might be polluted due to seepage from the tailings dam containing high concentrations of sulphates and metals.
- Acid Mine Drainage (AMD) and Acid Rock Drainage (ARD) are a concern due to sulphides mined and reduced acid buffering capacity of the country rock.

2.2.5 Matchless

- The Matchless Mine is situated in the Khomas Hochland to the west of Windhoek.
- Currently, the mine is under Care and Maintenance.
- The Friedenau Dam in the upper catchment of the Kuiseb River was built to supply the mine with water. The scheme, operated by NamWater, is still in operation but currently only small volumes are supplied to the mine.
- Farmers in the surroundings benefit from the dam water.
- The underlying meta-sediments of the Kuiseb Formation (Damara Supergroup) have a low to medium groundwater potential and borehole yields are not sufficient to meet the water demand of a larger mine.
- During Care and Maintenance very little water is consumed and no abstraction permit is required.
- There is no known groundwater monitoring taking place at the mine.
- Acid Mine Drainage is an issue of concern observed at the mine.

2.3 Lead-Zinc

2.3.1 Rosh Pinah

- The Rosh Pinah mine is situated in the Karas Region, 165 km south of Aus, which is 125km east of Lüderitz, approximately 23 km north of the Orange River, and operated by Trevali.
- The mine is situated on state-owned land which borders with privately owned farms.
- The current total water need at Rosh Pinah is 1 653 574 m^3/month. This does not include the demand for the proposed upgrade of the mine.
- The total amount is split between a number of demand units, namely mining (38 979 m^3), plant (39 307 m^3), drinking water (4 410 m^3), and golf course (1 217 m^3).
- The water for dust suppression is abstracted from a dam. On average, the rate for road dust suppression is 1 978 m^3/month, and for tailings dust suppression 1 655 m^3/month.
- Raw water supply for use in the mine, processing plant, and as potable water is from the Namwater Supply Scheme which abstracts water from the Orange River.
- A Water discharge and effluent permit (No. 658) was granted by the Department of Agriculture, Water and Forestry, and is valid until 31 January 2025.
- A 3-dimensional numerical groundwater model was constructed and run for the Rosh Pinah Mine, to simulate
  - Passive groundwater inflows into the underground mine as mining is progressing,
  - Development of a cone of drawdown because of underground mining,
  - Development and migration of a possible contaminant plume from the TSF.
- 15 monitoring water boreholes within and around the mine facilities and the Tailings Storage Facility have been drilled. The monitoring system is in place since 1997, and all monitoring boreholes are sampled quarterly and analysed by NamWater in Windhoek. Samples are analysed for zinc, lead, copper, arsenic, cadmium, and cyanide. The groundwater quality is reported in comparison with the 'Requirements for the purification of wastewater effluent' – General Standards, Water Act of 1956 (Act 54 of 1956).
- Water levels are very constant in the region, staying within 40 to 60m below surface for all measured boreholes. Water depths in the boreholes are taken every 2 weeks.

2.3.2 Skorpion

- Skorpion Zinc Mine is located some 20km northwest of Rosh Pinah, and operated by Vedanta.
- The project is currently under Care and Maintenance, but there are plans to re-open the mine soon.
- The water demand is assumed to be similar to Rosh Pinah mine although Skorpion is open cast and not underground like Rosh Pinah.
- Water is supplied via an existing pipeline from the Orange River, operated by NamWater. The water is treated to drinking water standard.

2.4 Gold

Namibia currently has two operating gold mines at Karibib and close to Otjiwarongo. A third one is under construction near Omaruru.

2.4.1 Navachab

- The Navachab Gold mine located approximately 14km south-west from Karibib and has been in operation since 1989. QKR Namibia (Pty) Ltd are the owners after taking over the mine from Anglo Gold Ashanti in 2015.
- Approximately 1 Mio m^3/annum are supplied to the mine via a pipeline from the Swakoppoort Dam.
- The NamWater operated Swakoppoort water scheme is the sole source of water.
- Navachab has a 20 year offtake agreement with NamWater, which was signed in 2018. The relevant DWA permit is in place.
- A dewatering borehole (DW22) on site is used to recycle seepage water from the tailings dam, reducing the inflow of polluted water into the mine pit.
- The mine operates 10 monitoring boreholes in the mining area and downstream. Groundwater samples are taken on a regular basis by mine staff. Analysis parameters include major ions and metals, and a database is maintained by the mine.

2.4.2 Otjikoto

- The Otjikoto Gold Mine, situated approximately half-way between the towns Otavi and Otjiwarongo in the Otjozondjupa Region, is owned and operated by B2Gold Namibia (Pty) Ltd.
- The water demand is approximately 2 Mio m^3/annum for processing, mining and dust suppression purposes.
- The only water source is groundwater from dedicated production boreholes tapping the Karibib Formation marble, and from boreholes dewatering the open cast and mine pits and the underground workings situated in Okonguarri Formation meta-sediments.
- The mine produces surplus water that has to be discharged into the environment. Currently there are investigations planned to artificially recharge the Karibib marble aquifer with the surplus water from the mine dewatering.
- Abstraction permit No. 10971 was initially issued by DWA in 2013, and is renewed every two years.
- A groundwater model was developed to predict the impact of abstraction on other groundwater users and to predict possible pathways of pollution plumes emanating from various sources in the mining area.
- The model supported the abstraction permit application to DWA and the initial Environmental Clearance Certificate and mining licence application with the Ministry of Environment and the Ministry of Mines and Energy, respectively.
- The groundwater model was updated a number of times over the years.
- In 2014 the permitted abstraction volume was increased to 2 Mio m^3/annum.

- Regular groundwater monitoring has been carried out since 2012 after the mine went into operation.
- In 2014, 29 monitoring boreholes located within the mining licence area were sampled and monitored on quarterly basis, using sampling pump.
- The samples were analysed for major ions and metals by specialist laboratories in Namibia and South Africa.
- The number of monitoring borehole has since increased as mining progressed from the Otjikoto pit into the northern Wolfshaag pit and later underground.
- Regional groundwater monitoring on 15 farms surrounding the mine is carried out annually.
- In total 40 boreholes are sampled and or monitored and analysis for metals and major ions is carried out in specialised laboratories in Windhoek and South Africa.
- The number of farms and regional monitoring boreholes has increased since.

2.4.3 Twin Hills

- The Twin Hills project is located about 20km north of the town of Karibib in the Erongo Region and owned by Osino Gold Exploration (Pty) Ltd..
- The project is currently still in the development and exploration phase and the water demand is low. Once in operation the water demand for processing, mining and dust suppression will be approximately 1.8 Mio m^3/annum.
- Water supply studies are still under way and one of the most important local sources is the Karibib marble syncline within which the mine is located.
- A number of potential production boreholes were drilled into fractured marbles, showing partly high yields between 20 and 40 m^3/h.
- Another project currently carried out is the construction of a sand storage – surface water and artificial recharge dam in the nearby Khan River.
- A third option is water supply via pipeline from the Karibib- Swakoppoort pipeline operated by NamWater. Negotiations between the parties are currently conducted.
- Osino Gold has obtained a groundwater abstraction permit no. 11553 from DWA in February 2021. The permit is valid for two years and allows the abstraction of groundwater from one borehole for domestic and exploration purposes. The allowed maximum abstraction is 14 600m^3/annum.
- Groundwater monitoring is carried out only at selected boreholes on neighbouring farms. No monitoring plan has been implemented yet.

2.5 Diamonds

2.5.1 Namdeb MA1

- Potable water is supplied to MA1 from Oranjemund Town, which in turn extracts the water from the Orange River aquifer by means of a series of boreholes.
- All MA1 operations, including mining and metallurgical processing, utilise sea water during their activities, for which an abstraction permit is in place.

2.5.2 Sendelingsdrif

- The Sendelingsdrif Mine is located along the Orange River approximately 80 km inland from Oranjemund and 20 km south of Rosh Pinah.
- Process water is abstracted from the Orange River and pumped to a reservoir near the treatment plant.
- An abstraction permit for up to 104 000 m^3 per month is in place.
- Since 2017, the plant has managed to recycle on average 90% of its water.
- Through this recycling effort, the actual abstraction is only approximately 8% of the permitted volume.

2.5.3 Elizabeth Bay

- The Elizabeth Bay mine is located some 25 km south of Lüderitzbucht.
- Plant utilises sea water for process water, and an abstraction permit is in place.
- However, there is currently limited abstraction since the plant is on care and maintenance for upgrading before full production will be resumed by September 2022.
- The mine currently repositioned its seawater intake to dewater a flooded mining area, and will thereqafter commission a planned new intake on the peninsula north of the mine. This intake has been designed and will be constructed towards the end of the year.
- For drinking water the mine is linked to the Koichab Pan water line which also supplies Lüderitzbuch, and the water of which gravitates down to Elizabeth Bay. Water tests are done on a periodic basis.

2.5.4 Debmarine Namibia

- Debmarine Namibia operates the large offshore license area Atlantic 1 to the west of Namdeb's Minig Area 1. A fleet of six production vessels and a dedicated exploration vessel as well as a sampling vessel mine and explore the sea floor at water depths of up to 140 m.
- All vessels are equipped with desalination plants to produce drinking water from sea water for human consumption.
- The processing plants on board the ship all work with sea water.

2.6 Tin

2.6.1 Uis

- The Uis Tin Mine is located some 28 km east of the Brandberg.
- Fresh water is supplied to the mine from a number of boreholes, which belong to the mine.
- The mine has abstraction permits in place for 78 000 m^3 annually.
- 95% of the fresh water used is recycled.

2.7 Lithium

2.7.1 Rubikon + Helikon

- The Rubikon and Helikon open cast Mines are located to the south of Karibib, and operated by Lepidico.
- A permit for the annual abstraction of up to approximately 210,000m^3 of groundwater from four boreholes within the Company's licence area was granted in 2017.
- Water intensity for the operation during the first five years of production is estimated to be 15l/kg of lithium hydroxide, rising to 25l/kg following the planned concentrator expansion.

2.8 Iron

2.8.1 Dordabis

- The Lodestone Iron Mine is located near Dordabis, some 60 km southeast of Windhoek, and operated by Lodestone Namibia.
- Potable water for personnel and minor site use is sourced from three registered boreholes on Farm Tsatsachas within the mining license area.
- The boreholes tap the underlying fractured hard rock aquifer adjacent to the Skaap River.
- There are several hydrological studies from SLR on this subject.
- The water demand of the current operation, which is surface mining, is approximately 40,000 m^3/annum.
- The DWA issued abstraction permit no. 11264 in April 2021 for 43 800 m^3 per annum.
- Phase A (2 million t per year mill feed) requires approximately 0.75 million m^3 of raw input water per year. This will be sourced from grey/semi purified water from the City of Windhoek Waste Water Treatment Plant, which can supply a maximum of 1.5 million m^3 of semi purified water to Lodestone.
- Phase B (6.25 million t per year Mill Feed) requires approximately 2.2 million m^3 of water per year. This will be sourced from Oanob Dam via a 110 km long pipeline.
- The Oanab Dam has an independent assured yield report which ensures that there are at least 5 million m^3 of assured yield over 20 years.
- Phase C (25 million t per year Mill Feed) requires approximately 14 million m^3 of water per year. This will be sourced from desalination from the coast. The 10 million t of product will also be piped down to Walvis Bay, so the backleg pipe will carry desalinated water.
- The Lodestone Iron Mine samples and monitors eight boreholes within the mining licence area on a quarterly basis. Samples are analysed for major ions and metals.
- Seven regional boreholes are sampled/monitored bi-annual on five neighbouring farms. The samples form these monitoring boreholes are also analysed for metals and major ions.

HIGH-LEVEL BASELINE STUDY

PRIVATE MINING SECTOR IN NAMIBIA

by

Martin Schneider & Alexandra Speiser

DRFN

Enhancing decision making for sustainable development

HIGH-LEVEL BASELINE STUDY
PRIVATE MINING SECTOR IN NAMIBIA

Abstract

Mining has been the backbone of the Namibian economy for more than a century, and commodities produced include copper, diamonds, gold, iron, lead, tin, uranium, and zinc, which are recovered from a variety of metallogenic provinces.

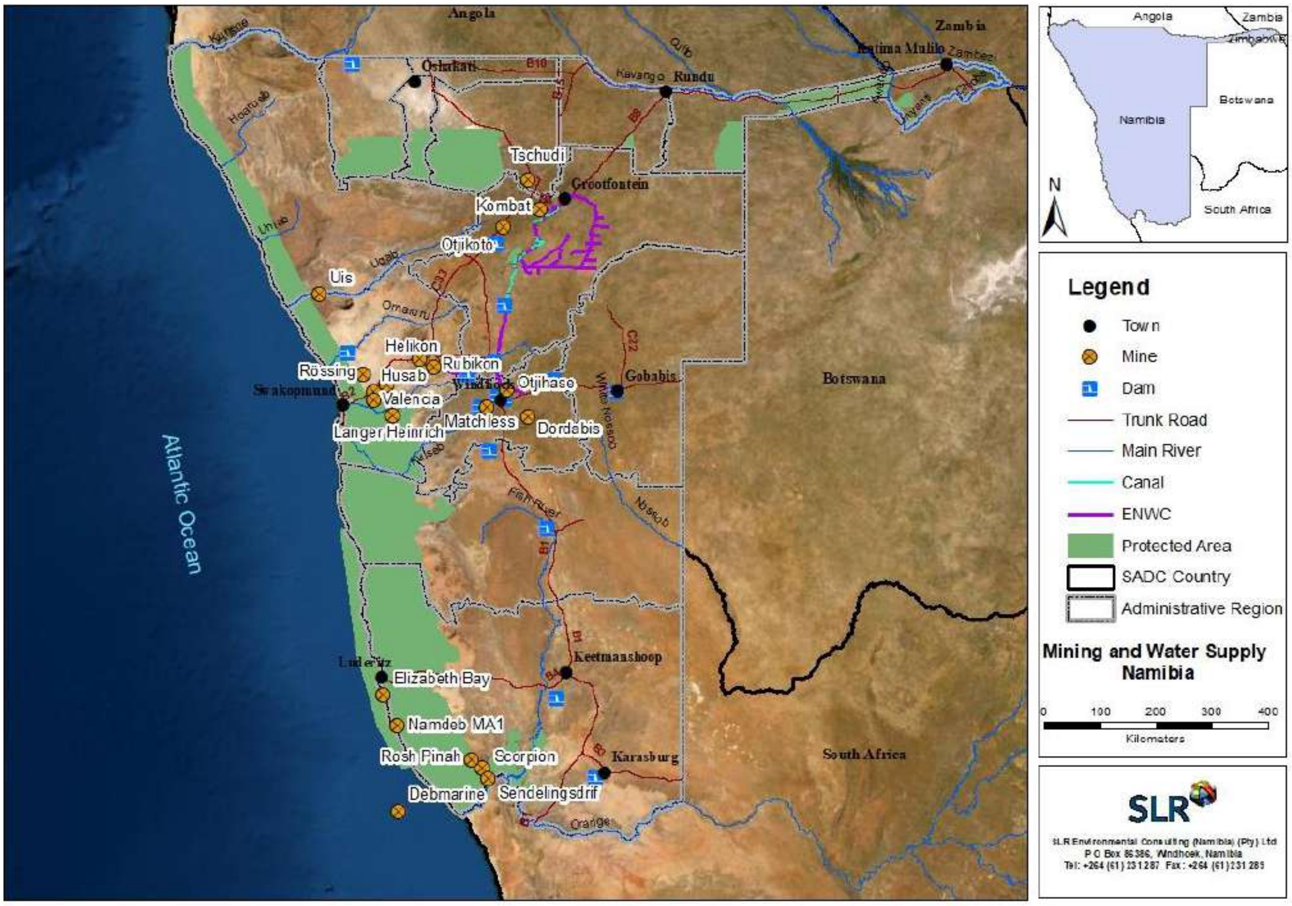
Diamonds are Namibia's most valuable commodity, contributing 2.6% to GDP, and 15.4% to all exports in 2021. Diamonds have been mined in Namibia since 1908, and the country hosts the World's largest diamond placer. In 2021, Namibia was also the 2nd largest producer of uranium in the World. Namibia's uranium activities are concentrated in the central western part of the country, where Late Neoproterozoic leucogranites carry minable amounts of uranium, and are also the source rocks for uranium deposits in younger sediments.

Copper has been mined in the Otavi Mountainland in the north of the country since the turn of the last century, most prominently in the famous Tsumeb Mine. However, there has also been intermittent production in the central part of the country, and zinc is produced in the far south. Namibia also has two gold mines, and a third one is in the process of being opened up. A variety of pegmatite deposits supports tin and lithium mining, mainly in the central part of Namibia. While not a traditional iron producer, the country also has a smaller iron ore mine since 2015.

1. General overview mining in Namibia

The earliest mining activities in Namibia date back some 400 years according to archaeological evidence of copper smelting in the area west of Windhoek. Namibia's oldest formal mine, the Matchless Mine, opened in 1856. Many famous discoveries would follow, including the Tsumeb Mine, which started production in 1906, and the discovery of the World's largest diamond placer in 1908. Since then mining has developed into the backbone of the Namibian economy, contributing more than 9% to GDP, and almost 55% of all exports. Mining is an important employer, and contributes substantially in the form of taxes, royalties and local procurement.

The diversity of Namibia's mines reflects the wide variety of metallogenic provinces. Commodities produced include copper, diamonds, gold, iron, lead, tin, uranium, and zinc. A geographical overview is given in the following figure.



2. Mining activity by commodity

2.1 Uranium

Almost all of Namibia's uranium activities are concentrated in the central western part of the country, also referred to as the Namibian Uranium Province. Here, Late Neoproterozoic leucogranites, termed alaskites carry minable amounts of uranium, and are also the source rocks for uranium deposits in young pedogenic and sedimentary sequences.

In 2021, Namibia was the 2nd largest producer of uranium in the World.

2.1.1 Rössing

- The Rössing Uranium Mine, some 60 km northeast of Swakopmund, is the World's largest open pit uranium mine, and with 46 years of operation the longest active uranium mine in the World. It is operated by majority shareholder CNNC.
- The primary ore comprises of uraniferous alaskites.
- The ore is mined from an open pit by conventional means using drilling, blasting, loading and hauling equipment.
- The ore is processed by leaching with sulphuric acid, slime separation in cyclones, counter-current decantation, continuous ion-exchange, solvent extraction, precipitation, filtration, and final drying and roasting.
- In 2021, Rössing produced 2882 t of uranium oxide.

2.1.2 Swakop Uranium

- Swakop Uranium's Husab Mine, in the Namib Naukluft National Park directly southwest of Rössing, is also one of the largest uranium mines in the World.
- Husab is operated by majority shareholder CGNPC.
- Its first production was in 2016, and since then the mine is ramping up to reach name plate production.
- The primary ore comprises of uraniferous alaskites.
- The ore is mined from an open pit by conventional means using drilling, blasting, loading and hauling equipment.
- The beneficiation process starts with crushing, followed by milling, leaching with sulphuric acid, counter-current decantation, ion exchange, solvent extraction, and final recovery by drying and roasting.
- In 2021, Swakop Uranium produced 3902 t of uranium oxide.

2.1.3 Langer Heinrich

- The Langer Heinrich Mine lies some 80 km east of Walvis Bay in the Namib Naukluft National Park. It first produced in 2007, but was placed on care and maintenance in 2018 due to the low uranium price.
- It is operated by majority shareholder Paladin Resources.
- A decision to restart the mine was taken in July 2022, and full production is anticipated for Q1 2024.
- The secondary ore comprises of uraniferous calcrete.
- The ore was mined from an open pit by conventional means using drilling, blasting, loading and hauling equipment.
- The ore was processed using conventional methods of crushing, scrubbing, separation using cyclones and screens, alkaline leaching, counter-current decantation, ion exchange, precipitation and calcining.
- Between 2007 and 2018, the Langer Heinrich Mine produced some 16 500 t of uranium oxide.

2.1.4 Trekkopje

- The Trekkopje Mine is situated 70 km northeast of Swakopmund, and operated by Orano.
- Since 2008, it was developed in three phases, as its ore body presents a technical challenge due to its low uranium content.
- Unfortunately, it had to be placed on care and maintenance in 2013 due to the low uranium price.
- The secondary ore comprises of uraniferous calcrete.
- The ore was mined from an open pit by conventional means using drilling, blasting, loading and hauling equipment.
- The ore was crushed by portable primary crushers near the pit and transported by conveyors to heap leach pads, where it was subjected to alkaline leaching, followed by ion exchange, solvent extraction, precipitation, filtration and drying.
- From 2012 to 2013, the Trekkopje Mine produced 437 t of uranium oxide.

2.1.5 Zhonghe Resources

- Zhonghe Resources is an exploration company with a mining license and a number of exploration licenses to the northeast of Rössing.
- Mineralisation is both, primary and secondary.

- The projects are in the exploration stage and no production has occurred yet.

2.1.6 Valencia

- Valencia is a uranium deposit located on the eastern edge of the Khan Valley some 80 km from Swakopmund.
- The primary ore comprises of alaskites.
- Valencia uranium has a definitive feasibility study and mining license in place, and is therefore construction-ready once the uranium price has reached the required level.
- The preferred mining method is a traditional open pit operation employing excavators, haul trucks and bench drills.
- The anticipated processing method is acid leaching.

2.1.7 Bannerman

- Bannerman Resources owns the advanced Etango exploration project 30 km southeast of Swakopmund.
- The primary ore comprises of alaskites.
- A Heap Leach Demonstration Plant was put in place in 2015 to establish the preferred leaching process method.
- The Definitive Feasibility Study for the establishment of an open cast mine is expected to be completed in September 2022.

2.1.8 Reptile Uranium

- Reptile Mineral Resources and Exploration is an advanced stage uranium exploration company with large tenements in the northwestern part of the Namib Naukluft National Park.
- Mineralisation is both, primary and secondary.
- Uranium mineralisation at the Tumas Project is hosted by calcretised palaeochannel sediments, very similar to Langer Heinrich, located some 27 kilometres northeast of that mine.
- The Definitive Feasibility Study for Tumas is expected to be completed in the latter half of 2022, and a Mining Licence has been applied for.

2.1.9 Elevate Uranium

- Elevate Uranium is the largest uranium tenement holder in Namibia and operates in the northwestern Namib Naukluft National Park. It also holds the Marenica project to the northeast of Trekkopje Mine under a Mineral Deposit Retention License.
- Its targets are secondary mineralised palaeo-channels.
- Active exploration is ongoing.
- Elevate Uranium owns the patented U-pgrade™ process that rejects greater than 95% of the mass of uranium ore by utilising commonly used beneficiation processes, which enable the removal of the non-uranium bearing minerals.

2.2 Copper

2.2.1 Tsumeb

- The Tsumeb Mine is situated in the town of Tsumeb in northern central Namibia.

- The Tsumeb ore body is a hydrothermal polymetallic pipe-like deposit in predominantly dolomitic successions of the Otavi Group.
- It was in operation from 1907 to 1991, but closed down just before the ore reserves were exhausted.
- Underground mining was by cut-and-fill method.
- Ore beneficiation took place in a classic flotation plant, however, to get better recovery of the oxide minerals of this multi-phase mineralisation, a gravity plant was added in 1987.
- The first smelter was erected at Tsumeb as early as 1907, and was the precursor of the current Tsumeb Smelter.

2.2.2 Tschudi

- Tschudi Copper Mine is located west of Tsumeb in the Otavi Mountainland (Oshikoto Region) and is owned by Weatherly International PLC.
- The disseminated copper-pyrite mineralisation is hosted by arenites of the Mulden Group.
- The operation is a conventional open pit.
- Ore was processed by heap leaching followed by electro-wining.
- The mine is currently under care and maintenance.

2.2.3 Kombat

- The Kombat Mine is located in the Otavi Valley some 37 km east of Otavi, and operated by Trigon Mining.
- Kombat Mine is the only mine in Namibia that has been developed in the early 20th century, in 1911, and which is still operating, albeit intermittently.
- There is currently only a small open cast mine, and operations have once more been suspended as from 01/08/2022 because of the low copper price.
- However for most of its productive life, the mine was an underground operation.
- The Kombat ore bodies are located in the contact zone between phyllite of the Kombat Formation and the underlying dolomites of the Tsumeb Subgroup.
- The various ore types include massive and semi-massive sulphides, vein-fracture systems, alteration breccias, mineralised fracture fillings, as well as some iron and manganese. They are of epigenetic, hydrothermal and metasomatic replacement origin.

2.2.4 Otjihase

- The Otjihase underground mine is located some 40km northeast of Windhoek and has been in operation intermittently since Independence.
- The mine first opened in 1975.
- The Otjihase Mine is currently under Care and Maintenance.
- The Otjihase mineralisation is closely associated with magnetite quartzite of the Matchless Amphibolite Belt, A MORB-type feature forming discontinuous layers in the schists of the Kuiseb Formation.
- The mineralisation is of the Volcanogenic Massive Sulphide type.
- Ore is mined by pillar-and-bay stoping.

- The plant is a conventional floatation operation.

2.2.5 Matchless

- The Matchless Mine is situated in the Khomas Hochland to the west of Windhoek.
- It is Namibia's oldest formal mine, and opened first in 1840.
- Currently, the mine is under Care and Maintenance.
- The Matchless mineralisation is closely associated with magnetite quartzite of the Matchless Amphibolite Belt, A MORB-type feature forming discontinuous layers in the schists of the Kuiseb Formation.
- The mineralisation is of the Volcanogenic Massive Sulphide type.
- Ore was mined by cut-and-fill stoping methods.
- The plant is a conventional floatation operation.

2.3 Lead-Zinc

2.3.1 Rosh Pinah

- The Rosh Pinah mine is situated in the Karas Region, 165 km south of Aus, approximately 23 km north of the Orange River.
- The mine is situated on state-owned land which borders with privately owned farms.
- The Rosh Pinah mine is 90% owned by Trevali Mining Cooperation and 10% by Namibian Broad-Based Empowerment Groupings and an Employee Empowerment Participation Scheme (EEPS).
- The mining licence No. 39 (ML 39) is held by PE Minerals. PE Minerals and RPZC have an Operational Agreement in which PE Minerals transferred all mining interest to RPZC. The Operational Agreement has been approved in writing by MME in 1999.
- The Rosh Pinah mine has been in continuous operation since 1969 and currently produces zinc and lead sulphide concentrates containing minor amounts of copper, silver, and gold.
- The Rosh Pinah Mine is hosted by the Rosh Pinah Formation (Hilda Subgroup of the Port Nolloth Group), forming part of the Neoproterozoic Gariep Terrane deposited onto a Palaeo-Mesoproterozoic basement of granite gneisses and supracrustals.
- The base metal sulphides at the Rosh Pinah mine are contained within the approximately 30-metre thick ore equivalent horizon (OEH). In the Rosh Pinah area, the Rosh Pinah Formation has been shown to be at least 1,250 metres thick.
- It is believed to represent a classic reworked sedimentary-exhalative (SEDEX) style exhalate deposit.
- The mining method includes: 2,000 tonne per day processing mill, flotation recovery plant, metallurgical and geochemical laboratories and a tailings facility.
- In 2021 RPZC produced 83,362 tonnes of zinc and 19,989 tonnes of lead.

2.3.2 Skorpion

- Skorpion Zinc Mine is located some 20km northwest of Rosh Pinah.

- The project is currently under Care and Maintenance due to geothechnical instabilities present in the pit, but there are plans to re-open the mine soon.
- The mine and associated Namzinc Refinery used to produce Special High Grade Zinc (SHG Zinc) from its open pit mine for export to the world markets.
- Skorpion Zinc is currently assessing options to safely mine the remaining ore and the conversion of its refinery to process primary zinc sulphides.

2.4 Gold

2.4.1 Navachab

- Navachab Gold Mine is located approximately 10km southwest of Karibib in Central Namibia.
- The Navachab Gold Mine is owned by QKR Namibia (Pty) Ltd.
- The mine is run as an open pit operation.
- Navachab has been operating since early 1990 and uses CIP (carbon-in-pulp) technology to produce doré bullion that is subsequently shipped off-site for refinement.
- The Navachab Mine produced 1 502 kg gold bullion in 2021.

2.4.2 Otjiikoto

- The mine is situated between Otjiwarongo and Outjo in north-central Namibia.
- The Otjikoto Mine is owned by B2Gold Namibia (Pty) Ltd.
- B2Gold acquired the Company's first African gold development project, the Otjikoto Gold Project, through a merger with Auryx Gold Corp. in December 2011. The Company received the Otjikoto Mining Licence in December 2012, and construction of the Otjikoto Mine commenced in April 2013. Within approximately 19 months, the first gold pour occurred on December 11, 2014, ahead of schedule. Underground mining started in 2022.
- The mine operates an open pit, and since the beginning of 2022 also some underground workings.
- In 2021, the Otjikoto Mine produced 4 763 kg of gold bullion.
- The Otjikoto Mine is expected to produce between 175,000 - 185,000 ounces of gold in 2022.

2.4.3 Twin Hills

- The Twin Hills project is owned by Osino Resources.
- The site is located approx. 12 km North of Karibib next to the C33 to Omaruru.
- Twin Hills was discovered in 2019.
- On 12 April 2021, the company released its maiden mineral resource estimate comprising 13.5 million t at an average grade of 1 g/t gold.
- The Twin Hills mine development is in progress.

2.5 Diamonds

Diamonds are Namibia's most valuable commodity, contributing 2.6% to GDP, and 15.4% to all exports in 2021. Diamonds have been mined in Namibia since 1908, and the country hosts the

World's largest diamond placer. 95% of the stones are of best gem stone quality, and Namibia is the World's leading marine diamond producer. Most operations belong to Namdeb Holdings, a joint venture between the Namibian government and the DeBeers Group, while the Elizabeth Bay mine, previously also a Namdeb mine, was recently sold to Sperrgebiet Diamonds.

2.5.1 Namdeb MA1

- Namdeb's Mining Area 1 in the southern coastal area reaches from the mouth of the Orange River near Oranjemund to north of Chameis Bay, a distance of about 100 km. The license extends from about 5.5 km offshore to about 35 km inland.
- The diamonds are mined from the gravels of marine raised beaches.
- The ore is recovered in small open cast operations utilising advanced sea wall mining techniques, overburden removal, excavating, and manual gravel recovery using transvac machines.
- The gravel is then transported to central recovery plants employing crushing if required, screening, dense medium separation, X-ray separation, and final hand sorting.
- Together with Sedelingsdrif, the MA1 produced 330 196 carats in 2021.

2.5.2 Sendelingsdrif

- The Sendelingsdrif Mine is located along the Orange River approximately 80 km inland from Oranjemund and 20 km south of Rosh Pinah. It started to produce in 2014.
- The ore comprises diamondiferous gravels of a proto-Orange River terrace.
- The ore is mined in an open cast operation employing overburden removal, waste stripping, excavation, and loading and hauling. Blasting is necessary only when cemented layers are encountered. Manual bedrock cleaning with transvacs is used in some areas.
- The treatment plant consists of a dry screening process, dense medium separation, and X-ray separation. The concentrate is transported to Oranjemund for final hand-sorting.
- Together with MA1, Sendelingsdrif produced 330 196 carats in 2021.

2.5.3 Elizabeth Bay

- The Elizabeth Bay mine is located some 25 km south of Lüderitzbucht, and has been in operation intermittently since 1926, when it had one of the most modern processing plants in the World. Since 2020, it has been operated by Sperrgebiet Diamonds, however only on a care and maintenance basis, while modifications to the operations are undertaken.
- The ore consists of 1 to 4 m thick unconsolidated diamondiferous sands and gravels underlain by 2 m of diamondiferous cemented gravels.
- The ore was and will be mined by conventional open cast techniques employing hydraulic excavators, loading and hauling with articulated dump trucks.
- The ore was and will be treated in a plant employing crushing, screening, scrubbing, dense medium separation, X-ray separation and final hand sorting.
- There has been no production in the last 2 years, but it is anticipated that production will resume in September 2022. Past production was around 200 000 carats annually.

2.5.4 Debmarine Namibia

- Debmarine Namibia operates a large offshore license area of some 600 000 ha, termed Atlantic 1 to the west of Namdeb's Minig Area 1. A fleet of six production vessels is responsible for about 70% of Namibia's diamond production. Exploration is carried out by a

dedicated exploration vessel. Mining takes place on the sea floor at water depths of up to 140 m.
- Namibia's marine diamond deposits on the continental shelf have a complex sedimentary history involving introduction of the diamonds by fluvial systems and subsequent reworking by marine coastal and nearshore processes during times when the sea level was lower.
- Two mining technologies are deployed to suit different ground conditions, namely airlift-drill technology, which uses a 6.8 m diameter drill bit working in overlapping circles on the sea floor; and the crawler technology, which uses a 280 t track-mounted crawler dredging the sea floor.
- Processing of the ore takes place in recovery plants on board the ships employing screening, dense medium separation and X-ray separation. The resulting concentrate is transported by helicopter to Oranjemund for final hand sorting.
- In 2021, Debmarine Namibia produced 1 136 000 carats of diamonds.

2.6 Tin

Namibia has a large variety of tin deposits, which have been mined on different scales since the colonial days. However, the only large-scale production took place at the Uis and Brandberg West Mines, of which only Uis is still in operation today.

2.6.1 Uis

- The Uis Tin Mine is located some 28 km east of the Brandberg Complex, and has intermittently been mined since 1911. Up to 1990 it was operated by the South African company ISCOR, during which time it was the largest hard-rock tin mine in the World. It was re-opened in 2018 by the current operator AfriTin.
- The ore comprises of unzoned, coarse-grained pegmatites carrying disseminated cassiterite mineralisation, and belonging to the rare-metal bearing pegmatite type.
- Mining is conducted in a conventional open pit operation with drilling, blasting, loading and hauling equipment.
- The processing plant has a complex set of crushers, namely a primary, a secondary and a tertiary crusher, followed by 2 quaternary crushers, taking the ore to -6 mm. Thereafter it passes through two stages of dense medium separation and finally shaking tables, resulting in a concentrate of 62%+ tin.
- The potential of producing lithium and tantalum as a by-product is currently under investigation.
- In 2021, the Uis Tin Mine produced 784 t of tin concentrate.

2.7 Lithium

Namibia also has a large variety of lithium deposits, which have been mined on different scales since the colonial days. However, the only large scale production has taken place at the Rubikon and Helikon Mines, which are currently in preparation for re-opening by Lepidico.

2.7.1 Rubikon + Helikon

- The Rubikon and Helicon Mines are situated on farmland some 30 km southeast of Karibib. They were mined in the past between 1951 and 1992.

- The ore comprises of highly differentiated pegmatites of the internally zoned lithium-caesium-beryllium-rubidium pegmatites, well known for the highest degree of alkali fractionation. Lithium ore minerals include lepidolite, petalite and amblygonite.
- Selective mining occurred in open pit, as well as underground open stoping operations, employing drilling, blasting, loading and hauling.
- After the re-opening, the operation with be open pit only.
- Beneficiation was mainly done by screening and hand sorting, however, a lepidolite flotation plant was in operation for some time at Rubikon.
- Lepidico has patented processes to produce both lithium carbonate and lithium hydroxide from hard-rock lithium-bearing minerals, and intends to erect a chemical plant for that purpose. Furthermore, caesium and rubidium contained in these lithium minerals are amenable to processing too by the company's proprietary technologies.

2.8 Iron

Namibia has not been a traditional iron ore producer, but its first iron ore mine, although first investigated in the 1950s, came into small scale production only in 2015, and is ramping up since. It is operated by Lodestone Namibia.

2.8.1 Dordabis

- The Lodestone Iron Mine is located near Dordabis, some 60 km southeast of Windhoek.
- The ore comprises of banded iron formation containing hematite and magnetite.
- Mining is conducted in a conventional open pit operation employing drilling, blasting, loading and hauling.
- Once fully operational, the plant will produce a 66% iron concentrate by screening, crushing, grinding, and gravity separation.
- In 2021, Lodestone produced 75 718 t of iron ore.

HIGH-LEVEL BASELINE STUDY

WATER MANAGEMENT IN NAMIBIA

by

Piet Heyns

Enhancing decision making for sustainable development

1. Introduction

Namibia is the most arid country in sub-Sahara Africa due to the huge difference between precipitation and evaporation. Freshwater scarcity thus remains a major environmental challenge. Less than 5% of the country is arable and only limited rainfall and groundwater sources are available to support socio-economic development. Although the target of the third National Development Plan (NDP3) to provide 95% of the population with sustainable access to safe water has been reached, sound and sustained water management to ensure social, economic, and environmental benefits remains high on the agenda. Scarce water resources must be shared between the growing population, increasing agricultural production and an expanding industrial sector, while environmental requirements must be accommodated, and pollution prevented at all costs. Water supply is therefore a major challenge in Namibia, especially in the rural areas where small settlements are in very remote places. Water must be transported over long distances from source to consumer. Capital investments are high and then recovery of water supply costs from a predominantly poor population in the urban and rural environment is a major challenge. The existing water supply infrastructure must be maintained, additional water supply infrastructure must be established, facilities must be operated, and fees collected to recover the capital and operating cost to supply water. The same applies to sanitation services and wastewater disposal. Appropriate water policy, legislation, regulations and timeous infrastructure development are therefore of great importance to achieve the national water security objectives.

2. Water management institutions in Namibia

2.1 The Cabinet Committee on Water Supply Security

The Cabinet Committee on Water Supply Security was appointed by President Hage Geingob in July 2016 to address an acute, looming water crisis in Namibia due to a lack of sufficient rainfall to generate runoff into the dams in central Namibia, as well as a failure to do adequate maintenance of existing water supply infrastructure and the planning the development of new infrastructure.

The CCWSS comprises Ministers of the relevant Ministries, i.e. Presidential Affairs, Agriculture, Water and Land Reform, Urban and Rural Development, Economic Planning, Finance, and the Director General of the National Planning Commission. The Committee is also assisted by a Technical Committee of Experts, comprising technocrats and experts from government, the strategic executive for infrastructure, water and technical services of the City of Windhoek, as well as the private sector.

Among others, the function of the committee is to review all existing water supply challenges, consider water supply solutions proposed by various stakeholders, including NamWater, the Department of Water Affairs and the Windhoek Municipality, to enable the Committee to propose an implementation plan and estimated cost on how to avert the projected water crisis.

The planning horizon was one month for an immediate, costed plan by mid-August to alleviate the anticipated water crisis in Windhoek. Once this plan has been adopted and implementation thereof is visibly on track, the Committee should turn its attention to other national water initiatives in a phased approach, including a construction programme and a capital expenditure programme over the following three years. An implementation report had to be available at the end of 2016.

This Committee achieved its immediate objectives and is still doing sterling work to improve the water supply situation in Namibia.

2.2 The Ministry of Agriculture, Water and Land Reform (MAWLR)

The Mission of the Ministry of Agriculture, Water and Land Reform (MAWLR) is to realise the potential of the agricultural, water and land sectors to promote efficient and sustainable socio-economic development to ensure a prosperous Namibia. Only the water related structure of the Department of Water Affairs in the Ministry is discussed. There are two directorates in the DWA.

2.2.1 Department of Water Affairs

2.2.1.1 Directorate: Resource Management

The mission of the Directorate is to promote and facilitate the environmentally sustainable development, management, and utilization of water as a scarce resource to achieve, on behalf of, and with all the citizens of the nation, sound socio-economic development in Namibia. The Directorate has three Divisions: Resource Management, Hydrology, Geohydrology and Water Law Administration

2.2.1.2 The Directorate: Water Supply and Sanitation Coordination

The Mission of the Directorate is to take full responsibility for the implementation of rural water supply for the rural communities on communal land. Its activities are directed towards the ultimate Government goal which is to promote and maintain the welfare of the people. The rural water supply support units will provide project management services, policy advice, training services, management of waterpoints pipelines, advice and support in rural water supply operations

2.3 The Namibia Water Corporation Ltd (NamWater)

The Corporation was established on the 1st October 1997 as a public company. The primary business of NamWater is bulk water supply to customers, in sufficient quantities, of a quality suitable for the customers' purposes, and by cost-effective, environmentally sound and sustainable means. The secondary business of the company is to render water-related services, supplying facilities and granting rights to customers upon their request. To enable, NamWater to supply potable bulk water it must plan, design, build, operate and maintain the bulk water supply schemes while operating according to sound business principles.

3 Water Policy

The administration of water affairs in Namibia is based on several pillars. These are the Constitution of the country, national and regional water policy, national, and international water law, water treaties, international water conventions, regional protocols, regulations formulated to implement national water legislation and the procedures developed to administrate the regulations. The term “regional” in this context refers to the Southern African Development Community (SADC).

What should also be kept in mind is that water policy has a formal and an informal side. It is possible that within the framework of a formal, generic policy statement and the subsequent legislation to formalize the practical implementation of certain policies, there are many internal water management policies which are not enforced by law but is practiced in the general administration of water matters. Some of these policies are contained in the regulations promulgated in terms of the law, others may be based on Cabinet decisions, and some may be part of the daily decisions by the management.

While water law can compel or prohibit behaviours (e.g., a law that prescribes that a permit is required for specific activity), a policy merely guides the actions to achieve a desired outcome such as the promulgation of an Act by Parliament to implement a policy. The technical regulations that prescribe how the Act must be implemented is drafted by the Ministry responsible for the administration of that Act and published in the Government Gazette. This means that regulations are not promulgated by Parliament but can be adjusted by the Minister as required when it needs to be done (e.g., when the cost of a license for a car increases every year) without having to obtain the “approval” of Parliament. The next step is to formulate the internal Ministerial procedures to administrate an Act and the regulations so that there is no ambiguity between Government and the public on how the procedures should be executed and who is responsible for what.

The policy documents most relevant to water resources and wetland resources in Namibia are the:

- Water Supply and Sanitation Sector Policy (WASP).
- National Water Policy (NWP).
- Water Supply and Sanitation Policy (WSASP).

The overall water planning and management functions, as well as the broad division of responsibilities within the water supply and sanitation sector are of extreme importance to achieve efficient water management. The most important functions to create and implement water and sanitation sector policy are primarily the

responsibility of the DWA. This requires the development of water policy and water legislation, the publication of water regulations, the strategic planning of water development and exercising control over the development, utilization, conservation, and protection of the natural water resources of the country. This control is vested in the administration of the water legislation and the legal system in Namibia.
Procedures must also be elaborated to guide the administration required to give effect to the decisions and actions. Procedures are required for each activity and all activities take place within the uniform boundaries of the methods employed in the day-to-day operations of the organization.
The need for potable water and basic sanitation services in Namibia was identified at independence as one of the major and basic essential needs that had to be improved, especially in communal areas. The Constitution of the Republic of Namibia clearly provides for the Government to assume responsibility for the overall management of the water and sanitation sector. It further stands to reason that the Government should be clear about its objectives and policies. Government should furthermore ensure that these responsibilities are carried out efficiently by appropriately structured institutions and with the best coordination possible between the various Governmental authorities, the private sector, water users and other beneficiaries.
In November 1990, the Government took the first steps to achieve the water policy objectives when Cabinet resolved to appoint an Inter-ministerial Committee to investigate the water and sanitation sector with the objective to recommend an appropriate water supply and sanitation sector policy. The Water Supply and Sanitation Sector Policy (WASP) was approved by Cabinet in September 1993

3.1 The Water Supply and Sanitation Sector Policy (1993)

This policy was approved by Cabinet on 21 September 1993. It became an urgent necessity after the independence of Namibia because the Government institutions were restructured, and mandates changed. The homeland authorities who had the responsibility for rural water supply and sanitation services, were abolished. Their staff was transferred to the Department of Agriculture in the new Ministry of Agriculture, Fisheries, Water and Rural Development. This caused confusion because the Department of Agriculture suddenly had rural water supply and sanitation related responsibilities, but the DWA in the Ministry was held accountable for those functions. The Department was at that time responsible for large scale bulk water supply and neither restructured to accommodate the staff allocated to the Department of Agriculture, nor received the additional staff to attend to the additional responsibilities, especially the sanitation function, which was actually in the ambit of the Ministry of Health and Social Services. The DWA therefore proposed that the allocation of the responsibilities for water supply and sanitation functions should be formalised by Government.
The WASP not only dealt with the policy principles regarding water supply and sanitation issues, water supply priorities and cost recovery for service delivery, but paved the way for the creation of a Directorate Rural Water Supply in the DWA, and an investigation to commercialize the bulk water supply function which led to the promulgation of the Namibia Water Corporation Act which established the Corporation (NamWater).
The WASP recognised that it is necessary to prioritise the uses of water in a country with limited water resources, when it comes to the allocation of water for competing demands. In this regard the first priority is water for domestic purposes, which include water for livestock watering for both subsistence and commercial farming. The second priority is for economic activities such as mining, industry, manufacturing, hydropower generation, irrigation, and recreation. Priorities for these activities will in each individual case have to be determined by their respective value in relation to the overall development objectives and plans for the country. Economic activities that employ large numbers of people will in most cases be a higher priority than the use of water for irrigation where mechanisation reduce the number of people employed. The policy also clarified the allocation of responsibilities in the water supply and sanitation sector, but those responsibilities have been adjusted over time. The present (December 2020) situation is:

- In 1993 the DWA remained responsible for bulk water supply, but responsibility for the rural water supply function was added and the name of the Ministry changed from to the Ministry of Agriculture, Fisheries, Water and Rural Development to the Ministry for Agriculture, Water and Rural Development. (MAWRD). At present the DWA is in the Ministry of Agriculture Water and Land Reform (MAWLR) and responsible for water resource management, as well as rural water supply and sanitation coordination.

- In 1997 the function for the supply of bulk water according to sound business principles was transferred from the DWA to the Namibia Water Corporation (NamWater), established under the Namibia Water Corporation Act No. 12 of 1997.
- The Local Authorities got the responsibility for urban water supply, water reticulation and the treatment of domestic sewage effluent in the cities and towns. Windhoek also became responsible for the reclamation and reuse of treated domestic effluent. Other towns are responsible for water supply, reticulation, and sewage treatment only (e.g., Outjo) or reticulation and sewage treatment only (e.g., Rehoboth).
- The Regional Authorities are responsible for water supply and sanitation services to small communities in villages and settlements.
- In 1993 the Ministry of Health and Social Services got the responsibility for the development of rural sanitation facilities at villages and settlements, but this is now the responsibility of the Regional Authorities, assisted by the Directorate Water Supply and Sanitation Coordination in the DWA.
- The private sector, such as commercial farmers, mines, and tourism lodges, is responsible for its own water supply and disposal of domestic sewage effluent.
- The mining sector is responsible to supply their own water or approach the DWA to provide bulk water and to dispose of mining effluent to avoid pollution and the reuse of water in the mining processes.

The WASP aimed to improve sustainable food self-sufficiency and security and provided a foundation for the equitable and efficient development of water supply in Namibia. The policy promotes the supply of water, as well as improved sanitation at an affordable cost to all Namibians. The objective here is to subject these developments to environmental impact assessments to guarantee their sustainability. The policy states that improved provision of sanitation can contribute to improved health, ensure a hygienic environment, protect water sources from pollution, promote water conservation, and stimulate economic development. The policy laid the foundations for the establishment of a Directorate of Rural Water Supply, the community-based management of rural water supplies, and the establishment of more than 200 Water Point Committees countrywide.

The policy grants communities the right, with due regard for environmental needs, to plan, maintain and manage their own water supply and to choose their own solutions and levels of service. Yet, the policy makes it clear that this right is subject to the obligation that the beneficiaries should contribute towards the cost of the water services provided.

Furthermore, the policy stresses the environmentally sustainable development and utilisation of water resources. The Water Point Committees are obliged to raise concerns about any developments or alterations that may pose a threat to the water supply and their water resources. They are also responsible for implementing specific management measures, such as the strict allocation of an ecological water reserve and water demand management measures.

With these provisions, the policy places strong emphasis on community involvement, participation, and responsibility.

3.2 The National Water Policy (2000)

In March 1998, the Government decided to initiate the Namibia Water Resources Management Review (NWRMR) to:

- Assess the existing arrangements for managing water resources and services.
- Promote the sustainable development of freshwater resources.
- Provide the population with equitable access to water, especially for the rural and urban poor.
- Ensure long-term social and economic development.

The NWRMR took a fresh, progressive look at the advances and initiatives in water resource management that have been made in both Namibia and elsewhere in the world. On this basis a set of new approaches and policies were recommended to address the contemporary challenges facing the country in conserving its limited and vulnerable resource base and to extend reliable water and sanitation services to the population. This work led to the adoption of a National Water Policy (NWP) in 2000. The NWP provides for community participation to lowest appropriate level in water resources management and the development of basin management plans that will serve as inputs to the national water master plan.

In 2002 Cabinet approved the National Water Policy White Paper, which formed the foundation of the Water Resources Management Act No. 4 of 2004 that was promulgated by Parliament, but de facto never entered into force.

The NWP provides a framework for equitable, efficient, and sustainable water resources management and water services, and stresses sectoral coordination, integrated planning, and management as well as resource management aimed at coping with ecological and associated environmental risks. It states that water is an essential resource to support life and that an adequate supply of safe drinking water is a basic human need. The policy makes it clear that water concerns extend beyond human needs for health and survival. Water is essential to maintain natural ecosystems, and the policy recognises that, in a country as dry as Namibia, all social and economic activity depends on healthy aquatic ecosystems. The NWP stresses that the management of water resources need to harmonise human and environmental requirements, recognising the role of water in supporting the ecosystem. One of the strategies to ensure environmental and economic sustainability is to ensure that in-stream flows are adequate – both in terms of quality and quantity – to sustain the ecosystem. This expectation is a huge challenge because the rivers in the interior of Namibia are ephemeral and many dry up in the dry season.

The NWP was developed to guide water resources management in Namibia. It is based on the country's physical and climatic setting, particularly its aridity, building on the legacy of the pre-independence water supply infrastructure and current trends in water development, specifically relating to water resources management. This policy clearly states that water concerns extend beyond human needs for health and survival, that water is essential to maintain natural ecosystems while all social and economic activity depend on healthy aquatic ecosystems. The policy further recognises the need for inter-sectoral coordination between all stakeholders involved in using and managing water resources. Salient principles contained in the policy include:

- **Integrated management and planning** – Management and planning of water resources should be integrated across economic, environmental, and social dimensions.
- **Development and intergenerational equity** – The country's water resources should be utilised, developed, and managed in a way that promotes equitable and sustainable socio-economic development without prejudicing the benefits and opportunities of future generations.
- **Ownership of water** – Namibia's limited and vulnerable water resources are an indivisible national asset, whose ownership is vested in the state on behalf of the whole society.
- **Equity** – All Namibians should have the right of access to sufficient safe water for a healthy productive life.
- **Water for ecosystems** – Water resources management needs to harmonise human and environmental requirements and recognise the role of water in supporting ecosystems.
- **Shared watercourses** – Namibia should strive to promote the equitable and beneficial use of international watercourses based on generally accepted principles and practices of international law, respect the rights of upstream and downstream users in other countries, strive to harmonise domestic legislation with the tenets of international law and respect the right of all stakeholders including basin communities to participate in negotiations and consultations at international level.
- **Recognition of economic value** – Economic value of water resources in Namibia should be recognised given their scarcity and vulnerability. Water abstraction, use, conservation, and management should be efficient and cost effective.
- **Stakeholder involvement** – Water resource use, planning, service provision and management should take place within a framework that encourages awareness and participation among stakeholders at all levels.
- **Information exchange** – Water resources information systems should be developed and made accessible to the public, and that institutions involved in the management and provision of water services should do so in an open and transparent manner.
- **Decentralisation** – The management of water resources and water services should be decentralised to the lowest practicable level are recommended.

- **Role of institutions** – There is a need to have institutional functions clearly defined; and
- **Capacity building** – Capacity building should be a continuous process of institutional and human development and should include participation by the public and private sectors, civil society, and community structures.

The Policy recognises the need to promote equitable and beneficial use of international watercourses based on generally accepted principles and practice of international law. This realisation originated from the 1974 Water Master Plan that identified the need for Namibia to negotiate for access to shared perennial rivers to complement the internal water sources. The policy proposes to protect water resources from pollution by enforcing the 'polluter pays principle' and regular water quality monitoring on all proposed projects. Furthermore, it proposes to improve knowledge on the vulnerability of critical wetland ecosystems and to develop strategies for their effective management. Two clauses within Section 2.3 on Water Use and Conservation Principles and Section 2.5 on Legislative and Regulatory Principles are particularly relevant to shared water resources:

- Precautionary environmental protection: The resource base shall be protected against any kind of contamination or pollution that could render any part of it unfit for beneficial human, economic and environmental purposes, applying the precautionary principle.
- Factoring environmental considerations in decision making: The need to protect the environment in general, and the aquatic ecosystems in particular, including their biodiversity and the nation's wetlands will be factored into the allocation of water resources for use and will include the prior assessment of the environmental impacts of proposed water uses.

The totality of the principles found in Namibia's policy framework for water resources management satisfies the criteria for sustainable use of shared watercourse systems and principles found in international law instruments that Namibia is party to and provides sound guidelines for future legislation and regulation

3.3 The Water Supply and Sanitation Policy (2009)

Water policy is not cast in concrete and can be changed, revised, or renewed over time as new approaches to water management are required. The effectivity of the WASP was assessed in 2006 mainly due to the slow progress with sanitation services which had only 50% coverage in comparison with water services that reached 95% coverage. The poor performance in the sanitation sector was attributed to "institutional fragmentation" which defeated the objectives of the WASP in the sanitation sector. In 2008 the WSASP was the third water policy adopted by Cabinet and although the directives in the previous two water policies, WASP, and NWP, have not all been accommodated in the WSASP, it does not mean that certain elements in the previous policies have been ignored or rescinded because they are still being applied. For example, the WASP already stated in 1993 that water resources and the environment are closely related. The sensitivity of the ecosystem to any changes in the water balance should always be respected and accommodated when water resources and new water infrastructure developments are planned. Measures to prevent the pollution of water resources and the environment should also be part of the management approach rather than trying to restore previous, or allow future, negative effects. This theme runs consistently through all previous policies and in the WSASP.

One of the main additions to the WSASP is that its principles are in line with the principles of integrated water resources management, including a strong focus on water demand management and the improvement of sanitation services.

Generally, it aims at ensuring equitable access to water resources sufficient to maintain life, health, and productive activities of the population.

Under this policy the Government is the custodian of all water resources and has the right to control all water use and disposal of effluent. Integrated supply and demand planning are required in both the short and long term. Further, the WSASP promotes sustainable water utilisation through suitable pricing, promotion of water-efficient technology, public information and awareness programmes, information sharing and co-operation between parties, the promotion of wastewater re-use and active support of applied research and data gathering to monitor water conservation.

There is also provision made for subsidies to those who cannot afford to pay the full costs of water, however, not all communities who cannot pay, receive subsidies.
Water resources and the environment of Namibia are closely related. Due cognisance of this fact should be taken and respected whenever any employment of water for development is valued. The sensitivity of the country's natural ecosystem to any changes in the water balance should always be appreciated. The possible pollution of water and other resources should also be guarded against. A pre-emptive management approach rather than trying to counteract eventual negative effects should form part of all planning and decision-making processes.

4 Water Legislation

4.1 The Constitution of the Republic of Namibia

There are three Articles in the Constitution that have direct bearing on the management of water resources. Chapter 11 of the Constitution addresses the principles of State policy regarding environmental management of water resources and the ownership of water. Chapter 21 addresses the legal status of international water agreements. The said Articles are:

- Article 95 deals with the promotion of the welfare of the people by adopting inter alia policies such as Article 95 (l) which calls for the maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilization living natural resources on a sustainable basis for the benefit of all Namibians, both present and future,
- Article 100 deals with the sovereign ownership of natural resources and states that land, water, and natural resources below and above the surface of the land and in the continental shelf and within the territorial waters and the exclusive economic zone of Namibia shall belong to the State if they are not otherwise lawfully owned. However, the reference to “if they are not otherwise lawfully owned” is not only ambiguous and open for interpretation, but often deliberately omitted when the Article is quoted.
- Article 144 states that unless otherwise provided by this Constitution or Act of Parliament, the general rules of public international law and international agreements are binding upon Namibia under the Constitution and shall form part of the law of Namibia.

The emerging dichotomy of the Article 100 is that it affects only the farming community on commercial land as far as water sources are concerned. This can be examined by looking at the present land tenure system which makes provision for the private ownership of land e.g., commercial farms and plots or erven in urban areas. However large tracts of land are either communal land, held in trust by the state, or nature parks that also belongs to the State, and technically the water resources are therefore owned by the State in any case and the State can allocate the water to any user, whether such use is granted or when such use is requested. The land and the water resources on or below the surface of privately owned land is theoretically part of the property because nobody would want to own a farm with the objective to farm commercially, and on business principles, if the water belongs to somebody else. The concept that if one owns something, like water in an arid country, you will take good care of it, is totally defeated if water belongs to the State. A commercial farmer will not invest money in water abstraction facilities or waste pumped water because he had paid for the water supply infrastructure and the operating cost of the service, which is therefore not free of cost in any case. He will also not pollute his water sources or use it in an unsustainable way, because that will ruin his farming activities. Water and property should clearly both be part of the ownership package. If the argument holds that water on privately owned land belongs to the State, then it can be argued that the State has an obligation to supply water to the farmer. (Which is being done in many cases on resettlement farms where it is expected by the resettled farmers that the State, to whom the land belongs, must assist to supply water, which is at the expense of the taxpayer while the commercial farmer who previously provided the same service himself when he owned that same farm and therefore did not burden the taxpayer. A similar situation exists on communal land where not only the water, but also the land belongs to the State. The capital cost of rural water supply infrastructure is, directly or indirectly funded with taxpayers’ money, and the operating cost to supply the water is heavily subsidized by the taxpayer because the rural communities find it difficult to pay the full economic cost so supply the water, while commercial farmers bear the full responsibility on their farms.

It would also be inequitable to serve some communities with water from sources that do not belong to them, while it is expected from a private landowner to protect the property (water) of the State on his land, but he is not assisted with the supply of water. The best the State can do is to monitor the sustainable abstraction of water on commercial farms through a permit system that may require information about the quantity of water abstracted, but many successful commercial farmers do that in any case because, by doing that, one can plan stock numbers, based on the availability of water and grass after a rainy season, thus enabling the farmer to reduce stock numbers when boreholes are yielding less water after a poor rainy season.

4.2 The Water Act, Act 54 of 1956

Only those Articles of the South African Water Act No. 54 of 1956, that cover issues that applied in a similar way to Namibia, had been made applicable in Namibia and according to Article 140 of the Constitution of Namibia, all laws which were in force immediately before the date of independence shall, subject to the provisions of the Constitution, remain in force until repealed or amended by an Act of Parliament or until they are declared unconstitutional by a competent court.

The Water Act of 1956 is generally referred to as the "Old Water Act", and often in the past tense, remains strictly speaking applicable until it is officially repealed and replaced with a new water act. Two attempts have been made to achieve that objective. The first was the Water Resources Management Act, Act 24 of 2004 (WRMA-24) that never entered into force. The second is the Water Resources Management Act 11 of 2013 (WRMA-11), promulgated by Parliament, but has not been signed into force because the Regulations, which are of a highly technical nature, are still with the Ministry of Justice for approval. As a result, the Minister has not been able to determine a date for the Act to come into operation as required by Section 134 of the Act. Thus, the "Old Water Act" remains applicable for the time being.

The main purpose for passing the WRMA-11, as its preamble states, is to consolidate and amend previous laws relating to the control, conservation and use of water for domestic, agricultural, urban, and industrial purposes in South Africa and made applicable in Namibia for the same purposes. The Act also aims to make provision for the control of the use of sea water for certain purposes, for the control of certain activities on or in water in certain areas and for the control of activities which may alter the natural occurrence of certain types of atmospheric precipitation.

Section 2.(m) of the Old Water Act clearly confirms the interest of the State in protecting water resources by giving the Minister the power to, amongst others, investigate water resources, plan water supply infrastructure, develop water schemes, operate water schemes, control water pollution, protect, allocate and conserve water resources, inspect water works, levy water tariffs and advise on all matters related to the water environment in general. It basically makes the DWA responsible for control over the use, allocation, disposal and conservation of all surface and groundwater resources in Namibia. Provision is made for the protection of river catchments, drilling of boreholes, and making of wells, controlling effluent discharge on land and into rivers as well as to authorise weather modification, such as cloud seeding.

The Act also aims to make provision for the control of the use of sea water for certain purposes (such as desalination), for the control of certain activities on or in water in certain areas (such as unsustainable groundwater abstraction) and for the control of activities which may alter the natural occurrence of certain types of atmospheric precipitation.

The implementation of the Act is guided by the Regulations made to prescribe water quality control, the construction of farm dams, the disposal of wastewater, the protection of artesian water sources and the use of large groundwater sources of national interest in declared groundwater water control areas.

Although the sections in the Water Act that were made applicable to Namibia are still enforced, the Act do not cover all the new policies and principles of water law required in an independent Namibia. To inform the drafting of the WRMA-11, Government considered the WASP, NWP and WSASP (water policies) as elaborated above. The Old Water Act distinguishes between private and public water. Private water is that which flows, naturally rises, falls, or generally drains or is directed into land but is not available for common use. Public water includes any water flowing or found in or derived from the bed of a public stream, whether visible or not. It should also be noted that during the German colonial period the major ephemeral rivers in Namibia all belonged to the State and was therefore "public water". Farms have been surveyed in such a way that the

farm boundaries did not include major rivers and those farmers did not have rights to that public water although their location was riparian to the river.
There is therefore no private property right to public water, and the sole and exclusive use and enjoyment of private water is vested in the owner of the land on which such water is found. The Act thus gives preferential abstraction rights to the landowners on whose land such water is found because the water is required for commercial agricultural purposes, unless the area in which the water resources occur, has been declared as a subterranean water control area and in such cases, water can also be allocated under a permit to enable the farmer to continue with commercial farming activities. The private-public water dichotomy might be unconstitutional in the current constitutional dispensation because whereas the Act provides for private and public water, the Constitution regards natural resources as common resources, thus they constitutionally belong to the State unless otherwise lawfully owned. Considering that all water is controlled by the state under the public trust doctrine emanating from Article 100 read together with schedule 5 of the Constitution, all the water can be regarded as a common resource – hence public. The Act, however, has some balancing provisions whereby the Minister of Agriculture, Water and Land Reform (MAWLR) has the power to control the amount of water to be used by a person who has private water rights. Connected to this in terms of Section 21, the Minister has the power to order a person to purify water he has contaminated. A person can, however, apply for an exemption from this duty and the Minister is empowered to consider whether to grant the application or not. The Minister can also solicit the advice of the DWA about the decision.
Section 23 prohibits pollution of public or private water, including underground water, or seawater. Sections 27 to 55 deal with control and use of subterranean water. The President is empowered to declare certain waters to be a subterranean water control area, if the Minister is of the opinion that it is in the public interest to do so. Once proclaimed, Cabinet has extensive powers to determine how that water is going to be abstracted and all concomitant matters.
This Act gives the Minister the power to investigate water resources, plan water supply infrastructure, develop water schemes, control pollution, protect, allocate and conserve water resources, inspect water works, levy water tariffs and advise on all matters related to the water environment in general. It makes the Department of Water Affairs, in MAWLR, responsible for the use, allocation, control, and conservation of Namibia's surface and groundwater resources.
What is interesting to note is that Section 174 deals with the application of Act in relation to certain land in South-West Africa. Section 174 (1) stipulates that the provisions of the Act shall apply in relation to any land in the territory of South-West Africa which, if it were within the Union of South Africa, would have been riparian to the Orange River in terms of this Act, and such land shall for the purposes of the application of the provisions of this Act be deemed to form part of the province of the Cape of Good Hope. Section 174 (2) states that or the purposes of sub-section (1) the Orange River shall be deemed to form a boundary of any land in the said territory which is situated on the bank of that River. Section 174 was not applied to Southwest Africa, but it is included here for background as it has obvious relevance.

4.3 The Water Resources Management, Act 24 of 2004

The Water WRMA-24 has been passed by Parliament, promulgated on 23 December 2004 by Government Notice 284 and published in the Government Gazette No 3357 . The objective of this WRMA-24 was defined to ensure that water resources of the country are managed, developed, protected, conserved, and used in a sustainable manner for the benefit of every Namibian. It also established the Water Advisory Council, the Water Regulatory Board, the Water Tribunal, and a special section on rural water supply management.
The WRMA-24 was based on the WASP and NWP and provided for the management, development, protection, conservation, and use of water resources. The Act introduced equitable access to water resources for all population groups in Namibia. It provided an integrated, enabling legislative framework within which Namibian water resources could be managed, and water services provided. The objective of the Act was to ensure that Namibia's water resources are managed, developed, protected, conserved, and used in ways, which are consistent with or conducive to be consistent with certain fundamental principles set out in Section 3 of the Act and promote:

- Equitable access to water resources by every citizen, in support of a healthy and productive life.

- Access by every citizen, within a reasonable distance from their place of abode, to a quantity of water sufficient to maintain life, health, and productive activities.
- Essentiality of water to support life and need for safe drinking water as basic human right.
- Harmonisation of human needs with environmental ecosystems and the species that depend upon the water, while recognising that those ecosystems must be protected to the maximum extent.
- Integrated planning and management of surface and underground water resources, in ways which incorporate the planning process, [and] economic, environmental, and social objectives.
- Management of water resources in such a way that sustainable development is promoted.
- Facilitating and encouraging awareness programmes and participation of interested persons in decision-making.
- Prevention of water pollution, and the principle that a polluter has a duty of care and liability to make good; and
- Meeting international obligations of and promoting respect for rights of the country regarding internationally shared water resources and to the abstraction of water for beneficial use and the safe disposal of polluting effluents.

The Act provided for basic human and environmental water needs, although not as specifically as stated in the NWP. Part 5 of the Act, provided for the establishment of Water Point User Associations at community level, consisting of those rural community members who permanently use a water point. Their function was defined as to operate and maintain the water point in question and to make decisions about water use regulations. The Act provided for a Water Point Committee to monitor and enforce compliance with such regulations and for the establishment of a Water Resources Management Agency as well as Basin Management Committees to manage water resources sustainably.

Part 4 of the Act paved the way for establishing basin management committees to promote the management of water resources on hydrological boundaries considering physical, climatic, ecological, and human factors affecting the quantity and quality of water resources. By 2011, eight basin management committees had been established.

The Act specifically dealt with the control of alien invasive species, stating that the Minister may declare any species to be alien invasive species and may make regulations for their control or eradication. Further, as the Act requires water resources management to operate according to the principles of environmental sustainability, this implies that where aquatic invasive species threaten water resources and wetland habitats they will be dealt with. Another fundamental principle upon which the Water Resources Management Act was based is that Namibia meets its international obligations and promotes respect for its rights regarding internationally shared water resources, resource quality, the abstraction of water for beneficial use and avoiding the discharge of polluting effluents.

Part 10, of the Act deals with internationally shared water resources, recognises the obligations of Namibia under international treaties and conventions such as the Convention on the Law of the Non-Navigational Uses of International Watercourses and the revised SADC Protocol on Shared Water Resources. Regarding shared water courses, the Minister was authorised to participate in the development of a common database, joint projects, conflict resolution and to establish institutional links and ensure stakeholder participation with neighbouring riparian states. The Act includes the obligation to collect and share data and information on internationally shared water resources and lists these in Section 55.

However, the WRMA-24 never came into force because a date for the commencement of the Act, as prescribed by Section 138(1)(b) of the same Act, has never been determined by the Minister. This was mainly because the Act instructed the Minister in Section 7 of the Act to establish a Water Resources Management Agency and to abolish the Department of Water Affairs as instructed by a Cabinet decision to that effect. The Minister was hesitant to abolish the DWA and since the Act was promulgated without the Regulations had been drafted, the implementation of the Act and the establishment of the Water Resources Management Agency could not be authorised until that had been done. The regulations for a water act are very technical in nature and the DWA did not have the capacity to prepare the regulations in a short space of time because most of the technical and engineering staff were transferred to NamWater. This caused a delay, and the fact that a new water policy was adopted in 2008, and an Integrated Water Resources Management Plan formulated by 2010, it was decided to revise the WRMA-24 to accommodate the new developments. It was therefore repealed by the Water Resources Management Act No. 11 of 2013 (WRMA-11)

4.4 The Water Resources Management Act No. 11 of 2013

Although the WRMA-11 has been passed by Parliament, signed by the President, promulgated on 19 December 2013 by Government Notice 332 and published in the Government Gazette No 5367, it has not yet been signed into law by the Minister as required by the Namibian Constitution, and is therefore not in force. The main reason why Minister has not yet determined a date for the Act to come into operation as required by Section 134 of the Act is the cause of the delay in the completion of the preparation of the regulations required to implement the Act. As stated before, the Regulations are highly technical in nature and took some time (7 years) to finalise. The MAWLR is now waiting for comments on the draft regulations by the Ministry of Justice. Once in force, the Act repeals both, the Water Act No. 54 of 1956 as a whole and the Water Resources Management Act No. 24 of 2004 (which had de facto never come into force).

The WRMA-11 was enacted to provide for the management, protection, development, use and conservation of water resources, the regulation and monitoring of water services and incidental matters. The aim of the Act includes to ensure that the water resources of Namibia are managed, developed, used, conserved and protected in a manner consistent with, or conducive to, specific fundamental principles including, among others, equitable access to safe and sufficient drinking water; the maintenance of the water resource quality for ecosystems; and the promotion of the sustainable development of water resources based on an integrated water resources management plan which incorporates social, technical, economic, and environmental issues. The Act provides for the establishment of a Water Advisory Council to advise the Minister on issues such as water policy development and review; water resources management; and water abstraction and use.

Furthermore, a Water Regulator is to be established under the Act, to determine the tariffs of fees and charges that may be levied by a water services provider or that are payable by licence holders for the abstraction of water or the discharge of effluent or the supply or re-use of effluent. The Water Regulator also performs other functions regarding water service providers, which must be licenced under the Act. Basin Management Committees are institutions that may be established under the Act to further the Government's objective in achieving the integrated management of water resources.

The Act aims to ensure that Namibia's water resources are managed, in a manner that is consistent with, or conducive to, specific fundamental principles as set out in Section 3 of the Act, namely:

- Equitable access for the population to safe drinking water as an essential basic human right to support a healthy productive life.
- Access by all people to enough safe water within a reasonable distance from their place of abode to maintain life and productive activities.
- Harmonisation of human water needs with the water requirements of environmental ecosystems and the species that depend on them, while recognizing that the water resource quality for those ecosystems must be maintained.
- Promotion of the sustainable development of water resources based on an integrated water resources management plan which incorporates social, technical, economic, and environmental issues.
- Availability of open and transparent information about water resources to the public.
- Recognition of the economic value of water in the allocation of water.
- Development of the most cost-effective solutions to establish infrastructure for the provision of water, including conservation measures.
- Supporting integrated water resources management through human resources development and capacity building.
- Promotion of water awareness and the participation of persons having interest in the decision-making process should form an integral part of any water resource development initiative.
- Cognisance of Namibia's international rights and obligations in the utilisation of internationally shared water resources and the disposal of waste or effluent.

- Consistency of water resource management decisions within the specific mandate from the Government regarding the separation of policy, regulatory and operational functions.
- Prevention of water pollution and implementation of the principle that a person disposing of effluent or waste has a duty of care to prevent pollution.
- A polluter is liable to pay all costs to clean up any intentional or accidental spill of pollutants.
- Cognisance of the regional diversity in water resources development and the decentralisation of responsibilities to the lowest level of Government where adequate and appropriate competency exists to manage water resources effectively.

In these fundamental principles, many general principles of environmental law are echoed, such as the principles of prevention, precaution and the polluter pays principle. The Act in terms of Section 4 of the Act imposes on the state an obligation to ensure that water resources are managed and used to the benefit of all people in furtherance of the aims of the Act.

Part 2 of the Act assigns a variety of powers and functions to the Minister regarding the management of water resources including among many others the powers to conduct water resources management planning and to ensure an adequate supply of water for domestic use.

The Minister is furthermore responsible for international negotiations related to internationally shared water resources and water related matters. Certain powers can be delegated to the Water Regulator, a basin management committee or to the permanent secretary or any other staff member of the ministry. Furthermore, according to Section 129 of the Act the Minister can make regulations relating to various issues pertaining to the management of water resources.

Part 3 of the Act provides for the establishment of a Water Advisory Council to advise the Minister on issues such as water policy development and review, water resources management, water abstraction and water use. The Water Advisory Council is established upon nomination and "consists of 11 members who are persons with extensive knowledge and experience in water resource management and from authorities or institutions responsible for or involved in water supply or water management."

Part 4 of the Act provides for a Water Regulator consisting of five members is to determine the tariffs of fees and charges that may be levied by a water services provider or that are payable by licence holders for the abstraction of water or the discharge of effluent or the supply or re-use of effluent. Part 10 of the Act provides for the establishment of a Water Regulator also performs other functions regarding water service providers, which must be licenced according to the provisions in.

Part 5 of the Act is designated to the management of rural water supply. Basin Management Committees are institutions that may be established to further the Government's objective in achieving the integrated management of water resources. The Act is also notable for its emphasis on community and stakeholder involvement in, and management of, water resources, through the establishment of basin management committees, several of which were operative for some time prior even to the development of the WRMA-24. For example, the committee for the Kuiseb River Basin was formed in 2003, with its own water resources management plan being developed in 2007. Included in a long list of duties of committees are obligations to promote community participation in the protection, use, development, conservation, management and control of water resources, to promote community self-reliance including the recovery of costs for the operation and maintenance of waterworks, and to prepare an integrated water resources management plan which will feed into an overall Integrated Water Resources Management (IWRM) Plan. The establishment of basin management committees is representative of a wider impetus for the decentralisation of Government functions in Namibia, especially relating to water resources management. However, many river basins in Namibia currently have no committee in place and only the Kuiseb committee appears to have a management plan in place. Namibia's Integrated Water Resources Management Plan of 2011 notes the need to increase the number and capacity of committees to improve equitable access to water. The Basin Management Committees have several functions, including the promotion of community participation and "to advise the Minister on matters concerning the protection, development, conservation, management and control of water resources and water resource quality in its water management area." with the option to establish Water Point Committees and local water committees to be "entrusted with the responsibility of managing and controlling the supply of water at any rural state waterwork."

Part 6 of the Act deals with internationally shared water resources and describes in more detail the functions of the Minister related to agreements on internationally shared water resources. Some agreements are listed but the list is incomplete. An amendment of the Act will be required to include those left out and to include new agreements made in future. These agreements have been ratified by Parliament and according to Article 144 of the Constitution they form part of Namibian law. They are therefore binding on Namibia. Instead of listing the agreements, Section 29(2)(e) would have been enough to state that regulations can be made by the Minister to give effect to the international agreements.

For the development, conservation, management and control of Namibia's water resources, the Minister must, in cooperation with regional councils, basin management committees and water services providers, prepare an Integrated Water Resources Management Plan to be submitted to Cabinet for approval and which is subject to review after ten years following Cabinet's approval. This Plan was only adopted by Cabinet in 2012 (Personal communication with the Deputy Executive Director of the DWA) but the plan must be revised every ten years. It is therefore due in 2022, but there was no budget for that activity.

Part 9 of the Act of the Act provides for the regulation of water supply, abstraction and the use of water advocates close cooperation between the Minister responsible for water affairs on the one hand and the Minister of health on the other.

As a rule, a non-transferable licence is required for the abstraction and the use of water This requirement does, however, not apply to the abstraction of water for domestic use and to owners of a private well for the abstraction of water for domestic use.

The licence, which is subject to a fee, may be obtained by application to the Minister and can be combined with a licence to discharge effluent as required according to Section 70 of the Act.

Part 12 of the Act addresses the control and protection of groundwater , including specific provisions regarding the construction of boreholes and wells and their respective licenses.

Part 13 of the Act deals with water pollution control and lays down the precautionary principle. A licence is required to discharge effluent or construct or operate a wastewater treatment facility or waste disposal sites.

Part 14 of the Act provides that Water Protection Areas can be declared on the initiative of the Minister or upon application by other persons having an interest, "in order to protect and enhance any water resource, riverine habitat, watershed, ecosystem or other environmental resource that is at risk of significant changes to resource quality, depletion, contamination, extinction or disturbance from any source, including aquatic or terrestrial weeds." The overall effect of declaring an area a water protection area is that there is a duty to comply with any limitation or prohibition imposed and specified in the notice of declaration of the water protection area.

Part 15 of the Act stipulates certain emergency powers for the Minister to limit the right to abstract and use water, for example in situations where there are water shortages or to control pollution.

Further provisions of the Act deal with water services plans and efficient water management practices; dams, dam safety and flood management; the control of activities affecting wetlands, water resources and resource quality (including the control of aquatic invasive species); water services provided by state; and servitudes which may be claimed by licence holders to give effect to that licence.

Offences are addressed by Section 127 of the Act and cover several acts related to abstraction or use of water not in conformity with the licence or the pollution of water resources. What is remarkable from a legal point of view is the establishment of an appeal body to be known as the Water Tribunal to hear and decide appeals against decisions by the Minister in matters specified in detail in Section 120, including for example, in cases where the issuance of a licence has been refused. The Water Tribunal will consist of a chairperson appointed by the Minister with the concurrence of the Judge President of the High Court and up to 6 other persons selected and appointed by the Minister.

Part 17 of the Act deals with dams, dam safety and flood Management which is of particular importance for disaster risk management in Namibia. This section prohibits construction work or other activity that causes, or is likely to cause, the natural flow conditions of water in, to or from a watercourse to be modified without the Minister's written approval. Safety measures for dams also come under scrutiny, requiring professional engineers' reports regarding the safety of dams, and creating a duty of care on the part of the engineer towards the public and the State, and requiring the owners of dams with potential safety risks to register them with the Minister. The Minister also has relatively extensive powers aimed at the prevention of flood risk.

The implementation of the WRMA-11 is of particular concern regarding the number of regulatory structures and the technical content such as dam safety, water pollution control, wetlands management etc. that must be administrated based on technical inputs from competent engineering and technical staff. In this context the Water Advisory Council, the Water Regulator and the Water Tribunal would require from the DWA to administrate the activities (convene meetings, take minutes, prepare technical and legal documents etc.). Some of these entities must report directly to the Minister, which seems to be very impractical in view of the many duties of the Minister. Furthermore, each of these groups is proposed as a body corporate (in this instance it is not clear whether they will fall within the existing state structures as body corporates, e.g., Local Authorities, or alternatively as completely new parastatal entities).
Another question is whether Namibia, a country with less than three million people, can even begin to consider the necessity for a governance structure that is much more complex than that of many countries with higher populations. This also raises the issue of cost in terms of the existing budgetary constraints, given the fact that the activities of the existing DWA are already underfunded while staff resources that are overstretched.

4.5 The Namibia Water Corporation Act, Act 12 of 1997

The Namibia Water Corporation Act establishes the water utility company, called NamWater, and places an obligation on NamWater to conduct its functions in an environmentally sustainable and sound manner. The Act also specifies the duty to conserve and protect the environment. It should conduct all activities with due regard for the protection and conservation of ecological resources and habitats. Water is allocated by the DWA through a permit regulatory system and NamWater is entitled to apply for a permit to impound surface runoff in ephemeral rivers, to abstract water from perennial rivers and to abstract groundwater. Certain Sections of the Act will be amended by the WRMA-11 when it enters into force.
Section 2(1) of the Namibia Water Corporation Act established a company to be known as the Namibia Water Corporation (NamWater) The objectives of NamWater are to carry out efficiently, the primary business of bulk water supply to customers, in sufficient quantities, of a quality suitable for the customers' purposes, and by cost-effective, environmentally sound and sustainable means; and the secondary business of rendering water-related services, supplying facilities and granting (lease) rights to customers upon their request.
The Act provides for the responsibilities of NamWater as well as to regulate its powers, duties, and functions; to provide for a more efficient use and control of water resources; and to provide for incidental matters.
NamWater was established as a commercial entity and has the duty to supply water and inter alia, must consider each application for bulk water supply by any potential customer, and subject to the availability of the required quantity and quality of water, must accept the applicant as a customer.
In Part 8, Section 40, the provision of water to customers is deemed an essential service (which means it cannot be suspended by labour actions or strikes), but NamWater has the right to interrupt or reduce water supply whenever a condition of drought causes an insufficient source yield; or when there is a breakdown of any water work; or if there is an emergency likely to endanger life or property.
Sections 5 and 6 of this Act set out the Objects and Functions of the Corporation, respectively. Section 5 requires the Corporation to act "in the best interests of the Republic of Namibia". This is not defined further, and it is perhaps worth noting that such a statement could be interpreted widely. It is perhaps reasonable to conclude that it is in the best interests of the country that NamWater provides appropriate water services at an affordable cost recovery regime instead of running the risk of bankruptcy and becoming dependant on Government bailouts as is the case with other parastatals who are supposed to operate on business principles.
Section 6(3) of this Act allows that the Minister may negotiate and conclude, on behalf of the State as the sole shareholder in the Corporation, the expectations of the Government in respect of the scope of business of the Corporation, its efficiency and financial performance, as well as the financial targets which the Corporation is expected to achieve over periods of at least five years at a time. This may be interpreted that the Minister may negotiate and agree with the Corporation on their expected profitability or financial performance and should NamWater be required to implement policies to supply subsidised water under Section 6(2), it would be reasonable to assume that such requirements and implications will be factored into the financial performance required of the Corporation, to be negotiated between the Minister and the Corporation.

It should be noted, that even after NamWater has been in existence for more than 20 years, the agreement between NamWater and the Government, regarding the scope of business and financial performance of NamWater, has still not been concluded. Such an agreement between the Government and NamWater should serve to provide a framework within which the general performance can be evaluated as well as guidelines according to which the income of the Company (water tariffs) can be determined.

Section 7 of the Act deals with the powers of the Corporation. The Act specifies that the Corporation has the power, but not necessarily the duty (according to an opinion from the Attorney General) to impose water on a full cost recovery basis. However, if the Corporation must operate as a commercial enterprise with the primary purpose to supply water in bulk, then it would be reasonable to assume that the levy tariffs for water supplied must cover the costs associated with its business activities as its primary source of income. The fact that tariff setting should be done in consultation with the Minister is slightly ambiguous, and do not provide any practical guidelines. For example, the annual increase in water tariffs, to cover the increase in cost due to inflation, can also be perceived to be a result of an unreasonable increase in salaries or only plain bad management, resulting in extra operating costs. It may also be that the approval of tariff increases could become a political issue and the Minister may then approve an arbitrary reduction in the tariffs proposed by NamWater for approval. As a result, this clause has led to much misunderstanding between NamWater and the Ministry.

Until such time as the independent Water Regulator, as contemplated in WRMA-11, comes into effect, NamWater and the Ministry (the Minister) should agree on the process to be followed to approve and publishing NamWater tariffs, as well as to negotiate a business performance contract for NamWater between the two parties.

Section 15 of this Act deals with subsidies for the supply of water by the Corporation. The Minister may enter into a written agreement with the Corporation for the supply of water services or facilities at a cost subsidised or fully paid for by the Minister with funds appropriated by Parliament for such purposes. In this way the cost for water services can be made affordable for those living in abject poverty. The argument here is: If you pay for something, you will not waste it.

In the case of cross-subsidisation, which is when consumers from one water scheme are charged more than the cost of supply to subsidise consumers of another scheme where the consumers are charged less than the cost of supply, it can be said, according to Section 15 of this Act, that such an arrangement requires the written approval of the Minister. It can also be reasonably assumed that, should the Minister instruct the Corporation to implement a Government policy of subsidisation under Section 6(2), and consequently agree on the financial implications to the Corporation under Section 6(3), he will approve and provide the funds for whatever subsidy is required, under Sections 15(1) and (2).

Section 30(1) deals with the financial provisions of the Corporation and entitles the Corporation to capitalise such portion of its profits as the Board may deem necessary for the financing of future capital works, and any amounts so capitalised and not immediately required to be expended shall be deposited in a reserve account. The reference to profits and the provision of operating a reserve fund is consistent with the operation of a commercial entity. However, profits are not defined in the NamWater Act and due to an anomaly in the tax legislation, NamWater is liable for tax, even if they do not make a profit, or receiving income more than expenditure.

According to Section 30(2), the Corporation may establish and operate such reserve funds as the Board may deem necessary and the management of these reserve funds is therefore left to the discretion of the Board, which implies that the Corporation may indeed make profits as befitting a commercial entity. As a rule of thumb, commercial entities capitalise 30 to 50% of their profit for investment purposes (future upgrades or expansion) and pay out the remainder of the profit as dividends. The issue of dividends on profits is also a contradictory issue since NamWater is not supposed to make “profits” because it makes the water itself more expensive for the consumers A similar arrangement to deal with this could possibly be negotiated between the Corporation and the Minister under Section 6(3).

Sections 32 and 33 of the NamWater Act provides for accounts, auditing and annual reporting that are consistent with the operation of a commercial entity.

Part 8 section 42. (3) subsection (2) does not exempt NamWater from complying with any provision of the Water Act, 1956 (Act No 54 0f 1956) or any other water law which requires a permit or authority to be obtained to impound or utilise water from water resources.

4.6 The Environmental Management Act, Act 7 of 2007

The Environmental Management Act (EMA), 2007 (Act No. 7 of 2007), was promulgated by Parliament on 21 December 2007 and published in the Government Gazette No.3966 dated 27 December 2007. The Act entered into force on 6 February 2012.

The purpose of the act is to promote the sustainable management of the environment and the use of natural resources by establishing principles for decision making on matters affecting the environment; to establish the Sustainable Development Advisory Council; to provide for the appointment of the Environmental Commissioner and environmental officers; to provide for a process of assessment and control of activities which may have significant effects on the environment; and to provide for incidental matters.

Environmental management has been defined as a multi-layered process associated with the interactions of state and non-state environmental managers with the environment and with each other. Environmental managers are those whose livelihoods are primarily dependent on the application of skill in the active and self-conscious direct or indirect, manipulation of the environment with the aim of enhancing predictability in a context of social and environmental uncertainty

Undertaking environmental management can bring about higher standards of safety and security by addressing global warming as a cause for environmental disasters or can bring benefits to the food security of people. by protecting the quality of water resources in order to preserve fish stocks as a source of food.

The principles of environmental management have to be applied by Government institutions and private persons including companies, institutions and organisations, when doing or planning things, which may have a significant effect on the environment and the EMA clearly reflects the general principles of environmental law as already developed at an international level, and contained in various international environmental texts such as the Stockholm or the Rio Convention:

- Renewable resources must be used on a sustainable basis for the benefit of present and future generations
- Community involvement in natural resources management and the sharing of benefits arising from the use of the resources, must be promoted and facilitated
- The participation of all interested and affected parties must be promoted and decisions must take into account the interest, needs and values of interested and affected parties
- Equitable access to environmental resources must be promoted and the functional integrity of ecological systems must be taken into account to ensure the sustainability of the systems and to prevent harmful effects
- Assessments must be undertaken for activities which may have a significant effects on the environment or the use of natural resources
- Sustainable development must be promoted in all aspects relating to the environment
- Namibia’s cultural and natural heritage including, its biological diversity, must be protected and respected for the benefit of present and future generations
- The option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long term as well as in the short term must be adopted to reduce the generation of waste and polluting substances at source
- The reduction, re-use and recycling of waste must be promoted
- A person who causes damage to the environment must pay the costs associated with rehabilitation of damage to the environment and to human health caused by pollution, including costs for measures as are reasonably required to be implemented to prevent further environmental damage
- Where there is sufficient evidence which establishes that there are threats of serious or irreversible damage to the environment, lack of full scientific certainty may not be used as a reason for postponing cost-effective measures to prevent environmental degradation; and
- Damage to the environment must be prevented and activities which cause such damage must be reduced, limited or controlled.

The EMA assigns general functions to Minister of Environment and Tourism (Section 4)as well as the

- The Sustainable Development Advisory Council (Sections 6 to 15)

- The Environmental Commissioner (Sections 16 and 17)
- Environmental Officers (Section 18)

One mechanism aiming at the realisation of the objectives of the Act is the provision for environmental plans to ensure better co-ordination amongst Government agencies. The organs of State that are supposed to draft such management plans are to be listed by the Ministry of Environment and Tourism in the Government Gazette according to Section 24.
The Act provides for administrative mechanisms such as the necessity of environmental clearance certificates and environmental assessments.13 The EMA's Sections 27 to 48, together with the Namibia's Environmental Assessment Policy and the Environmental Impact Assessment Regulations form the basis of all environmental assessments in Namibia. Procedures and Guidelines for Environmental Impact Assessment and Environmental Management Plans have been drafted in 2008.1

To obtain an environmental clearance certificate, a person who wants to carry out an activity listed in Section 27 of the EMA must follow a multi-stage process in line with Sections 32 to 37 of the EMA. Some of the activities that may not be undertaken without an environmental clearance certificate are:

- Energy generation, transmission and storage activities
- Waste management, treatment, handling and disposal activities
- Mining and quarrying activities
- Forestry activities
- Land use and development activities
- Tourism development activities
- Agriculture, irrigation and aquaculture activities
- Water resource developments
- Hazardous substance treatment, handling and storage
- Infrastructure development

The EMA provides diagram for the stages and procedures to be followed during an environmental assessment and also elaborates an enforcement and appeals procedure. A solid legal framework for environmental management in Namibia and implementation of the Act slowly gains pace. The most important step towards making the Act functional was, without doubt, the appointment of the Environmental Commissioner, whose duties, functions and responsibilities under the Act are substantive.

5 Water Treaties

Effectively managed transboundary water resources can serve as a tool for cooperation, joint planning, building trust, sustainable development, supporting preventive diplomacy between basin States and foster regional peace. Water can have an overreaching value capable of uniting conflicting interests and promoting consensus building among countries and societies. In order to incorporate all social, political, economic, environmental, physical and cultural characteristics of an international watercourse system, water should be managed based on hydrogeographical boundaries and thus not only on administrative and political boundaries. Both the Rio Earth Summit (UNCED 1992) and World Summit on Sustainable Development (WSSD 2002) explicitly recognised that integrated transboundary water resources management is a necessary tool for achieving sustainable development. However, in some cases the absence of detail legal and institutional frameworks, along with effective dispute resolution mechanisms and guidelines for cooperative management involving the riparian countries
Studies in Namibia in the early seventies of the twentieth century indicated that the long-term sustainable yield of the water resources in the interior of the country will not be enough to support the anticipated socio-economic development, which was 7% at that time, until the end of the century and that water must be imported from the perennial rivers on the borders of Namibia to assuage the thirst of the nation. However, the potential for water conflicts over transboundary waters can be high, especially in times of scarcity.

The only other option to import water is to use desalinated sea water, but the capital investment required, and operating cost will be much higher when supplied from the coast because the sea water must first be desalinated, and the fresh water elevated more than a thousand metres from sea level into the interior of the country. The cost of the long-distance pipelines required and the infrastructure to desalinate and pump the water, as well as the energy cost will be much higher than access to the perennial rivers, such as the Kunene or the Okavango. Desalination is an expensive option but is the only solution to supply additional water for development at the coast.

After the independence of Namibia, the country was a sovereign country for the first time since the colonial times. The master water plan had to be completed to obtain an equitable and reasonable share of the water in the transboundary rivers and the Government acted on the advice of the DWA to embark on a project to establish water commissions between Namibia and the other basin states on the Kunene, Cuvelai, Okavango, Zambezi, and the Orange rivers.

Each country has its expectations about the use of shared water sources and the downstream states have their fears about the possibility that their access to a share of the transboundary water will be denied. The purpose of those water commissions is therefore to build mutual understanding and trust while executing joint studies to determine the magnitude of the shared water resources and how much water each state would reasonably require. When the quantity of water that is sustainably available has jointly been assessed and all parties have indicated what their planned measures are in using their share of the water, the "sting" is taken out of the situation and cooperation can thrive.

5.1 International Treaties

5.1.1 The Helsinki Rules

The International Law Association (ILA), having received the Report of the Committee on the Uses of the Waters of International Rivers, approved the Articles on the Uses of the Waters of International Rivers set forth in that Report in Helsinki, Finland in August 1966 and resolved that those rules shall be known as the Helsinki Rules on the Uses of Waters of International Rivers. These rules are an international guideline regulating how rivers and their connected groundwaters that cross national boundaries or are contiguous to national boundaries in the case of rivers, may be used. The Helsinki Rules have been recognized as a basis for consideration in negotiations about water use in the preambles of all the water commission agreements between Namibia and States co-riparian to the perennial rivers flowing on the northern and southern borders of Namibia. A brief overview of the Helsinki Rules is given below and only those chapters and articles that relate to water use, pollution and conflict resolution are discussed.

The Helsinki Rules was used as a basis for discussion, negotiation, mutual understanding and cooperation between the basin States riparian to the border rivers of Namibia since the first watercourse Agreements on transboundary water sources were reached in late 1960's, until 2000 whereafter the Agreements refer to the Revised SADC Protocol on Shared Watercourses and The Law of the Non-Navigational Uses of International Watercourses, also known as the UN Waters Convention (UNWC).

5.1.1.1 Introduction

The general rules of international law as set forth in UNWC are applicable to the use of the waters of an international drainage basin except as may be provided otherwise by convention, agreement, or binding custom among the basin States. An international drainage basin is defined as a geographical area extending over two or more States determined by the watershed limits of a system of waters, including surface and underground waters, flowing into a common terminus.

A "basin State" is a State the territory of which includes a portion of an international drainage basin. However, surface runoff in ephemeral or perennial river are flowing across the landscape and are easy to recognise as "flowing into a common terminus", but with the flow of subterranean waters its less clear and in many cases require extensive studies to determine the flow and which States qualify for a share. In the case of Namibia, one of the shared "rivers" is the ephemeral Cuvelai drainage basin which has numerous streams only flowing from southern Angola in the rainy season and terminating in the Etosha Pan. The flow into the pan is endoreic because it is an internal landlocked terminus, not ending in an ocean. There is also a body of groundwaters flowing underground from the highland in southern Angola and emerge as sub-artesian water in the Ohangwena Aquifer in the Ohangwena Region in central northern Namibia. A similar aquifer is the Stampriet

Artesian Basin in the eastern part of the Hardap and !Karas Regions in Namibia The Stampriet Artesian Basin drains underground across the border between Namibia and Botswana while the ephemeral Nossob River crosses the border between South Africa and Namibia on the surface.

5.1.1.2 Equitable utilization of the waters of an international drainage basin

Each basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin. The question here is what is meant with a reasonable and equitable share. The Helsinki rules give guidance about what must be done to determine the share by examining "relevant factors" in each case. The relevant factors which can be considered include, but are not limited to:

- The geography of the basin, including the extent of the drainage area in the territory of each basin State.
- The hydrology of the basin, including the contribution of water by each basin State.
- The climate affecting the basin.
- The past utilisation of the waters of the basin, including existing utilisation.
- The economic and social needs of each basin State.
- The population dependent on the waters of the basin in each basin State.
- The comparative costs of alternative means of satisfying the economic and social needs of each basin State.
- The availability of other resources.
- The avoidance of unnecessary waste in the utilisation of waters of the basin.
- The practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses.
- The degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.

The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable share, all relevant factors are to be considered together and a conclusion reached based on the whole assessment.

It stands to reason that this method to determine the share of a State identifies may issues that can be considered, but to reach the point where an actual allocation can be made is extremely difficult to achieve in practice. One of the main reasons is that basin States must be able look into a crystal ball and take decisions about an allocation that can be completely inadequate when development possibilities arise that had never been anticipated and countries would always like to play it safe and insist on a large share, regardless of the environmental consequences.

To cover for this the Rules state that a use or category of uses is not entitled to any inherent preference over any other use or category of uses and a basin State may not be denied the present reasonable use of the waters of an international drainage basin to reserve for a co-basin State a future use of such waters. In simple terms. You cannot claim water that you will not be able to use in the reasonably foreseeable future.

The only way to deal with such an issue about future water uses, is when a large dam is built to vest the interests of the basin States in the quantity of water claimed. A good example of this approach is the development of the proposed Noordoewer Vioolsdrift Dam on the lower Orange River. The Namibian interests is to secure the water supply for domestic use, mining and irrigation along the lower Orange River and the South African interests is to make the operation of the large dams in the upper reaches of the Orange River basin more efficient, by achieving higher yields. The investment in the construction of the dam, would be based on the quantity of water that each State will benefit from, thus maximizing the benefits, and achieving more water security by making the investment. In this way the yield available for Namibia and for South Africa will be secured in the agreement between the States.

The Rules also make provision that an existing reasonable use may continue in operation unless the factors justifying its continuance are outweighed by other factors leading to the conclusion that it be modified or terminated to accommodate a competing incompatible use. A use that is in fact operational is deemed to have been an existing use from the time of the initiation of construction related to the use or, where such construction is not required, the undertaking of comparable acts of actual implementation.

Such a use continues to be an existing use until such time as it is discontinued with the intention that it be abandoned. A use will not be deemed an existing use if at the time of becoming operational it is incompatible with an already existing reasonable use.

5.1.1.3 Pollution

The term "water pollution" as used in Rules, refers to any detrimental change resulting from human conduct in the natural composition, content, or quality of the waters of an international drainage basin. This issue is always a threat to a downstream basin State such as Namibia who is at the bottom end of the headwaters of all the perennial rivers flowing on the borders of the country. The Orange River is of particular concern because Namibia is "at the bottom end of the sewer" running from the industrial and mining heartland of South Africa to the Atlantic Ocean.

Therefore, consistent with the principle of equitable utilisation of the waters of an international drainage basin, a basin State must prevent any new form of water pollution or any increase in the degree of existing water pollution in an international drainage basin which would cause substantial injury in the territory of a co-basin State. Each State should take all reasonable measures to abate existing water pollution in an international drainage basin to such an extent that no substantial damage is caused in the territory of a co-basin State. This applies to water pollution originating within territory of the State, or outside the territory of the State if it is caused by the conduct of the State causing the pollutions.

In the case of a violation of the rule to avoid pollution, the State responsible shall be required to cease the wrongful conduct and compensate the injured co-basin State for the injury that has been caused to it.

In a case a State fails to take reasonable measures to terminate pollution, it shall be required promptly to enter negotiations with the injured State with a view towards reaching a settlement equitable under the circumstances.

5.1.1.4 Procedures for the Prevention and Settlement of Disputes

The Rules also relates to procedures for the prevention and settlement of international disputes taking the legal rights or other interests of basin States and of other States into consideration regarding the waters of an international drainage basin.

Consistent with the Charter of the United Nations, all member States are under an obligation to settle international disputes as to their legal rights or other interests by peaceful means in such a manner that international peace, security, and justice are not endangered.

States should resort progressively to the means of prevention and settlement of disputes stipulated. States are under a primary obligation to resort to means of prevention and settlement of disputes stipulated in the applicable treaties binding upon them and they are limited to the means of prevention and settlement of disputes stipulated in treaties binding upon them only to the extent provided by the applicable treaties.

With a view to preventing disputes from arising between basin States, each State is obliged to furnish relevant and reasonably available information to the other basin States concerning the waters of a drainage basin within its territory and its use of, and activities with respect to such waters.

A State, regardless of its location in a drainage basin, should in furnish to any other basin State, the interests of which may be substantially affected, a notice of any proposed construction or installation which would alter the regime of the basin in a way which might give rise to a dispute. The notice should include such essential facts as will permit the recipient to assess the probable effect of the proposed alteration.

A State providing such a notice of a planned measure should afford the recipient a reasonable period to assess the probable effect of the proposed construction or installation and to submit its views thereon to the State furnishing the notice. If a State has failed to give the notice, the alteration by the State in the regime of the drainage basin shall not be given the weight normally accorded to temporal priority in use in the event of a determination of what is a reasonable and equitable share of the waters of the basin.

In case of a dispute between States as to their legal rights or other interests, they should seek a solution by negotiation. If a question or dispute arises which relates to the present or future utilisation of the waters of an international drainage basin, the basin States could refer the question or dispute to a joint agency to survey the international drainage basin and to formulate plans or recommendations for the most efficient and beneficial use in the joint interests of all such States. The joint agency should be instructed to submit reports on all matters within its competence to the appropriate authorities of the basin States concerned and the agency should in appropriate cases invite non-basin States, which by treaty enjoy a right in the use

of the waters of an international drainage basin, to associate themselves with the work of the said agency or that they be permitted to appear before the agency.
If a question or a dispute is one which is considered by the States concerned to be incapable of resolution in the manner set forth, it is recommended that they seek the good offices, or jointly request the mediation of a third State, of a qualified international organisation or of a qualified person.
If the States concerned have not been able to resolve their dispute through negotiation or have been unable to agree on the measures recommended by the agency, it is recommended that they form a commission of inquiry or an ad hoc conciliation commission, which shall endeavour to find a solution, likely to be accepted by the States concerned about the dispute.
It is recommended that the States concerned agree to submit their legal disputes to an ad hoc arbitral tribunal, to a permanent arbitral tribunal or to the International Court of Justice if:

- A commission could not be established or
- The commission has not been able to find a solution or
- A solution recommended has not been accepted by the States concerned, or
- An agreement has not been otherwise arrived at.

In the event of arbitration, the States concerned have recourse to the Model Rules on Arbitral Procedure prepared by the International Law Commission of the United Nations at its tenth session b/in 1958.
Recourse to arbitration implies the undertaking by the States concerned to consider the award to be given as final and to submit in good faith to its execution.
The means of settlement referred to in the Rules are without prejudice to the utilisation of means of settlement recommended to, or required of, members of regional arrangements or agencies and of other international organisations.

5.1.2 The UN Waters Convention

5.1.2.1 Background

The International Law Association (ILA), a nongovernmental organization founded in 1873, has a consultative status with several United Nations (UN) agencies. The ILA's work on international water law began in 1954. The general principle of ILA's work is contained in Article 4 of the 1966 Helsinki Rules, which state that the equitable utilization principle governs the use of international drainage basin waters.
The International Law Commission (ILC) was established by the General Assembly in 1947 to undertake the mandate of the Assembly, under article 13(1)(a) of the Charter of the United Nations to "initiate studies and make recommendations for the purpose of encouraging the progressive development of international law and its codification".
In the late 1960s, the UN decided to assign the international water law topic to ILC for detailed study. In May of 1997, after more than quarter of a century of working on the topic and considerable discussion during the period 1991–1997 on the draft codification on international water law, the UN General Assembly adopted a framework convention on the Law of the Non-Navigational Uses of International Watercourses on 21st May 1997, widely known as the UN Watercourses Convention (UNWC). This Convention codified the principles of sharing international watercourses, building on the 1966 Helsinki Rules. The Convention came internationally into force on 18 August 2014 because more than 35 UN Member States ratified the document. Namibia signed the Convention on 19th May 2000 and is therefore a signatory. Parliament ratified the Convention on 29th August 2001, and it became part of Namibian international water law.
The Law of the Non-Navigational Uses of International Watercourses is elaborated in a users' Guide which has 273 pages. The Convention is presented in seven Parts and contains 34 Articles. Advice is also provided about Arbitration in an Annex with 39 Articles. The rest of the Guidelines provide a detailed explanation regarding the interpretation and understanding of the Articles. Guide can assist in fostering understanding between experts (lawyers and non-lawyers), in developing a common understanding of the applicable rules and principles to address issues regarding international watercourses.

5.1.2.2 Summary of the UN Waters Convention

The main aim of the UNWC is to overcome major obstacles due to the absence of detail legal and institutional frameworks, along with effective dispute resolution mechanisms and guidelines, to achieve cooperative management of transboundary water resources among the riparian countries.

Some of the key challenges in managing transboundary waters are adapting to climate change, changing river flow patterns, floods, and droughts, meeting growing water demands due to population increase, industrialization, increasing agricultural production fed by irrigation and ecological changes in the water environment. The Convention applies to uses of international watercourses and measures of protection, preservation and management related to those uses.

For the purposes of the Convention, "watercourse" means a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole, normally flowing into a common terminus. An "international watercourse" means a watercourse that is situated in more than one State and a "watercourse state" means a State Party to the Convention.

Nothing in the present Convention shall affect the rights or obligations of a watercourse State arising from agreements in force when it became a party to the Convention, but the parties to such agreements can adjust the agreements to harmonize them with the Convention. An agreement between some of the watercourse States will not affect the rights or obligations under the Convention of watercourse States that are not parties to such an agreement. Every watercourse State is also entitled to participate in the consultations and negotiations as well as to become a party to any watercourse agreement that applies to the entire international watercourse.

Watercourse States are obliged to use the watercourse in an equitable and reasonable manner to attain optimal and sustainable benefits, considering the interests of the other watercourse States concerned and the protection of the watercourse. All States must participate in the use, development, and protection of water resources in an equitable and reasonable manner, including the right to utilise the water and the duty to cooperate in the protection of the watercourse.

The factors relevant to equitable and reasonable utilisation in the Convention are like those in the Helsinki Rules but more emphasis is placed on the analysis of alternatives and the participation of all parties affected in negotiating different options and solutions.

Watercourse States shall take all appropriate measures to prevent the causing of significant harm to other watercourse States. If harm is nevertheless caused to another watercourse State, the States causing such harm shall take all appropriate measures, in consultation with the affected State, to eliminate or mitigate such harm and, where appropriate, discuss the question of compensation.

Watercourse States shall cooperate, based on sovereign equality, territorial integrity, mutual benefit, and good faith to attain optimal utilization and adequate protection of an international watercourse. This can be achieved by the establishment of joint water commissions to facilitate cooperation on relevant measures and procedures. Namibia is party to such commissions established on all the rivers systems shared with the other riparian States.

All watercourse States have the obligation to cooperate based on sovereign equality, territorial integrity, mutual benefit, and good faith to attain optimal utilization and adequate protection of an international watercourse. Pursuant to this, watercourse States shall exchange readily available data and information on the condition of the watercourse, regarding the hydrological, meteorological, hydrogeological, and ecological conditions and issues related to the quality of the water originating in an upstream State.

No use of an international watercourse enjoys inherent priority over other uses and in the event of a conflict between uses it shall be resolved with reference to articles 5 to 7 of the Convention and having special regard for the requirements of vital human needs.

A State party to the Convention has an obligation to inform the other parties about its plans about using the water resources of a shared river system and possible effects on the condition of the watercourse. Such notification shall be accompanied by available technical data and information, including the results of any environmental impact assessment, to enable the notified States to evaluate the possible effects of the planned measures.

Here it should be noted that when Namibia conducted environmental studies on the development of the proposed Epupa and Baines dams on the Kunene, the proposed Noordoewer-Vioolsdrift dam on the Orange River and the recently completed Neckartal dam by informing the other watercourse states about the planned measures and requesting their participation in the environmental assessments. The same was also

done with the ENWC which will draw water from the Okavango River when the proposed pipeline link between Rundu on the Okavango and Grootfontein is completed. In the case with the studies on the Orange River, the challenge was to agree on the harmonization of the respective environmental policies and laws in each State and consensus was achieved by a joint decision to use the South African policy and legislation as the guideline and to negotiate outcomes in good faith and mutual acceptance.
The Convention provides procedures for the notification about planned measures without with adverse effects, the period within which an informed State should reply to the notification, extending the time to render a reply if the informed State requires more information, the obligation to supply such information if requested and what to do when there is no response.
The Convention also provides for cases where the urgent implementation of planned measures is required, especially when public health, public safety or other equally important interests are at stake. In such cases there must be a formal declaration of the urgency of the measures, information about the measures contemplated, the immediate implementation and consultations with any affected States to alleviate the consequences of such implementation.
Part 4 of the Convention deals with the protection and preservation of ecosystems, the prevention, control and reduction of pollution, the introduction of alien or new species in a shared watercourse system, as well as the protection and preservation of the aquatic environment at the terminus of a river system. The Convention also provides guidelines about the flow regulation in shared rivers and the operation of the flood control infrastructure.
In Part 5 of the Convention addresses harmful conditions and emergency situations. Watercourse States must take all appropriate measures to prevent or mitigate conditions that may be harmful,
resulting from natural causes or human conduct, such as floods, water- borne diseases, erosion, siltation, erosion, drought, or desertification. Emergency situations are imminent threats such as floods earthquakes or industrial accidents. The Convention recommend that watercourse States should jointly identify the potential threats and develop appropriate contingency plans to respond effectively.
Part 6 of the Convention deals with miscellaneous issues such as water infrastructure installations during armed conflict, the release of data and information compromising defence security and the protection of the interests of the people in a transboundary river system and the settlement of disputes.
The UNWC covers the basic international law principles regarding the management of international water resources which can briefly be summarised as the:

- Sovereignty principle: Each nation has the right to develop its own policies, laws and institutions and their own strategies for natural resources development and utilization.
- Transboundary principle: Upstream water users have a responsibility towards downstream water users, and vice-versa. This principle is in a sense the extension of the equity and precautionary principles across national borders.
- Equity principle: All people have basic rights of access to resources for their survival and development. Society should not be put at a serious disadvantage in this respect.
- Intergenerational principle: Future generations should not be deprived from access to an adequate resource base.
- User-pays principle: Users should pay the real cost of water services, considering the ability to pay. A different, and more contentious, principle is that water is an economic good, and that users should pay a tariff according to the economic value of water, if this is not conflict with the equity principle.
- Polluter-pays principle: Entities causing damage to the natural resources system should pay for the repair of damage.
- Precautionary principle: Governments are obliged to protect citizens against risks and from disasters, even if the precise effects have not yet been unequivocally established by scientific proof. This principle aims to prevent or reduce pollution by specific `new' pollutants and to preclude irreversible changes to ecosystems.
- Prevention principle: Where there is scientific proof of the cause-effect relationship between pollutants and unacceptable conditions, measures must be taken to prevent or rectify the situation.

- Precautionary principle: Preventive action should not be delayed on the grounds of lack of scientific information proving conclusively that there is an unacceptable situation.
- Stand-still principle: Areas and nature reserves that are in ecological equilibrium should not be allowed to deteriorate.
- Polluter Pays principle: A polluter must pay for the pollution caused.
- Sustainable development: Countries should cooperate to find the most cost effective and affordable solutions to solving unacceptable water misuse and environmental damage.

5.2 Regional Water Treaties

5.2.1 SADC Water Protocols

The Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) Region was signed on 28 August 1995, Johannesburg, South Africa, by His Excellency the President of the Republic of Namibia, Dr Sam Nujoma. It was ratified on 2 July 1997. The Protocol entered into force in the SADC on 29 September 1998. The main objective of the Protocol is to describe the general principles for the equitable, reasonable, and environmentally sustainable utilization of internationally shared watercourse systems in the SADC Region. The Protocol calls for cooperation between the basin States party to the Agreement and encourage the establishment of river basin institutions for the effective implementation of the provisions of the Protocol.

The main objectives and functions of the river basin institutions are also elaborated with reference to policy, legislation, utilization of water, planning and development of infrastructure, research, pollution control, water quality monitoring, data management and environmental matters.

Provision is also made for general matters such as amendments to the Protocol, dispute resolution, withdrawal, and entry into force.

In view of the adoption of the UN Waters Convention in 1997 and the fact that the first Protocol only entered into force in 1998, it was decided to revise the Protocol by incorporating the applicable articles in the Convention to strengthen the Protocol. The 1995 Protocol will therefore not be further elaborated here.

5.2.2 The Revised Protocol on Shared Watercourses

The Revised Protocol on Shared Watercourses of the Southern African Development Community repeals and replaces the 1995 Protocol on Shared Watercourse Systems. This Protocol recognises international consensus on several concepts and principles related to water resource development and management in an environmentally sound manner.

The policy acknowledges the Helsinki Rules, the UN Convention on the law of the Non-Navigational Uses of International Watercourses and Agenda 21 concepts and facilitates the establishment of shared water agreements.

The scarcity of water restricts economic development and social upliftment in the SADC region. Successfully managing water resources in southern Africa will contribute to reaching SADC's vision of sustainable development in the region:

The people of southern Africa call for a desirable future in which the region's environment is conserved among all the competing uses of water, recognising the constraints inherent in natural ecosystems so that the environment can be sustainably improved, used and managed in the spirit of social and environmental justice.

The Protocol aims to foster closer cooperation for judicious, sustainable, and coordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration and poverty alleviation. In order to achieve the objective, this Protocol, by virtue of Article 2, seeks to promote and facilitate the establishment of shared watercourse agreements and shared watercourse institutions for the management of shared watercourses; advance the sustainable, equitable and reasonable utilisation of the shared watercourses; promote a coordinated and integrated environmentally sound development and management of shared watercourses; promote the harmonisation and monitoring of legislation and policies for planning, development, conservation, protection of shared watercourses, and allocation of the resources thereof; and promote research and technology development, information exchange, capacity building, and the application of appropriate technologies in shared watercourses management. Recognising the principle of the unity and coherence of each shared watercourse, SADC states undertake to harmonise the water uses in the shared watercourses and to ensure that all necessary interventions are consistent with the sustainable development of all watercourse states and observe the objectives of regional integration and harmonisation of their socioeconomic policies and plans. The utilisation of shared watercourses (including agricultural, domestic, industrial, navigational, and environmental uses) within the SADC region is open to each watercourse state, in respect of the watercourses within its territory and without prejudice to its sovereign rights, in accordance with the principles contained in the Protocol. Member states are obliged to respect the existing rules of customary or general international law relating to the utilisation and management of the resources of shared watercourses. According to Article 3.4 of the Protocol, member states commit themselves to maintain a proper balance between resource development for a higher standard of living for their people and conservation and enhancement of the environment to promote sustainable development. Watercourse states in their respective territories undertake to utilise a shared watercourse in an equitable and reasonable manner considering the interests of the watercourse states concerned, consistent with adequate protection of the watercourse for the benefit of current and future generations, and they participate in the use, development, and protection of a shared watercourse in an equitable and reasonable manner. Such participation includes both the right to utilise the watercourse and the duty to co-operate in the protection and development thereof, as provided in this Protocol. Furthermore, the Protocol states that member states must take all appropriate measures to prevent the causing of significant harm to other watercourse states. Where significant harm is caused to another watercourse state, the state whose use causes such harm is to take all appropriate measures to eliminate or mitigate such harm and, where appropriate, to discuss the question of compensation. Disputes between member states regarding the interpretation or application of the provisions of the Protocol which are not settled amicably, are to be referred to the SADC Tribunal under the SADC Treaty.

The Protocol established several SADC water sector organs (Committee of Water Ministers, Committee of Water Senior Officials, Water Sector Coordinating Unit, and Water Resources Technical Committee and sub-committees) and shared watercourse institutions. The Committee of SADC Water Ministers met in Maseru, Lesotho, in September 2011, where it has been stated that:

as droughts and floods, thus necessitating coordinated management of our shared water courses and resources. For the SADC region with its multiplicity of shared watercourses, issues of cooperation and joint planning and management of the development and utilisation of our shared resources is of paramount importance.

5.3 Agreements to Manage Shared Water Resources

In every river basin there are upstream and downstream States. All States have their expectations about using the water in their territories in the basin and downstream States have their fears about the magnitude of consumptive use of water for development in the upstream States. The way to manage that is basically to do joint studies to determine the yield of the available water sources and the most probable water using developments in each State. The management of shared transboundary water resources is accomplished through joint water commissions established between the relevant basin States and guided by international water law principles, regional integration bodies such as SADC, the SADC Water Sector Division, and the African Ministers' Council on Water (AMCOW). Various bilateral and multilateral water commissions have been established,80 in the SADC region and as far as Namibia is concerned, almost all the Agreements included in the discussion below have been ratified and forms part of the law of Namibia because they are part of the general rules of public international law and are international agreements binding upon Namibia under the Constitution.

The main purpose of a water commission is to advise the basin States about the sustainable development of water resources in a shared river basin, but they are not bodies that implement water infrastructure development. They may facilitate joint studies to determine the development potential of the resource base of the basin, including its people. This work is called a diagnostic assessment of the prevailing and future development possibilities and the water requirements as well as the interventions required to supply in the water demand without compromising environmental concerns beyond the agreed mitigating measures identified. A commission would normally appoint a consultancy to do the work while staff of each of the

relevant Government Ministries or Departments (i.e., Water, Agriculture, Justice, Foreign Affairs) in each State will also participate in the work and in this way the work is done on a joint basis and the reports on the results would be agreed and uncontested between the staff involved.
A diagnostic assessment is followed up by a strategic action plan for the river basin and that provides a framework within which each basin State can do its conservation duties and anticipated water developments while the other States will be aware of those developments. The duty of the Commission is to monitor the developments and jointly advise the Governments about the progress with the ongoing monitoring and development activities. In this context each State will be informed about the planned measures of the other States and hopefully remove the sting of the scorpion on the political front.

5.3.1 Water Commission Institutional Structure

The structure of each water commission is different, but a generic structure is shown in Figure 6.1 to facilitate an explanation of how a commission function. The basin States party to the agreement that established a water commission is represented as "Basin Sates" at the top in in the organogram. In the SADC, the number of basin states can vary between two states on the Kunene (Angola and Namibia) and eight states on the Zambezi (Angola, Botswana, Malaŵi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe.)
When a commission took a joint decision, the leader of each delegation in the commission must report this joint decision to its government and the path normally goes through the office of the head of the water ministry/department to the water minister's office and further to cabinet for a decision or approval. Although this method is appropriate in theory, there may be technical issues that get lost on the way because not all people that get informed are technical people. To make sure that the same joint decision is conveyed in the same way to all the ministers it became necessary to invite the ministers of the different states to a joint meeting where everybody present gets informed by the same message. This activity is represented by the "Council of Ministers" and provides the opportunity to get the responsible ministers together with the commission to discuss the proposal, answer questions and obtain contributions from each minister present. At the end of the day the proposal is technically really a joint proposal adopted by consensus by all the basin states.

The "Commission" comprises the members of the delegations from each state and is normally limited to three and one member of each delegation is the leader of a delegation. The members are supposed to be experts in the various disciplines they bring to the table, e.g., an economist, a lawyer, a scientist, or an engineer. The delegation may also comprise additional technical staff, such as engineers, scientists, hydrologists, environmentalists, or other experts as required from different ministries/departments when certain issues must be discussed in greater detail.
From the above it is clear that the civil servants in a government represented in a commission, cannot do the work that may be required on top of their normal duties at home. That is why a commission has a Secretariat that operates on behalf of the different governments. The "Commission" in the Figure 13.5 has full time administrative and limited technical staff in the "Secretariat" and they deal with the "Technical Committees", "Cooperating Partners" and any joint "Operating Authority" in the river basin. The technical committees comprise staff from the water departments in each state, or consultants. The cooperating partners are the funding agencies, donors, non-governmental organizations, consultants etc and their activities are coordinated by the secretariat. The administrative duties of the "Secretariat" are to organize meetings, workshops, coordinate activities and do general administrative duties. Some secretariats may also be tasked to provide services to any joint "Operating Authority" that is responsible, for example, the operation of a joint hydropower plant or irrigation project. Here it should be noted that the commission or secretariat do not operate the schemes, but their duties are limited to the monitoring of water use and other activities in the basin, such as environmental issues and communicating with the communities in the basin.

5.3.2 The Kunene River Agreements

5.3.2.1 Joint Commission of Cooperation between Angola and Namibia

Since 1886 two border agreements and five water use agreements have been concluded between the Colonial Powers before Namibia became independent in 1990. The first border agreement was between Germany and Portugal and the second between Portugal and the Union of South Africa who was appointed

as the mandatory for territory of German Southwest Africa. (In essence, South Africa was never a “colonial power” regarding Namibia).
After the independence of Namibia, it became necessary to renegotiate the existing Kunene agreements to enable the continuation of the Kunene development project that commenced in 1969 but was on hold since 1973 when the civil war broke out in Angola before the independence of Angola in 1975.
This resulted in an Agreement between the Governments of the People’s Republic of Angola and the Republic of Namibia to establish the Angola-Namibian Joint Commission of Cooperation (JCC), signed on 18 September 1990 in Lubango, Angola . Although the agreement was only ratified on 2nd July 1997 it entered into force immediately due to the cordial relations between the parties.
The JCC agreed at its first meeting to endorse and affirm the previous border and water use water agreements between the Colonial Powers, i.e., Germany, Portugal, and South-Africa on the borders between Angola and Namibia, as well as development of the Kunene Scheme.

5.3.2.2 Terms of Reference and Constitution of the Permanent Joint Technical Commission

The Terms of References and Constitution of the Permanent Joint Technical Commission (PJTC) for the Cunene River was drafted and agreed upon on 18 September 1990 in Lubanga, Angola, pursuant to the provision of Article 2.2 of the Third Water Use Agreement for the Kunene River signed on 21 January 1969 in Lisbon, Portugal.
The PJTC was instrumental in the development of the Kunene Project which entailed the construction of three dams in Angola: the Gove Dam, the Calueque Dam, and the Ruacana Diversion Weir, as well as the Ruacana Hydropower Plant in Namibia at the Ruacana Falls. The purpose of Gove Dam is to impound the summer rainfall and to release the water on a continuous basis during the year to provide water to the hydropower station at the Ruacana Falls. The purpose of the Calueque Dam is to regulate the weekly flow to Ruacana and supply water that is pumped into canal taking the water into northern Namibia. The purpose of the Weir at Ruacana is to divert water into the generators in the underground power station to generate electricity during the whole year.

5.3.2.3 The First Border Agreement

This Agreement between the Governments of Germany and Portugal is about respecting the Limits of their respective Possessions and Spheres of Influence in Southern Africa. Signed on 30 December 1886 in Lisbon, Kingdom of Portugal. by the Envoy Extraordinary and Minister Plenipotentiary, Councillor Richard von Schmidthals and Secretary of State of Foreign Affairs, Councillor Henrique de Barros Gomes.
This agreement was ambiguous and open for interpretation because it said that the Kunene will be the border between the two territories and although the agreement said that the middle of the Kunene (or the deepest valley in the river) would be the centre line of the border, it failed to define exactly where the border line from the coast, along the border line into the interior would end.

5.3.2.4 Second Border Agreement

Agreement between the Government of the Union of South Africa and the Government of the Republic of Portugal in relation to the boundary between the mandated Territory of Soutwest Africa and Angola. The South African Authorities at the negotiations about the border wanted the border to run along the middle of the Kunene River from the coast to a point, more or less where the Calueque dam had been built on the Kunene. The Portuguese authorities wanted the line along the river to start at the coast but stop at the top of the Ruacana Falls. The Germans were originally against this position because that would mean that they had to elevate water more than 400 m (metres) from a position downstream of the said falls into Ovamboland while the difference in elevation at Calueque would only be about 20 m. The South African authorities supported this view of the Germans for the same reason, but the South African Authorities then agreed that the border may start at the top of the Ruacana Falls, provided that the border agreement must reflect a compromise that South Africa will have access in perpetuity to a more favourable point upstream of Ruacana for the abstraction of water from the Kunene (at Calueque). At the end of the negotiations, it was agreed to keep the border starting at the top of the said falls in exchange for South Africa having access to the Calueque dam site in Angola in perpetuity, but the Portuguese Authorities then insisted that there must be a separate Border Agreement and a separate Water Use Agreement. The South African delegation failed to notice that the concessions made about the border and access to the water in the two separate agreements were not reflected in both agreements. This has been a bone of contention and falls in the same category as the agreement on the border between South Africa and Germany on the Orange River where one party was ill prepared and was swindled by the other party.

5.3.2.5 The First Water Use Agreements

The First Water Use Agreement (together with the Second Border Agreement) between the Government of the Union of South Africa and the Government of the Republic of Portugal was signed on 1 July 1926 in Cape Town, Union of South Africa. The agreement dealt with the use of the water of the Kunene River for purposes of generating hydraulic power, as well as the "inundation" and irrigation in the Mandated Territory of Southwest Africa.

5.3.2.6 Second Water Use Agreement

The Second Water Use Agreement between the Government of the Republic of South Africa and the Government of the Republic of Portugal dealt with "rivers of mutual interest" and the Cunene River Scheme. This agreement dealt with "rivers of mutual interest" and "the Kunene River Scheme". The agreement set out general principles for mutually beneficial water management and "best joint utilisation". The activities envisaged comprised technical collaboration, including sharing hydrological and other data, as well as further negotiation on major schemes. In addition, this Agreement set out the basis for further work on specific schemes on the Kunene, namely pumping water for use in Ovamboland, more electrical power from Matala for Southwest Africa and the principle to build a hydroelectric power plant at Ruacana.

5.3.2.7 Third Water Use Agreement

This detailed Water Use Agreement between the Government of the Republic of South Africa and the Government of Portugal regarding the first phase development of the water resources of the Kunene River Basin was negotiated and drafted in Lisbon by the South African and Portuguese delegations from 7 to 10 October 1968 and agreed upon by means of an exchange of notes signed on 21 January 1969 in Lisbon, Portugal.
The agreement detailed works to be carried out in the first phase and these included to:

- Regulate of the flow of the Kunene by means of dams at Gove and Calueque in Angola and a diversion Weir at Ruacana in Namibia.
- Increase the power generation capacity at the existing Matala dam on the Kunene in Angola.
- Supply water for humans, livestock and irrigation in the middle Kunene area in Angola.
- Supply water to northern Southwest Africa for humans, livestock, and irrigation in Ovamboland, today known as the Omusati, Oshana, Ohangwena and Oshikoto Regions.
- Develop a 240 Megawatt (MW) hydroelectric power station at Ruacana. This facility has recently been upgraded to generate 347 MW.

The agreement established a Permanent Joint Technical Commission (PJTC) to act in an advisory capacity to the respective Governments about the construction and operation of the Kunene scheme, as well as the financing arrangements for the various components of the schemes. This mandate was later extended to include the management of the whole Kunene Basin.

5.3.2.8 Fourth Water Use Agreement

This is an agreement between the Governments of the People's Republic of Angola and the newly independent Republic of Namibia to endorse and affirm the old agreements between the Colonial Powers, (Germany, Portugal, and South Africa), to re-establish the PJTC and the Joint Operating Authority on the Kunene River. It was signed on 18 September 1990 in Lubango, Angola. It was ratified by Parliament on 2 July 1997. This was agreement was unique in the world because it endorsed the principles of the previous three water use agreements with specific aims to:

- Establish a joint operating authority on the Kunene.
- Ensure the maximum beneficial regulation at Gove Dam.

- Ensure the continuous operation and adequate maintenance of the water pumping works at Calueque Dam and the diversion weir at Ruacana.
- Task the Permanent Joint Technical Commission to evaluate the development of further hydroelectric schemes on the Kunene River to accommodate the present and the future needs for electricity in both countries.

5.3.2.9 Fifth Water Use Agreement

Protocol of Agreement between the Government of the People's Republic of Angola and the Republic of Namibia on the Development of a Hydro-electric Generating Scheme, in principle, on the Kunene River. It was signed on 24 October 1991 in Lubanga, Angola.

This agreement is pursuant to Article 2 of the Fourth Water Use Agreement of 1990 and laid the foundation for further studies to develop a new hydroelectric scheme proposed on the Kunene River at Epupa. The PJTC was instructed to prepare a pre-feasibility study report about the technical and economic feasibility of such a scheme, inclusive of environmental and ecological studies, to advise the respective Governments about the implementation of such a facility.

The proposed scheme at Epupa met with great opposition by the environmental lobby and an alternative site at Baynes is most probably the most viable to implement.

5.3.3 The Okavango River Agreement

5.3.3.1 Permanent Okavango River Basin Water Commission (OKACOM)

Agreement between the Governments of the Republic of Angola, the Republic of Botswana, and the Republic of Namibia, on the establishment of a Permanent Okavango River Basin Water Commission (OKACOM). The Agreement was signed on 15 September 1994, Windhoek, Namibia. The Agreement was Ratified on 2 July 1997.

5.3.4 The Orange River Agreements

In 1987, shortly before Namibia became independent, a Joint Technical Committee (JTC) was established between the Republic of South Africa and the Transitional Government of National Unity of Southwest Africa/Namibia. The purpose of the JTC was to support the activities of the irrigation farmers in Namibia and South Africa where the Orange River was contiguous along the border between the two countries, and specifically at the Joint Noordoewer-Vioolsdrift Irrigation Scheme. In 1992, two years after Namibia became independent, the JTC was replaced by the Permanent Water Commission (PWC) between Namibia and South Africa.

There are at present three Water Commissions on the Orange River. They are the bilateral Lesotho Highlands Water Commission (LHWC) between Lesotho and South Africa, the bilateral PWC between Namibia and South Africa and the multilateral Orange-Senqu River Commission (ORASECOM) between Botswana, Lesotho, Namibia, and South Africa. See Figure 13.6.

The LHWC is responsible for the management of the Lesotho Highland Water Project and oversight of the Trans-Caledon Tunnel Authority (TCTA) which must plan, finance, implement and operate sustainable and accessible water resource infrastructure. The TCTA was originally established as a special purpose vehicle to fulfil South Africa's treaty obligations in respect of the Lesotho Highlands Water Project.

At a PWC meeting between Namibia and South Africa in Swakopmund, Namibia, in May 1995 the Namibian Delegation proposed that a basin wide Orange River Basin Water Commission must be established between the four basin States, Botswana, Lesotho, Namibia and South Africa. It was agreed by the PWC to write a joint letter in which the said proposal was presented to all the Orange River basin Governments. It was further agreed that South Africa would approach Lesotho and Namibia would approach Botswana, respectively through the existing bilateral commissions between Botswana and Namibia and between Lesotho and South Africa. This proposal was met with mixed feelings but was again mooted by Namibia at a SADC Water Ministers meeting in Cape Town in 1997. Minister Kader Asmal of South Africa took the lead to support the proposal by Namibia and with the support of the other Ministers, Namibia was appointed to "make it happen" by preparing a draft treaty for consideration. This led to the establishment of the Orange-Senqu River Commission (ORASECOM).

The establishment of ORASECOM was indicative of the endeavours of the basin States to cooperate and this facilitated huge interest by many cooperating partners to support the Commission with studies, capacity building and development. The ORASECOM has a Secretariat, stationed in Pretoria, South Africa, to coordinate all the activities of the Commission in the respective countries. On 3 November 2020, the ORASECOM was 20 years old.

The ORASECOM agreement was revised and signed on the 18 December 2018. Copies of the original and revised agreements can be obtained from the DWA or the ORASECOM Secretariat.

5.3.5 Joint Technical Committee

Three years before the independence of Namibia an Agreement of Cooperation was reached between the Transitional Government of National Unity of Southwest Africa/Namibia and the Government of the Republic of South Africa regarding the control, development and utilization of the water of the Orange River The agreement was signed on 13 November 1987 in Windhoek, Namibia. The agreement provided for the establishment of a Joint Technical Committee (JTC) to serve as an interim arrangement for the management of the lower Orange River until Namibia became independent. The purpose of the JTC was to make recommendations to the two Governments about the abstraction and allocation of water from the lower Orange, the creation and maintenance of water supply infrastructure of joint interest, the prevention of pollution and control over the abstraction of allocated water. What is important to note is that although the boundary along the lower Orange was ambiguous, South Africa conceded that Namibia is in principle entitled to utilize water from the Orange River because Namibia is a co-riparian, basin State.

5.3.6 Permanent Water Commission

Agreement between the Governments of the Republic of Namibia and the Republic of South Africa on the establishment of a Permanent Water Commission (PWC) on water matters of mutual interest (but concentrating at present on the lower Orange River). The Agreement was signed on 14 September 1992 at Noordoewer, Namibia and Ratified on 2 July 1997. The objective of the Commission is to act as technical adviser to the Parties on matters relating to the development and utilisation of water resources of common interest to the Parties and shall perform such other functions pertaining to the development and utilisation of such resources as the Parties may from time to time agree to assign to the Commission. The functions and powers of the Commission are to advise the Parties on the reasonable demand for water from common water resources; investigations, separately or jointly by the Parties, related to the development of any water resource of common interest including the construction, operation and maintenance of any water works in connection therewith; the prevention of and control over the pollution of common water resources, soil erosion affecting such resources, etc. The Commission conducted several studies and projects on the lower Orange to support the activities of the Joint Irrigation Authority (JIA), the maintenance of the canal system, and two Joint Feasibility studies between South Africa and Namibia on the management of the Lower Orange River and the development of a dam on the lower Orange, about six kilometres upstream from Noordoewer. The estimated cost of the different dam options is between 4,9 and 3,3 billion Namibian Dollar/South African Rand.

5.3.7 Vioolsdrift and Noordoewer Joint Irrigation Scheme

The agreement between the Governments of the Republic of South Africa and the Republic of Namibia on the Vioolsdrift and Noordoewer Joint Irrigation Scheme (on the lower Orange River) was signed on 14 September 1992 at Noordoewer, Namibia. The agreement was Ratified on 2 July 1997.

The irrigation scheme was completed in 1935 and built during the depression in South Africa. Water is diverted by a weir, located upstream from the irrigation scheme in the Orange River, into a canal system that starts on the South African side of the river and criss-cross the river to reach irrigation fields on the northern and southern banks of the river in Namibia and South Africa. Although the canal system starts at the weir on the South African side of the river, the irrigation fields are on both banks of the river, and it is imperative that the farmers on both sides of the river must work together to operate and maintain the water supply infrastructure. Therefore, the agreement also established a JIA which reports to the PWC.

5.3.8 Orange-Senqu River Commission (ORASECOM)

This is an agreement between the Governments of the Republic of Botswana, the Kingdom of Lesotho, the Republic of Namibia, and the Republic of South Africa on the establishment of the Orange-Senqu River Commission (ORASECOM). It was signed on 3 November 2000 at Okapuka, Namibia. by Honourable Minister Helmut Angula, Minister of Agriculture, Water and Rural Development of the Republic of Namibia. Ratified on 06 June 2001. The driving force behind the establishment of ORASECOM was the Namibian delegation to the PWC between South Africa and Namibia where Namibia proposed the establishment of a basin-wide Orange River water commission. The South African delegation was not very enthusiastic about the proposal because it was argued that Botswana makes no contribution to the flow of the Orange although it is basin State, but Namibia prevailed and the ORASECOM was established.

5.3.9 Revised Orange-Senqu River Commission Agreement

Revised Agreement between the Governments of the Republic of Botswana, the Kingdom of Lesotho, the Republic of Namibia, and the Republic of South Africa on the establishment of the Orange-Senqu River Commission (ORASECOM) was signed on 14 December 2018 at Maseru, Lesotho. This agreement is in the process of ratification.

The main reason for the revision is the adjustments to the structure of the commission to accommodate the Forum of the Parties, the Council of Commissioners, Task Teams, and the Secretariat.

6.5.1 The Zambezi River Agreements

6.5.1.1 Joint Permanent Water Commission (JPTC)

This is an agreement between the Governments of the Republic of Botswana and the Republic of Namibia on the establishment of a Joint Permanent Water Commission (JPWC) (The name changed from Committee to Commission.). It was signed on 13 November 1990, Windhoek, Namibia and Ratified on 2 July 1997. The agreement relates to water matters of common interest and concentrated its activities mostly on the Kwando – Linyanti – Chobe River System that is a tributary of the Zambezi River forming the border between Botswana and Namibia in the eastern part of the Caprivi Region in Namibia.

The main purpose of the Commission was to attend water matters of common interest and a research project in the Eastern Caprivi between Botswana and Namibia to control the Kariba Weed (Salvinia molesta) infestation in the Quando-Linyanti-Chobe River system which is a tributary of the Zambezi River. The weed was brought under control by a research project to test the introduction of a weevil (Cyrtobagous salviniae) for biological control. The weevils eat the leaves of the weed but prefer the buds. Its larvae eat the roots, rhizomes, and the buds. As the plants die, they turn brown and sink to the bottom of the waterway where they decompose. The project reduced the area of the plant mats on the water, but the weevils die when they have eaten all the weeds, and they must be continuously bred to replace those that died, which means it is a never-ending project.

The Commission concentrated its work on Policy and a Legislative Review of Wetland Use and Management in Namibia. They concentrated mostly on the Kwando – Linyanti – Chobe River System. The JPWC was also instrumental in getting the Okavango River basin States together to establish a basin wide Commission on the Okavango.

The JPWC became inactive due to the Kasikili/Sedudu Island border dispute between Namibia and Botswana and the fact that the OKACOM that was established in September 1994, took over the responsibility of advising the respective governments on issues and developments related to the Okavango River. The negotiations leading to the establishment of the Zambezi River Commission (ZAMCOM) further reduced the need for the JPWC to meet because the Kwando – Linyanti – Chobe River System is a tributary of the Zambezi River and can therefore be included under the ZAMCOM.

6.5.1.2 The Zambezi Watercourse Commission (ZAMCOM)

Agreement between the Governments of the Republic of Angola, the Republic of Botswana, the Republic of Malawi, the Republic of Mozambique, the Republic of Namibia, the United Republic of Tanzania, and the Republic of Zimbabwe on the establishment of the Zambezi Watercourse Commission (ZAMCOM). It was signed on 13 July 2004 in Kasane, Botswana and ratified on 15 March 2005.

The objective of the Commission is to promote the equitable and reasonable utilization of the water resources of the Zambezi Watercourse as well as the efficient management and sustainable development thereof. To that end the Commission shall have the following functions:

- collect, evaluate, and disseminate all data and information on the Zambezi Watercourse as may be necessary for the implementation of this Agreement.
- promote, support, coordinate and harmonise the management and development of the water resources of the Zambezi Watercourse.
- advise Member States on the planning, management, utilization, development, protection and conservation of the Zambezi Watercourse as well as on the role and position of the Public regarding such activities and the possible impact thereof on social and cultural heritage matters.
- advise Member States on measures necessary for the avoidance of disputes and assist in the resolution of conflicts among Member States regarding the planning management, utilization, development, protection, and conservation of the Zambezi Watercourse.
- foster greater awareness among the inhabitants of the Zambezi Watercourse of the equitable and reasonable utilization and the efficient management and sustainable development of the resources of the Zambezi Watercourse.
- co-operate with the institutions of SADC as well as other international and national organisations where necessary.
- promote and assist in the harmonization of national water policies and legislative measures.
- carry out such other functions and responsibilities as the Member States may assign from time to time; and
- promote the application and development of this Agreement according to its objective and the international water law principles in the UN Conventions and the Revised SADC Protocol on Shared Watercourses

6.5.2 Cuvelai Watercourse Commission

Agreement between the Governments of the Republic of Angola and the Republic of Namibia on the establishment of the Cuvelai Watercourse Commission (CUVECOM), signed on 16 September 2014 in Windhoek, Namibia. This agreement is in the process of ratification.

The Commission is developing a bulk water supply project in the Cuvelai basin in southern Angola. It is a project that is similar like the water distribution pipeline network in northern Namibia and the pipelines in Angola will at the beginning be supplied from Calueque Dam in Angola, via the Namibian canal and pipeline system, crossing the border at Oshikango in Namibia to Santa Clara in Angola to link up with the Angolan water supply distribution network to numerous small communities.

7. Integrated Water Resources Management Plan

The main objective of an Integrated Water Resources Management Plan (IWRMP) is to achieve a sustainable water resources management regime and adequate infrastructure contributing to social equity, economic efficiency and environmental sustainability. An IWRMP is not a plan to develop a specific water project but to implement a comprehensive plan to address all the relevant activities that will ensure sustainable management of water resource use, water supply services and effluent disposal, as well as addressing capacity building activities and funding requirements. This includes all water that is used for personal hygiene, sanitation, stock and wildlife drinking, industry, mining, and irrigated agriculture.

In 2004 the Government launched Vision 2030 for Namibia. This provides the overarching framework for the development of Namibia with the main goals to improve the quality of life of its people and achieving the status of a developed country by the year 2030.

The IWRM plan was conceived in November 2004 when the Global Water Partnership in Southern Africa hosted a workshop at a Symposium in Windhoek where the concept and implementation of an integrated water resource management plan (IWRMP) for each country in Southern Africa was introduced and encouraged.

In early 2006 the Namibian delegation who attended a meeting of the African Minister's Council on Water (AMCOW) had discussions with representatives of the African Development Bank (AfDB) to obtain assistance for Namibia to develop an IWRMP. The AfDB offered funding and in April 2006 the Namibia Water Partnership hosted a planning workshop to discuss the implementation of an IWRMP. This led to the preparation of a proposal for the development of an IWRMP on behalf of the DWA Fin the Ministry of Agriculture, Water and Forestry (MAWF). The DWA submitted the document to the AfDB for consideration and in May 2007 an Agreement was signed between the AfDB and the DWA to fund the preparation of the IWRMP. This funding enabled the DWAF to retain a consortium of consultants led by Windhoek Consulting Engineers (WCE), in close cooperation with the Ministry of Agriculture, Water and Forestry (at that time) and the Namibian National Water Partnership. The IWRMP for Namibia was completed in 2010 and the 1993 WASP, the 2000 NWP and 2008 WSASP, as well as the existing Water Act and the not yet in force 2004 WRMA were reviewed to determine to what extent the adopted policies support the preparation and implementation of the proposed IWRMP.

The existing water policies and water development plans of service providers such as NamWater, the Directorate Rural Water Supply in the DWA, the Local and Regional Authorities, as well as the plans of the basin management committees, were assessed and taken into consideration during the preparation of the national IWRMP. The IWRMP also called for regional IWRM plans. At present the four Regions in northern Namibia, Ohangwena Oshana, Omusati and Oshikoto, where half of the population of Namibia lives, have a Regional IWRMP in place. Government adopted the IWRMP in 2012. The IWRMP addressed all aspects of water management by means of themes that are elaborated in detail in the plan. The objectives and actions required in IWRM to address the issues were grouped in the following themes:

- Policy, legislation, regulations, and procedures.
- Institutional support for water administration, infrastructure development and financial management.
- Capacity building for engineers, scientists, technicians, artisans, and labourers.
- Stakeholder involvement and awareness about resource use and infrastructure maintenance.
- Groundwater, surface water and unconventional water are assessed to enable sustainable management.
- Knowledge management through data collection, monitoring of resources and demand.
- Monitor the effects of climate change, droughts, and floods.
- Water demand management and water use efficiency.
- Sanitation and effluent discharge control to protect aquatic ecosystems and the environment.
- Investment to facilitate IWRM.

The overall goal in addressing water resources management is sustainability. Planning and implementation of IWRM is not a linear exercise but it is cyclical and must be accompanied by regular evaluation, assessment of progress and re-planning.

A wealth of knowledge exists about the climate, rainfall, runoff, surface water and groundwater resources. Information has been gathered over more than a hundred years including measurements, investigations and research by scientists and engineers. Namibia has been able to meet the growing demand for water to sustain development through innovation and exceptional ingenuity. There is no reason to believe that this could not be maintained with the proper development of human resources and adequate financial investments.

The country has a huge body of experience in the planning, design, construction and operation of water infrastructure development operation and maintenance. Water awareness training, water demand management, community participation and an acute knowledge of the need to be on top of technological developments to maintain access to adequate supplies of water of an acceptable quality for different kinds of uses.

The practical implementation of the proposed IWRMP will ultimately depend on the organizational efficiency of the existing water sector institutions in place, the capacity of the human resources employed in those institutions and the financial resources made available. However, the implementation of water management activities at the community level should receive priority attention to succeed with the IWRMP.

It is essential that the legal framework must be in place and enforced. Although there are good policies, these need implementation, effective legal backing, and competent administration to enforce the control over water issues by the DWA. Essential role players such as the Water (and Sanitation) Advisory Council and the Water Regulator are key to the success of IWRM.

Integrated water resources management is an important responsibility of all stakeholders in the water sector, i.e., all water service providers, related management and governance entities and all water users in Namibia. Effective stakeholder participation at all levels is required in all decisions concerning water resources allocations and management, with the focus of capacitating stakeholders for managing specific water resources activities, thus ensuring ownership and overall responsibility.

Water Demand Management (WDM) is a fundamental part of an integrated approach to the sustainable management of the water sector and contributed significantly to avoid disaster to a lack of water availability in 1980, 1997, 2014 and 2019. Within the Namibian context the WDM strategy attempts to improve cost recovery, the management and maintenance of infrastructure and the reduction of inefficient consumer demand to reduce the pressure and reliance on conventional water resources as well as infrastructure operation and maintenance. This, in turn, results in a net financial benefit to the supplier as well as its customers and serves the protection of the water environment.

Capacity building and institutional development are essential elements for implementation of IWRM in Namibia. IWRM capacity building must be focused on all stakeholders to ensure effective and balanced water use and water resource conservation for water resource security.

Information systems must be strengthened to keep them relevant and up to date. Funding is crucial to a successful IWRM Plan. In analysing the possible options and instruments available to Namibia for developing a funding strategy there are several approaches and instruments available, domestically as well as internationally. Namibia has come a long way in creating the enabling environment necessary for ensuring that the investments to be made in the WSS can be mobilised, but there are however several issues that are critical to the feasibility of any investment programme and associated funding strategy which must be incorporated into future financial planning. The current underperformance of service providers in terms of financial management must be addressed as a matter of urgency. Namibia is wasting valuable and scarce resources through financial mismanagement. Funds from central government that could be utilised to finance Water Supply and Sanitation programmes and projects are being utilised to finance bad debt.

The overall goal in addressing water resources management is sustainability. Planning and implementation of IWRM is not a linear exercise but it is cyclical and must be accompanied by regular evaluation, assessment of progress and re-planning.

The water sector objectives are specifically aligned to the Poverty Reduction Strategy and the National Poverty Reduction Action Programme. The WRMA-11 is based on IWRM principles and provides overall guidance in the water and sanitation sector. The overarching goals for the water sector are also fully aligned to meeting the Millennium Development Goals (MDG) and the sub regional goals articulated in the Revised SADC Protocol on Shared Watercourse Systems in the SADC and the SADC Water Policy.

The key challenges of the water sector are the operationalisation and implementation of the policies, legislation, and proposed plans. The technical, institutional, financial, socio-economic and many other issues are addressed under the consolidated, National IWRM Plan that will assist to achieve Vision 2030 within the set time framework. Namibia will also increasingly need to use the maximum potential offered by transboundary water resources. Hence the Government has taken steps to ensure sustainable cooperation with the neighbouring sovereign states within the existing international Water Treaty frameworks and the SADC Watercourse Protocol. Transboundary cooperation on beneficial use of shared water resources will be greatly enhanced leading to joint project implementation and operational management. The following issues drive the need for IWRM:

- Shortcomings in the management of water; a focus on developing new sources rather than managing existing ones better, and top-down sector approaches to water management result in uncoordinated development and management of the water infrastructure.
- Growth in population, increased economic activity and improved standards of living lead to increased competition for and conflicts over the limited freshwater resources.
- A combination of social inequity and economic marginalisation forces people living in poverty to overexploit land and other natural resources, with damaging impacts on water resources.
- Water demand has increased faster than the growth in population. (Indicating an improvement of the standard of living.

- The threat of pollution increases the risk of water scarcity.
- More and more development has greater impacts on the environment.
- Current concerns about climate variability and climate change demand improved management of water resources to cope with potentially more intense floods and droughts.

The overall long-term impact of the IWRM Plan will be to enable Namibia to achieve a sustainable water resource management regime contributing to social equity, economic efficiency, and environmental sustainability in the country. This will result in improved health and sanitary conditions of communities, improved water related livelihoods, gains to agriculture from improved land and water management, reduced risk of floods and droughts.

7.1 Regional and Local Water Plans

Water infrastructure planning provides a framework to ensure the availability of water sources when demand grows due to development and the timeous provision of water supply infrastructure to meet the managed water demand. Regional Authorities have the responsibility for the development of water schemes in the rural areas with the assistance of the DWA or NamWater. Local Authorities have the responsibility to reticulate water to urban communities and can provide their own water or buy water in bulk from NamWater. These responsibilities are covered in the Regional Councils Act No 22 of 1992, as amended and Local Authorities Act No 23 of 1992, as amended.
One of the most important policies regarding water scheme development and water use is that the “local” water sources within (say) a five to ten kilometres (km) radius, should be developed first. The next step is a “regional” water scheme where water resources may be more than a hundred kilometres away from the consumer point. The final step is a “national” water scheme which is linked to one of the perennial border rivers of Namibia and may stretch over more than 700 km such as the ENWC which is still under development. NamWater also divided the country into six Management Areas to facilitate and streamline water supply operations and logistic issues.

7.2 Latest Planning Studies

Studies that are in various staged of starting or nearing completion:

- Engineering Consulting Services to Undertake the Consolidation and Comparison of the Three Long Term Water Sources Considered to Supply Windhoek and Related Areas

- A Prefeasibility Study into the Augmentation of the Water Supply to the Central Area of Namibia and the Cuvelai

- Water Master Plan Update Study for the Central-North Area in Namibia

- Assessment and Evaluation of the Condition of the Hardap Irrigation Water Supply Scheme and Possibility of Rehabilitation.

- Consulting Services for Review and Update of the National Integrated Water Resources Management Plan of August 2010

- Medium-Term Water Supply Alternatives for the Central Area of Namibia
- Development of an Integrated Resource Management Plan for the Cubango- Okavango River Basin

SUMMARY

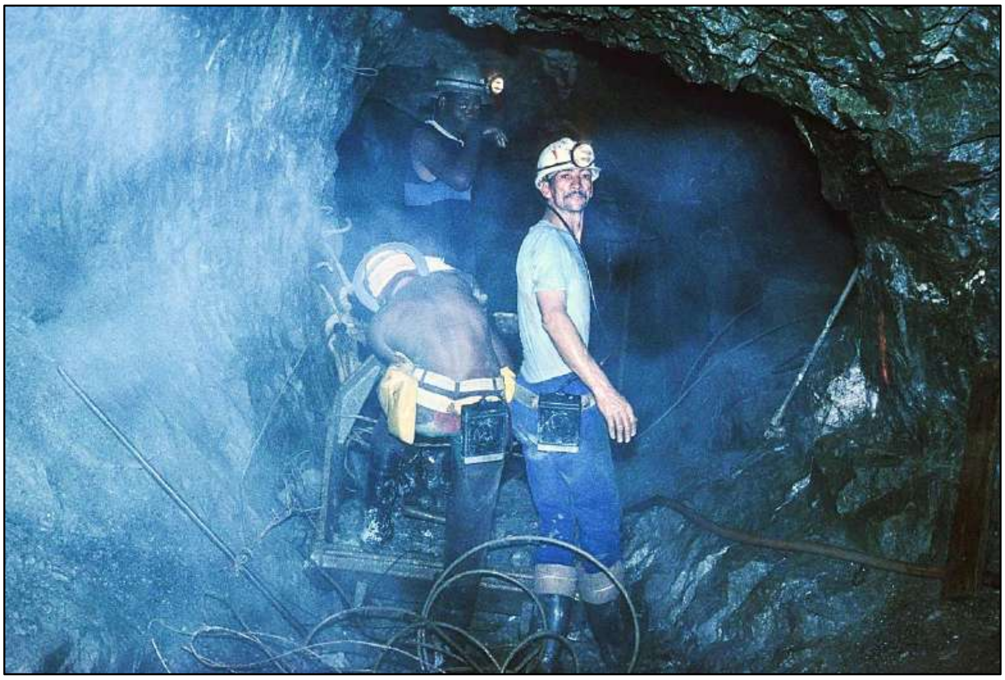
The report summarises the legal and administrative framework governing the water resources in Namibia. It encompasses all Government entities, their functions, and roles as well as their administrative structures. The report equally outlines the functions of established statuary bodies and committees promulgated by the Government of the Republic of Namibia (GRN).

The management of all water resources in Namibia are explained within their relevant context and in line with the established acts, rules and objectives as well as international water conventions with neighbouring countries like South Africa, Zambia, Angola and Botswana.

Water legislation is explained within the context of the constitution of the GRN as well as the the involvement of all local and regional authorities at all tiers of Government. Water Supply and Sanitation Sector Policy (WASP); National Water Policy (NWP) and Water Supply and Sanitation Policy (WSASP) are explained in detail.

REPORT ON MINING METHODS, EQUIPMENT AND BENEFICIATION PROCESSES:

KLEIN AUB COPPER MINE
OTJIKOTO GOLD MINE (B2GOLD)
ROSH PINAH ZINC MINE
TSUMEB SMELTER (DUNDEE PRECIOUS METALS)



by

Martin Schneider & Alexandra Speiser

DRFN

Enhancing decision making for sustainable development

REPORT ON MINING METHODS, EQUIPMENT, AND BENEFICIATION PROCESSES:

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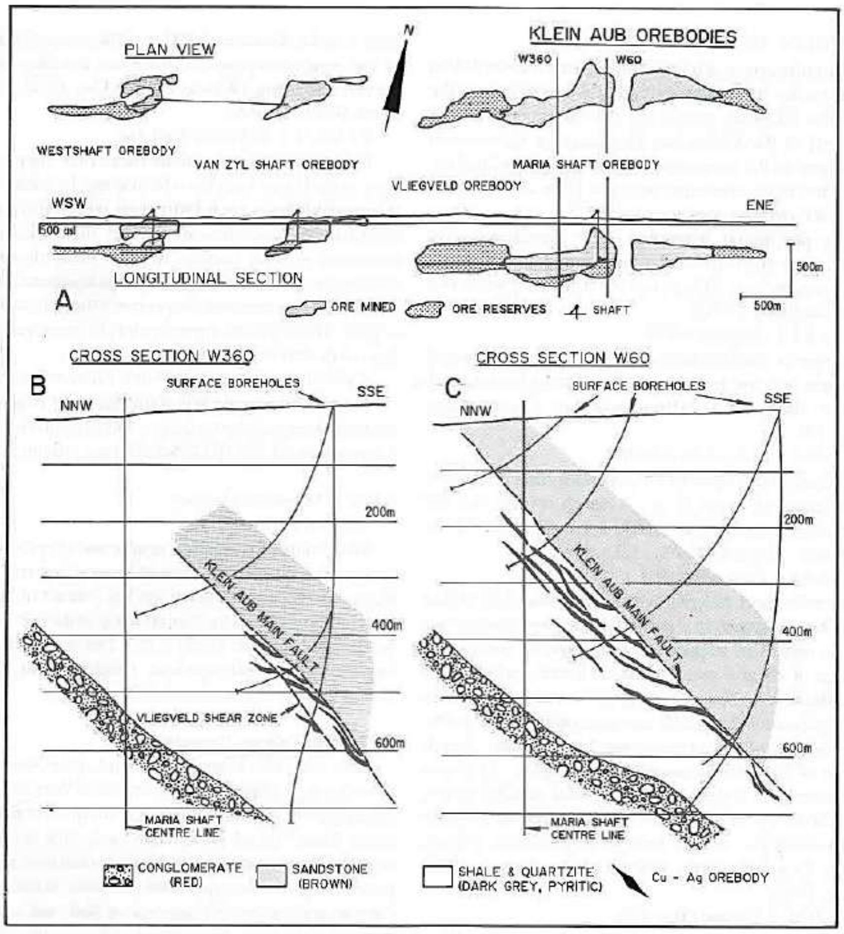
1. Klein Aub Copper Mine

The occurrence of copper on the farm Klein Aub 350 was first recorded by Rimann (1915). In 1927, the mineralised zone was explored by test pits, trenches and a 10 m inclined shaft under the direction of Dr. Hans Merensky, however with disappointing results. In the late 1950s, most of the known strike of the copper- bearing horizon had been pegged. After an intensive diamond drilling campaign in 1959 to 1960, which established a potential of 1 million t of ore, the deposit was investigated by various exploration companies (Erongo Exploration, 1964a; 1964b). In 1966 the property was brought into production by the Klein Aub Copper Company, having proved ore reserves to maintain an initial 450 tons per day mill.

The occurrence of copper over a strike length of about 7.5 km is confined to 7 argillite beds in the Kagas Member of the Klein Aub Formation. These units are intercalated in a stratigraphic succession of approximately 100 m, and range in thickness from a few centimetres to a few metres. They maintain a fairly constant distance from one another, and dip southwards at approximately 45^{o}, subparallel to a prominent breccia zone. In depth the units flatten out and are eventually cut off by the breccia (Schneider & Borg, 1988).

Essentially three separate, sigmoidal ore bodies can be distinguished, the West-shaft ore body, the Van Zyl-shaft ore body and the Maria- shaft ore body. The latter links up with the “Vliegveld ore body” which is only known from exploration drilling and is situated between the Van Zyl- and Maria-shaft ore bodies. The only orebodies mined were the Van Zyl lode in the west and the Maria ore body in the east. The grade of the ore varies considerably throughout, the higher copper concentration being found in the Van Zyl lode (Borg, 1987).



The Klein Aub ore bodies (after Borg, 1987)

The mineralogy of the copper ore at the Klein Aub Mine is quite complex. Chalcocite is the most abundant copper sulphide and accounts for probably more than 85% of the total copper sulphides. It is accompanied by djurleite, digenite, bornite, chalcopyrite, covellite, cuprite, native copper, malachite, wittichenite (klaprotholite), native silver, pyrite, galena, hematite and magnetite. In the oxidised zone of the ore body, which stretches from surface to a depth of about 20 m, malachite and chrysocolla are predominant. Up to 50 g/t silver as well as some gold are mainly associated with chalcocite.

The minerals are disseminated within coarser laminae of fine sand and silt within shale, or occur as nodular and lenticular aggregates in quartzite, as cement to detrital grains, as replacement of early pyrite, as cleavage parallel lenticles, as fillings in brittle fractures and as concentrations along slickensided shale layers.

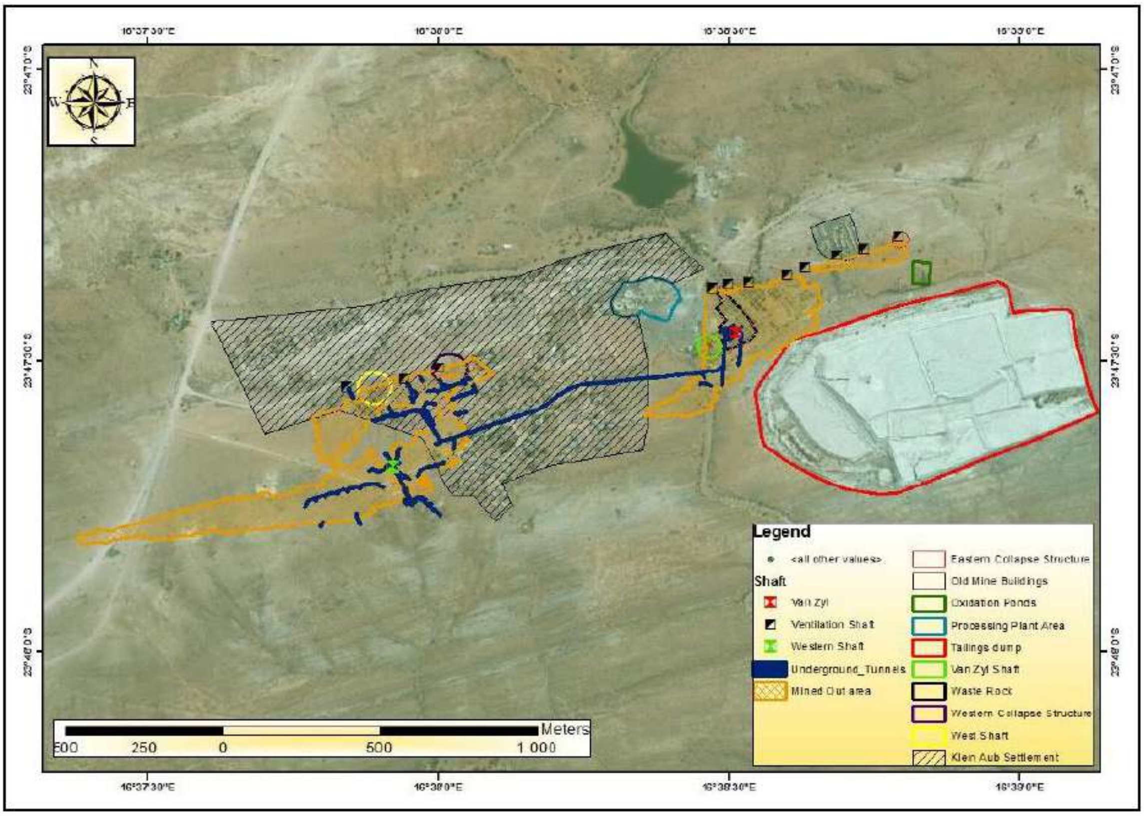
Essentially two different styles of mineralisation can be distinguished. Disseminated mineralisation accounts for approximately 55% of the total mineralisation. Some 45% of the mineralisation is hosted by fractures or other tectonic features such as breccia zones and cleavage planes. Minor ore mineral zonation is developed within the Klein Aub ore bodies, mainly up-dip, and with increasing distance from the Klein Aub Fault, chalcocite mineralisation gradually develops into a narrow bornite and chalcopyrite zone before grading into unmineralised pyrite- bearing sediments (Schneider & Borg, 1988).

Locally within the ore beds there may be a maze of quartz-ankerite stringers in highly sheared and tightly folded argillite. The distribution of the mineralisation is clearly structurally controlled within the stratabound framework. Regional folding coupled with weak metamorphism caused partial recrystallisation and internal adjustments of the copper-bearing sediments. The remobilised elements concentrated within the newly formed structures, although part of the original mineralisation remained unaffected in its original disseminated form.

Borg (1987) developed an ore genesis model for the Klein Aub deposit. It is suggested that the ore formed mainly during an epigenetic multi-phase event. During Doornpoort Formation times the deposition of coarse red alluvial fan sediments by braided river systems forming a thick sequence of oxidised red beds was accompanied by the extrusion of basaltic lava flows. The Klein Aub Formation represents a major environmental change. Due to a marine transgression, fine-grained sediments were deposited in a shallow marine or lacustrine environment. Minor precipitation of copper sulphides in a reducing environment probably took place. Sediment compaction occurred due to continuing burial under accumulating clastic sediments, followed by basin dewatering. The fluids migrated upwards, therefore leaching copper from all available source rocks, especially from permeable zones of basaltic flows. During the peak of the Damaran age metamorphism fluids altered portions of the Doornpoort Formation basalts and leached major amounts of copper and some silver from them. The by now strongly metal-enriched fluids then migrated upwards from the volcanic units and percolated through the overlying sediments. A major fault system at Klein Aub focussed the fluid flow upwards along faults. The mineralising fluids then precipitated sulphides in the reducing environment of the Klein Aub Formation, upgrading the earlier, diagenetic mineralisation considerably.

Ruxton (1986) suggested a period of copper release and concentration of a basement copper source during semi-arid to arid weathering. Subsequent uplift and erosion led to the transport of copper initially as copper sulphate and later as fine malachite particles in the suspended sediment load of alluvial fan distributaries. The deposition of detrital malachite at lake margins adjacent to zones of major sediment and water discharge is envisaged, with further concentration by lacustrine currents. Bacterial action and the breakdown of organic matter during diagenesis led to the formation of sulphides and subsequent copper fixation.

The Van Zyl and Maria ore lodes were each served by a vertical production shaft and a subinclined auxiliary shaft. Horizontal development per level extends over 2500 m in the Maria area and for some 1900 m in the Van Zyl area. By the end of 1980 down-dip mining had advanced to approximately 350 m below the surface. The Van Zyl lode was mined by a panel method (80% extraction) followed by pillar extraction at a daily production rate of 160 t. The Maria ore body was mined by a wide raise method (+ 85% extraction) and pillar recovery which accounted for a further + 8% extraction. The production from the Maria area approximated 900 t of ore per day (Malone, 1985).



Klein Aub tunnels and mined out area (after Moses et al. 2015)

The ore was processed in a plant applying crushing, milling and floatation. The resulting chalcocite concentrate was with up to 56% copper very lucrative. It was sold to the Tsumeb smelter, where it attracted a bonus payment because of the up to 0.2 g/t gold contained in the concentrate. There were also up to 155 ppb PGMs in the concentrate, however, the majority of the PGMs reported to the tailings, and it is estimated that the tailings dam material at Klein Aub contains around 1 ppm/t PGMs.

The Klein Aub Copper deposit contained 7.5 million t of ore averaging 2% copper and 50 ppm silver. Of these, 5.5 million t were mined in the period 1966 to 1987. Due to low copper prizes and the comparatively low grade the mine became subeconomic in 1987. At the time of mine closure the ore reserves amounted to 2 million t (Schneider & Borg, 1988).

Production of copper concentrates (45- 56% copper, 700-1100 g/t silver, 0.2 g/t gold) of the Klein Aub Mine (Schneider & Seeger, 1992)

Year	Ore mined (t)	Cu concentrate (t)
1966	41 138	460
1967	186 519	7 428
1968	250 787	9 983
1969	258 315	10 965
1970	225 037	8 926
1971	222 353	9 590
1972	179 193	7 617
1973	163 769	6 460
1974	234 282	9 575
1975	253 839	8 674
1976	289 334	12 441
1977	279 650	12 025
1978	310 329	13 389
1979	318 400	13 576
1980	321 549	16 405
1981	306 200	14 155
1982	294 600	11 464
1983	259 400	10 043
1984	249 357	9 917
1985	214 120	10 064
1986	230 000	7 501
1987	38 347	1 265

Following are some photographs from the time when the mine was in operation.

Klein Aub overview from tailings dam ca. 1984 (Photo: G Borg)

Van Zyl Shaft and plant ca. 1984 (Photo: G Borg)

Maria Shaft and tailing dam ca. 1984 (Photo: G Borg)

Klein Aub underground workings ca. 1984 (Photo: G Borg)

2. Otjikoto Gold Mine (B2Gold)

The first regional gold-focused exploration activity commenced in 1995. Work included geological reconnaissance, airborne magnetic surveys, ground magnetic, electromagnetic and induced polarization surveys, rotary air-blast (RAB), reverse circulation (RC) and core drilling, and Mineral Resource estimation. Since acquisition in 2011, B2Gold has completed additional drilling, a feasibility study in 2012, and has updated Mineral Resource and Mineral Reserve estimates. Commercial production started in 2015. Mining is currently conducted from the Otjikoto and Wolfshag pits.

The mining operations use conventional open pit mining methods and equipment. Mining is based on a phased approach with stockpiling to bring high-grade forward and provide operational flexibility. Ten geotechnical domains have been defined in two oxidation domains (calcrete and oxidized; fresh rock), and pit slope angles vary by geotechnical domain. Inter-berm angles range from 30–60º. Beginning at the 1465 RL, 15 m wide geotechnical berms are included in the design on 60 m intervals. These criteria were the basis for the OSA applied in the optimization analysis.

Groundwater is actively extracted ahead of mining from a single dewatering borehole situated between the Otjikoto and Wolfshag pits. Excess water that accumulates in the pit due to groundwater seepage and rainwater accumulation is collected in sumps located in low spots in each pit and pumped to the return water dam. A phased development strategy was applied in the LOM to smooth the mine production schedule by deferring waste stripping, and to bring high-grade material forward. Tabulations were developed for each of the phases based on the Mineral Reserve gold cut-off grade of 0.45 g/t. The mineralization was then subdivided based on the stockpiling strategy of delaying the processing of most of the low-grade material until the end of the mine life. Development is based on the Otjikoto and Wolfshag deposits each being mined in four phases for a total of eight phases.

Phase 1 has already been completed for both deposits. Wolfshag Phase 4 represents the final expansion to the ultimate pit. The current LOM plan assumes processing of approximately 5.5 Mt from the Mineral Resource low-grade stockpile when higher grade feed is not available. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability. The stockpile has an average grade of 0.43 g/t Au, which is similar to the break-even processing cut-off grade, so processing of this stockpile will be determined when processing capacity is available.

Where possible, ramps were located in the east wall of both pits to mitigate potential geotechnical hazards associated with planar and wedge-forming structures present in footwall structures along the west wall. A nominal ramp and road width of 27 m, including drainage and safety berms, was used for dual lane truck operation. Ramp widths were reduced to 20 m in the lower levels of the phase designs to allow for single lane haulage on the final benches. Ramp grades were designed to a maximum of 10%. Temporary ramps will be used, as needed, for initial access to stages.

Ore is hauled by truck from the pit to a stockpile, the ROM pad or direct-tipped into the crusher. The highest-grade material is direct-tipped or placed on the ROM pad depending on the plant feed requirements. Production drilling and blasting is done on10 m benches with patterns and powder factors varying by material type and geological conditions. Mining operations are scheduled for 365 days per year with a 15% decrease in the production rate during the rainy season, December through March. Vertical advance is limited to two operating benches per pit phase. This will involve the movement of an average of 38.5 Mt/a of material to sustain processing of 3.5 Mt/a. Mine and mill production are scheduled for eight years with the mining rate dropping the last two years with material from the low-grade stockpiles supplementing the process feed. Haul truck numbers will increase from the current 23 to 26 as the haul distances increase due to the deepening of the pits and distances from the pits to the WRSF.

Two Caterpillar 6018 shovels are generally operating on 10 m benches to remove waste. Ore is selectively mined with Liebherr 984 excavators using three flitches of 3.33 m each. These excavators are also used to mine difficult areas. The two R9250 excavators alternate between ore and waste, as needed. Caterpillar 992 and 990 wheel loaders offer flexibility and are used to supplement the mine production and for stockpile reclaim.

The metallurgical testwork results and information in the 2012 feasibility study provided the data to finalize the process design criteria and the Otjikoto mill flowsheet. The process recovery uses conventional designs and equipment.

The original design of the Otjikoto mill was based on a gravity/whole ore leach flow sheet with a nominal treatment rate of 2.5 Mt/a and a plant availability of 94%. A 25% design factor was included for sizing the primary crusher, conveyors, ball mill, thickeners, cyanide destruction circuit, reagent systems and mainstream pumps which would facilitate a future expansion. A pebble crusher was installed in the SAG mill circuit and two leach tanks were added to the leach circuit in the second half of 2015 to expand the mill capacity from 2.5 to 3.1 Mt/a.

Gold is recovered by gravity concentration/intensive leaching and by a cyanide leach/CIP process for treatment of gravity tailings. The Otjikoto mill design is robust and able to process the three major ore types (XR1 – oxide, XR2 – pyrite-dominant, XR3 – pyrrhotite-dominant) and now Wolfshag over the range of ore grades mined, and with variable materials handling and metallurgical characteristics. The process flow sheet consists of the following: crushing; grinding; gravity concentration and intensive cyanidation; cyanide leaching of gravity tailings; carbon-inpulp (CIP); cyanide destruction; tailings disposal; acid wash and elution; electrowinning and gold room; carbon regeneration; reagents make-up and distribution; air services and plant water service.

The mill fresh water consumption was 1 Mm^3/a at the mill design throughput of 2.5 Mt/a. Fresh water consumption is now permitted for 2 Mm3/a with the expanded mill throughput. Fresh water is supplied from wells for both potable and process needs. Average overall plant power consumption during steady state mill operation is approximately 25–26 kWh/t of ore processed. Electrical power is generated on site using heavy fuel oil generators, and by a new solar power plant that was commissioned in 2018. Reagents are conventional for gold operations, and reagent consumptions for Wolfshag ore are similar to Otjikoto ore (Garagan et al., 2019).

The Otjikoto Gold Mine Plant (Photo: G Schneider)

3. Rosh Pinah Zinc Mine

The Rosh Pinah mineralization was discovered during regional geological mapping in 1963. Initial drilling revealed the presence of 2.9 million t of ore containing 5.8% zinc, 1.2% lead, and 0.15% copper. Subsequent exploration established additional ore of much higher grade. The deposit has been mined uninterruptedly since 1969 (Wartha & Genis, 1992).

The current mining method used at Rosh Pinah is lughole open stoping (LHOS) without backfill, and mining primary, secondary, and, where appropriate, tertiary stopes, in an underhand (top-down) extraction sequence. Mining without backfill since 1969 has resulted in significant voids within the historical and currently mined areas.

Access to the production areas is via multiple interconnecting declines, which also provide fresh air intake into the mine.

Ore is sourced from five steeply dipping mineralized zones, with an increasing proportion derived from the Western Orefield (WF3), as the Eastern Orefield (EOF), and the Southern and Central Orefield (SF3, SF3, and BME) are depleted.

The mine works at a 24-hour, three-shift cycle with primary blasting taking place at the end of the day shift. Material is loaded by rubber-wheeled LHDs and transported by truck either to an underground ore tip or out of the mine to a waste rock dump. The ore passes through a grizzly, equipped with a hydraulic rock-breaker, on its way to the underground primary crushing station, where it is crushed to <150mm size and transported to the surface via an inclined conveyor drift. Waste rock is trucked out of the mine and dumped on one of two designated rock dumps which are located within the Mining Licence area.

The current Rosh Pinah concentrator utilizes a conventional three-stage crushing and ball milling circuit followed by flotation. In the concentrator, the cyclone product is subjected to two differential flotation processes, namely the lead floatation circuit and the zinc floatation circuit.

In the lead floatation circuit, the lead is initially floated using sodium normal-propyl xanthate, dextrin, sodium cyanide, senfroth 20 and water, with the aid of conventional agitation flotation in the lead rougher and scavenger banks. The sodium normal-propyl xanthate ensures that the mixture is hydrophobic, so that in later steps the lead sticks to the air bubbles. The tails of the lead circuit go through to the zinc circuit. The lead rougher concentrate is floated through a series of cleaner cells consisting of a column cell, 'Tankcell' and 'Smartcell'. The overflow water of the lead thickener is pumped to the tailings dam.

In the zinc floatation circuit, the zinc is floated off in the zinc circuit using senfroth 20 and copper sulphate. The mixture is fed through a battery of conventional agitation cells in the rougher circuit. The zinc is collected in the rougher and cleaned cells. Both the lead and zinc column cells were retrofitted with Microcell spraying systems. Air is pressed into these cells with high pressure which allows for the forming of more and smaller air bubbles, to which the Pb and Zn respectively stick. The tails from the zinc circuit are first thickened using anichem 8861 and the residue pumped to the tailings dam located approximately 2 km to the south-east of the plant. The overflow of the zinc thickener goes back into the zinc circuit.

From the concentrator, the lead and zinc concentrates pass through separate belt filters that dewater the concentrate prior to being stockpiled on drying pads. The drying pads have a concrete floor and are bounded by approximately 1 m-high walls. The water from the belt filters is pumped to the thickener.

In August 2021 Trevali (the owner of RPZC until 2022) announced positive results from the independent Rosh Pinah Expansion "RP2.0" NI 43-101 Feasibility Study (FS) at its 90%-owned Rosh Pinah mine in Namibia. The FS considers the potential for ore production expansion from 0.7 Mtpa to 1.3 Mtpa. The FS is based on a scenario to expand the current throughput through the upgrading of the processing plant, construction of a paste fill plant (including a water treatment plant), surface crushing facilities, and development of a dedicated portal and ramp to the Western Orefield (WF3) deposit.

The Expansion Feasibility Study includes the following changes at the mine:

Processing Plant: The FS incorporates an upgrade to the comminution circuit to include a new single stage SAG mill and pebble crusher. The upgrade also includes primary crushing upgrades, an ore blending system, along with other circuit modifications to provide increased flotation, thickening, filtration and pumping capacity to achieve the target throughput of 1.32 Mtpa. The upgrade will also include several flowsheet modifications aimed at improving both the concentrate grade and metal recoveries.

Underground Development and Infrastructure: A dedicated portal and decline to the WF3 deposit will be constructed to support the increase to mine production levels and reduce operating costs. The trucking decline is 3.9 km in length, excluding level access and stockpiles. For construction purposes, the decline is separated into five independent legs to enable concurrent development and reduce overall construction time. Internal legs of the trucking decline will be developed off existing development, with take-off positions selected to minimize interaction with the underground operation.

The new trucking decline will act as an additional fresh air intake within the ventilation network and will enable direct ore haulage from the WF3 zone to a new surface primary crusher station utilizing large-scale (60 tonne) trucks. Ore sourced from other areas (EOF, SF3, SOF, and BME) will be transported to the existing underground crushing system using the existing 30 tonne truck fleet and conveyed to surface via the existing conveying system.

Paste Fill Plant: A paste fill plant designed to operate at both the current 0.7 Mtpa and the 1.3 Mtpa targeted throughput rate has been included. The paste plant construction is assumed to commence in Q1 2022 (approximately 12 months before the expansion project's commencement) as it improves both the safety conditions and economics of the current mine configuration as a standalone project. Paste filling the stopes rather that leaving them void will improve ground stability, increase ore recovery, and reduce dilution. It will also reduce surface tailings as a portion of new and existing tailings will be redirected underground to be used as paste fill. It is also critical to fill existing voids (particularly within WF3) to achieve the increased production target and preferred mining sequence considered as part of the expansion project.

Mobile Equipment: The existing small-scale underground trucks and load-haul-dump (LHD) fleet will continue to be used primarily in the current mining areas. This will reduce capital expenditure associated with purchasing new mobile equipment, increasing development profiles and changing the existing underground crushing and conveying system. As mining extends deeper and average haulage distances increase in WF3, new large-scale trucks and LHDs will be purchased for the more efficient transportation of material to surface reducing costs over the life-of-mine (Speiser, 2021).

Rosh Pinah Mine with the settlement in the foreground (Photo: Chamber of Mines of Namibia)

4. The Tsumeb Smelter (Dundee Precious Metals)

Tsumeb has a long tradition of smelting, as the local people have smelted the copper ores for time immemorial and traded the copper for other goods. The first smelter plant was erected at Tsumeb as early as 1906-07. It consisted of two lead-copper blast furnaces, which were fired with first-class German coke. Only after World War I was coke obtained from South Africa. Third furnace was added in 1923 and a Cotrall precipitator for the recovery of cadmium was installed in 1925. In 1930 a rotary furnace was acquired to roast the cadmium-bearing flue dust. Due to World War II, the smelter came to a standstill in 1940. During the 1950s, the Tsumeb concentrates were smelted and refined at overseas smelters. However, the ever-increasing transportation costs made it necessary to erect a new and larger smelter at Tsumeb in 1960-62 (Schneider & Seeger, 1992).

The smelter of the Otavi Minen- und Eisenbahn-Gesellschaft, Tsumeb, 1909 (Photo: National Archives)

Today’s facility, which was bought by Dundee Precious Metals in 2010, is amongst the most modern and efficient complex smelters in the World. It consists of a primary smelting furnace, the Ausmelt furnace, two Peirce Smith Converters, bag houses and cooling towers, a slag milling plant, two high voltage distribution sub-stations, a materials handling facility, two oxygen plants, a fume extraction system and a sulphuric acid plant. The smelter is one of only a few smelters in the world that can treat complex copper concentrates. Blister copper and sulphuric acid are the smelter products. The blister copper is delivered to refineries in Europe and Asia for final processing to copper metal. Sulphuric acid is a critical component in the mining industry, particularly for uranium and copper production businesses, and therefore the smelter provides a by-product of copper for other mining operations in Namibia.

The Ausmelt process is one of the most energy efficient smelting technologies available. In this process the direct injection of fuel into the slag bath and ability to utilise the energy released during the oxidation of the feed reduces the fuel requirements compared to alternative processes. The addition of post combustion air with the Ausmelt Lance Shroud System is used to maximize the recovery of energy available in the system. This energy may be used in other sections of the plant or for electricity generation. This further reduces the plant’s energy requirements and minimises green house gas emissions.

The Ausmelt TSL Process can handle a wide range of feed materials including low grade concentrates, complex polymetallic ores, materials with high impurity contents and secondary and industrial waste materials. These materials, which are often problematic for conventional smelting technologies, are becoming increasingly important feed sources.

Ausmelt copper smelting entails dropping moist solid feed into a tall cylindrical furnace while blowing oxygen-enriched air through a vertical lance into the furnace's matte/slag bath. The products of the process are a matte/slag mixture and a strong SO_2 offgas. The matte/slag mixture is tapped periodically into a fuel-fired or electric setting furnace for separation. The settled matte (~60% Cu) is sent to conventional converting. The slag (0.70% Cu) is discarded (www.dundeeprecious.com).

The offgas (25% SO_2) is drawn from the top of the smelting furnace through a vertical flue. It is passed through a waste heat boiler, gas cleaning and on to a sulfuric acid plant. A small amount of oxygen is blown through the side of the smelting furnace or lance (about halfway up) to ensure that sulfur leaves the furnace as SO_2 rather than S_2. This prevents sulfur condensation in the gas cleaning system. Most of the energy for smelting comes from oxidizing the concentrate charge. Additional energy is provided by combusting (i) oil, gas, or coal fines blown through the vertical lance and (ii) coal fines in the solid charge (www.totalmateria.com).

Peirce-Smith converters (PSCs) have been used in the copper smelting industries for more than a century for the purpose of removing iron and sulphur through oxidation reactions to obtain blister copper and converter matte respectively. This process step is referred to as conversion. The conversion process used in removing iron and sulphur from matte is a complex phenomenon involving phase interactions, many chemical reactions, associated heat generation, as well as product formation (Kyllo and Richards, 1998a). The PSC is a cylindrical horizontal reactor (circular canal geometry) where air at subsonic velocity (Mach < 1) is injected into matte through submerged lateral tuyeres along the axis of the converter. The converting process is semi-continuous and autothermal. Since there are chemical reactions taking place with products being formed, quality and quantity of mixing are important (Chibwe et al., 2015).

The acid plant, part of the Tsumeb smelter (www.metso.com)

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WAMINA: Sustainable and climate adapted Water Management in Mining Industry of Namibia

SASSCAL-Namibia Node

Windhoek, February 2023

TABLE OF CONTENTS

CHAPTER 1: BACKGROUND INFORMATION

In the mining industry, the impact of climate change and how the industry can respond to it has increasingly been a topic of discussion over the past decade. In Namibia, mining is no stranger to harsh climates; much of the mining industry operates in inhospitable condition of water stressed to water scarcity areas. The forecast of hazards such as floods, water-stress, drought, and heat indicate that the effects will get more frequent and intense, increasing the physical challenges to mining operations. This is more delicate because Namibia is one of the most arid countries in the world. The pressure on freshwater resources is felt by most of the mines across the country where groundwater is the main available water source. This resource is under immense pressure from increasing urban population, agricultural and industrial growth.

Similar to other countries across the globe, in Chile, 80 percent of copper production is located in extremely high water-stressed and arid areas; by 2040 it has been estimated to be 100% (Rüttinger, 2016). In Russia, 40 percent of the nation's iron ore production, currently located in high water-stressed areas, is likely to move to extreme water stress by 2040 as well (Rüttinger, 2016). It is evident that water is an integral part of all mining operations, and no mine can operate without water. In this respect, it is crucial that mining sector, communities, and other stakeholder groups work together to manage water resources effectively. Sustainable water use is an emerging concept within the industry which supports the sustainable and equitable production and use of water in mining operations in the era of climate change.

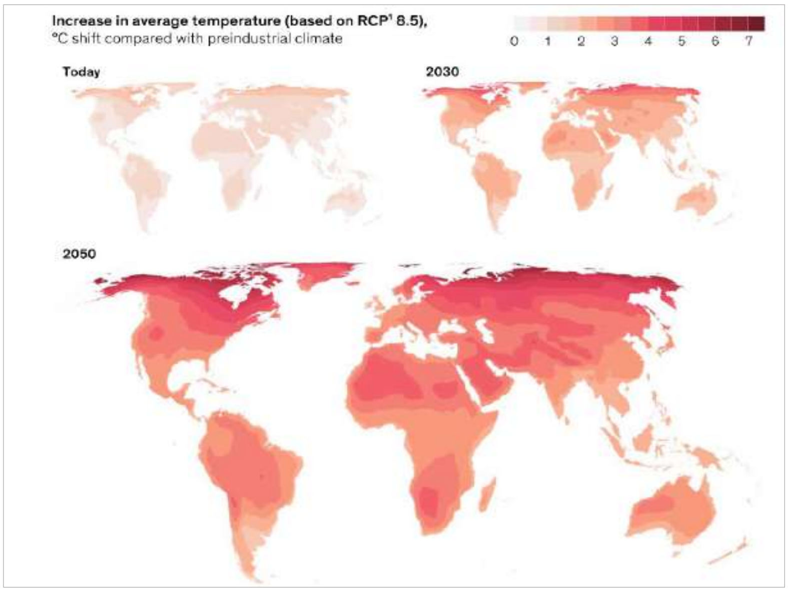


Figure 1: Global average temperatures are expected to increase between 1.5 and 5 degrees Celsius relative to today in many locations by 2050.

Global water resources are under increasing pressure and it is widely recognized that a holistic approach to water management is required in order to achieve resource sustainability and to secure future access and operation of mines (Musiyarira et al., 2017). Climate change is expected to place more pressure on available water resources, with some regions predicted to become much drier and other regions wetter and by 2040, extremely water stress is expected in some parts of the world as indicated in figure 2 below.

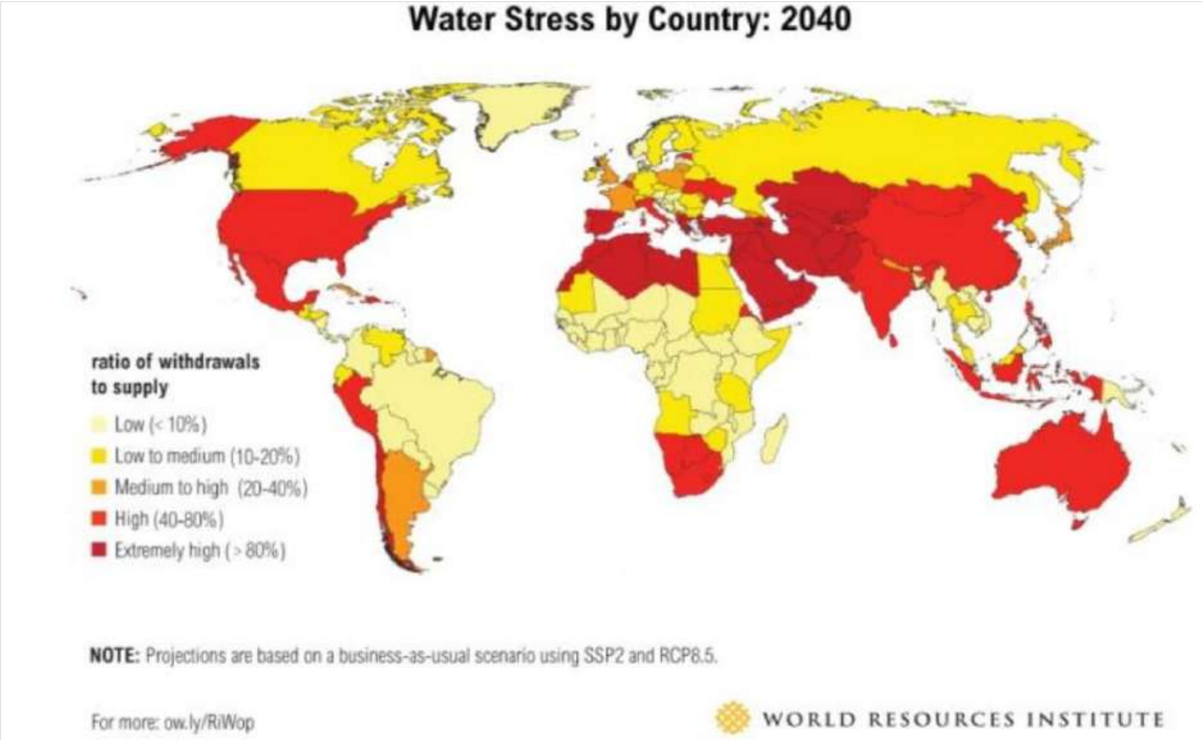


Figure 2: Water stress by country (Source: Maddocks, A. et al., 2015)

The effect of climate change is felt globally, for example the per capita of fresh water availability is steadily decreasing and the trend will inevitably continue as the world's population grows (Rüttinger, 2016). Many regions of the world are reaching a point of "freshwater stress", where freshwater resources can no longer support the demands of human populations also affecting mining operations (Rüttinger, 2016). In respect to this global problem, the approach to water management cannot remain business as usual as it needs a paradigm shift in the implementation of the best practices which minimize the potential for adverse environmental, social, and economic impacts. In this paper, an overview of mining industry in Namibia is discussed as well as climate change and water use in respect to mining industry.

1.1. Objective

1. Overview of challenges faced by mining industries in Namibia due to climate change and sustainable use of water.

The mining sector plays a key role in socio-economic development of many resource-rich economies. The sector has been and remains the backbone of the economy as reflected by its average annual economic growth, contribution to GDP, job creation, income generation, and a key source of government fiscal receipts and foreign exchange earnings, among others (Iiyambo, 2010; Krugmann & Alberts, 2012; Musiyarira et al., 2017). The sector has also led to the establishment of towns while remaining committed to the achievement of national goals of poverty reduction, employment creation and skills development (Krugmann & Alberts, 2012). There are various natural resources mined in Namibia including diamonds, uranium, copper, gold, lead, tin, lithium, cadmium, zinc, salt and vanadium, all together contribute to about 25% to the country's income (Musiyarira et al., 2017). However, this sector requires energy which sometimes is driven from hydropower generation as well as large quantities of water to operate. Notwithstanding the foregoing, however, the sector remains susceptible to water insecurity and climate change (KPMG Global Mining Institute, 2014).

To add complexity, Namibia is a primary source for gem-quality diamonds mined inland and offshore, and is the fifth-largest producer of uranium in the world (Musiyarira et al., 2017). Namibian mines are distributed across the country (figure 3), known to produce additional products such as gem quality rough diamonds, uranium oxide, special high-grade zinc and acid-grade fluorspar, as well as gold bullion, blister copper, lead concentrate, salt and dimension stone (Christina, 2006).

Tragically, most of these mines are found in water-stressed areas and they are increasingly in competition with different users, presenting challenges to the security of supply. The future of mining companies and society depends on the availability of freshwater resources, which are increasingly under pressure.

Most of the Namibian mining activities occur in the Central Namib, an ecologically sensitive area containing parts of the Namib-Naukluft and Dorob National Parks, where the climate experiences low and erratic rainfall, soaring temperatures and strong seasonal winds that cause high water evaporation rates (Iiyambo, 2010). According to Christina (2006) the potential for significant impacts is greater when mining occurs in remote and environmentally or socially sensitive areas. Mining activities can have both positive and negative environmental, economic, and social impacts on communities. For groundwater, as rainfall decreases there is a strong tendency towards increase groundwater use. Figure 3 below shows the distribution of mines in some parts of the regions in Namibia.

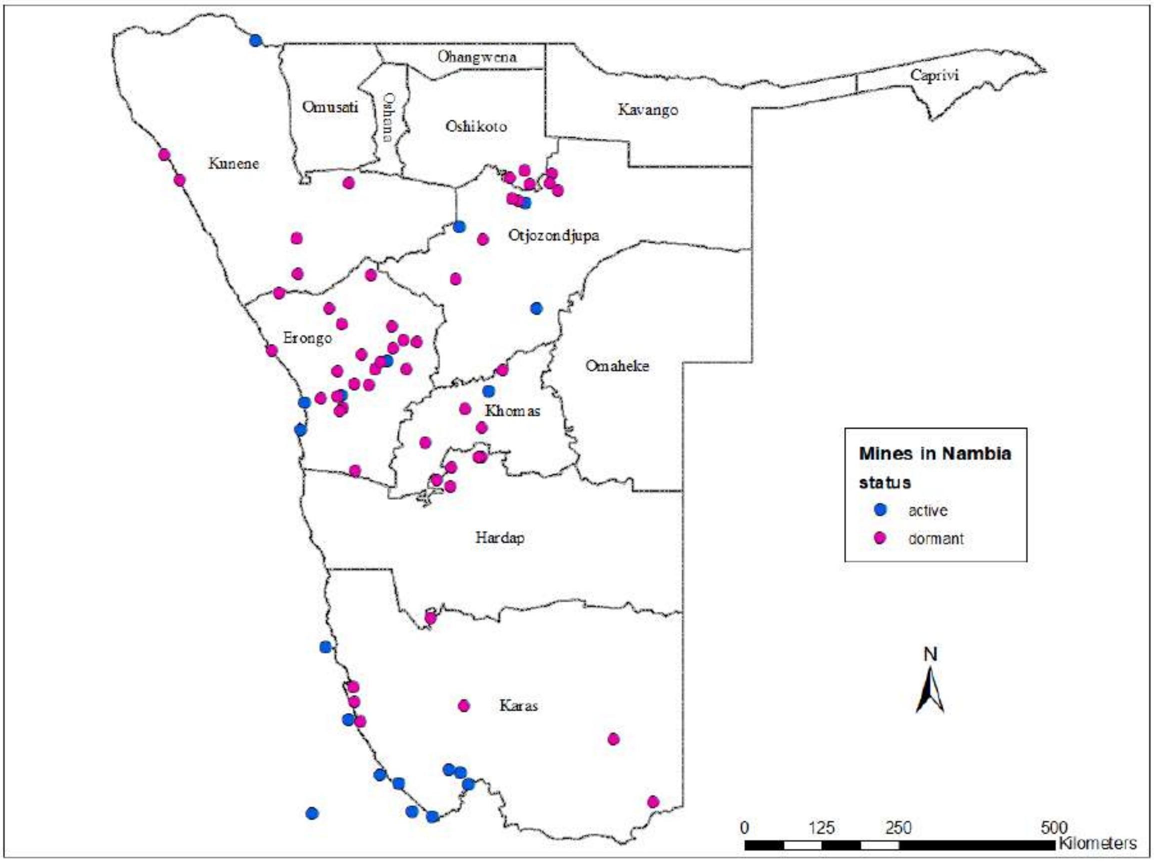


Figure 3: Data source (Ministry of Mines and Energy). Map of Mines in Namibia

In times of drought, low levels of water supply compromise the mining operations (KPMG Global Mining Institute, 2014). Furthermore, the sea level rise and extreme weather events associated with climate change are also a threat to the stability and effectiveness of mining infrastructure and equipment, environmental protection and site closure practices, and the availability of transportation routes. Climate change may also impact the availability, stability and cost of water and energy supplies required in mining industries especially that they are already operation in harsh environment. Table 1 is a representation of water use in various sectors in Namibia. Although the mining industry's overall "water footprint" is relatively small compared to other sectors, most mining companies have recognized the importance of fresh water and the need to take actions to reduce mining industry's water consumption. Despite the efforts, water consumption is still projected to increase. In 2008 it was recorded at 16.1 Mm^3, by 2030, water consumption is projected to be at 20.3 Mm^3. According to the Chambers of mines, about 50 million cubic meter of fresh water per year is required for about seven operational Uranium mines (KPMG Global Mining Institute, 2014).

Table 1: Water demand projections [Mm3] in Namibia. Source: (IWRM Plan Joint Venture Namibia, 2010)

Consumer group	2008	2015	2020	2025	2030
Urban	66	80	91.1	103.5	117.2
Rural Domestic	10.3	10.6	10.9	11.1	11.4
Livestock	86.8	86.8	86.8	86.8	86.8
Irrigation	135.3	204.6	344.6	379.8	497.2
Mining	16.1	17.2	18.1	19.1	20.3
Tourism	19.1	27.5	31.9	35.2	38.9

To improve resiliency and reduce water demand, mining companies will have to use water sustainably during their operations. This involves recycling of used water and reduce water loss from evaporation, leaks, and waste. They can reduce evaporation by putting covers on small and medium dams and other water sources. In the long term, more capital-intensive approaches can be practiced. New water infrastructure, such as dams and desalination plants, is expensive but sometimes necessary. Companies can also rely on so-called natural capital, like wetland areas, to improve groundwater drainage.

CHAPTER 2: NAMIBIA'S CLIMATE CHANGE INFORMATION

2.1 Namibia's Rainfall Trends and Spatial Distribution

Namibia's rainfall decreases from northwest to southwest and majority of the country is characterised by desert conditions (Henschel, et al., 1998). In addition to low rainfall, Namibia has generally low but highly variable precipitation ranging from a maximum of about 650 mm/a in the northeast to less than 50 mm/a along the coast (Wilhelm, 2012). It is estimated that country-wide on average only about 2% of the rainfall ends up as surface run-off and as little as 1% of the rainfall effectively recharges groundwater resources (Zeidler et al., 2010). Given the country's very dry and unpredictable climate, water availability, i.e., secure, equitable and universal access to fresh water – tends to be a critical limiting factor for social well-being and economic development. This highlights the need for an efficient use and effective management of scarce water resources and puts a premium on water security. Namibia is characterised by arid and semi-arid climates where much of its mining industries operates. Dry conditions persist throughout much of the year due primarily to the proximity of the Atlantic Ocean and the influence of the cool northward flowing Benguela ocean current that results in persistent high pressure off the coastline (Colin, 2010; Noureldeen et al., 2020). There is a single rainy season occurring in the summer (November to April) associated with the southward migration of the Inter-Tropical Convergence Zone (ITCZ). Coastal fog is also prevalent and acts as a vital source of water for the desert fauna and flora, providing up to five times more water than through rainfall in some coastal regions (World Bank Group, 2021).

The annual rainfall for the past 40+ years suggests that the driest and wettest years occurred in the past 12 years for most parts of Namibia (see figure 4, 5 & 6 below). The rainfall was high in Zambezi region and other Northern regions as seen in the figures below, but due to its extreme variability, water security continues to be a problem across all regions. A downward trend in rainfall over the past 40 years is observed. This shows how climate change could potentially result in a decrease in water availability across the country, because of the potential decrease in rainfall in the coming years. Eventually affecting many sectors including mine operations due to water shortage

The north-eastern and central and south-eastern received above average rainfall.

The central and north-western, western, and south-western part of Namibia received below average rainfall.

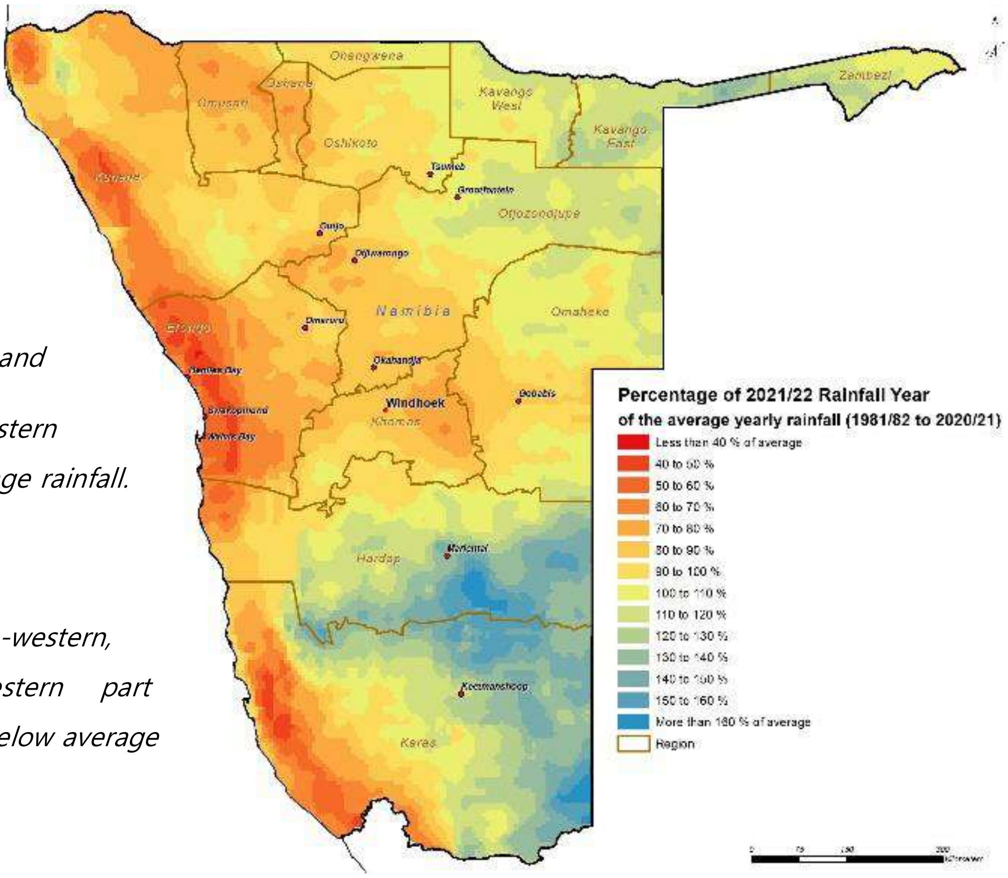
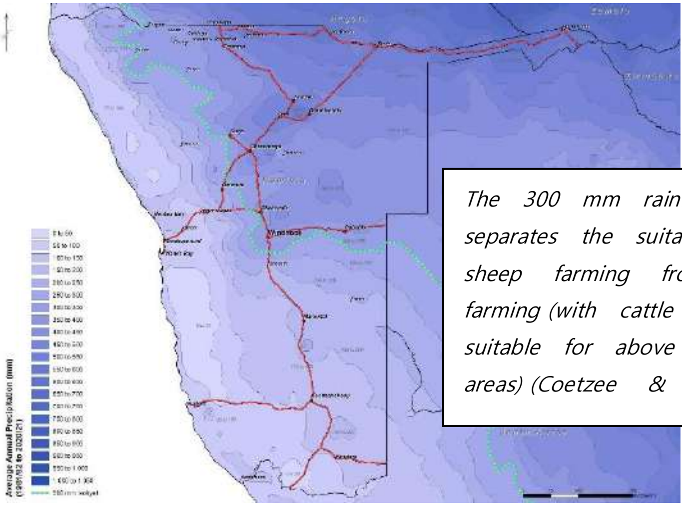
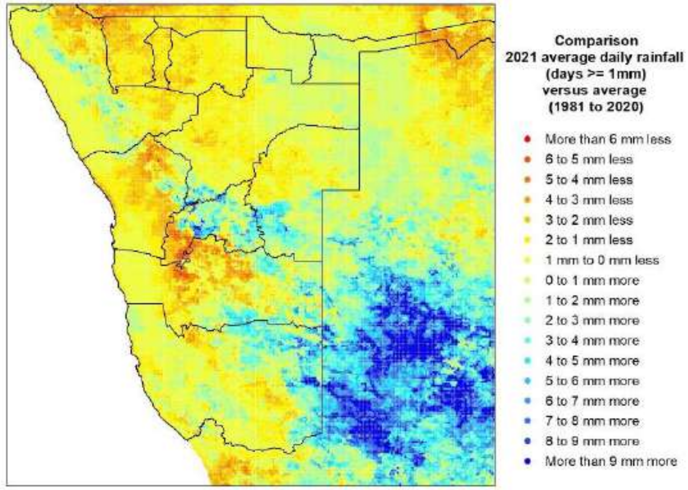
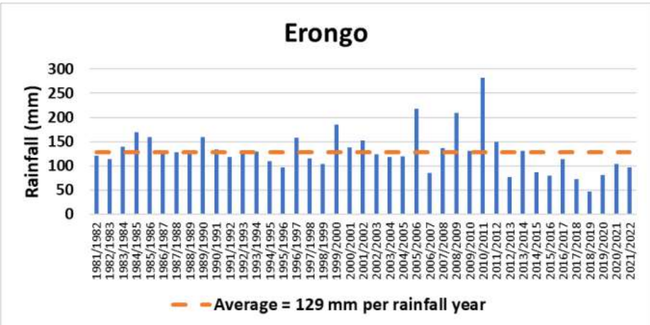


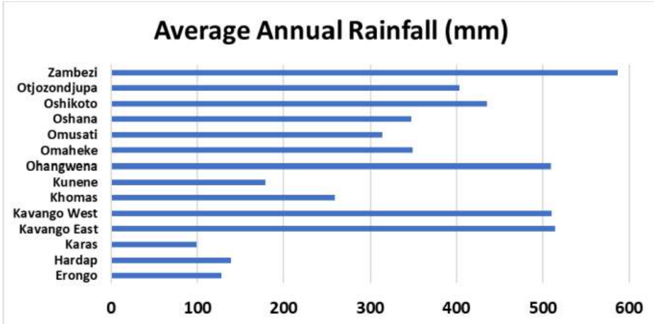
Figure 4: Rainfall spatial distribution

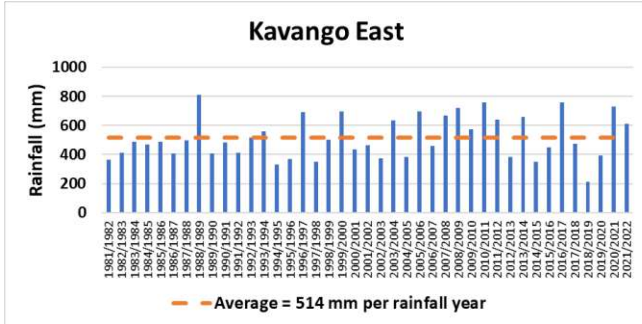


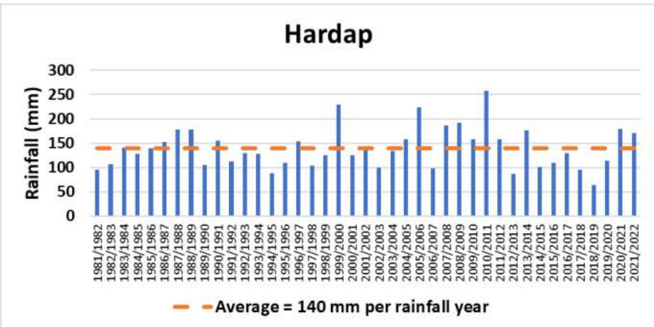
The 300 mm rainfall isohyet separates the suitability for sheep farming from cattle farming (with cattle farming suitable for above 300 mm areas) (Coetzee & Werger)

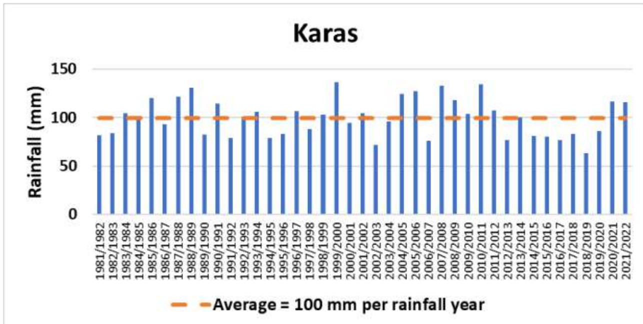












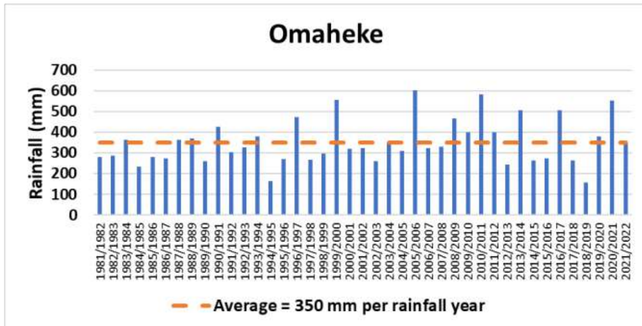


Figure 5: Average Annual Rainfall (mm) by Region, Source: SASSCAL 2022. Data Source: CHC Chirps 2.0

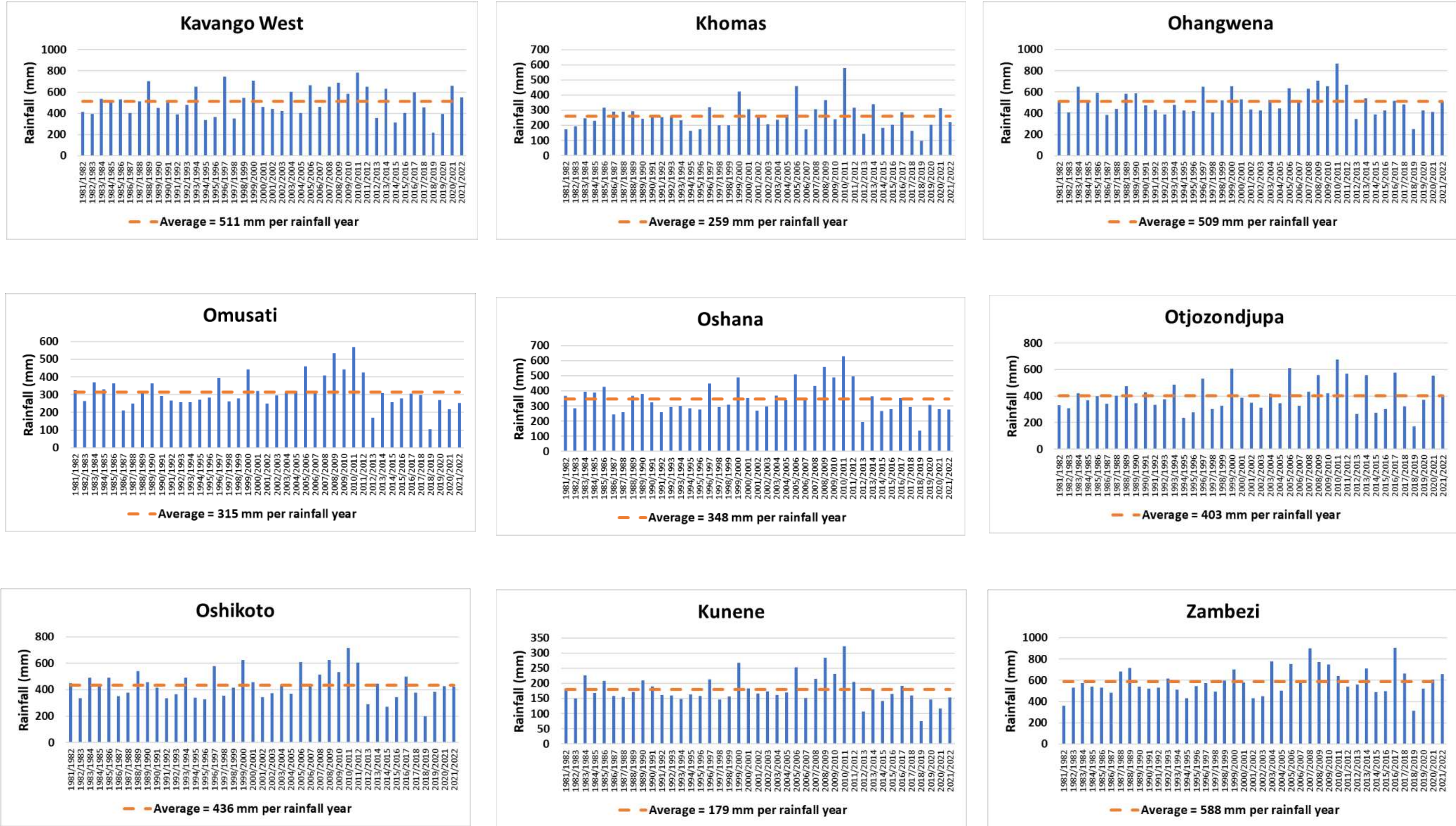
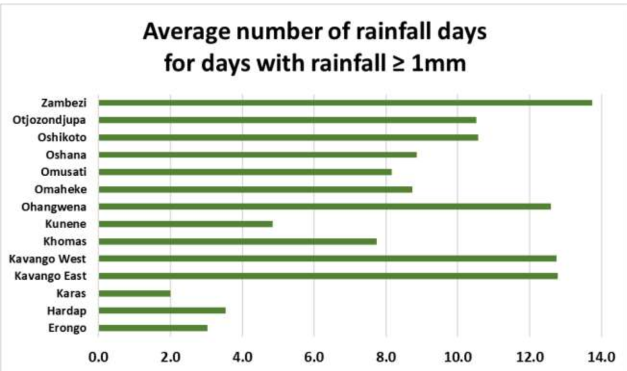
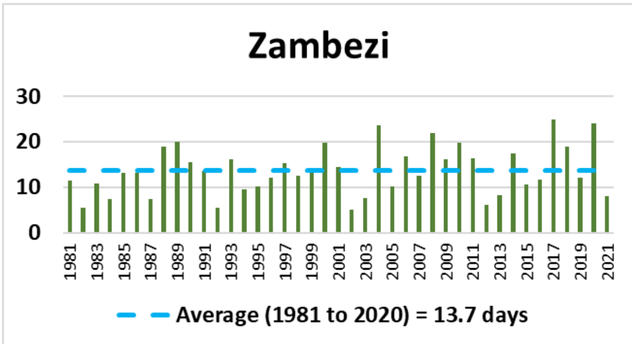


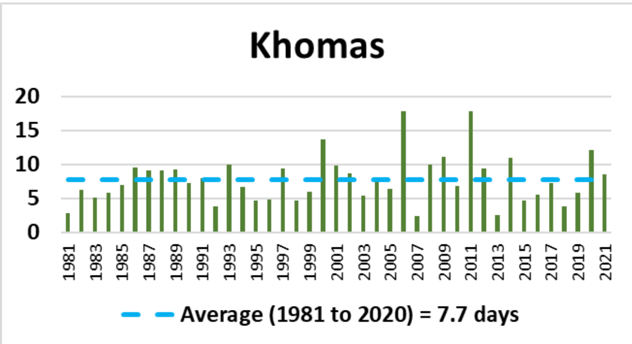
Figure 6: Average Annual Rainfall (mm) by Region, Source: SASSCAL 2022. Data Source: CHC Chirps 2.0

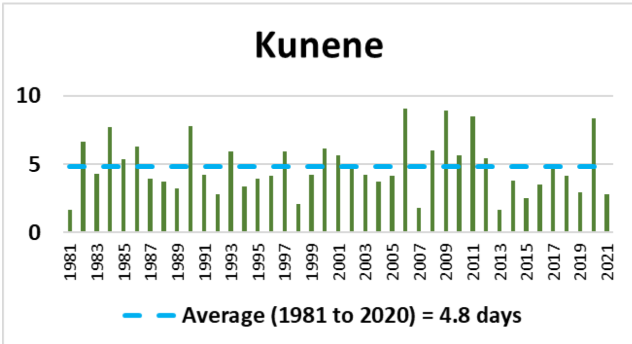
2.2 Climate Indices

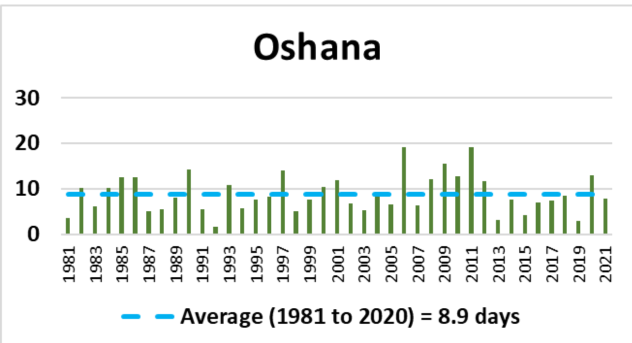
A lot of important information on a rainfall season is lost by just analyzing monthly or annual data. The monthly analysis, as well as the annual rainfall total, provide no insight on the rainfall frequency and pattern that are relevant to, amongst other, flood producing rainfall events, the creation of valuable pasture and crop production. To this end, the WMO proposes a number of climate indices, which include the SDII, the Simple Precipitation Intensity Index, that summarizes the number of rainfall days and average daily rainfall for rainfall days with more than or equal to 1 (one) mm of rainfall. It is clear from the regional graphs, that a high number of rainfall days does not imply "good" rainfall, if these didn't produce significant downpours (see fig 7 below).

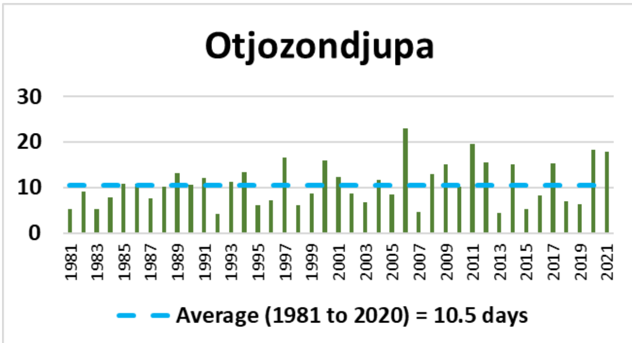












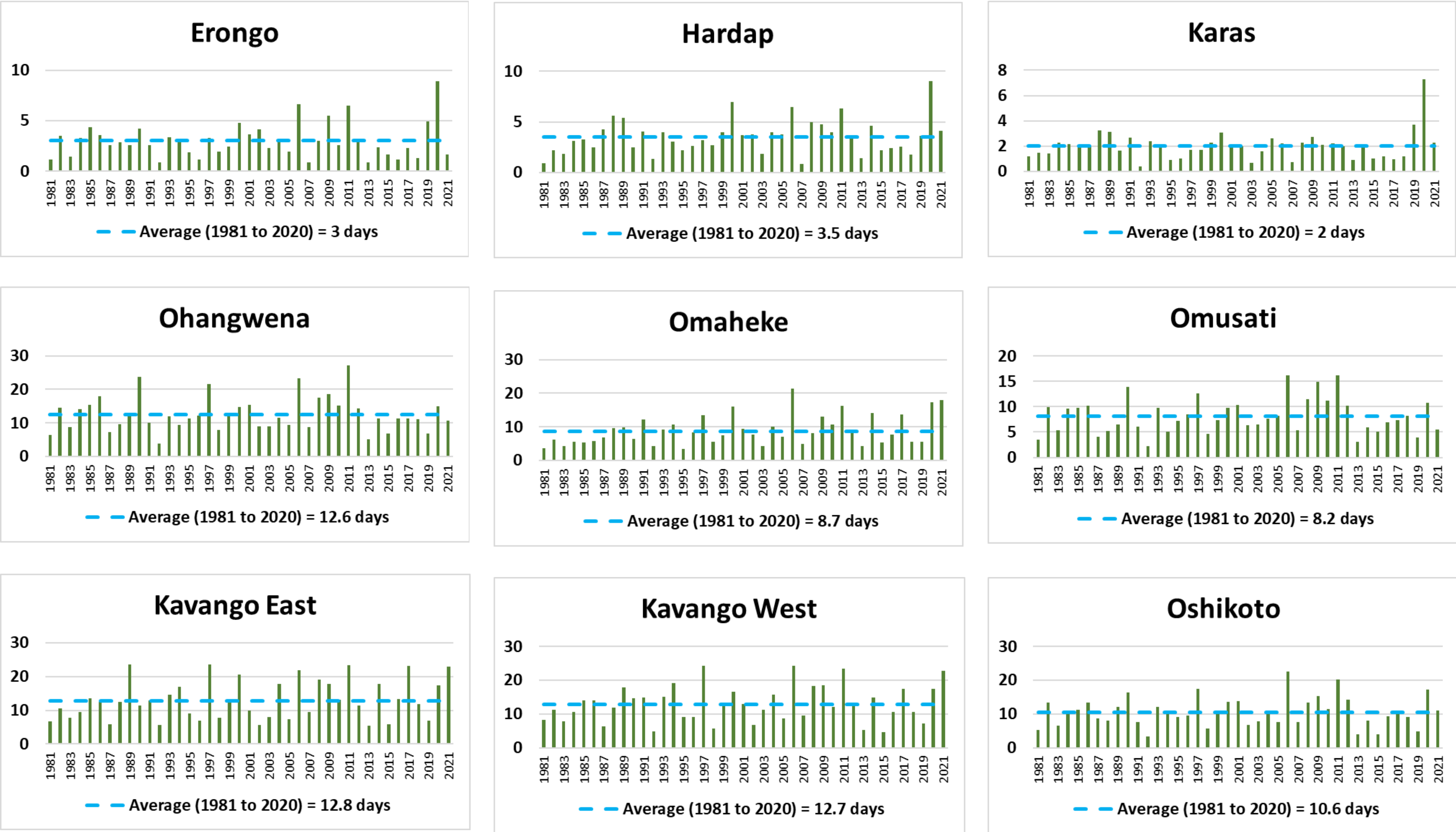


Figure 7: Average Number of Rainfall days for days with rainfall. Source: SASSCAL 2022. Data Source: CHC Chirps 2.0

2.3 Rainfall projection in Namibia

While rainfall trends in Namibia are highly variable, GERICS analysis indicates total precipitation rates are likely to reduce by as much as 19% by the 2080s (Dirkx et al., 2008). The largest decrease in projected rainfall is for the typical dry season, April to October, with likely reductions from 5% to as much as 65% (Cubasch et al., 2001). Meanwhile, the country's typical wet season, November to March, is expected to receive a small increase in precipitation (Zeidler et al., 2010). The greatest reduction for the interior of the country will occur from December to February. Other projections indicate that the Northern and central parts of the country where most of the population is found, may experience a decline in rainfall to a more significant degree than other parts of the country (Wilhelm, 2012) as presented in figure 8.

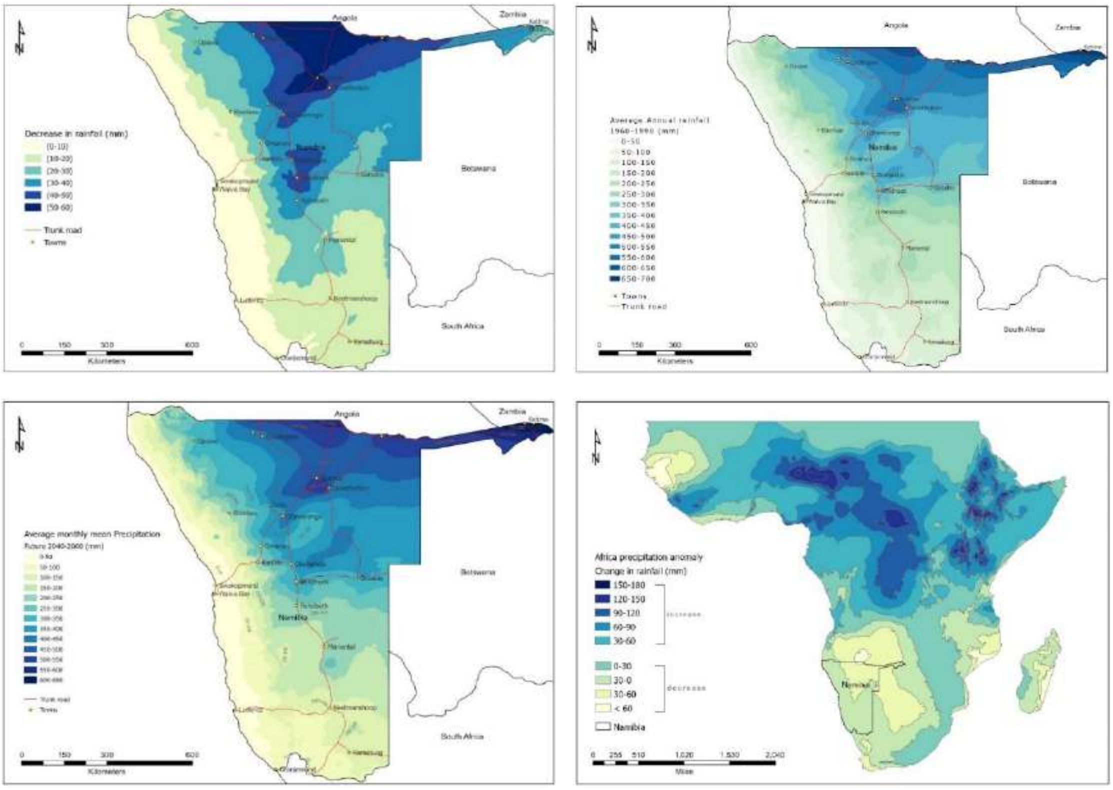


Figure 8: Projected changes in rainfall from 2040 to 2060. Data Source: Multi-Model (CMIP5) Ensemble Projected Changes (32 GCMs) in Precipitation by 2040–2059 (left), Relative to 1986–2005 Baseline under RCP8.5. (Source: SASSCAL 2022)

2.4 Daytime Land Surface Temperatures of Namibia 2021 and Historic (2001 to 2020)

Land Surface Temperature (LST) is the brightness temperature of land surface and is driven by solar radiation and related to air temperature. It translates into the temperature your hand would perceive if you lay it on the land surface. It is often used as an indicator for monitoring the state of crops and vegetation and assessing plant stress. Figures (9 and 10) below provide information on daytime land surface temperature in Namibia.

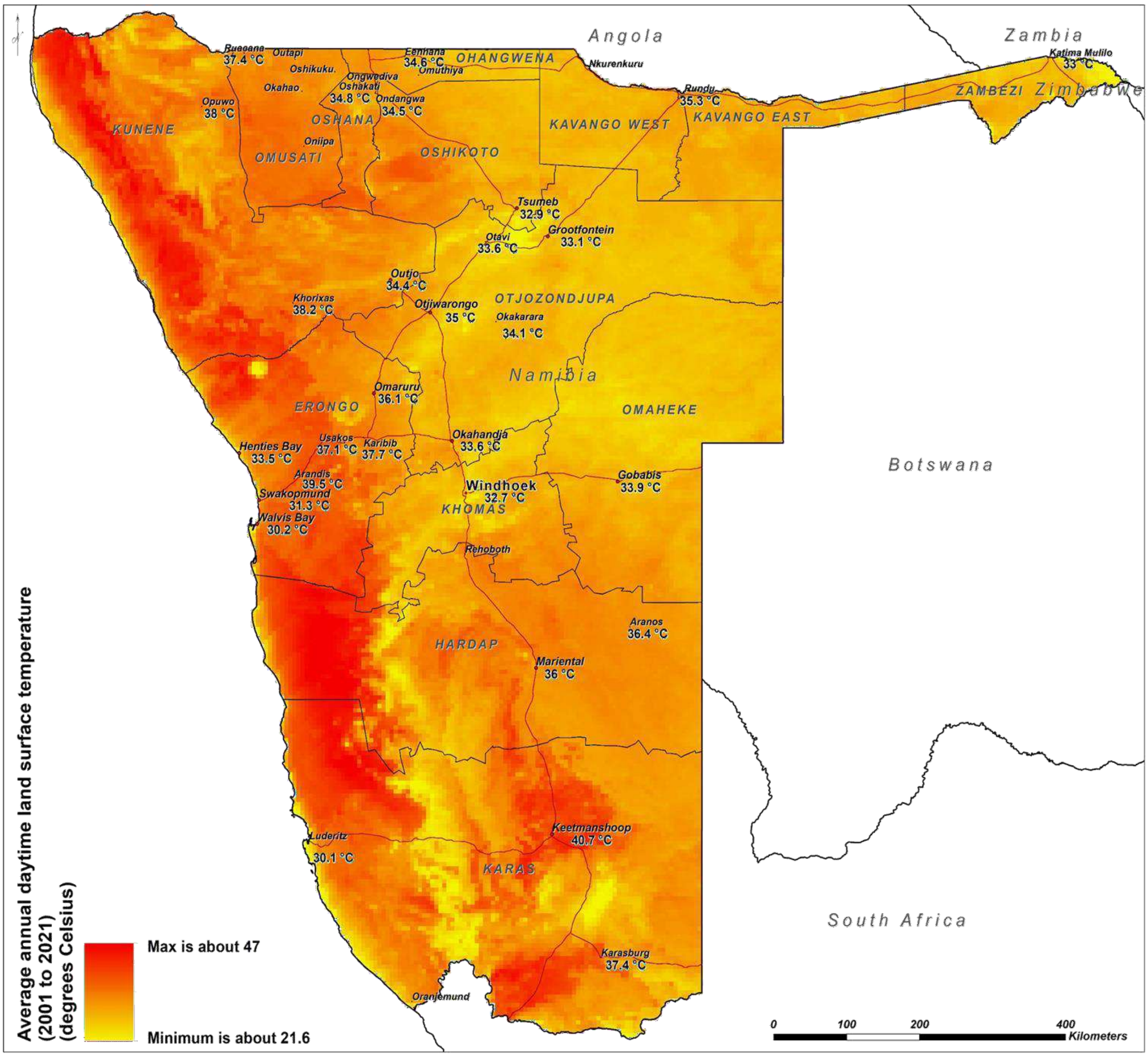


Figure 9: Average annual daytime land surface temperature. Source: (SASSCAL 2022). Data source: MODIS MOD11C3

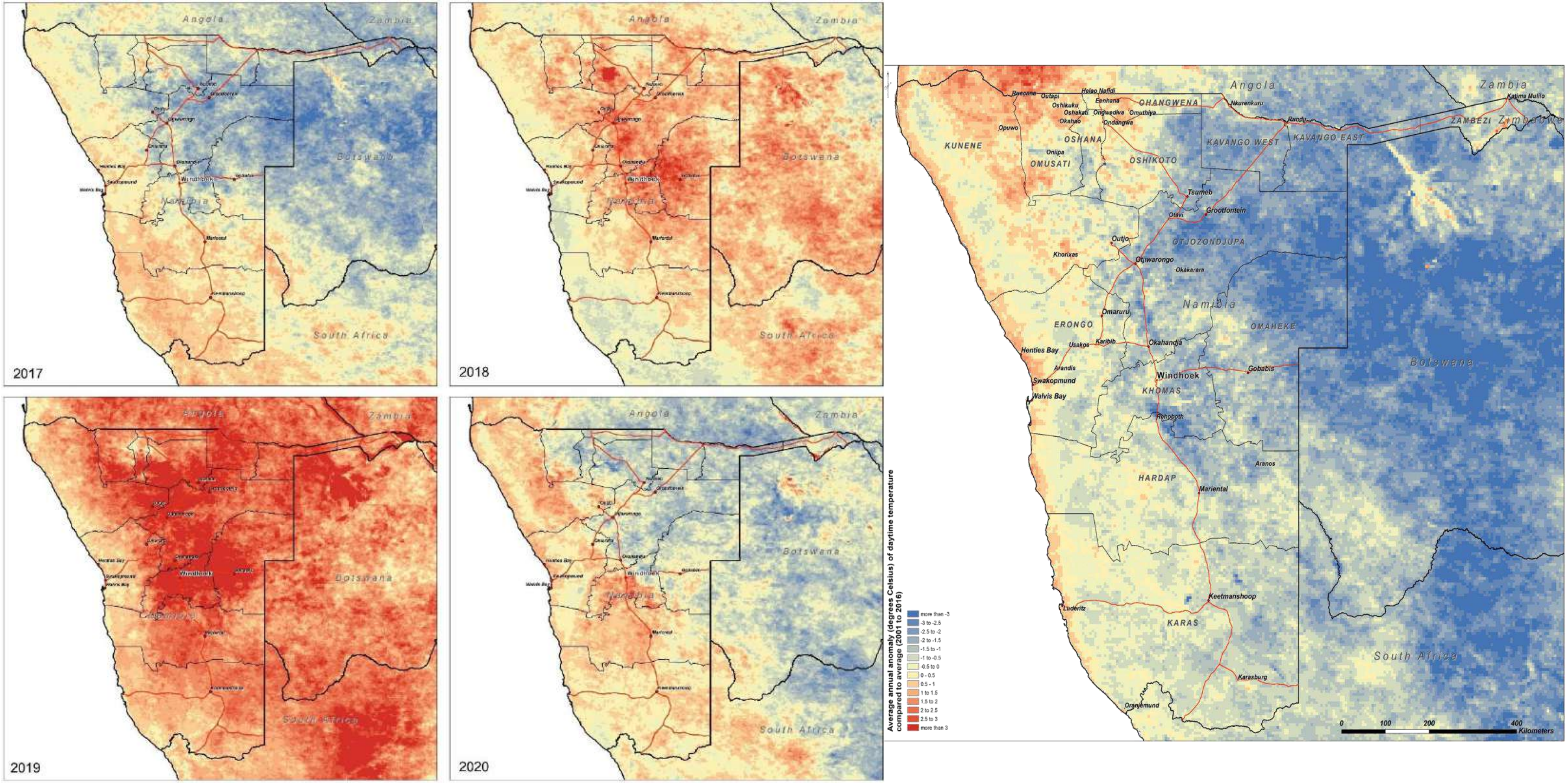


Figure 10: Average Annual Anomaly Daytime Land Surface Temperatures in Namibia. Source: SASSCAL 2022. Data Source: MODIS MOD11C3 Monthly Daytime Land Surface Temperature (2000 to 2021).

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CHAPTER 3: INFORMATION WATER SOURCES IN NAMIBIA

Namibia has no perennial rivers within its borders (Dirkx et al., 2008). This makes the water availability situation direr, especially in the driest parts of the country. In addition to the ephemeral rivers and boreholes as the main water sources, providing 22% and 50% of Namibia's freshwater respectively, the only other source is perennial rivers which are at Namibia's borders with the neighbouring countries; and thus, Namibians cannot use these rivers as a source for large water extractions without the consent of the neighbours. This is because Namibia has international obligations regarding the abstraction of water from these rivers, as well as other uses. Instead of having a sustained surface flow, there are ephemeral rivers that feed the groundwater table, causing Namibia to have a wide range of aquifer containing groundwater with an overall national groundwater safe yield of 300 million m^3 /year (Iiyambo, 2010). However, groundwater resources in Namibia are vulnerable to over abstraction and pollution (Zeidler et al., 2010). High temperature that leads to high evaporation has been so far compromising the situation of water insecurity across the country. The shortage of water clearly calls for intervention by the relevant water authorities as well as action from all the consumers. In the quest to meet the needs through using available freshwater sources, it is important to consider the sustainability of the environment. It is, therefore, necessary that the sustainability of the water sources and their environments be well looked after for the provision of freshwater to continue in mining sector and others. For example, capturing of ephemeral surface water may affect downstream users as well as the natural environment (ecosystems) which leads to insufficient vegetation for livestock as well as little or no freshwater for groundwater recharge (Lendelvo et al., 2018). So far, one of the big consumers of water are the mines (KPMG Global Mining Institute, 2014). Due to international uranium prices that are going up, Namibia has offered prospecting and mining licences to a number of new mines that are expected to be commissioned in the near future with uranium increasingly being considered as a source for long-term clean energy; and this is largely motivated by the current debate on clean energy and climate change (Iiyambo, 2010). Additional mines will inevitably lead to an increase in demand for freshwater due to high demands for water for them to operate, placing huge stress on the few water resources available.

3.1 Mines and water in central-Namib

The main source of water in central Namib is groundwater and this is due to the fact that this part of Namibia receives less than 22 mm of rainfall per annum (Iiyambo, 2010). The groundwater reserves are recharged through rainfall which falls over 200 km away from the region, with some people in this region obtaining water from wells; which is done manually, while others obtain water from boreholes (Henschel et al., 1998). One of the direct impacts of low precipitation is limited supply of freshwater. Limited artificial recharge takes place but only during years with abnormally high rainfall, which is a rare occasion (Dirkx et al., 2008).

It has been observed that due to increasing mining activities in the region, the demand of water is needed for operations. The Central Namib Water Scheme, the system of water supply comprising of alluvial aquifers in two ephemeral rivers; namely the Kuiseb River and the Omaruru River have been so far providing water to the mines in the region (Henschel et al., 1998). Water in this area is administered by the Namibian water cooperation (NAMWATER). NAMWATER is a publicly administered institution which supplies bulk water; and it is one of the two institutions tasked with the responsibility of supplying water to the end users. Another institution called Rural Water Supply which falls under the Ministry of Agriculture Water and Land Reforms makes use of small-scale technology, as opposed to bulk water supply which uses "large-scale dams, transport, and storage technology", with their end users being mining companies, other industries, urban centres etc, and whose water is transferred over much longer distances. Figure 11 depicts the distribution ephemeral rivers, the main water sources in the area. The mines use the underground water of the Swakop and Khan Rivers due to its lack of salinity in comparison to the seawater. However, if this usage is not monitored properly, there are concerns that the rivers will be depleted due to mining activities (Henschel et al., 1998).

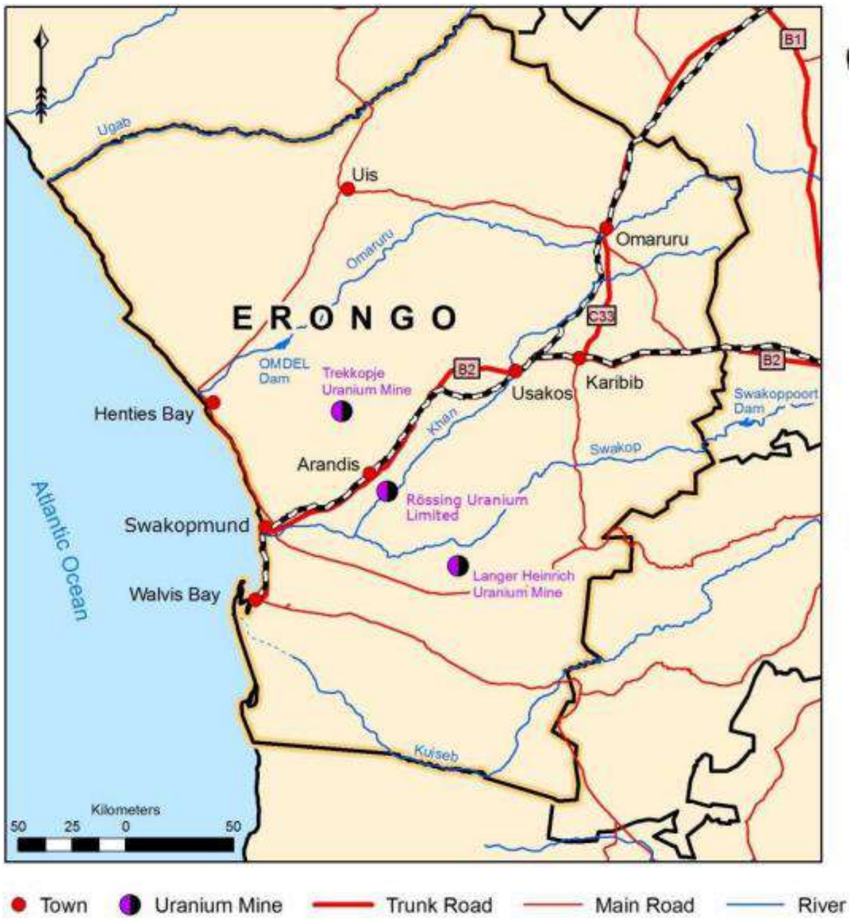

Figure 8: The Central Namib mines (Source: Iiyambo, 2010)

Despite the extraction of groundwater, there is still very high demand for water in this incredibly arid area. Mining operations use water mainly for cooling, underground procedures like hydraulic drills and processing including flotation and leaching. In addition, the mine requires adjacent supporting infrastructure such as housing and transport, which also requires water (Khawaji et al., 2008). Mines like uranium mine have built desalination plants to meet their demand such as the Trekkopje mine as it demands 25 million cubic meters per year. Water recycling includes the tailings storage facilities and recovery bore holes/trenches, and the treated effluent from the sewage treatment plant. Tailings at uranium mines are generally covered with water to keep the radon and radioactivity under control.

It is evident from Figure 12 that current water demand has exceeded supply of water predicted to 2030, under the scenario, where demand management and recycling are implemented.

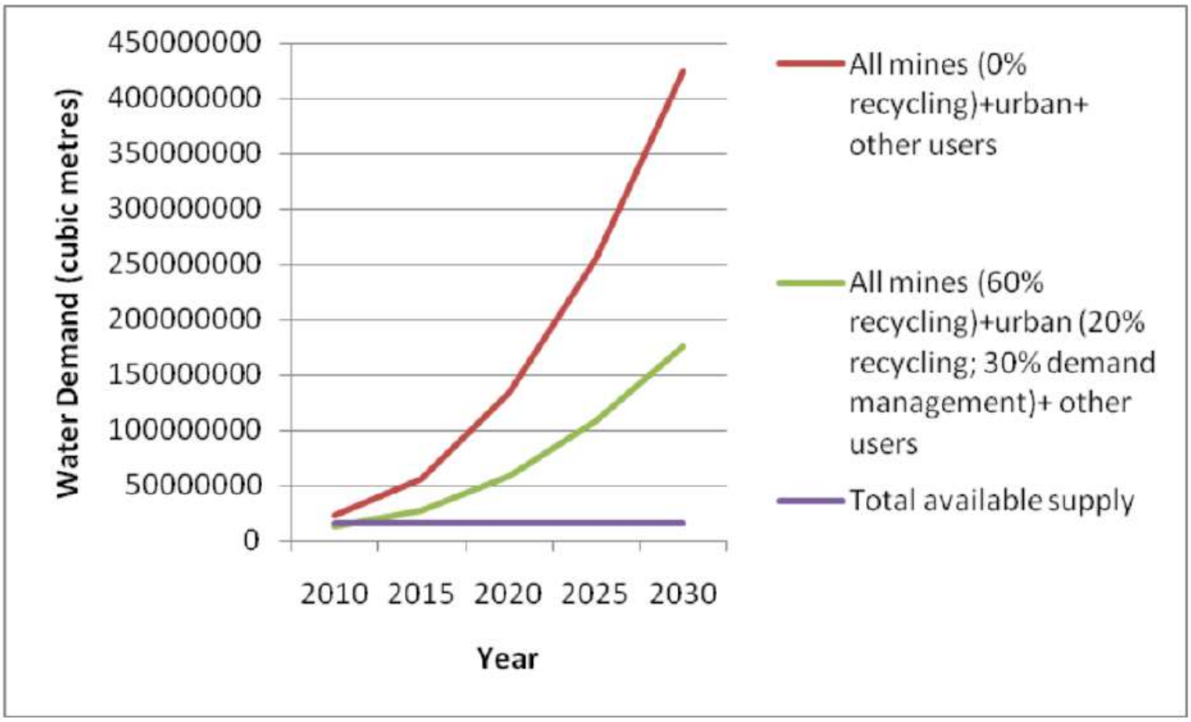

Figure 9: Total water demand versus total available supply in the Erongo Region (source: Iiyambo, 2010)

Since this region is so dry, there will be a need for alternative water sources if demand is to be met in the future. To secure sustainable water supply for the future; there is need to expand water use plans to reach many years in the future. Caution should be taken though with regards to making long-term projections because of the effects of variable environments as well as climate change.

One way of doing this is to align the countries development plans with the available freshwater resource and determine if the available resources will sufficiently cater for the socio-economic developments in the region. If the available freshwater resources are found to be insufficient, then the second step would be to explore alternatives for increasing supply which in this case more desalination plant for sea water.

3.2 Mines and water use in the north and central north of Namibia

Most of the mines in this area get their water from the Karst Aquifer sub-catchments in the vicinity of Grootfontein and Tsumeb. The Grootfontein, Tsumeb, Otavi and Karas area is endowed with large-scale high-quality groundwater resources that are extensively used for irrigation purposes and domestic use. In 2012, it was found that Tsumeb sub-catchments have a long-term sustainable safe yield of 18 million cubic metres per annum and the stored water in the aquifer is more than 800 million cubic metres (Krugmann & Alberts, 2012). However, the mines operating in the Karst area continue to compete for groundwater with irrigation activity. Krugmann and Alberts, 2012 reported that the mining industry was considered diligent when it comes to the management of water for industrial purposes. This diligence arises for several reasons such as large amounts of water required by the individual mines, high expenditure on fresh water supply, the need for precise inputs of water in the mining processes, proven financial benefits of alternatives such as recycling from the slime's dams and environmental obligations. Irrespective of this, it was also pointed out that water demand from mines will go high if not properly controlled due to climate change. Determining water withdrawals to meet demand for the mines is not straightforward. Water sources can include self-extracted water, distributed water, or reuse water, and sometimes water is abstracted from a combination of all three sources. In copper mining for example, water is fundamentally used as an input in the traditional flotation beneficiation process, in smelting and electro refining and, in the hydro-metallurgical process. However, every joint process or operation in mining requires a greater or lesser volume of water to contribute towards process efficiency.

3.3 Mines and water use in south-west Namibia

The common mine in south west Namibia is Namdeb Holdings of which 50% is owned by the Government of the Republic of Namibia and 50% by De Beers (Christina, 2006). Unlike other mines, the mines found in this part of the country such as Namdeb Holdings has long term mining concessions both on land and offshore, adjacent to the Orange River and offshore in the shallow waters. As such, water is not as problematic as other part of the country. However, the main challenges for mines in this area as documented by Victoria (2021) are changes in price, exchange rate factors and fuel are the biggest cost drivers and they place strain on the cash flow for the mines.

CHAPTER 4: POSSIBLE WAYS OF REACHING WATER DEMANDS IN MINING INDUSTRY

4.1 Recycling wastewater

Wastewater recycling is a viable alternative freshwater source for many water users. In addition to providing sanitation to urban inhabitants, wastewater systems are important because they allow for recycling which provides additional freshwater to urban dwellers and mines. However, when considering wastewater recycling it is important to consider both the economic as well as environmental dimensions (Tarrass et al., 2008). Some Namibian towns recycle wastewater, but only the capital city Windhoek recycles the wastewater to the quality of potable water, whilst the rest treat wastewater to a quality falling short of potable water quality and hence this water is only used for purposes such as landscape irrigation (AQUASTAT survey, 2015). Just like Windhoek which recycle up to 35% of potable water (du Pisani, 2006), likewise the mines can take up the challenge. Recycling does not only have the benefit of increasing available supply, but also the benefit to the environment by reducing the amount of waste that would otherwise be discharged into the natural environment. It is therefore at the best interest of mining companies to recycle wastewater to potable quality to meet water demand not only for operation but likewise for consumption.

4.2 Seawater desalination

More than 97% of water on earth is sea water, while freshwater constitutes only 2% of freshwater resources on earth, most of which is groundwater (Khawaji et al., 2008). Desalination is seen as a good solution to freshwater supply especially in arid Namibia. Due to increased population, better living standards as well as economic development, there is an urgent need for additional freshwater resources in many parts of the world (Khawaji, et al., 2008). Desalination is currently being used in all Arab countries (du Pisani, 2006), and is a source of freshwater to an estimated 75 million people across the world (Khawaji et al., 2008). Due to advances in technology, seawater desalination is not as expensive as it was in the past; and for this reason, more desalination plants can be utilised by mines in Namibia to meet water demand during their operations now and in the future.

4.3 Fog harvesting

According to Batisha (2003), fog is a feasible source of supplementary water supply in arid regions. Fog harvesting has proven a success in different parts of the world (Shanyengana et al., 2002). This makes water affordable to the rural poor and a cheap method of providing urban centres and industries. The quality of fog water is suitable for human consumption as well as other purposes including agriculture (Batisha, 2003). Parts of the coast of Namibia can go for long periods of time without recording any rainfall. This means fog harvesting could be a reliable supplementary source of water for areas such as these (along the Namibian coast), where its feasibility was first investigated in the year 1995 (Shanyengana et al., 2002).

In addition to low rainfall in coastal areas, fog occurs on up to 200 days per year and reaches distances of up 60 km inland and at the coast of Namibia, the amount of precipitation received from fog is said to be seven times higher than that received as rainfall (Leggett, 2006). The amount of water that can be collected, however, would mainly depend on three main factors, namely: fog bearing winds; the persistent occurrence of fog episodes and high fog occurrence. Also, the methods for collecting fog water are very ecological friendly, since it only uses water which is heading for the atmosphere and hardly deprives the ecosystems off freshwater (Shanyengana et al., 2002). It is therefore a challenge to mines especially those at the coast to exercise this technology which might be a solution to water scarcity.

CHAPTER 5: CONCLUSION

Namibia is a water stressed country with a limited amount of freshwater. Freshwater resources are under pressure from ore processing, industrialization, urbanization, and the demands of a growing population. In Namibia, ore processing, coupled with anticipated increase in water demand for human consumption and other uses, has created significant stress on the limited water resources of the country. Mining industries should therefore take very serious strategies of water recycling, reuse fog harvest as well as the minimization of losses. Mining industrial leaders should recognize that reducing the water footprint of mining activities must be one of the key performance indicators for management.

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NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Review of Mine Water Management Practices in Namibia

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as a contribution to the development of a proposal for funding from the BMBF

1.0 Introduction

Namibia is one of the driest countries in sub-Saharan Africa and most vulnerable to climate change (World Bank, 2021). This environmental reality dictates the need to improve water-use efficiency across all mining process components and underlies this study's purpose. Water is the second most important commodity in mining after orebody itself, and one of the most significant challenges the mining industry faces is water management. Water is a vital input for all mining operations, including closure—water is used for several functions in mining, such as processing, mineral conveyance, dust suppression, etc. Most of the mines in Namibia are located in water-stressed areas, and these are increasingly facing competition from different users, presenting challenges to the security of supply. The dependency and impact on a shared resource create material risk for the mining and metals sector that requires effective management. However, it is widely recognized that a holistic approach to water management is necessary to achieve resource sustainability and secure future access (ICMM, 2017).

According to the Namibia water statistics, the mining industry is the fourth highest water consumer after Irrigation, livestock, tourism, etc. Though other sectors consume more water, the primary concern with water used in mining is that, in most cases, it cannot be recycled for human consumption. The industry requires a large amount of fresh water for day-to-day operations; only a small part of the water is supplemented through recycling. The mining sector has felt water constraints acutely, to the point of building the first desalination plant by the Orano mine in the Erongo region. Nonetheless, Namibia is one of the countries that could face an especially significant increase in water stress by 2040 (Maddocks et al., 2015).

Therefore, the future of mining depend**s** on the sustainability of the earth's water resources, which are increasingly under pressure. Water scarcity is consequently a constraint for Namibian development. This means that businesses, farms, and communities in these countries may be more vulnerable to water scarcity than they are today, as shown in Figure 1. This study seeks to analyse the mining companies' water management strategies and benchmark these leading practices across the globe.

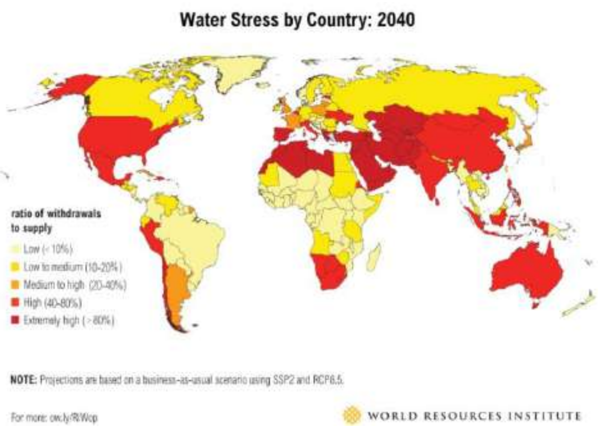

Figure 1. Water stress by country (Maddocks et al., 2015)

2.0 Mining Activities in Namibia

Mining has a long and complex history in Namibia. The earliest evidence of mining in the country is proven through archaeological evidence of copper smelting near the present-day Matchless Mine, which dates back to the 17th century (Schneider, 1998). Namibia's mineral industry is endowed with a wide variety of minerals, which can be grouped into six major groups: precious metals, nuclear fuel minerals, gemstones, base minerals, rare earths, ferroalloy minerals, and industrial minerals. The minerals industry continues to grow with significant exploration activities underway in battery minerals, notably lithium, graphite and cobalt, and rare earths. The country is among the world's top ten gem-quality diamond producers, conducting these mining operations on land and offshore. In addition, uranium oxide produced in the country is exported as "yellow cake." Namibia has significant uranium mines capable of providing 10% of the world's mining output and is currently the world's second-largest producer of uranium (World Nuclear Association, 2022). The country also produces various industrial minerals, including wollastonite, bentonite, graphite, limestone, and salt. Classification of the minerals produced in Namibia is presented in Table 1, and Figure 2 shows the location of mines in Namibia.

Table 1: Minerals produced in Namibia.

Mineral Classification	**Minerals or Metals**				
Precious and Semi-Precious Stones	Diamonds	Coloured Gemstones			
Nuclear Fuel Minerals	Uranium				
Base Metals	Copper	Zinc	Lead	Cobalt	Lithium
	Tin	Tantalum			
Precious Metals	Gold	Silver			
Steelmaking/Ferroalloy Metals	Iron	Manganese	Tungsten	Vanadium	
Rare Earth Elements	Dysprosium	Yttrium	Lanthanum	Cerium	Gadolinium
Industrial Minerals	Phosphates	Salt	Dimension stone	Limestone	Gypsum
	Graphite	Silica sand	Clay		

The Namibian mining industry strives to play an active role in sustainable development by implementing world-class environmental practices. Through implementing these practices, exploration and mining companies can maintain a good relationship with regulators, lawmakers, investors, and the communities in which they operate (NCE, 2019). In Namibia, this led to the industry and government working together to produce a Best Practice Guide for the Mining Sector in Namibia. Although the mining industry's overall' water footprint is relatively small compared to other sectors, most mining companies have recognized the importance of fresh water and the need to reduce the mining industry's water consumption. Mining is vital for the growth of the Namibian economy, and the country must therefore reconcile development objectives and mineral exploitation with environmental protection for its long-term socio-economic growth and stability.

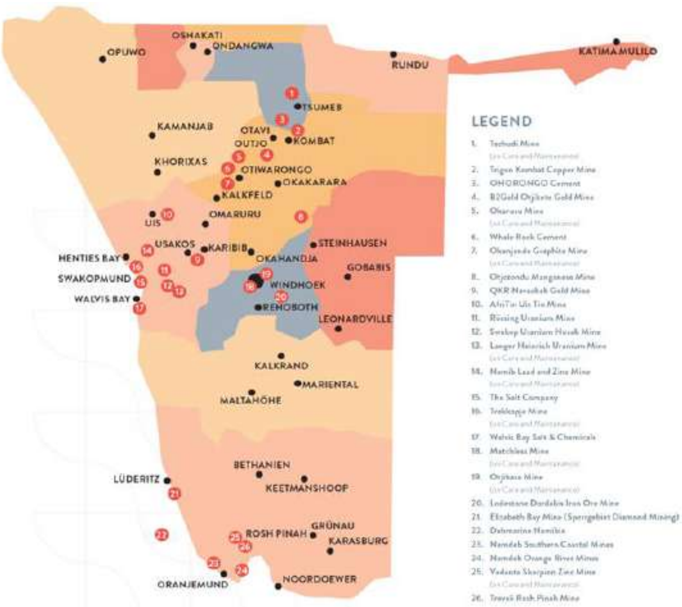

Figure 2: Map of mines in Namibia (Chamber of Mines, 2022)

3. Legal Framework in Namibia

Namibia is one of the few countries incorporating environmental sustainability in her constitution. Article 95 emphasizes the importance of environmental protection by stating that Namibia shall actively promote and maintain the welfare of her people by adopting policies aimed at the maintenance of ecosystems, essential ecological processes, and biological diversity of Namibia and the utilization of living natural resources on a sustainable basis for the benefits of all Namibians (Constitution of Namibia, 1990). Water is increasingly recognized as a critical issue for sustainable development.

The Ministry of Environment and Tourism and Forestry (MEFT) was established in 1990 and is responsible for safeguarding Namibia's environmental resources. Since then, the MEFT has implemented far-reaching policy and legislative reforms in the environmental sphere in an attempt to alleviate many of the constraints that the environment places upon people and vice versa. Namibia's Policy for Prospecting and Mining in Protected Areas and National Monuments aims to promote sustainable development in Namibia by allowing prospecting and mining in protected areas with strict environmental management. The policy stipulates that any mining developments in a National Park must be balanced against the risk of negatively interfering with the potential for long-term sustainable growth.

The Namibian government has also implemented various policies and regulations to promote sustainable water use and conservation in the mining sector. For instance, the government has established a national water policy that outlines the principles and guidelines for managing and using water resources. The policy emphasises the need for sustainable use and management of water resources to ensure their long-term availability and the protection of the environment. In addition to these practices, the Namibian government has also implemented policies and regulations to ensure sustainable water use in the mining industry. For example, mining companies are required to obtain water use licenses and comply with strict water quality standards.

3.1 Water Quality Regulations

It is required that all mine water in Namibia is adequately monitored and analysed to ensure compliance with regulatory standards, according to the required industrial and domestic effluent discharge exemption permit under sections 21(5) and 22(2), and 110 of the Water Act (Act 54 of 1956) and Parts 11 – 13 of the Water Resources Management Act, No. 11 of 2013 (NCE, 2019). This Act provides for managing and conserving Namibia's water resources, including the whole or any part of a watercourse or aquifer, the sea, and meteoric water.

The Water Act, No. 54 of 1956, is the primary extant statute that most directly regulates groundwater abstraction for mining purposes. The Water Resources Management Act No. 11 of 2013 was enacted to ensure that the water resources of Namibia are managed, developed, used, conserved, and protected in a manner consistent with, or conducive to, the fundamental principles set out in the Act. The Act was passed and published but is not yet in force, providing more specific procedures for water abstraction permitting that are much more tailored to Namibia's climate and geohydrology than the Water Act of 1956. Once enacted, it will supplant the Water Act (IGF, 2018). Other laws also bear on the management of water resources. These include the Environmental Management Act, No. 7 of 2007; the Minerals Act, No. 33 of 1992; the Namibia Water Corporation Act, No. 12 of 1997; and the Traditional Authorities Act, No. 25 of 2000. For much of the country, the only water resource is groundwater, and these reserves are very fragile, and their scope and condition are little understood. Some critical points of Water Resources Management Act 2013 that are related to mining are

- A person may not cause or allow any groundwater to run to waste from a borehole, well, shaft, mine, or other excavation except when the water interferes or threatens to interfere with mining operations or the performance of any other underground work.

- Except under the authority of a groundwater disposal license issued by the Minister, a person may not abstract and dispose of groundwater from a mine or other excavation to facilitate mining or other underground operations.
- A lessor of land or premises where the lessee carries on any industrial, mining or other activity that may cause water pollution is responsible for remedying the effects of any pollution caused by such action if the lessee fails to remedy the effects of such pollution.
- To issue a license to discharge effluent or operate a wastewater treatment facility or a waste disposal site, Minister may also request the application of cleaner production techniques in industrial, agricultural, and mining activities designed to improve efficiency in the use of resources by reducing or preventing pollution and waste generation at the source thereof.
- Limitations or prohibitions may be imposed in respect of a water protection area related to operations for mining, dredging, or the reclamation of land.

The Environmental Management Act is in line with modern legislative trends, including adherence to the polluter pays principle, the inherent need to incorporate adequate provisions to achieve 'reduction-at-source' in the areas of pollution control and waste management, and the need to consider alternatives and to avoid or minimize adverse impacts wherever possible (IGF, 2018). Before a mine can commence with its activities, it must obtain a Record of Decision and a Letter of Authorization. However, the Letter of Authorization from the MEFT is not a blanket permission to implement the project. The applicant is still required to obtain a sectoral license or permit, depending on the nature of the envisaged project. Individual mines are responsible for managing their wastewater and industrial effluents and applying for exemption permits if required.

The Minerals (Prospecting and Mining) Act, 1992 (Act 33 of 1992) stipulates that it shall be a term and condition of any mineral license that the holder of a such mineral license shall: prepare in such form as may be determined by the Commissioner for the approval of the Commissioner: an environmental impact assessment indicating the extent of any pollution of the environment before any prospecting operations or mining operations are carried out and an estimate of any pollution, if any, likely to be caused by such prospecting operations or mining operations. If any pollution is expected to be generated, an environment management plan indicating the proposed steps to be taken to minimize or prevent to the satisfaction of the Commissioner any pollution of the environment in consequence of any prospecting operations or mining operations carried out under such mineral license (MME, 1992). The above clause is essential in preventing the pollution of water resources by the mining industry.

3.0 Global Mine Water Management Practices

Water is the second most important commodity in mining after orebody itself, and one of the greatest challenges facing by the mining industry is water management. A water balance model is commonly used to monitor and management of water in the industry. The mining environment is dynamic regarding the mineral type, the methods used to extract the mineral, processing methods used in mineral liberation, external conditions such as seasonal climatic variations, etc. Thus, it is impossible to develop one size fits all water management strategy for the mining industry, requiring a thorough understanding of existing conditions. According to Western Australian Water in mining guidelines (2013), the objective of a water management plan must

- Ensure all possible water sources are considered when planning water supply for mining operations.
- Ensure that fit-for-purpose water is used wherever possible and high-quality water is used only when it is essential or no other suitable water source is available and with the fewest adverse effects.
- Maximise water-use efficiency at all mine sites, particularly water-deficient sites, to reduce the need for water to be abstracted from the environment.
- Optimise the use of mine dewatering surplus, either onsite or off-site, to maximise efficiency and reduce adverse effects of releases to the environment.
- Minimise the adverse effects of the abstraction and release of water on environmental, social, and cultural values.

- Ensure mining activity does not adversely affect the quality and quantity of public-and-private drinking water supplies.
- Adopt a consistent approach for reporting water use, which links to the national water accounting framework and enables sharing of water information.
- Ensure the cumulative effects of mining operations are considered and managed.
  Distinguish between mining activities that relate to consumptive uses (e.g., ore processing) or non-consumptive purposes (e.g., dewatering and surplus water disposal requirements)
- ensure water management planning includes consideration of mine voids after mining operations cease
- Use a monitoring and evaluation process to adaptively manage the effects of abstractions and releases on the water resources.
- Maximise cooperation in water management activities between nearby water users to reduce impacts on the environment.
- Develop and maintain positive relationships between stakeholders so they share the information needed to manage water resources properly.
- Plan for, and manage, the effects of climate variability and change.

Reducing freshwater resources globally puts a lot of pressure on industries to conserve water resources and avoid water contamination. Several methods and technologies were developed in mining to save water resources in compliance with environmental norms. Some of these approaches are reducing the volume of water required for mining operations, using lower quality, alternative water sources such as seawater when possible, treating mining water for reuse and protecting the quality of water discharged after use. Some of these practices are discussed in sections 3.1 to 3.4.

3.1 Multi-stakeholder Engagement

Public participation has become an indispensable condition in water management; several legislations and policies support the involvement of less vocal, marginalized, and local communities at all levels of water management. Solutions generated locally with stakeholders are more likely to lead to appropriate actions, promote flexible and adaptive working practices, and foster and strengthen the development capacity of local organizations and communities. Water resource in a mining area is shared between communities living in the area and the mining operations. Thus, the roles and responsibilities in water provision, maintenance of infrastructure, and water quality monitoring should be shared between the mining industry, government, other private organisations, and local communities. Moreover, stakeholder involvement in water management can help to define long-term solutions to water management situations. Tools for effective and transparent data communication include staging online forums, including third parties or community members in all phases of monitoring, and providing data in an accessible and unbiased manner.

3.2 Fit-for-Purpose Water Treatment

In the mining industry, water is used for several purposes, such as mineral processing, including comminution practices, classification by screening and hydrocyclones, dust suppression, slurry transport, and drinking, among others. Water reuse is an option to increase the water supply and decrease the dependence on freshwater supply. Globally, 7000 Mm^3/year of reclaimed water was used after treatment in 2011, comprising 0.59% of total water use (EU, 2016). Non-potable reuse is common, although potable reuse has been practiced in Namibia since 1968 and in Singapore in 2002 (Asano et al., 2007). Water is reused in agriculture (32%), landscape irrigation (20%), industrial uses (19%), urban uses (8%), environmental enhancement (8%), recreational uses (7%), groundwater recharge (2%), indirect potable use (2%), and others (2%) (EU, 2016, Lautze et al., 2014). For example, mines use poorer-quality water in areas that aren't impacted by water quality and save better-quality water for sensitive areas. The water quality required for each activity may differ; thus, mines must select a need-appropriate water treatment technology that meets their project-specific needs. This not only conserves water resources through recycling but also energy. For example, water quality for dust suppression may not be as good as drinking water.

3.3 External Water Contamination Control

Mining exposes a lot of water rock; when fresh external water, such as rainwater and snowmelt runoff, comes in contact with the waste rock can produce acid mine drainage. Rainwater and surface drainage from the mine site will continue carrying acid away and depositing it in nearby water sources, including groundwater, lakes, rivers, and streams. This severely degraded the water quality, killing off aquatic life and making the water unusable. Thus, reducing the potential for external water contamination needs to be top of the agenda for mining corporations. Not only does this positively impact the surrounding environment, but it will also drive significant cost savings when minimizing the volume of water requiring treatment. Water quality control options can consist of methods to limit reactions between water and mine wastes and manage the flow of potentially impacted waters. Surface water runoff needs to be prevented from entering the mine site - this can be achieved by building upstream dams to reduce the potential for water contamination from exposed ore and waste rock. Other methods include locating mine wastes in areas with limited usable water resources, isolating mine wastes from the environment through the use of liners and caps, and subaqueous disposal of tailings and other mined materials, which uses overlying water to limit the amount of oxygen that can react with the materials. Water flow management on a mine site can include leachate collection systems, diversion features for run-on and runoff water, and tunnels and cut-offs (e.g., grout curtains or bulkheads) for water within underground workings. Further, capturing drainage water from precipitation at the mine site through liners and pipes and directing the water to tailings dams to prevent potentially contaminated water from entering groundwater or flowing off-site will help with water management. To reduce the volume of contaminated water, in dry regions, enough water may be evaporated so that no water needs to be discharged, resulting in the containment of contaminates at the mine site (SME, 2022).

3.4 Water Management in a Tailings Facility

In the past few years, several tailings dam failure incidents have been reported around the world. The release of large quantities of processing waste and water had catastrophic impacts on the surrounding community and environment, and the costs and clean-up work for the operating company are severe. Thus, the effective management of mine-affected water in tailings dams represents a significant safety, environmental and commercial priority for mining operators with these important facilities designed to store wastewater, a byproduct of the mining beneficiation process. The methods outlined in sections 3.4.1 to 3.4.2 are practiced internationally for tailing dam water management.

3.4.1 Water Evaporation System

The safety, environmental, and commercial risks of tailings dams can be mitigated by implementing a water evaporation system designed to remove excess water, reduce dam water levels and ensure compliance with global standards.

3.4.2 Water Recovery from Tailings

Filtered dry stacked tailings is one technique used to recover water from the tailings. This technique produces an unsaturated cake that allows storage of this material without the need to manage large slurry tailings ponds, as shown in Figure 3. Pressure or vacuum force is used to recover water. The most common filtration plant configurations are drums, horizontally or vertically stacked plates, and horizontal belts. The application of this technology has many advantages, including increased water recovery from tailings, reduced Tailing Storage Facility (TSF) footprint (impacted areas), decreased physical instability risk, and better community perception. This technology can recover 80-90% of the water from the tailings,

Dewatering technologies can reduce tailings volume by an additional 5-10%, but more importantly, sufficient water is removed, creating a dry, stackable material, as shown in Figure 4. Dewatered tailings can still contain 10-20% moisture, but the material behaves more like a solid, making it possible to dry stack the tailings in containment areas. After being placed in the containment areas, the low-moisture tailings are stable, significantly reducing safety and environmental risks.

Figure 3: Dewatered cakes (tailings) discharge from a Filter Press into a pile (Zink, 2020)

Figure 4: Water recovery from tailings (Cacciuttolo, 2022)

4.0 Namibia Water Practices in the Mines

Over the last few years, the mines have applied several different water management strategies which are aimed at reducing their freshwater intake, reducing the volumes of effluent discharged to the environment, minimizing the deterioration in water quality in the mine circuits, and treating the water to the required level for reuse or discharge (Musiyarira et al., 2017) Namibia's industrial leaders have increasingly recognised that reducing the water footprint of mining activities must be one of the key performance indicators for management. Realizing that the water life cycle challenges cannot be solved by any one party acting alone has been fundamental in ensuring environmental compliance within the mining industry in Namibia.

The ICMM (2014) report on catchment management strategies reveals that historically mining has approached water as an operational issue, managed inside a fence with a focus on water efficiencies and control of effluent discharges to demonstrate good corporate practices and minimize risk. One of the central tenets of the ICMM Water stewardship framework is the need for the industry to move from managing water as solely an 'inside the operational fence' issue to adopting a catchment-based approach that considers other users. Impacts of sub-standard water management may not only be felt at a local level but may escalate rapidly to become national and international issues, consuming large resources. Namibia has water availability challenges, so water management remains a critical issue. Most mining companies in Namibia have been developing a vision of water stewardship, which includes a broader concept of catchment water management as opposed to the individualistic water management approaches of the past.

4.1 Water Consumption Patterns in Namibian Mines

Water consumption patterns in Namibian mines vary depending on the type of mineral being extracted, the location of the mine, and the water management practices in place. However, some general trends in water consumption can be observed. According to Namibia's Ministry of Agriculture, Water, and Land Reform, mining consumes around 5-6% of the country's total water resources. This is significant, considering Namibia is a semi-arid country with limited water resources. To address the high water consumption in mining operations, Namibian mines have implemented various water management practices, such as water conservation and reuse, desalination, groundwater management, water quality management, monitoring, and control, among others. These practices aim to reduce water consumption and promote sustainable use of water resources in the mining sector. Overall, while the mining sector in Namibia is a significant water user, implementing effective water management practices has helped mitigate the impact of mining operations on water resources in the country. Figure 5 shows the philosophy that informs water management practices in Namibian mines.

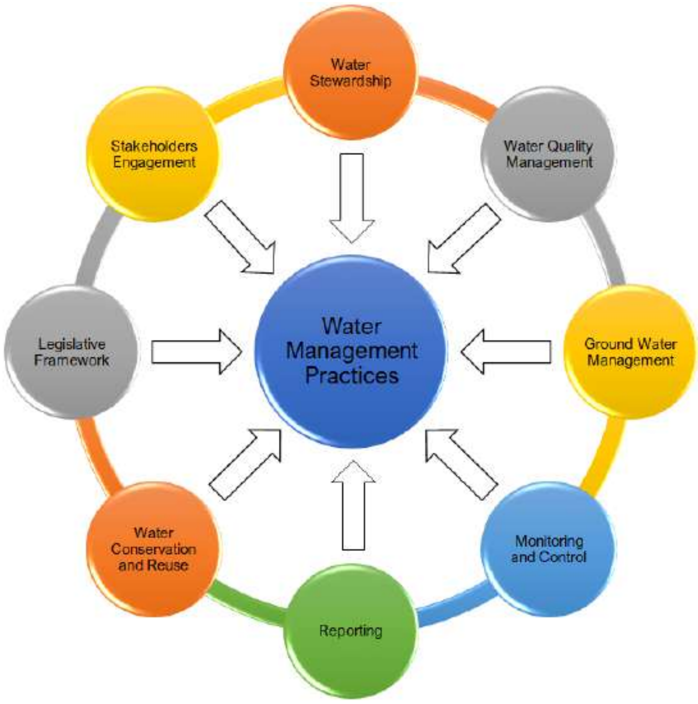

Figure 5: Water management practices used in Namibia.

4.2 Water Conservation and Reuse

Mines use water-efficient technologies, such as closed-loop systems and water recycling, to reduce water consumption and minimize water wastage. The water reuse and recycling rate in ore processing is often very high at mine sites, especially in areas with arid climates (Rankin 2011). Several innovative water conservation practices are being developed and implemented to reduce water use. Recognizing and adopting best practice principles are considered fundamental cornerstones of sustainable development for the Namibian mining industry. Best practices are the development of operation-specific methodologies that integrate global and local knowledge. This enables planning to produce the best available and most practicable methods to address an operation's site-specific requirements and conditions. Best practices, by nature, are not static but continuously evolving in response to new technology, increased understanding and awareness of environmental and social impacts, and increasing regulatory requirements and public expectations.

An excellent example of water conservation, recycling, and reuse was Skorpion Zinc. The mine was committed to minimising water use and recycling water, with the ultimate goal of a Zero Discharge Philosophy. Skorpion Zinc refinery had a closed loop system, with all water recycled back into the system. In line with Skorpion Zinc's Water Management Policy and the drive to conduct business responsibly, Skorpion Zinc assessed its challenges with solution balance in the refinery. A careful review of the Solution Balance was undertaken, and corrective actions were implemented to reduce the water consumption to levels below design capacity. In addition, domestic effluent was treated and recycled into an artificial wetland (Bird Pond) to divert birds away from its processes. Different water conservation projects were identified through reduction, recycling, and progress monitoring against water consumption reduction targets. Although Skorpion has attained significant success concerning water management, the mine continued to explore other avenues for further water reduction before it went on care and maintenance (NCE, 2019).

4.3 Rossing Uranium Water Management Strategies and Recycling

The Management of water at Rossing falls under the Environmental and Water Division. Rossing has been monitoring and managing the water resources system in conjunction with the Tailings Storage Facility (TSF) management. Figure 6 outlines the TSF with embarkments and the water and seepage control points around the mine. The mine has been recycling some of the water from the TSF back to the plant for other non-essential applications not associated with uranium extraction. This has led them to reduce water consumption significantly. The Tailings Storage Facility (TSF) management heavily depends on how water is used at the plant and the recycling at the TSF (Figure 7). It is essential that the net water balance that leaches out is of sufficiently neutral pH (pH7.0-8.0) to be within the Ministry of Environment and Tourism regulations on Environmental management and the discharge of water to natural water courses such as the Khan River, where Olive and vegetable farmers abstract water downstream of Rossing mine (Rossing,2021). To achieve this, Rossing Uranium Limited recycles water that leaches out of the TSF into the groundwater drainages and monitors its pH as it moves towards the Khan River.

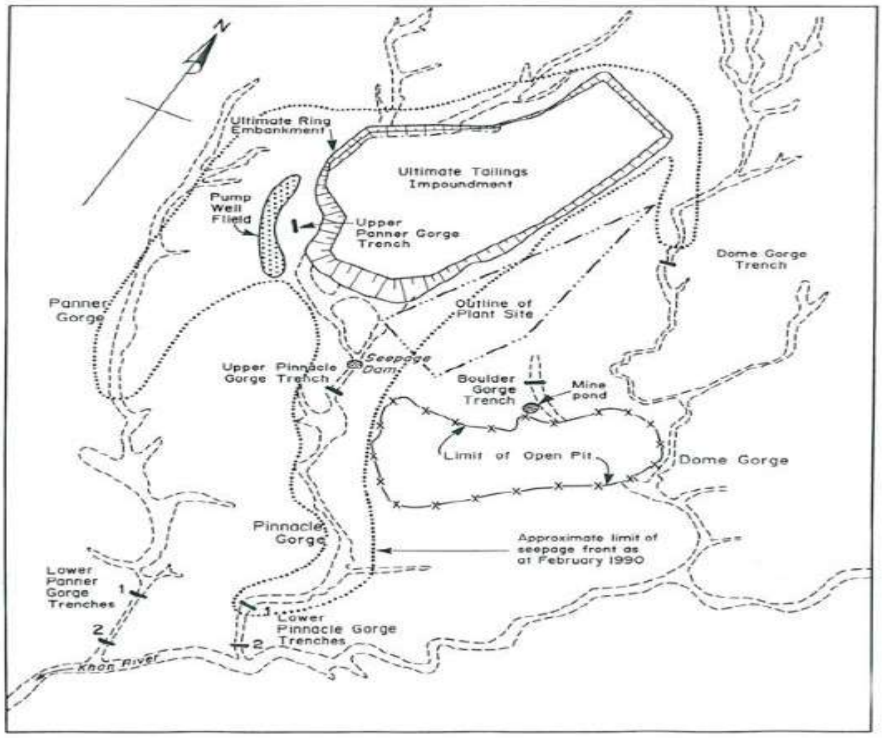

Figure 6: An outline of the Rossing Mine with water control points for seepage monitoring.

Figure 8 shows a statistical bar chart of planned water use, actual water used at the mine, and the amount of fresh use at the mine over the years 1994-2021 as a percentage of every tonne of U_3O_8 produced, the years 1997-1998 had the highest water usage. The amount has significantly reduced at present. The TSF receives 21,519 cubic metres of water per day from the Processing plant, and 12,805 cubic metres per day are recycled from the TSF to the plant as of 2021 (Figure 7). The net change in storage of 485 cubic metres per day is lost as leachate into the groundwater and evapotranspiration. This is the water that needs to be addressed as it percolates into the groundwater on its way to the Khan River.

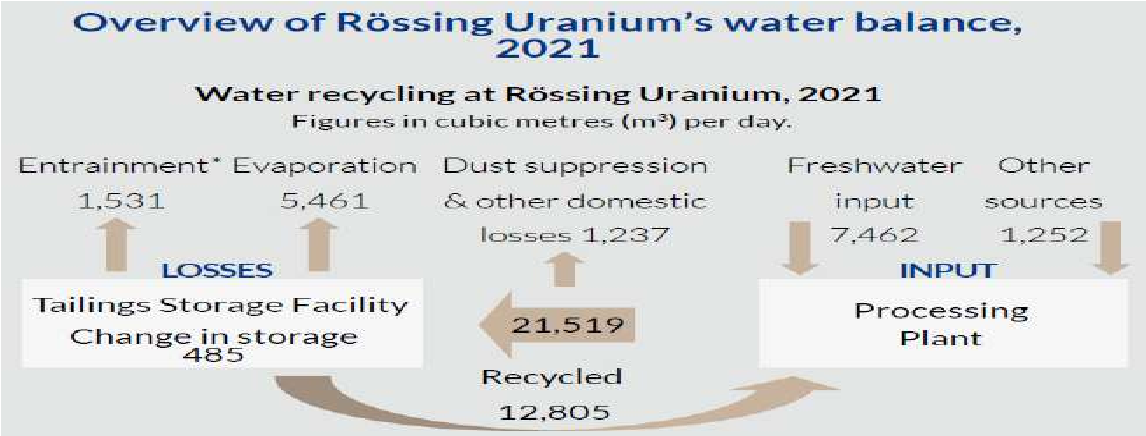

Figure 7: Monthly Water recycling at Rossing Uranium in 2021; Souce: (Rossing, 2021)

Literature studies show that freshwater consumption was reduced over the past three decades from an average high of 0.65 m^3 to an average low of 0.33 m^3 per tonne of uranium ore milled, as shown in Figure 8. This freshwater reduction resulted in substantial financial savings and delayed water augmentation through desalination (Musiyarira et al., 2017). Therefore, water segregation plays a crucial role in the water management strategies the mines advocate, leading to decreased freshwater consumption per tonne of milled ore.

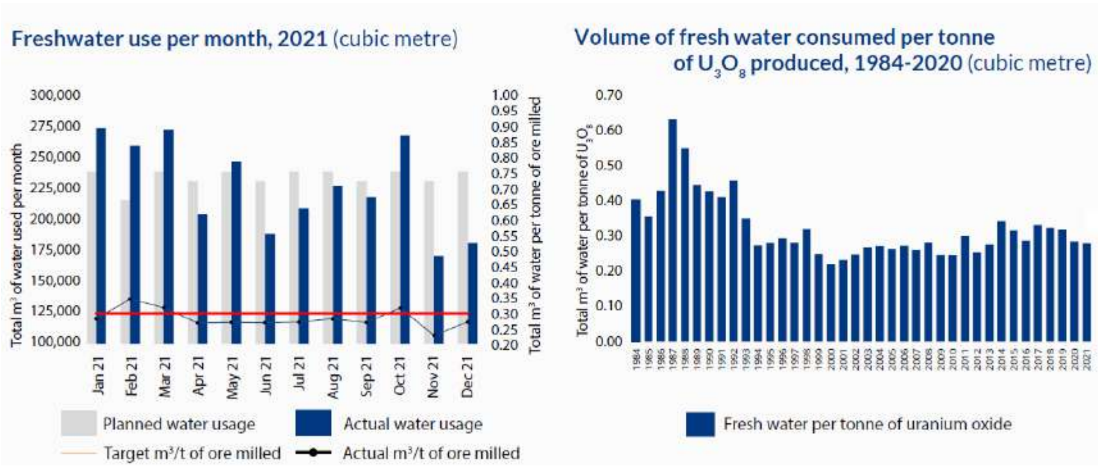

Figure 8: Freshwater use per month in 2021 on the left and right, the volume of freshwater consumed per ton of U_3O_8. produced (1984-2020).

Figure 9 is a schematic diagram showing Rossing's conceptual water management model.

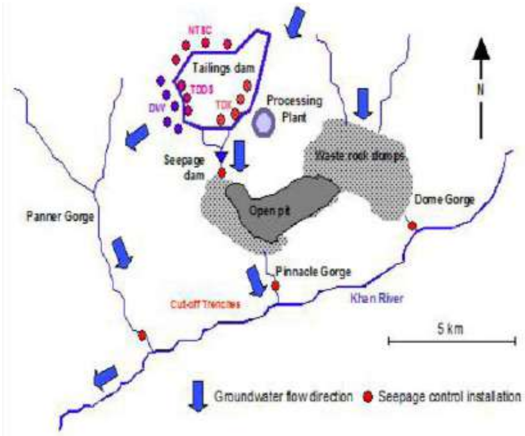

Figure 9: Groundwater flow direction from the TSF of Rossing Uranium Limited, Source (Rossing, 2021)

The TSF, control boreholes are installed, where if the pH is too low, the water is pumped back to the plant for re-use. The water in the pit is also systematically dewatered and recycled for other purposes, such as dust control and washing of plant floors.

At Rossing mine, all spillages in the Processing Plant are captured and channeled to a large recycle sump for reuse. In addition, effluents from the workshops are treated to remove oils, and sewage is processed in the onsite sewage plant. These semi-purified effluents are used in the open pit for dust suppression.

At the deposition pool (active paddy) of the TSF, water is recycled and reused continuously in the Processing Plant, minimising surface evaporation and infiltration into the tailings pile. Water that infiltrates the TSF is recovered by pumping boreholes and open trenches installed on the facility to reduce the underground water volume within the tailings pile (Rossing, 2021).

4.4 Water Demand and Security

According to the World Bank, water demand is determined by four major driving forces, population, technology, trade, and the environment. The past two decades have seen increased population, building activities, the establishment of numerous industries, and new uranium mines in the Erongo region in Namibia. All this resulted in a steep water demand growth to the extent that it almost exceeded the available resources. This led Orano, formerly Areva Namibia Uranium Company, to build its desalination plant with a 20 million cubic meters capacity per annum. Of late, there has been a growing outcry from mining companies in the Erongo region to set up their desalination plants to secure water supply for their operations. Rossing and Husab Mines have engaged the government with proposals for setting up the plants. The born of contention has been on who will own the rights to the water and what would happen to the desalination plant when the mine closes prematurely or after the life of mine. These discussions are ongoing; they will have to agree sooner or later since they must reconcile development and water security. The case study in section 4.5 shows how water security is becoming a risk to operations in the gold sector in Karibib.

4.5 Water Security Issues and Recycling at Navachab Mine

Navachab mine is one of the primary consumers of water sourced from the Swakoppoort Dam by NamWater. NamWater uses the same pipelines to supply Karibib Town Council and Otjimbingwe village. NamWater pumps the raw water to the Karibib Water Treatment Plant, where the water is treated and distributed to the three entities: Navachab Mine, Karibib Town Council, and Otjimbingwe Village settlement. From Swakoppoort Dam, the water is pumped to the Ongava Reservoir, which feeds the Navachab Mine and Karibib Town Council.

The storage facilities consist of the following reservoirs:

- The Okongava reservoir is a PVC-lined, open earth bank reservoir with a capacity of 15 000 m^3. The reservoir is divided into two compartments, each with a capacity of approximately 7 500 m^3. The full supply level is at 1 289.43 mAMSL, and the lowest abstraction level is at 1 286.36 mAMSL. From these reservoirs, the water is gravity fed to Karibib and Navachab Mine. The inlet structure and split between the two reservoirs is outside the fenced area.

Okongava-Karibib/Navachab Scheme storage facilities consist of the following:

- The 500 m^3 concrete raw water reservoir at the Navachab Mine, is located on a hill at the eastern side of the mine premises. The concrete reservoir is cylindrical and is covered with a corrugated IBR roof and steel support structure. Inlet and outlet pipes to the reservoir are constructed above ground and appear to be in reasonable condition. Although Navachab Mine owns the reservoir and is not the responsibility of NamWater, it can be reported that the concrete appears to be in good condition, and no leaks were visible on the joints in the walls.

- The Karibib terminal reservoir is a 1 250 m^3 potable water reservoir located downstream of the Treatment Plant and used to store treated water for Karibib town. The reservoir is close to the treatment works and situated at the highest point in town. Treated water is pumped by means of the Clearwater Pumps to the reservoir inlet pipes, which pass through the base of the reservoir walls. The outlet pipes are below ground and discharge into the town's water reticulation. The inlet and outlet pipes and fittings appear in a reasonable condition where visible above ground and the manholes.

The Karibib Town Council, where research on water losses is almost complete, shows that the LA receives 34,000 m^3 of water from NamWater per month, and only 25,500 m^3 is accounted for in the supply system. This is a 25% water loss of 8,500 m^3 per month; per year, it amounts to 102,000 m^3 of lost water. Hence the dire need to have below-ground detection mechanisms such as magnetometers and acoustic technologies. As a result of the large quantities of water lost, a plan to reuse wastewater at Karibib has been suggested. The coming on board of a new mine between Omaruru and Karibib, Osino Twin Hills Mine, will put further pressure on freshwater resources, such that the optimisation of wastewater reuse will go a long way to reducing the water deficit. For Osino, NamWater cannot currently supply all the fresh water they require, and that will put constraints on the re-opening of the mine. Current estimates are that Osino Mine requires between 250 m^3/day to 300 m^3/day. This amount can be realised from the water reuse of the Wastewater Treatment at Karibib Town Council (KTC).

In a properly studied concept of using wastewater-treated water (Figure 10 and Figure 11) and slowly increasing this capacity over time, with minimal investments, Osino can have adequate water for most services at the mine and augment its water budget from groundwater boreholes near the Twin Hills property.

In the Erongo Region, due to a high concentration of mines and limited water resources, it can be shown that there is a need to persuade the Local Authorities (Town Councils) to adopt the idea of water recycling and selling or availing of recycled treated water to neighbouring mines such as Navachab, Rossing, Husab, Langer Heinrich and the soon to open in 2025-2026 Osino Gold Twin Hills Mine. Instead of using fresh water for most purposes, e.g., dust control, equipment cleaning; non-plant services; recycled water from the wastewater treatment plants can be used.

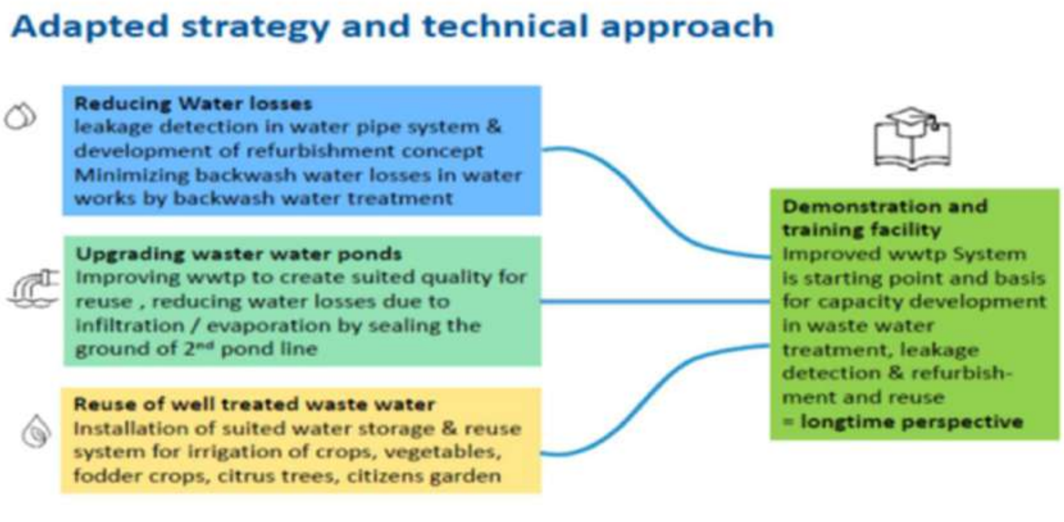

Figure 10. Adapted strategy to increase water availability in the Karibib Area for Navachab Mine, Karibib Town, and possibly Osino Twin Hills Mine, expected to come online in 2025-2026.

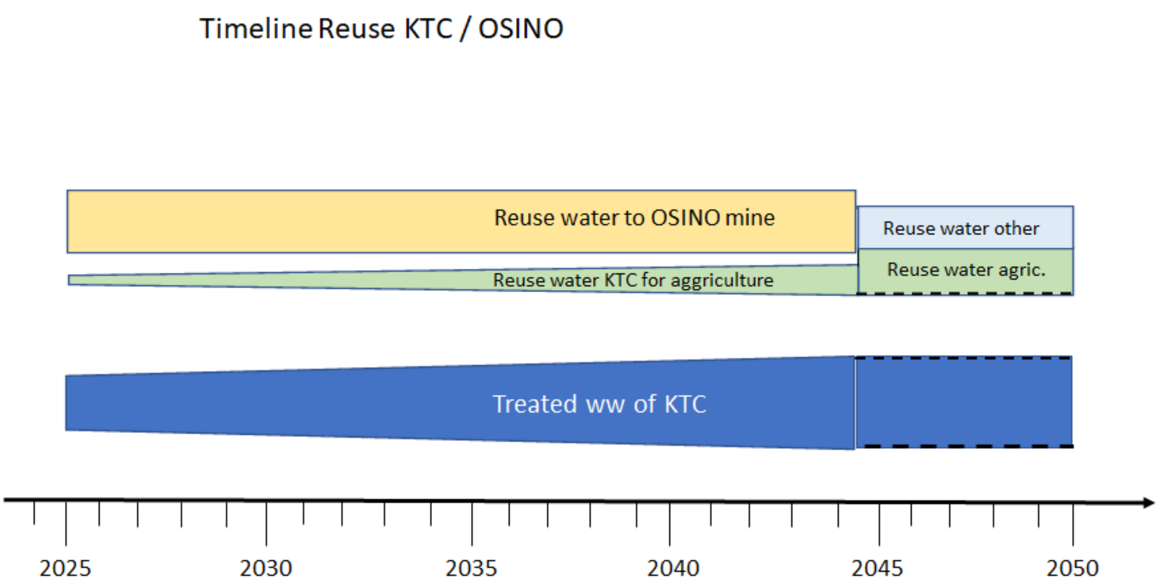

Figure 11. Forecasting of the water from the proposed recycling facility at Karibib to augment water volumes from NamWater

4.6 Monitoring and Control

Using water in mining can affect surrounding surface water and groundwater quality. In response to environmental concerns and government regulations, the mining industry worldwide increasingly monitors the water discharged from mine sites (Houlding, 2016). It has implemented several management strategies to prevent water pollution. Water issues and management vary from site to site and must be addressed locally. Water plays a vital role in any mining operation, and managing water is fundamentally part of many operational activities at a mine. Each situation has its unique water characteristics. All mines in Namibia are obliged to adequately monitor and analyse water in compliance with the industrial and domestic effluent discharge exemption permit under sections 21(5) and 22(2) of the Water Act (Act 54 of 1956). Water usage at mines can potentially affect the quantity and quality of surface and groundwater downstream. One of the tools needed to achieve the aim of surface and groundwater protection is an effective water quality monitoring program, which includes water quality sampling and analysis (including surface water, groundwater, sewage effluent, and leachates); monitoring of pH and flow volumes of seepage points; monitoring of water table elevations, and potable water quality monitoring. Remedial actions need to be taken based on the results of monitoring data evaluation. Ultimately, a water monitoring program should be designed to cover remedial actions and achieve sustainable water management. At Rössing Uranium Limited, one of the oldest operational mines in Namibia, hydro-chemical data have been collected within the mining grant since the start of operations in 1976. About 150 sites have been monitored for groundwater composition at varying intervals (mostly monthly or quarterly) initially, later reduced after evaluating long-term trends and the composition of a water balance for the mine.

Section 17 of Part V of the EMA empowers the Environmental Commissioner to conduct inspections to monitor compliance with the Act and conditions stipulated in the Environmental Clearance Certificate. If monitoring and/or inspections reveal that a developer is not abiding by the conditions of the Environmental Clearance Certificate or has contravened the EMA, the Environmental Commissioner has the power to suspend or cancel the Certificate for a period s/he may determine. The certificate can be reinstated once the environmental Commissioner is satisfied that the person concerned has rectified the failure that led to the suspension. Mines carefully monitor and manage their groundwater resources to ensure sustainable use and avoid over-extraction. Namibian mines also face unique challenges related to water management, such as the high salinity of groundwater in certain regions, which can affect the quality of the water used in mining operations. Therefore, groundwater is monitored to assess the water level of the aquifers and the possible impact of abstraction on the water systems. Most mines have an existing groundwater monitoring network, whereby boreholes are located in the mining area, non-mining areas, and on neighbouring farms.

4.7 Water quality management

Mines treat and monitor the quality of water discharged from their operations to minimize environmental impact. Water treatment technologies can be classified mainly as passive or active treatment. Active treatment requires the input of chemicals and energy. Passive technologies use natural processes such as plant systems, gravity, and microorganisms (Fraser Institute, 2012). The pollution level determines the treatment technology that will be used, and the technology used depends on the water quality requirements. The focus of water treatment has historically been on removing contaminants; however, this often results in secondary waste streams. Many active treatment systems create byproducts such as sludges and brine, which must be considered in the long-term viability of the site-wide water management strategy (Simair, 2022). Namibian mines have realized that each mine is unique in water quality and needs, requiring a customized and site-specific approach to water treatment. While traditional turnkey water treatment systems still have a role in the overall water treatment and water management strategy, it is now recognised that they work best as part of a more comprehensive strategy. Some other considerations of a site-specific approach include:

- End use of water
- Water chemistry and constituents targeted for treatment
- Lifespan of the treatment system
- Lead time for system operation
- Constructible land area
- Climate
- Periodicity of treatment
- Site infrastructure that can be repurposed (e.g., pit lakes, mine pools, tailings ponds)
- Availability of local materials

4.8 Stakeholder Engagement

The mining industry in Namibia operates in a semi-arid region with limited water resources. As a result, mining companies work closely with local communities and stakeholders to ensure sustainable water use and minimize their operations' impact on water resources. This includes engaging in community-based water management initiatives, such as building water infrastructure and supporting water conservation programs. To achieve this, public meetings, interviews, and consultations are held to reveal community concerns related to mining activities. This initiative has led to more freshwater availability, decreasing the competition for water between mining operations and human consumption. The all-inclusive stakeholder engagement strategy employed by the uranium mines was seen as an excellent leading practice that other countries seeking to balance

4.9 Reporting

Reporting is an essential mechanism for authorities to ensure compliance from mining companies to the conditions outlined in the Environmental Clearance Certificate, the EMP, and any other requirements such as permits and licenses (NCE, 2019). Namibian reporting requirements for exploration and mining companies are outlined in the Minerals (Prospecting and Mining) Act, No. 33 of 1992. Mines belonging to global companies also do internal reporting on various aspects determined by their parent companies; some also do annual reporting to the public—to give stakeholders an overview of activities, including interaction with society, the economy, and the environment (NCE, 2019. Mining companies submit (also voluntarily) annual environmental reports to various state departments (i.e., the Directorate of Environmental Affairs, the Directorate of Mines, and the Directorate of Water Resource Management). However, these annual reports on environmental performance are not prescriptive in format or content for reporting. It is best practice to have a reporting format in place. In compliance with conditions stipulated in the water permits issued by the Department of Water Affairs at the

Ministry of Agriculture, Water, and Land Reform (MAWLR), annual reports about water abstraction, disposal and management of effluent, and vegetation monitoring are submitted to the head office in Windhoek.

5.0 Possible Areas for Improvement

While Namibian mines have implemented comparable water management practices to the best practices in the world, there are still areas where they can improve.

5.1 Reviewing and Enforcing Legislation

The ultimate way of ensuring the sustainability of mining is through developing and strengthening legislation and sound policies coupled with enforcement mechanisms and putting proportionate pressures on the industry to instill sound corporate citizenship principles in all their operations. In as much as there has been such enforcement, there are still capacity challenges for the enforcement agencies, which is further complicated by having overlapping roles and responsibilities in administering environmental-related Acts administered under different line ministries. The best way to ensure that mining is done sustainably is to enforce standards and protocols for pollution prevention and monitoring strictly.

The Water Act of 1956, which governs the use of water resources, is outdated, and the Water Resources Management Act (2013) was passed but is not enforced. As a result, implementing the effluent permitting process for mining entities is inconsistently applied. Namibia does not have its effluent discharge guidelines and relies on South African standards. Environmental compliance reporting to the MEFT occurs on a biannual basis; however, the MEFT has limited resources for reviewing environmental clearance certificates and biannual reports in a timely manner (IGF, 2018). It is unclear to what extent mining entities report volumes of water abstracted and discharged, and its quality, to the MAWF as required. MAWL and MEFT have a disjointed approach to enforcing compliance with water or discharge permit requirements. There is no legal requirement for companies operating in Namibia to comply with international standards or guidelines for key environmental risk areas, for example, in the design of tailings storage facilities. The Environmental Commissioner has limited ability to enforce fines or penalties for non-compliance with the law; cases that require legal enforcement are handed over to the police.

Legislation has not been passed to prevent and regulate the discharge of pollutants from mine sites, establish a waste planning and management system, and enable Namibia to comply with its obligations under international law. The draft Pollution Control and Waste Management Bill was developed to do so, but despite being drafted in 1999 it has not yet been adopted by the government. In the absence of such legislation, the EIA process requires that mining entities ensure that structures are designed and operated in accordance with responsible waste management standards. Like many others in Namibia, the mining sector produces hazardous waste, and the disposal of this waste is problematic, as the country does not have a registered hazardous waste site compliant with international standards. This poses a problem for international companies operating in Namibia, as they have internal standards that require hazardous waste disposal at registered facilities. The Chamber of Mines' environmental subcommittee recognizes the need for a hazardous waste site, and the sector is working with key stakeholders to develop a strategic waste site (IGF, 2018).

5.2 Capacity Building for Government Officials and Communities

The Ministry of Agriculture, Water, and Land (MAWL) has limited capacities to enforce and apply appropriate penalties for not complying with the Water Act due to financial and human resources. In contrast, the penalties set in the Act are inadequate. The Ministry of Environment and Tourism (MET) is mandated to regulate environmental performance but lacks the technical skills, resources, and equipment to regulate effectively. The government could use funds from the treasury for human capital development and work with local universities to build the capacity. In addition, international agencies and mining companies could be called upon to raise awareness and build capacity in local communities. The social license to operate has become a key threat to mining operations.

5.3 Water Research

The most worrying fact found by this study is that during the past decades, the global mining industry has dedicated only small expenditures to Research and development, compared to the 15% to 40% levels in other sectors (ICMM, 2019). The same applies in Namibia, where, with the prevailing low commodity prices, most companies have embarked on cost-cutting measures, including activities related to strategic research for the organizations. Mining companies will continually need to undertake water-saving actions and initiatives, set targets, and develop a vision of water stewardship, including a broader concept of catchment water management. Modern water management practices and mine designs significantly reduce the potential for water contamination at mine sites (Houghton, 2016). In general, old abandoned mine sites have a higher potential to pollute nearby waterways because the water control techniques that modern environmental regulations now require were not in place when the mine was opened or closed. Knowledge of water management and impact reduction has dramatically increased over time, and preventing water contamination is now an essential component of mine operation and closure plans.

5.4 Reducing Carbon Footprint and Planning for Closure

Most mines in Namibia have started using solar energy in their operations. There is a need to increase the use of renewable energy sources in water treatment and desalination processes to reduce the carbon footprint of mining operations. Most mining closures' significant challenges and costs are linked to water monitoring and treatment. In 2018, a Mining Policy Framework Assessment revealed no legal framework for mine closure or relinquishment. While the Minerals (Prospecting and Mining) Act refers to remedying the environmental impacts that result from the cancellation and/or abandonment of mining rights, the legislation does not explicitly address the ideals of life-cycle responsibility or concurrent or post-closure rehabilitation. Based on the assessment and capacity training carried out by the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF), the government is developing a mine closure framework from a regulator's viewpoint since there is already one that the Namibian Chamber of Mines developed.

6.0 Conclusions

Namibia is a water-stressed country with a limited amount of fresh water. This study sought to investigate the strides made regarding water management practices in mining in Namibia. The strategies employed by the Namibian mining industry involve inclusive stakeholders' engagement and joint water stewardship approaches, recycling and reuse, and minimizing losses. Namibian mines have implemented various water management practices to address their unique challenges in the semi-arid region. These practices promote sustainable use and conservation of water resources while minimising the impact of mining activities on the environment and local communities. It is clear that demand management, through the improvement of water-use efficiency across the whole water chain, is vital for future economic sustainability in the sector. Overall, water management practices in Namibian mines have played a crucial role in ensuring the country's mining industry's sustainable use and conservation of water resources. Realising that the water challenge cannot be solved by any one party acting alone has been fundamental in ensuring environmental compliance within the mining industry in Namibia. Overall, Namibian mines' water management practices are comparable to the world's best practices for water management. Still, there is always room for improvement and continued innovation in this critical area of mining operations.

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OF SCIENCE AND TECHNOLOGY

Successful rehabilitation of dryland mined areas requires knowledge of soil moisture patterns over long periods and large areas: Comparing relatively cheap iButtons with established methods for measuring soil moisture

A report prepared by T.D. Wassenaar

As a contribution to the development of a proposal for funding from the BMBF

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Successful rehabilitation of dryland mined areas requires soil moisture monitoring to optimize the use of water

Report by Theo D. Wassenaar[1]

10 February 2022

Introduction

Mining is an important cause of disturbance to ecosystems. Ecological disturbances in drylands (defined as an area with an aridity index < 0.65) cause a number of challenges for the restoration of ecological structure and function (Aronson et al., 1993), most of which are related to the high variability of water availability and accessibility to organisms. Disturbance caused by mining exacerbates this effect because it tends to result in a loss of all topsoil and with that also the valuable biological factors that support the establishment of organisms and the development of structure and function. To colonizing organisms it thus presents a novel, biologically impoverished substrate with physical properties that makes it largely unsuitable for plant and other organisms' survival and establishment Cooke & Johnson, 2002).

In drylands, a key requirement to understand the likelihood of survival of plants used in rehabilitation is data on soil moisture dynamics which can vary considerably across space and time (Rosenbaum et al., 2012). The amount of moisture in the soil, integrated over time, synthesizes the combined effect of climate, substrate and vegetation on the dynamics of dryland ecosystems (D'Odorico et al., 2007). Data on soil moisture dynamics, at scales from local to small catchment, therefore allows a clearer understanding of how to recover ecological properties that were lost due to mining. These properties are key to being able to manipulate ecosystem changes after disturbance and include factors such as *inter alia* pulsed increases in microbial activity (Frossard et al., 2015), the fine-scale positive feedback effects of vegetation on soil moisture (D'Odorico et al., 2007), and the relationship of plant survival rates to soil moisture variability (Reynolds et al., 2004).

The dynamics of soil moisture that are relevant for restoration – and thus the kind of data that are required – ranges across several spatial scales, from the local, landscape level, which is often inside a mine's immediate sphere of influence, to the small catchment scale, which may extend well beyond the mine's immediate footprint. The same is true for variation across time – an understanding of ecosystem recovery requires knowledge of variation in soil moisture across weeks, seasons and years (Rosenbaum et al., 2012).

Numerous soil-moisture sensor designs exist (Zazueta & Xin, 1994; Mittelbach et al., 2012), most of which use some form of electromagnetic differential as indicator of moisture content, calibrated for specific soil types. All are sensitive (to varying degrees) to soil texture, bulk density and sometimes soil temperature, curtailing their widescale use across many soil types (Leib et al., 2003). Their relatively

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high cost and the fact that most require to be tethered to a logging station of some kind decreases the number of sensors that can be deployed at one time (and thus the spatial granularity of measurement), and the distance that a sensor can be from a data logger (and thus the spatial extent over which they can be used simultaneously).

Box 1: Abbreviations

GWC:	Gravimetric Water Content
RH:	Relative Humidity
TDR:	Time Domain Reflectometry
VWC:	Volumetric Water Content

Commonly available instruments use the capacitance technique or the time domain reflectometry (TDR – Box 1) (Ventura et al., 2010). Both methods use the relatively higher dielectric constant of water when compared to that of soil, to establish a calibrated relationship between changes in voltage and the soil's volumetric water content (VWC). Capacitive sensors measure the apparent moist soil dielectric constant as a function of the charge time of a capacitor buried in soil and requires an empirical calibration equation (Cobos 2006) to describe the relationship between the output voltage and the VWC for each soil. The TDR device propagates a high frequency electromagnetic wave along a cable connected to a parallel conducting probe inserted into the soil. The signal is reflected back to the meter from the end of the probe, and the instrument measures the time between sending and receiving the pulse (Ventura et al., 2010). The accuracy and precision of both types of techniques are affected by salinity, soil type and temperature. Driven largely by their most common use, which is to determine soil moisture for irrigation decisions, a lot of emphasis is placed on absolute accuracy of measurement (Leib et al., 2003) and less on only precision. Remote sensing approaches tend to work better when the spatial scale increases (Bogena et al., 2015), but these also require ground-truthing at scale.

An alternative approach that has been attempted a few times is to measure the relative humidity of soil pore spaces using a low-cost, easily deployable hygrochron. These small devices, known commercially as iButtons (Figure 1), were designed for the measurement of temperature and relative humidity in food transport. The ~17mm diameter iButton can be attached to many surfaces and can log data for various lengths of time depending on the frequency setting. These devices are relatively accurate and provide valuable medium- to long-term data on changes in both temperature and humidity, at least when deployed as designed. Despite some negative reports about using them in soil (Fawcett et al., 2019), they have been used for measuring changes in moisture and humidity in litter (Wang et al., 2015) and soil (Schagen et al., 2021). When measuring in litter, the iButtons would still be fully in contact with the atmosphere (Wang et al., 2015) but when used in soil they measure the relative humidity of pore spaces. The latter presents several difficulties for interpretation of results, as pore spaces can be continuously saturated with moisture even when the soil is relatively dry – the atmosphere within air-dry soil (a gravimetric water content of 2%) has a relative humidity of 98% (Coleman et al., 2004). This, as well as problems with free-water saturation has led to some resistance against its wider use for measuring soil moisture.

Figure 1. An iButton.

However, the iButtons have several potential advantages that make them – at least theoretically – viable contenders worthy of more intensive investigation. These include small size, ability to log data untethered to an external logger and relative low cost. Additionally, soil water potential in drylands is often below the –1.5 MPa that is generally considered to be wilting point for many crop species. All the common methods of measurement of VWC based on the dielectric constant of water struggle to perform at the low water potentials characteristic of drylands, severely restricting our understanding of critical thresholds for plant survival on e.g. mine wastes in the arid zone. It is therefore especially important that we find a solution for in situ measurement of soil moisture in drylands. The measurement of RH, which does not rely on electric potential differences as determined by water behaviour in microscopic pore spaces, could be such a way providing that the limitations can be overcome. It is also theoretically possible that RH will be a more direct indicator of plant-available moisture as it reflects water that is free enough to change into a gaseous phase.

In the current report I compare the values of soil moisture content (in a standardized substrate mixture) measured as VWC, soil RH and gravimetric water content (GWC) over a period of 72 hours in a controlled environment. I additionally compare in-situ estimates of soil moisture, measured as RH and VWC, in a typical garden soil. My overall aim is to use these contrasts to demonstrate the potential for using iButtons for distributed soil moisture monitoring, and to define those aspects of the measurement process that would be amenable to refinement and improvement in an expanded and more controlled experiment. In comparing these three measurement devices, I used GWC as a control trend, reasoning that it is the most accurate indication of the trend in the amount of water molecules by weight in the soil material, notwithstanding the modifying effects of texture and temperature (I did not have access to facilities where soil temperature could be held constant). I thus wanted to determine whether 1) either the soil RH or VWC showed any obvious deviations from the GWC trend, and 2) expecting some issues with the RH measurement, whether these problems were fatal flaws or whether there were some potential solutions given a more comprehensive setup and better facilities.

Methods

I conducted two experiments. In the first, conducted in a controlled environment, I filled four 500 ml clear plastic containers with a 2:1 mixture of ~970 g of washed sand (commercially produced filter sand) and a sandy loam soil obtained from my garden. The garden soil was sieved with a ~3 mm sieve to produce a more homogenous mixture. Two of the containers were saturated with water, receiving ~204 g of water each, while ~150 g of water was added to the other two to create a non-saturated treatment.

Soil water content was measured using:

1) iButton temperature and RH loggers (Figure 1; Analog Devices, Inc[2], USA; model DS1923-F5#, temperature range = –20 °C - +85 °C, relative humidity range = 0 – 100% RH),

[2] https://www.analog.com/en/products/ds1923.html#product-overview

2) Decagon ECH2O EC5 soil moisture meter (Figure 2; METER Group, USA; measuring range of 0 to 100%, at a resolution of 0.001 m^3/m^3 in mineral soils and a generic accuracy of 0.03 m^3/m^3). The EC5, as well as a soil temperature sensor and air temperature and RH sensors (Figure 4d) were connected to a HOBO Mirostation data logger.
3) An A&D FX 1200i electronic balance (A&D Company, LtD, Tokyo, JAPAN; with an accuracy of 0.01 g and maximum capacity of 1,220 g). This balance is frequently calibrated by the technicians at the Engineering laboratory at NUST.

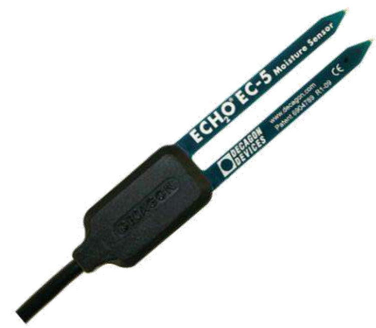


Figure 2. The probe of the Decagon ECH2O EC5.

All four of the substrate containers received an iButton, which was installed in a custom-made plastic holder constructed from electrical conduit connector and pipe such that the iButton's measuring hole was held facing a cylindrical volume of ~11 mm deep and 20 mm diameter (Figure 3). The open, cylindrical volume was covered with two layers of a fine nylon mesh to prevent ingress of soil and to provide a space much larger than the soil's pore spaces into which soil water vapour could diffuse (Figure 4). Two of the containers each also received an EC5 soil moisture probe (Figure 2, Figure 4d, set to measure every two minutes) and a soil temperature probe.

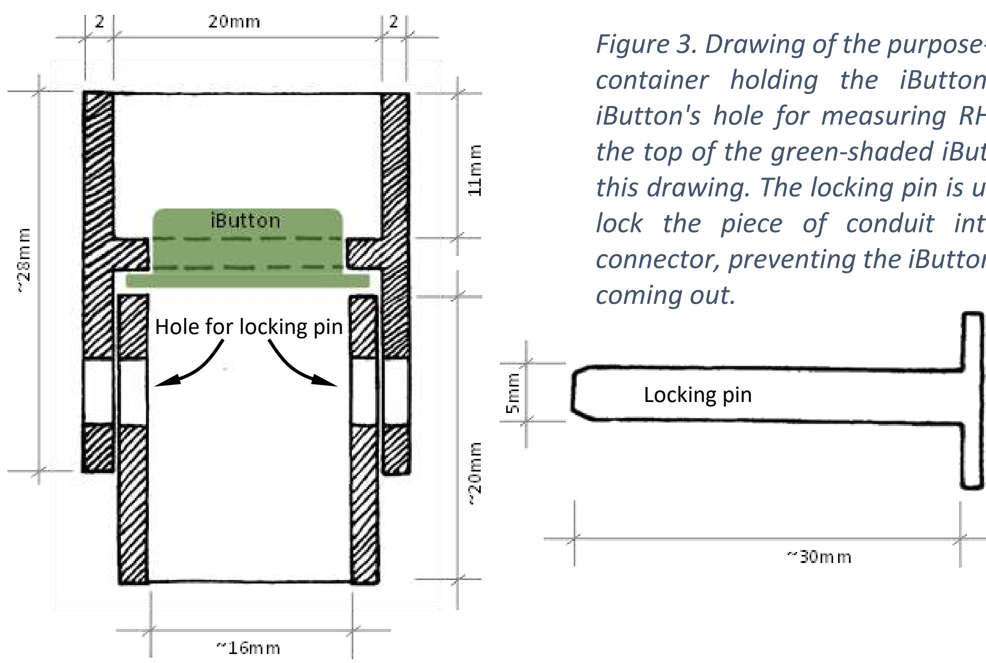
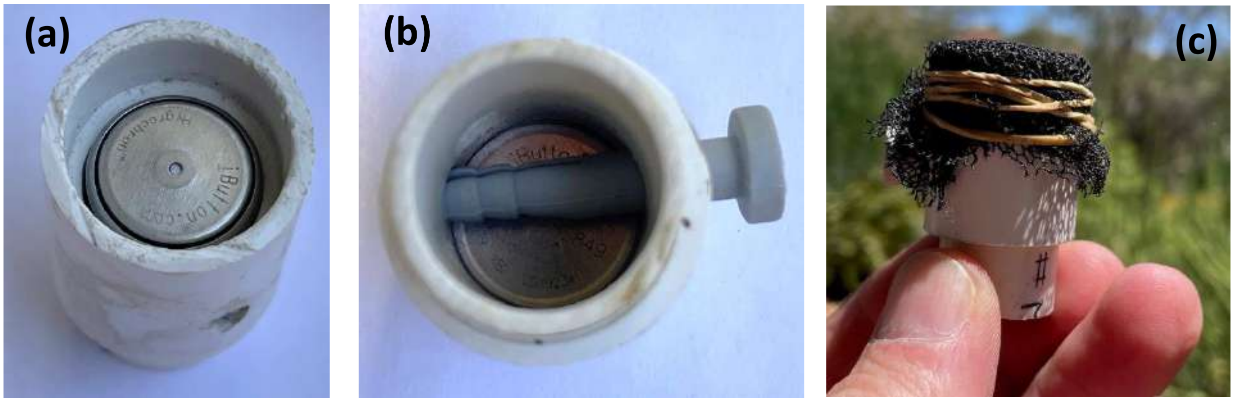


Figure 3. Drawing of the purpose-made container holding the iButton. The iButton's hole for measuring RH is at the top of the green-shaded iButton in this drawing. The locking pin is used to lock the piece of conduit into the connector, preventing the iButton from coming out.

The two soil containers without the EC5 sensors were weighed on the FX1200i electronic balance at approximately half-hourly intervals for the first ~24 hours, and at hourly intervals thereafter for a total of 88 hours. For the last few hours, the successive decrease in weight between measurements was less than 0.004 to 0.006 $g.minute^{-1}$. One large standing fan and one small desktop fan were trained on the workbench with the soil containers and were in continuous operation for the full duration of the experiment, being switched off only for weighing.



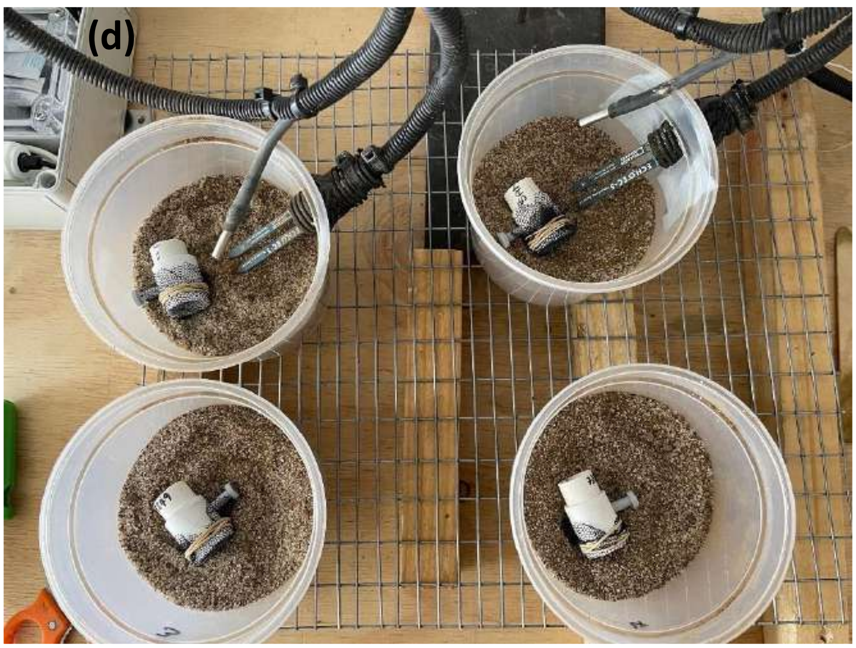


Figure 4. The iButton was placed inside the holder with the iButtons' measuring hole facing up (a) and was "locked" in place on the bottom side using a plastic pin (b). Two layers of a fine nylon mesh was fixed over the upper side, to prevent ingress of soil particles in the open volume in front of the iButton. One iButton plus holder was placed on its side on a bed of ~2cm soil in each soil container and covered with soil (d) to the edge of the container. Two of the soil containers also received a EC5

In the second experiment, I installed, in two locations in my garden, two iButtons and one EC5 into a soil profile (both the temperature and soil moisture probes). The garden soil was thoroughly dry, having not received any rain in the preceding month. At location 1 I wetted the soil to saturation and allowed the moisture to drain through the profile and to dry out to less than field capacity before installing the sensors. At location 2 the extremely dry soil forced me to wet three small patches using a spray bottle, one for each of the sensors, to allow installation. These wet patches influenced the start of the measurements but were relatively small and shallow and thus dried out quickly.

Figure 5. Experiment 2. Installation of the Ec5 with its associated sensors and the two iButtons on a dry soil profile in my garden. The two solid white arrows are pointing t the location of two iButtons which were inserted with the open end of the holder pushed snugly against the soil. The dashed white arrow points to the location of the ECH2O EC5 soil moisture sensor and soil temperature probe. The black arrow points to the solar shade for an air temperature and RH sensor. The latter are fixed above the HOBO Microstation data logger. The dark patches are wet soil, necessitated to allow the placement of the sensors in the hard dry soil. These wet patches dried out within 12 hours. The whole setup was shaded using a small brown polypropylene canvas. This set of measurements were contrasted with a similar setup in soil that was just below field capacity.

Data were downloaded using the proprietary software for the EC5 and iButtons, and manually entered in a spreadsheet in the case of the weight data. None of the measurements could be started at precisely the same time. All time series were thus standardized to an idealized measuring period to allow direct comparisons of measurement profiles over the same time period. Because of the low levels of replication that was possible in this experiment, no statistical methods were used to compare any of the trends.

Results

In Experiment 1, the EC5 delivered astounding results. Although the experiment was not set up to test linearity, the clear congruence between the GWC and VWC (Figure 6) suggests that the method is reliable, at least in the soil moisture range that I tested. For unknown reasons the EC5 tracked the rate of loss of water better when the soil was properly saturated at the start of the experiment than in the relatively dry soil, where the rate of change in weight was marginally slower than the rate of change in VWC towards the end of the experiment (Figure 6). This might have been caused by the lack of calibration of the EC5 sensor to the specific substrate I used, but the low level of replication (n = 2) prevents any further speculation as to the cause of this.

The two iButtons in both treatments showed large differences in their absolute values of RH, although their trends appear to be similar (Figure 6). This is more so in the non-saturated treatment than in the saturated one, where the one iButton showed an exaggerated version of the trend in the other one (Figure 6).

The % RH stayed at 100% for half the time even though both GWC and VWC had already started dropping (Figure 6). Despite this, % RH started declining sometimes quite rapidly after that (Figure 6). The RH values dropped as low as 45% in the saturated treatment.

Soil temperature as measured by the temperature sensor attached to the EC5 setup and the sensor on the iButton tracked each other perfectly, but appeared to have only a weak relationship with levels of % RH and none with VWC in either treatment (Figure 6).

Results in Experiment 2 partly confirmed the results from experiment 1, and showed added environmentally-induced variation. The iButtons again struggled to get below 100% RH, especially in the wet soil treatment (Figure 7). In the wet soil the iButtons took more than 50% of the full time period to detect the beginning of the decline in % RH, while VWC started dropping almost immediately (Figure 7b). In the dry soil, both the EC5 and the iButtons accurately reflected the starting condition where the soil had to be wetted to install the sensors, but soon generally dry soil condition (Figure 7a).

The daily pattern in both VWC and %RH reflected the diurnal cycle of a drop and then rise in ambient temperature (Figure 7). This caused a similar but opposing daily cyclical pattern in RH and VWC, with %RH decreasing and VWC increasing with increasing ambient temperature (Figure 7). This correlation with temperature was clearly evident in the dry soil treatment, but less so in the wet soil treatment, except for VWC (Figure 7).

In both experiments, VWC dropped to below zero, except in the wet soil treatment in experiment 2. This reflects the lack of proper calibration of the sensor in the soil material we used.

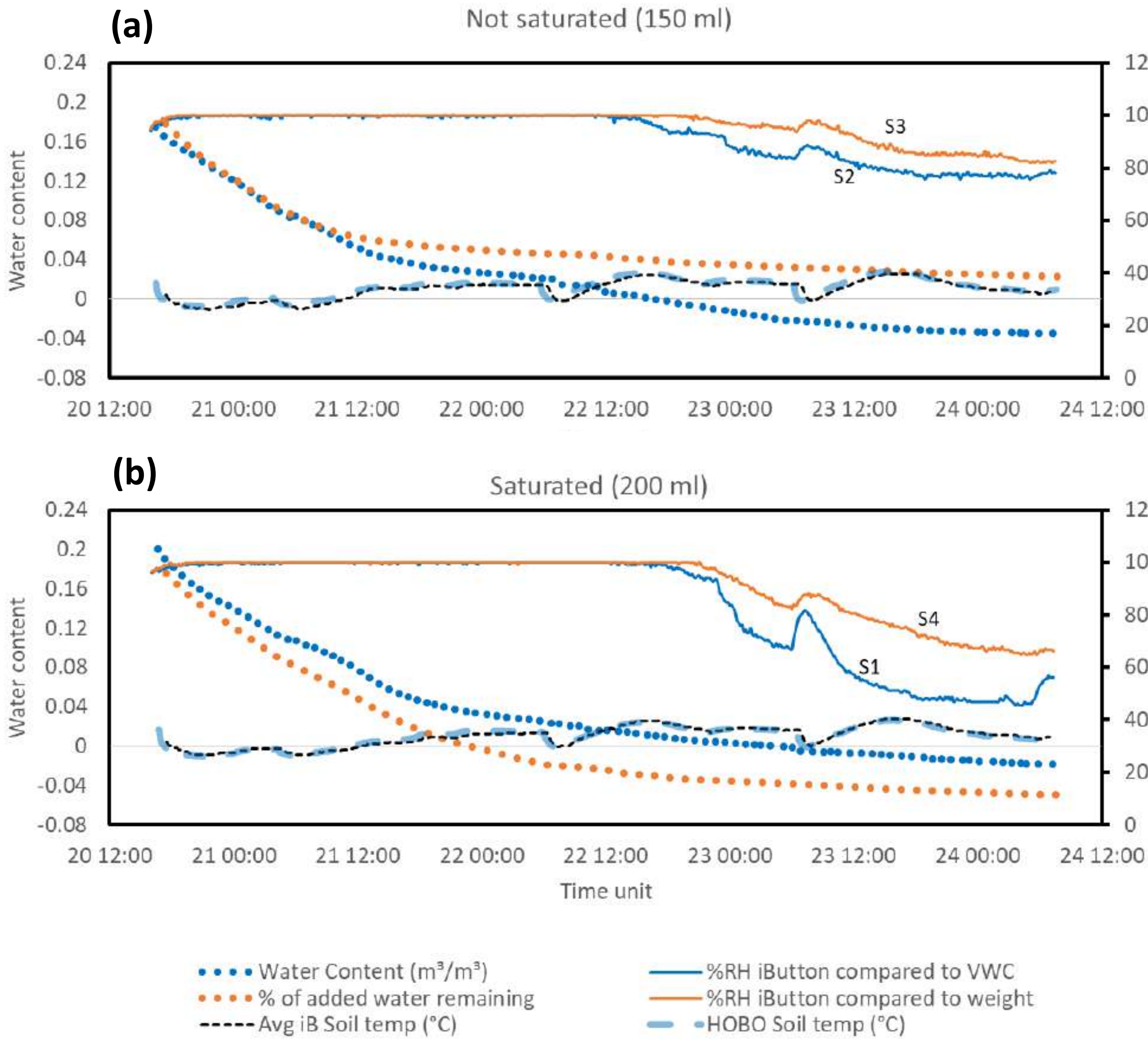


Figure 6. Experiment 1: The trends in RH, VWC and GWC for a soil container that is not saturated (a) and fully saturated (b) at the start of the experiment. Measurement commenced about 3 hours after wetting. In addition the soil temperature as measured with the EC5's associated soil temperature probe, as well as the average soil temperature as measured with the two iButtons used in each treatment is given.

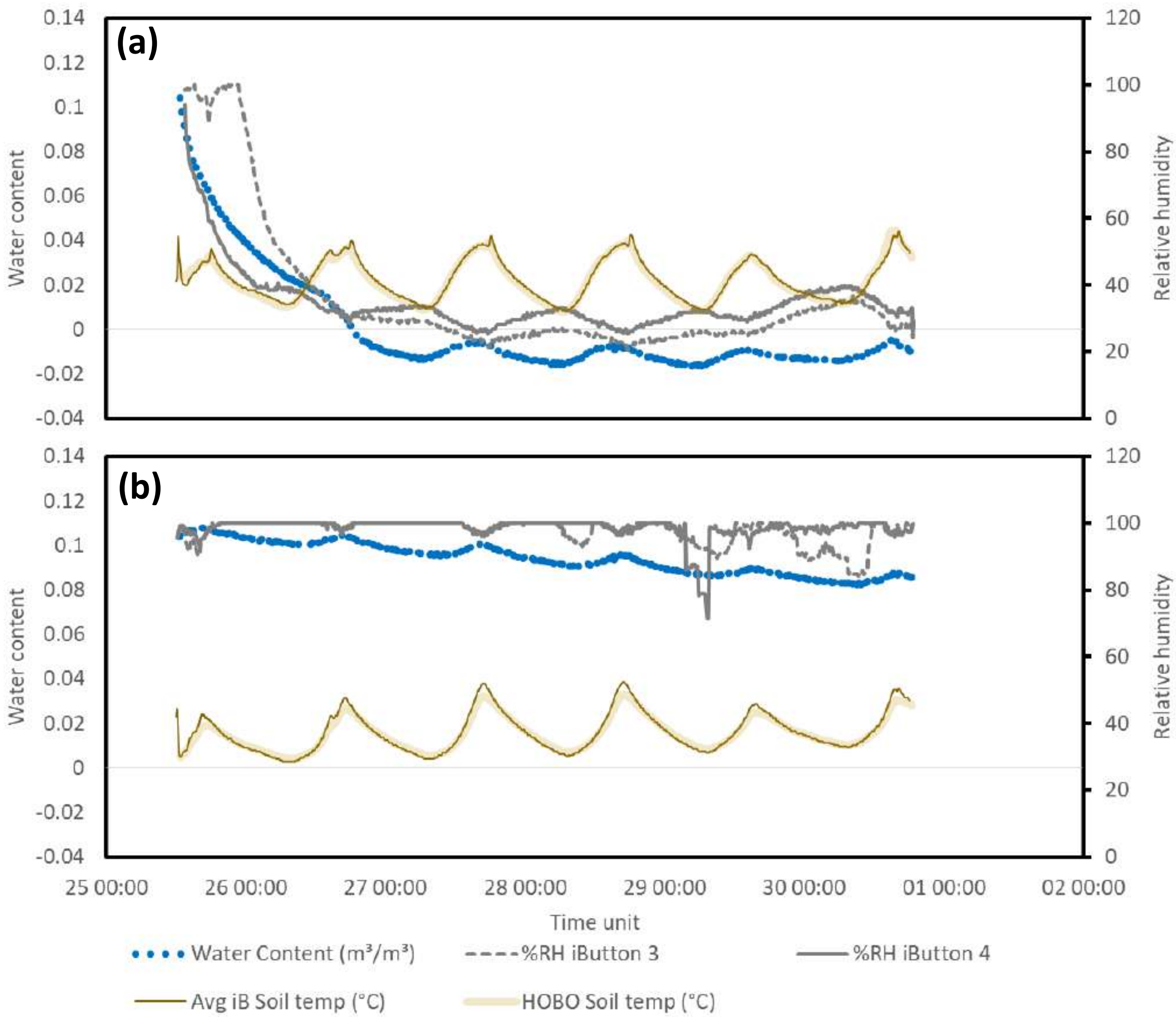


Figure 7. Experiment 2: The trends in soil moisture in terms of VWC (blue dotted lines, measured with an EC5) and % RH as measured using two iButtons per treatment, clearly reflected the two treatments, namely dry soil (a) and wet soil (b). The high values at the start of the experiment in (a) is the result of having to wet a small portion of soil to install the sensors. Also shown is the soil temperature as measured using the temperature sensor that was set up with the EC5 and an average across the two iButtons per treatment.

Discussion

The immediate conclusion from our results is that the iButtons, which measured the %RH of the air in the soil pore spaces, performed poorly compared to both the EC5 and gravimetric approach. The air in the soil pore spaces only dropped below 100% RH after at least 56% and 84% of the initial volume of water that I had added in respectively the non-saturated and saturated treatments was lost. In the in-situ experiment (wet treatment), both iButtons showed 100% RH for a long period before becoming highly variable without a clear a declining trend that reflected that of the VWC measured at the same time.

In addition, especially in the in-situ experiment, %RH clearly showed the influence of the soil temperature, decreasing when the temperature increased and vice versa. It is thus difficult to relate the RH value at any point accurately to the volume of water that is available for plant use, at least as long as the soil is relatively wet. The amount of variation between iButtons in both experiments was also curious, as I was convinced that the conditions inside the soil containers were much closer than the differences in %RH would suggest (see e.g. Figure 6a). However, these could simply have been caused by poor mixing of soil and sand or small pockets of clay material that affected water availability differently. In experiment 1 the RH as measured by both iButtons in the wetter sand started declining at least two hours later than the non-saturated treatment but dropped much lower. This is somewhat anomalous but could again be explained as poor sample preparation or differential effects of the fans.

Some of the problems I experienced echoed those of Fawcett et al. (2019), who also struggled to get good results in very wet soil conditions and failed to obtain a correlation of soil RH with VWC. In contrast, Schagen et al. (2021) reported no problems (but apparently did not query the iButtons' ability to measure in soil) and Wang et al. (2015) only pointed out that there is a need to measure ambient RH simultaneously with litter RH, to be able to correct for the effect of ambient conditions. The latter study was however conducted with the iButtons in contact with the atmosphere and is thus not directly comparable.

Despite these problems though, which were expected from the start, the study produced some unexpectedly good results. First, I did not have the equipment to dry out the soil samples to the levels that a desert plant would experience. I therefore expected to be measuring RH value over 90% for the duration of the experiment and was pleasantly surprised when the levels in all iButtons started dropping, going as low as 46% in the one saturated sample in Experiment 1. Notwithstanding the cyclical blips in RH in response to temperature, the trend was clearly downwards and echoed that of the VWC. The best result was the very similar patterns in the RH and VWC in the dry soil treatment in Experiment 2. Although this soil was probably still relatively wet compared to proper desert soils, this treatment came much closer to representing the conditions we are likely to experience in the field in the arid zone and is indeed one of the main reasons why I tested iButtons.

iButtons have several potential and real advantages over other methods. First, their small size means that they can be deployed relatively unobtrusively, avoiding problems with vandalism and theft. They are also relatively inexpensive, even when compared to the cheaper versions of the capacitance type of devices. Finally, they contain an integrated data logger capable of storing 8192 8-bit readings or 4096 16-bit readings with user-set measurement intervals. This translates to about 170 days of 2-hour measurement intervals (Analog Devices, Inc; Undated). Its temperature accuracy of ±0.5°C from -10°C to

+65°C and humidity resolution of 0.6% RH (Analog Devices, Inc; Undated) falls well within the resolution that is useful for ecological studies. Despite the apparent problems with the iButtons when trying characterize soil moisture, their advantages theoretically make them a viable option for distributed sampling over ecologically meaningful periods and spatial scales. At the very least it requires careful investigation to evaluate potential solutions for their apparent weaknesses.

Conclusion/Implications

The experiment showed that despite the iButton's reported weaknesses, they are capable of detecting trends in soil moisture that are similar to those measure by a capacitative sensor like the EC5, especially in dry soils. As the monitoring of soil moisture in restoration/rehabilitation applications in the arid zone will almost certainly encounter soil moisture levels well below permanent wilting point of 1.5MPa, a range where most capacitive sensors encounter problems. The current study's results were encouraging enough to conclude that it must be repeated at larger scale, with more replications, using more types of sensors for control and in more controlled conditions and different substrate types.

Relative humidity is a physical parameter with well-known controls. As such it should be possible to devise ways in which the combination of temperature and RH can be used to obtain a more accurate estimate of plant-available moisture in a range of substrates.

Recommendations

A sub-proposal for an expanded version of this study should be included in the proposal for Phase 2. The experimental design for that proposal should be an expanded version of the one used in the current report, with a laboratory-based phase followed by one or two field phases depending on the availability of testing sites. The factors that should be investigated are:

1. Prompted by the differences found in the current experiment, the precision of measurements among different iButtons should be investigated to determine whether the current results were due to substrate differences (thus real differences in sensed RH of pore spaces) or differences between the iButtons themselves, either the sensors or the custom-made housing.
2. The relationship between VWC and GWC must be established across a longer period (at least two seasons) and with different substrate textures , to determine the validity of using VWC as a control trend.
3. Systematic investigation of the differences between substrate texture in the RH of pore spaces.
4. Determine the relationship between the shape and volume of the measurement space in front of the iButton and the real and perceived RH in pore spaces and the potential for improvement of the holder's design.
5. Determine the potential for using a dry air injection into the measurement volume of the iButton holder at short intervals to overcome the problem of saturated pore spaces at the wetter end of the spectrum.

Acknowledgments

I thank Helvi Shikwambi who expertly and graciously assisted me in setting up various versions of the experiment and who tried several since-rejected ways of measuring soil weight. Her work pointed they way out of several early traps we found ourselves in. MalliKarjun Pillalamarry and Harmony Musiyarirwa assisted in finding laboratory space and an electronic balance at the Faculty of Engineering.

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BERICHT

Überblick über die Rohstoffverteilung, die Bergwerke, Bergbauaktivitäten sowie die ökologischen und sozialen Probleme und Auswirkungen der Rohstoffgewinnung in Namibia, Südafrika, Sambia und Botswana.

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Inhalt

Namibia

In Namibia gehört der Bergbau zusammen mit der Landwirtschaft zu den Haupttreibern des ökonomischen Wachstums. Namibia war 2014 der viertgrößte Exporteur von „non-fuel“-Mineralen in Afrika und gehörte zu den 10 weltführenden Diamantproduzenten. Neben Diamanten werden auch Uranium, Kupfer, Magnesium, Zink, Silber, Gold, Blei, Halbedelsteine und Industriemineralien abgebaut. Diamanten und Uranium machen dabei den größten Umsatz aus (KPMG, 2014).

Die Größe des Sektors ist vor allem auf die hohe geologische Diversität zurückzuführen. Die Mehrheit der aktiven und historischen Minen kommen dabei in der westlichen Küstenebene und im zentralen Plateau vor. Diamantreiche Strände und Flussbette sind entlang des Oranje Rivers und der westlichen Küste vorzufinden. Verschiedene unedle bzw. edle Metalle und uranhaltige Granite kommen vor allem im Damara Orogen, im Gariep Gürtel und in der Othavi Lithologie in zentralen und westlichen Teilen des Landes vor (Salom & Kivinen, 2020).

Durchschnittlich tragen die Gewinne aus dem Mineralstoffsektor mit 11,5 % zum GDP (gross domestic product) und über 50% zu Deviseneinnahmen bei. 2 % aller Angestellten sind in der Minenindustrie angestellt (Jemwa & Mosweu, 2021).

2021 lag der Beitrag zum GDP bei 9,1%. Insgesamt wurden N$ 1.553B an Unternehmenssteuern gezahlt. Die Umsätze lagen bei N$ 32.374B. (BON, 2021).

Informeller, kleinskaliger Abbau existiert vor allem in der westlichen Erongo-Region. Allerdings fehlen hier Zahlen zu der Anzahl bzw. dem Beitrag zur namibischen Wirtschaft (Salom & Kivinen, 2020).

1. Rohstoffe

Diamantabbau

Der Abbau von Diamanten findet hauptsächlich im „Orange River“ und der umliegenden Region statt. Der Fluss markiert die Landesgrenze Namibias zu Süd-Afrika. Immer wieder kommt es diesbezüglich zu Streitigkeiten, da der genaue Grenzverlauf nicht eindeutig geklärt ist (Nördliches Ufer des Flusses vs. Mitte des Wasserstroms) (KPMG, 2014). Auch in den Küstenbereichen – besonders in der Region Karas im Süden Namibias – sind viele Abbauminen zu finden (Ministry of Mines and Energy, 2022).

Geologisch handelt es sich im Küstenbereich um neogene Alluvialböden aus Sand, Kies und Calcrete. Dünenformationen sind vorhanden. Einzeln sind Vorkommen von Gneiss, Granit, und anderen mafischen Gesteinen aus der Namaquan Formation zu finden. Auch Dolomit, Schiefer, Glimmerschiefer, Amphibolith, Quarzit und Diamictit – ebenfalls aus der Namaquan Formation – kommen vor. Im Bereich des „Orange Rivers“, ebenfalls hauptsächlich in der Region Karas, kommen neben den bereits aufgeführten Gesteinen auch Andesit, Dazit und Rhyolith aus Kheisianischer Formation und Granit und Syenit aus Namibischer Formation vor (Ministry of Mines and Energy, 2022).

Die Namibische Nationalbank geht von einer Abbaumenge von 1,5 Mio Karat in 2021 aus, was einem Zugewinn von 2,7% im Vergleich zu 2020 entspricht (BON, 2021).

Preislich liegt der Verkauf von Diamanten im Schnitt bei US$ 400 pro Karat (Jemwa & Mosweu, 2021).

Nach der Chamber of Mines of Namibia (2021) sind folgende Minen derzeit aktiv:

Tabelle 1: Übersicht über die derzeit akiven Diamantminen und ihre Betreiber in Namibia (Chamber of Mines of Namibia, 2021)

Betreiber	**Besitz**	**Minen**	**Abbauort**	**Abbaumenge (2021)**
Debmarine Namibia	Namdeb Holding (100%) - Government (50%) - DeBeers (50%)		Offshore	1.136.000 Karat
Namded Diamond Corporation	- Tochtergesellschaft der Namdeb Holding (100%)	- Southern Coastal Mines - Mining Area No.1: 1928 – 2042 - Orange River Mines Daberas: 1999 – 2022 - Sendelingsdrif: 2014 – 2024 - Northern Coastal Mines - Beach & Marine Contractors: 1991 - 2022	Minenkonzessionen im Süd-westen Namibias: - die größten in der Region der Stadt Oranjemund; - mehrere Minen entlang des „Orange River"; - Im Flachwasserbereich der Küste ➔ Landminen der Namded Holdings	330.195 Karat
Sakawe Mining Corporation	- Atligo (85%) - Epangelo Mining (8%) - Longlife Mining (4%) - National Youth Service (2%) - Employees (1%)		Offshore	51.329 Karat

Uraniumgewinnung

Uranium wird vor allem in den mittel-westlichen Regionen Namibias abgebaut (KPMG, 2014). Besonders in der Region Erongo ist viel Uraniumvorkommen bekannt. (Namibia Mining Cadastre Map Portal).

Insgesamt gibt die namibische Nationalbank eine Abbaumenge von 7050t für 2021 an, die Einnahmen von 35,28 US$ pro Pfund einbrachten (BON, 2021).

Folgende Firmen führen derzeit aktive Minen (Chamber of mines, 2021):

Tabelle 2: Übersicht über die derzeit aktiven Uraniumminen und ihre Betreiber in Namibia (Chamber of mines of Namibia, 2021)

Betreiber	**Besitz**	**Minen**	**Abbauort**	**Abbaumenge (2021)**
Langer Heinrich Uranium	- 75% Paladin Energy Ltd - 25% China National Nuclear Corporation	Langer Heinrich Uranium	Namib Naukluft National Park, 90 km östlich der Walvis Bucht in der Region Erongo	Nil *Momentan in Pflege und Wartungszustand aufgrund der schlechten Weltmarktpreise für Uranium.*
Orano Mining Namibia	Uramin Inc.	Trekkopje uranium mine	70 km nordöstlich von Swakopmund in der Region Erongo	Nil
Rössing Uranium Limited	- China National Uranium Corporation (68,62%) - Iran Foreign Investment Company (15,29%) - Industrial Development Corporation of South Africa (10,22%) - Government of Namibia (3,42%)	Rössing Mine	Namib Wüste, bei der Stadt Arandis, 70 km Entfernung zur Küstenstadt Swakopmund in der Region Erongo	2.882t Uraniumoxid
Swakop Uranium	- Epangelo Mining Company (10%) - China General Nuclear (90%)	Husab uranium mine	60 km von der WalvisBucht, nahe der Stadt Swakopmund in der Region Erongo	3.902t Uraniumoxid

Goldproduktion

Die BoN beziffert die Abbaumenge mit 7104kg, die bei einem Preis von 1800 US$ pro Feinunze lagen (BON, 2021).

Tabelle 3: Übersicht über die derzeit aktiven Goldminen und deren Betreiber in Namibia (Chamber of Mines of Namibia, 2021)

Betreiber	**Besitz**	**Minen**	**Abbauort**	**Abbaumenge (2021)**
Navachab	QKR Namibia Mineral - Holdings (Pty) Ltd (92,5%) - JG Investment Investments (Pty) Ltd (EpangeloGold) (7,5%)	Navachab Gold Mine	Nahe der Stadt Karibib in der Region Erongo	1502 kg
B2Gold Namibia	- B2Gold Namibia (Pty) Ltd.(90%) - EVI Mining Company Ltd. (10%)	Otjikoto Mine	Zwischen Otavi und Otjiwarongo im Norden Namibias in der Region Otjozondjupa	4763 kg

Basis- und Batterieminerale

Laut BoN lag die Menge von abgebautem Zink 2021 8,5% unter dem Wert von 2020. Der Preis lag zuletzt bei 3003 US$/t. Andere wichtige Metalle in dieser Kategorie sind Kupfer, Zinn und Blei.

Tabelle 4 Übersicht über die derzeit aktiven Basis- und Batteriemineralminen und deren Betreiber in Namibia (Chamber of Mines of Namibia, 2021)

Metall	**Betreiber**	**Besitz**	**Minen**	**Abbauort**	**Abbaumenge (2021)**
Zinn	AfriTin Mining (Namibia)	AfriTin Mining Limited	Uis Tin Mine	Erongo Region	784t Zinnkonzentrat
Kupfer (&Schwefelsäure)	Dundee Precious Metals Tsumeb	- Dundee Precious Investments B.V. (90 %) - Local BEE (8%) - Employee Share Trust (2%)	Tsumeb Mine	Tsumeb, 430 km nördlich von Windhoek, nahe des Etosha Nationalparks, Region Oshikoto	42.010t Kupfer 200.308t Schwefelsäure
Eisen	Lodestone Namibia	Lodestone Holdings Group (Namibia)	Lodestone iron ore mine	20 km nördlich von Dordabis, 75	75.718t Eisenerz

Metall	Betreiber	Besitz	Minen	Abbauort	Abbaumenge (2021)
				km von Windhoek, region Khomas	
Zink und Blei	Rosh Pinah Zinc Corporation	- Trevali Mining Corporation (89,96%) - PE Minerals (1,63%) - Jaguar Investments (7,84%) - Rosh Pinah Employee Empowerment Participation Scheme Trust (0,57%)	Rosh Pinah mine	800 km südlich von Windhoek, 20 km nördlich des Orange Rivers, nahe er Stadt Rosh Pinah, am Rand der Namib Wüste, Karas Region	83.362t Zinkkonzentrat 19.989t Bleikonzentrat
Zink	Skorpion Zinc	Vedanta Resources durch die Tochterfirma Vedanta Limited	Skorpion Zinc Mine	Nahe Rosh Pinah, Karas Region	Nil
Kupfer	Trigon Mining Namibia	- Trigon Metals (80%) - Epangelo Mining (10%) - Havana Investments (10%)	Kombat Mine	Südlicher Rand der Otavi Mountains, 37 km östlich der Stadt Otavi, Otjozondjupa Region	Nil

2. Ökologische und soziale Auswirkungen

Generell werden kurz-, mittel- und langfristige Auswirkungen des Rohstoffabbaus unterschieden. Zu den Folgen des Bergbaus gehören eine erhöhte Erosion, Biodiversitätsverlust und die Kontamination von Boden, Luft, Grund- und Oberflächenwasser durch Chemikalien und Feinstaub (Jemwa & Mosweu, 2021).

Gesundheitliche Probleme

Recherchen zeigen, dass die Exposition mit Minenstaub bzw. das Leben nahe von Abbaustätten hohe Risikofaktoren für Asthma sind. Zusätzlich begünstigen die einhergehenden Umweltfaktoren, wie das hohe Staubvolumen und das Fehlen von natürlichem Licht bzw. frischer Luft, die Entstehung von Stress und psychischen Krankheiten (Jemwa & Mosweu, 2021).

Von Acid Mine Drainage (AMD) ausgelöste hohe Säurekonzentrationen führen zu Hautverbrennungen und dem Absterben von aquatischem Leben. Außerdem werden giftige Metalle wie Arsen, Kadmium, Chrom und Blei aus der Gangart herausgelöst. Der korrosive Charakter der Schwefelsäure verursacht bei direkter Exposition schwere Hautirritationen und –verbrennungen, schwere Lungenschäden, lebensbedrohliche Akkumulationen von Flüssigkeiten (Lungenödem) und irreversible Augenschäden bis zu totaler Blindheit. Bei Verschlucken der Säure entstehen Verbrennungen im Mund, Hals, Ösophagus und Magen. Eine langfristige Exposition selbst zu geringen Konzentrationen von Schwefelsäure kann zu Dermatitis und einer Erosion der Zähne führen (Jemwa & Mosweu, 2021).

Soziale Probleme

Von Minengesellschaften wird erwartet, Menschenrechte, die Gemeinschaft und die Gesellschaft in denen sie operieren zu berücksichtigen. Dafür müssen sie auf nachhaltige und ethisch-sozial verantwortungsvolle (ethical corporate social responsibility: CSR) Praktiken setzen, um Vorteile für ihr Geschäft zu erzielen. Die „CSRs“ sind dabei jedoch nicht gesetzlich festgehalten und auch nicht durch zur Verfügung stehende Daten der Minengesellschaften nachvollziehbar (Jemwa & Mosweu, 2021).

In Namibia leben derzeit 17,4% der Bevölkerung unterhalb der Armutsgrenze. Verglichen mit der letzten Erhebung aus 2015/16 (28,8%) ist dies zwar eine gute Entwicklung, verglichen mit Ländern mit gleichem Einkommensniveau jedoch immer noch ein sehr hoher Prozentsatz (NPC, 2020).

Insgesamt ist die Afrikas Region südlich der Sahara (SSA – Sub-Saharan Africa) die weltweit am stärksten von Armut betroffene Region. 27 der 28 ärmsten Ländern gehören zu SSA, alle mit Armutsraten von über 30%. Die absolute Anzahl an von Armut betroffenen Menschen hat sich seit 1990 um 48,6% gesteigert, von 278 Millionen auf 413 Millionen im Jahr 2015. Diese Entwicklung wird von der NPC vor allem auf den Bergbau, der wenig mit dem Konsum- und Einkommensniveau der Armen verbunden ist, zurückgeführt. Die Einkommensungleichheit in Namibia liegt mit einem Gini-Index von 59,1% (Stand 2015 aus World Bank, 2022) auf dem dritthöchsten Level weltweit (NPC, 2020).

Arbeitssicherheit

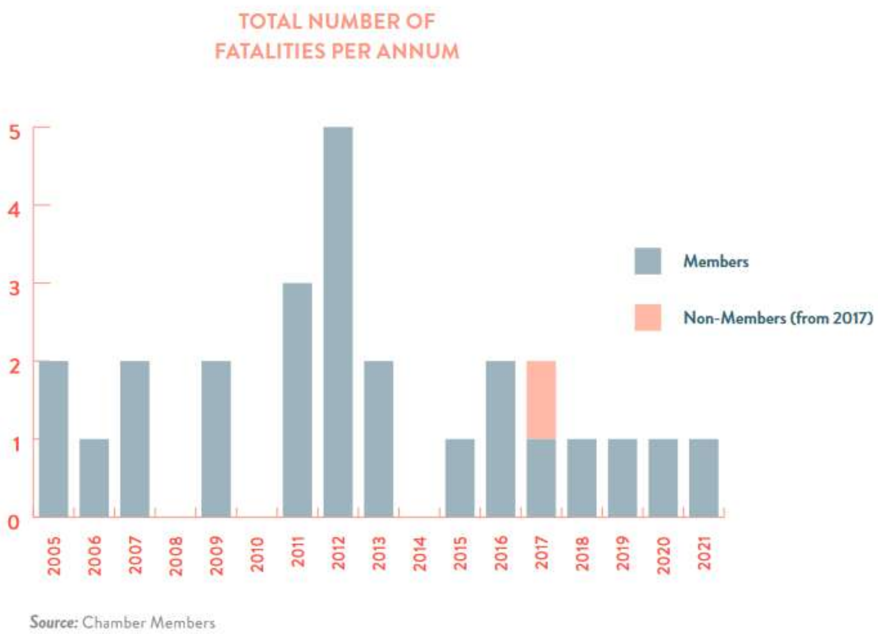

Abbildung 1: Anzahl der Todesfälle pro Jahr (Chamber of Mines of Namibia, 2021)

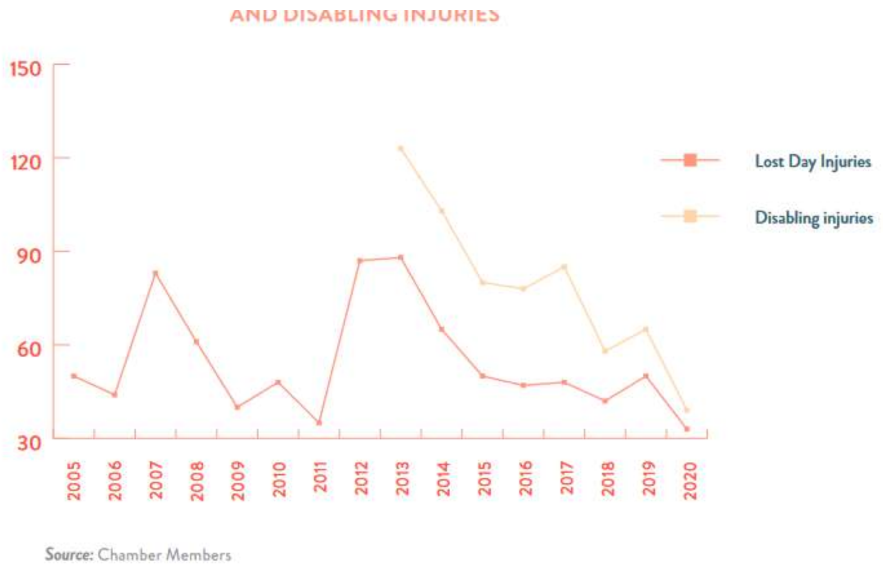

Abbildung 2: Gesamtzahl der Verletzungen mit Ausfalltagen und Behinderungen pro Jahr (Chamber of mines of Namibia, 2021)

Im Januar 2021 gab es einen Todesfall im Okatji-Marmorsteinbruch in der Nähe von Karibib. Der tödliche Unfall ereignete sich mit einem Frontlader, der von der oberen Arbeitsbank abrutschte und eine etwa 7 Meter hohe Klippe hinabstürzte. Laut Sicherheitsausschuss der „chamber of mines" wurde eine besorgniserregende Tendenz von Unfällen mit hohem Potential in namibischen Steinbrüchen, insbesondere bei nicht Kammermitgliedern beobachtet. Die Industrie registrierte zudem einen leichten Anstieg der Unfälle insbesondere der Verletzungen mit Ausfalltagen und Verletzungen mit langfristigen Beeinträchtigungen (Chamber of mines of Namibia, 2021).

Ökologische Probleme

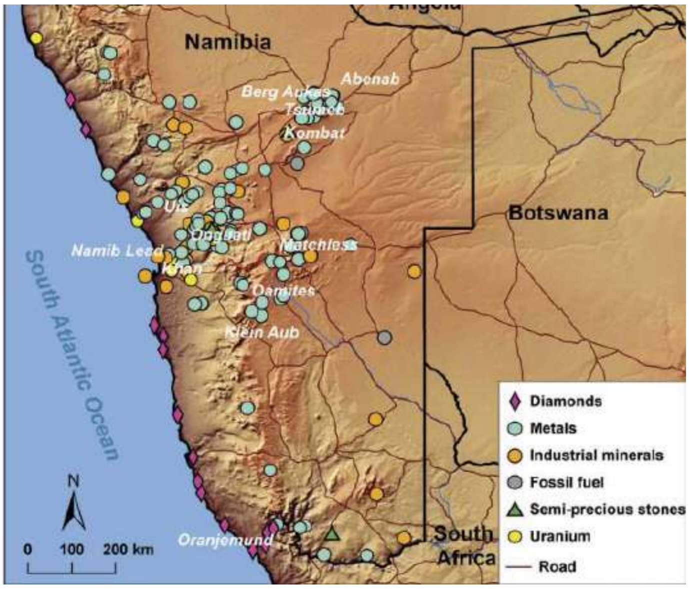

Abbildung 1: Verteilung von geschlossenen und verlassenen Minen in Namibia und deren Hauptrohstoff (Aus Salom & Kivinen, 2020)

Nach Salom und Kivinen (2020) sind in Namibia über 250 Minen verlassen, ohne dass Rehabilitationsmaßnahmen durchgeführt wurden. Eine verlassene Mine (abandoned mine) ist eine Minenstätte, die nicht ordnungsgemäß geschlossen wurden. Der Besitzer kann dabei nicht ermittelt werden, oder er ist nicht zahlungsfähig bzw. -willig nach Ende der Produktion (Salom & Kivinen, 2020). In 2011 hat die deutsche Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) zusammen mit der Geological Survey of Namibia (GSN) eine Bestandsaufnahme für alle geschlossenen bzw. verlassenen Minen mit dem Titel: „Risk assessment handbook for shut down and abandoned mine sites in Namibia" durchgeführt. (Die Quelle war auf Elsevier leider nicht für die Uni Potsdam freigegeben, alle folgenden Referenzen dazu stammen aus Salom & Kivinen, 2020). Dabei wurden Informationen zu Besitzer/Betreiber, Ort/Koordinaten, primären und sekundären Rohstoffen, mineralischer Gruppe, regionaler- bzw. Standortgeologie, Abbaumethode, Verarbeitung und historischer Produktion, Schließungen und Umweltgefährdungen zusammengetragen. Die Bestandaufnahme kommt auf insgesamt 157 nicht ordnungsgemäß geschlossene Minen. Laut Salom & Kivinen handelt es sich hierbei allerdings nur um die bekannten Minen, ihren Recherchen zu Folge seien es 250 verlassene Minen. Nur wenige sind davon intensiv auf soziale Risiken ökologische Probleme untersucht worden. Bis jetzt umfasst die Liste der verursachten Probleme Bodenverschmutzung, Oberflächen- und Grundwasserverschmutzung, Luftverschmutzung durch äolischen Transport von Abraumhaldenmaterial, in den Fluss erodiertes bzw. verlagertes Abraumhaldenmaterial, instabile und ungesicherte Strukturen, gefährliche offene Grubenbaue und Chemikalien sowie die Minderung der Ästhetik.

Zu einigen Minen gibt es detaillierte Berichte zu ökologischen Auswirkungen.

<u>Kombat: (Mapaure et al, 2011)</u>

Hier wurden besonders die Auswirkungen von Verschmutzung durch Bergbauhalden auf Pflanzendiversität, Zusammensetzung und Struktur der semiariden Savanne auf Flächen in unmittelbarer Nähe, westlich der Mine untersucht. Als Referenzflächen wurden Flächen mit einem Abstand von mindestens 5km zur Mine in südlicher bzw. südöstlicher Richtung ausgewertet. Auf den minennahen Flächen wurden signifikant erhöhte Konzentrationen von Arsen, Chrom, Kupfer, Blei und Zink im Boden festgestellt. Insgesamt lagen bis zu 11mal höhere Konzentrationen als die von international empfohlenen Richtlinien vor. Darüber hinaus sank die Artenvielfalt besonders im Bereich der Gehölze, da Pflanzen mit hoher Sensibilität gegenüber Verschmutzung verschwanden, während tolerante Arten sich stärker verbreiten konnten.

Klein Aub, Rehoboth-Land in der Region Hardap: (Hahn et al, 2004)

Die Gemeinde neben der in 2018 stillgelegten Mine ist von Erosion und äolischen Transport von Haldenmaterial betroffen. Ein Wind-Monitoring ergab, dass in Klein Aub der Wind hauptsächlich aus östlicher Richtung weht.

Darüber hinaus ist auch die Stabilität der Mine unzureichend. Zusammenbruchsmerkmale wurden schon in der noch aktiven Phase in der Region zwischen Kope Fluss und westlichem Schacht festgestellt. Diese haben sich zwar weitgehendst stabilsiert, sollten allerdings große Mengen an Wasser für Agrikultur oder andere Zwecke hochgepumpt werden, könnte sich der Zustand wieder verschlechtern.

Die Trinkwasserversorgung der lokalen 1200 köpfigen Gemeinde ist unzureichend. Durch die erhöhte Sulfat-Konzentration (444-560mg/l) kann das Trinken leichte Verdauungsproblemen verursachen.

Oamit Kupfer Mine, Rehoboth-Land in der Region Hardap: (Salom & Kivinen 2020, Hahn et al, 2004)

Aktiv in den 1970er bzw. 1980er Jahren. Ähnlich wie in Klein Aub enthalten die Abraumhalden Kupfer, Uran, Blei und Zink. Auch hier wird das feinkörnige Material äolisch erodiert und verlagert. Der Einsturz der alten unterirdischen Grubenbaue hat eine sehr gefährliche Situation geschaffen. Außerdem wurde festgestellt, dass die Abwasseraufbereitungsanlage am südwestlichen Rand der Abraumhalde außer Betrieb ist, so dass unbehandelte Abwässer mit hohen Ammoniak- und Nitritkonzentrationen direkt in den angrenzenden Fluss Oamites eingeleitet werden.

Matchless Mine, nahe Windhoek in der Region Khomas: (Hahn et al, 2004, Salom & Kivinen, 2020)

Erosion und saures Grubenwasser aus den alten pyritreichen Abraumhalden der Matchless Mine (1983 geschlossen und 2011 wiedereröffnet) führten zu einer Schwermetallverschmutzung des Wassers und der Sedimente des Matchless Flusses.

Namib Lead Mine, nahe Arandis in der Region Erongo: (Hahn et al, 2004)

In der Umgebung der Namib Lead Mine haben der windtransportierte Abraumstaub und belastete Stromsedimente für die Umwelt negative Auswirkungen. Abraummaterial mit erhöhten Niveaus von Blei, Zink, Arsen, und Cadmium werden durch Wind- und Flusstransport in der Umgebung verteilt.

Dazu ist die Umgebung sehr unsicher, da keiner der Schächte ordnungsgemäß geschlossen bzw. gesichert wurde. Chemikalien sind in der Umgebung geblieben und überhängende oxidierte Abraumhalden sind ebenfalls gefährlich.

<u>Khan Mine, nahe Arandis in der Region Erongo: (Hahn et al, 2004, Salom & Kivinen, 2020)</u>
Die Khan-Mine (betrieben von 1916-18 und 1965-74) ist ebenfalls von unzureichender Sicherheit betroffen und zieht Belastungen der nahe gelegenen Khan Schlucht durch Abraumhaldenmaterial mit sich. Die in der Schlucht gesammelten Sedimente gemischt mit dem erodierten Haldenmaterial kennzeichnen sich durch ein erhöhtes Level von Kupfer, Zink, Blei und Barium.

<u>Onguati Mine, nahe Kakatswa Onguati in der Region Kunene: (Hahn et al, 2004)</u>
Die Gefahren, die von den seit 1971 stillgelegten Gruben der Onguati Mine ausgehen, sind offene Stollen und Schächte, Metallschrott und eine Verunreinigung des angrenzenden Baches durch Abraummaterial. Ein Abraumdamm, der sich direkt im Bett eines angrenzenden Baches liegt und dessen Lauf blockiert, zeigt die Auswirkungen der Erosion. Es ist zu erkennen, dass Abraummaterial im Flussbett über eine Strecke von 1,5 bis bis 3 km transportiert wird. Darauf deuten auch die Kupfer- und Wolframkonzentrationen, die um ein Vielfaches höher sind als im lokalen Hintergrundrauschen.

<u>Berg Aukas Zin-Blei-Vanadium Mine, nahe Grootfontein in der Region Otjozondjupa: (Salom & Kivinen, 2020)</u>
Eine umfassende Untersuchung zu Umweltauswirkungen und Geochemie stellte eine Schwermetallkontamination (Blei, Zink, Kupfer, Cadmium, Arsen, Quecksilber) der Oberböden in der Region um den Berg Aukas durch vom Wind verwehten Staub von Schlacken- und Abraumhalden bzw. durch historisches Rösten von Erzen fest. Die Gebäude der Berg Aukas Mine, die von 1967 bis 1978 aktiv war, wurden vom Nationalen Jugenddienst als landwirtschaftliche Berufsschule genutzt. In der Nähe der Abraumhalden gab es landwirtschaftliche Versuchsflächen.

Zusätzlich zu den genannten Problemen hinterlassen geschlossene Minen „Geisterstädte“ und sichtbare Beeinträchtigungen durch das Zurücklassen von verlassenen Gebäuden, alten Maschinen und anderen Konstruktionen. Beispiele solcher Gegenden sind die verlassene Minenstandorte Abenab (1921- 1947, nahe Grootfontein in der Region Otjozondjupa) und Uis (Salom & Kivinen, 2020).

In 2019 wurde ein Katalog mit dem Titel: „Best Practice Guide: Environmental Principles for Mining in Namibia- Setting the Namibian best practice standard for the entire mine life cycle from exploration, projects & constructions, mining & processing, through to care & maintenance, closure & rehabilitation” von der Chamber of Mines, der namibischen “chamber of Environment” der namibischen Regierung und Mitgliedern der namibischen Bergbauindustrie herausgegeben. Dieser scheint, nach meinen Recherchen nicht rechtlich bindend zu sein (Chamber of Mines et al., 2019)

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Südafrika

Die Republik Südafrika (RSA) gehört zu den weltweit führenden Ländern in Bergab und Mineralverarbeitung. 2017 produzierte Südafrika folgende Weltmarktanteile der entsprechenden Ressourcen (YAGER, 2022):

- 80% gefördertes Rhodium
- 72% gefördertes Platin
- 63% raffiniertes Rhodium
- 66% raffiniertes Platin
- 46% Chrom
- 44% Vermiculit
- 39% gefördertes Palladium
- Jeweils 31% Mangan und raffiniertes Palladium
- 29% Ferrochrom
- 24% Zirkon
- 22% Industriegranat
- 11% Vanadium
- 7% Feingold
- 6% Diamanten
- 5% Flussspat
- Jeweils 4% Kohle, Eisenerz und gefördertes Gold
- Jeweils 2% Kobalt und Nickel
- Jeweils 1% Kobalt, gefördertes Blei und rostfreier Stahl

2022 trug der Bergbausektor nach vorläufigen Schätzungen des Minerals Council South Africa R493,8 Mrd beziehungsweise 7,53% zum GDP bei. Insgesamt waren 475, 561 im Sektor beschäftigt. Der Wert der Bergbauproduktion lag bei R1,18 Bio (Minerals Council South Africa, 2023).

Laut einem Statement der South African Reserve Bank, hätte der Bergbausektor ohne Herausforderungen in der Transportlogistik und andere einschränkende Faktoren besser abschneiden können (South African Reserve Bank, 2022).

1. Rohstoffe

Ein Überblick über die Minen und die Menge von produziertem Mineral ist von der USGS ab Seite 40.20 in verschiedenen Tabellen festgehalten (YAGER, 2022).

Im Folgenden werden die Gewinne und Produktionen der 10 größten südafrikanischen Bergbauunternehmen wie sie unter https://briefly.co.za/29502-list-biggest-mining-companies-south-africa.html gelistet sind, aufgeführt.

Tabelle 5: Übersicht über die Produktions- und Gewinnhöhe der 10 größten südafrikanischen Bergbauunternehmen (nach https://briefly.co.za/29502-list-biggest-mining-companies-south-africa.html, Stand 13.02.2023) aus den jeweiligen Jahresberichten der Abbaufirmen

Firma	**Produktion**	**Gewinn**	**Quelle**	**Anmerkungen**
Anglo-american South Africa	• 32,2 mct Diamante • 647 kt Kupfer • 64,0 kt Nickel • 2,400 koz raffiniertes Platin • 1,628 koz raffiniertes Palladium • 347 koz raffiniertes Rhodium • 63,8 Mt Eisenerz • 14,9 Mt metallurgische Kohle • 3.7 Mt Manganerz	US$41,6 Mrd	(Anglo American plc, 2022)	Die Firma ist in insgesamt 15 Ländern aktiv. Ich habe leider keinen Bericht nur zu südafrikanischen Operationen gefunden.
BHP Billiton Energy Coal South Africa Ltd	• 253,2 Mt Eisenerz • 1.547 kt Kupfer • 42,8 Mt Kohle • 76,8 kt Nickel • Kaliumkarbonat	US$34,1 Mrd	(BHP, 2022)	Widerspruch zur Website. Unter https://www.bhp.com/what-we-do/global-locations wird gar kein Projekt in Süd-Afrika angezeigt???
Rio Tinto	• 319,7 Mt Eisenerz • 54,3Mt Bauxit • 3.151kt Aluminium • 494 kt gefördertes Kupfer • 1.014 kt Titanoxidschlacke • 9,7 Mt Eisenerzpellets und - konzentrat	US$25,3 Mrd	(Rio Tinto, 2022)	In 35 Ländern aktiv. In Südafrika werden im Rahmen der Operation „Richards Bay Minerals“ Zirkon, Rutil, Eisen und Schlacke gefördert (https://www.riotinto.com/en/operations/south-africa/richards-bay-minerals)
Kumba Iron Ore Ltd	• Sishen Mine: 28,0 Mt Eisenerz • Kolomela Mine: 12,8 Mt Eisenerz	?	(Kumba Iron Ore Limited, 2022)	Tochterfirma von Anglo-American
Sibanye Stillwater	• 27.747kg Gold • 1.896.670 4Eoz Platinmetalle	US$ 11.643 Mrd	(Sibanye Stillwater, 2022)	Die Produktionswerte gelten, wenn ich es dem Bericht richtig entnommen habe nur für die südafrikanischen Operationen. Der Gewinn umfasst Operationen aus mehreren Ländern

Firma	Produktion	Gewinn	Quelle	Anmerkungen
Wesizwe Platinum	• Die unterirdische Erzaufbereitungsanlage ist derzeit (2021) in der Lage, 50 kt pro Monat zu produzieren -> Ausbau auf 83 kt pro Monat bis Ende 2023 • Abgebaut werden PGMs (Kupfer, Nickel, Ruthenium, Iridium und Chrom)	Verlust von R24.520.000	(Wesizwe, 2022)	Fokus derzeit auf Ausbau und Investition
Northam Platinum	• 716 488 oz 4E raffinerte Metalle	R34,1 Mrd	(Northam, 2022)	
African Rainbow Minerals	Nur für Südafrika: • 13,1 Mt + 3,1 Mt Eisenerz • 4,1 Mt Manganerz • 119000t Ferromangan mit hohem Kohlenstoffgehalt • 56000t Ferromangan mit mittlerem Kohlenstoffgehalt • 211000t Ferromangan	R14.364 m	(African Rainbow Minerals, 2023)	
Palabora Mining Company Ltd				Leider kein Jahresbericht auf der Website https://www.palabora.com/index.asp
Kimberley Ekapa Mining Joint Venture				Leider ebenfalls kein Jahresbericht auf der Website https://ekapa.co.za/

2. Ökologische und soziale Auswirkungen

Soziale Probleme

Aufgrund von anhaltenden strukturellen Problemen, insbesondere im Energiesektor, und einer geringen und ungleichen Entwicklung im Humankapital ist die wirtschaftliche Leistung des Landes schwach. Sie wuchs zwischen 2012 und 2021 im Durchschnitt nur um 1,0%, was im gleichen Zeitraum zu einer Schrumpfung des Pro-Kopf-Einkommens von 5,6% führte. Das GDP stieg 2021 zwar um 4,9%, liegt aber immer noch unter dem Niveau vor der Corona-Krise. Die Arbeitslosigkeit ist mit 38,7% hoch. Im zweiten Quartal von 2022 waren 821.000 Menschen weniger als vor Corona beschäftigt. Der Verlust von Arbeitsplätzen betraf vor allem wirtschaftlich schwache Haushalte und verschärfte so die ohnehin schon hohe finanzielle Ungleichheit (Gini Index von 67 in 2018). Infolgedessen werden ein Anstieg der Armutsquoten auf ein Niveau von vor mehr als einem Jahrzehnt und zusätzliche 1,5 Millionen Menschen, die verglichen mit 2019 unterhalb der Armutsgrenze leben müssen, erwartet (World Bank Group, 2022).

SOUTH AFRICA

Table 1	2021
Population, million	60.0
GDP, current US$ billion	421.2
GDP per capita, current US$	7015.8
International poverty rate ($2.15)[a]	20.5
Lower middle-income poverty rate ($3.65)[a]	40.0
Upper middle-income poverty rate ($6.85)[a]	61.6
Gini index[a]	63.0
School enrollment, primary (% gross)[b]	98.4
Life expectancy at birth, years[b]	64.4
Total GHG emissions (mtCO2e)	560.7

Source: WDI, Macro Poverty Outlook, and official data.
a/ Most recent value (2014), 2017 PPPs.
b/ WDI for School enrollment (2019); Life expectancy (2020).

Abbildung 2: Überblick über die wichtigsten armutbeschreibenden Parameter in Süd-Afrika (World Bank Group, 2022).

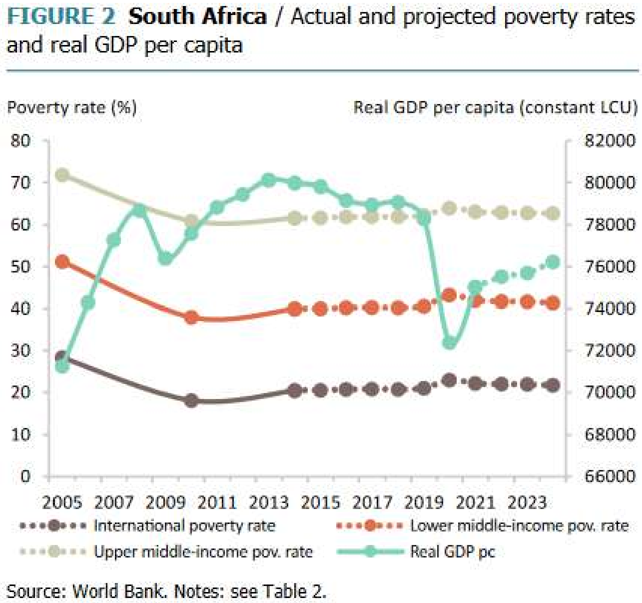


Abbildung 3: Tatsächliche und prognostizierte Armutsquoten und reales Pro-Kopf-GDP für Süd-Afrika (World Bank Group, 2022)

Am 09.02.2023 rief Südafrikas Präsident Cyril Ramaphosa aufgrund der anhaltenden Energiekrise den nationalen Notstand aus. Es kommt teilweise täglich zu Stromausfällen von bis zu 10 Stunden. Der Präsident plant nun, einen Energieminister zu ernennen, der die Versorgungsprobleme in den Griff bekommen soll. Die wirtschaftliche Leistung wird wegen der Stromausfälle nach Schätzungen um 2 Prozentpunkte in diesem Jahr schrumpfen (ZEITonline, 2023).

Arbeitssicherheit und Gesundheit

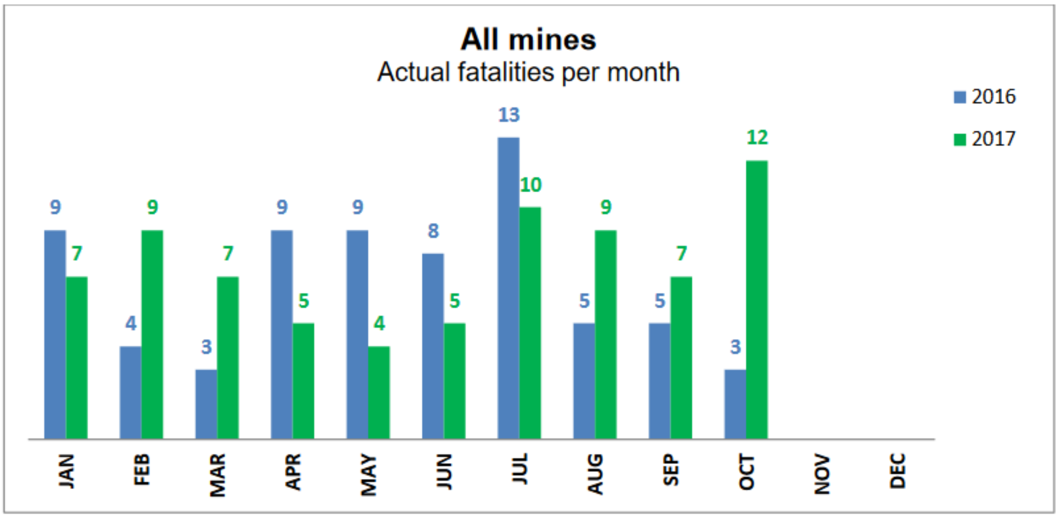


Abbildung 4: Todesfälle in südafrikainschen Minen von Januar bis Oktober für die Jahre 2016 und 2017 (Department Mineral Resources, 2017)

Das „Department Mineral Resources“ veröffentlichte bis 2017 umfassende „Gesundheits- und Sicherheitsberichte“. Der letzte stammt aus dem Oktober. Danach waren auf der Website https://www.dmr.gov.za/mine-health-and-safety/mine-accidents-and-disasters#collapse01 leider keine aktuelleren mehr aufgeführt.

Ein Überblick über die Ursachen der Unfälle wird in folgender Grafik gegeben:

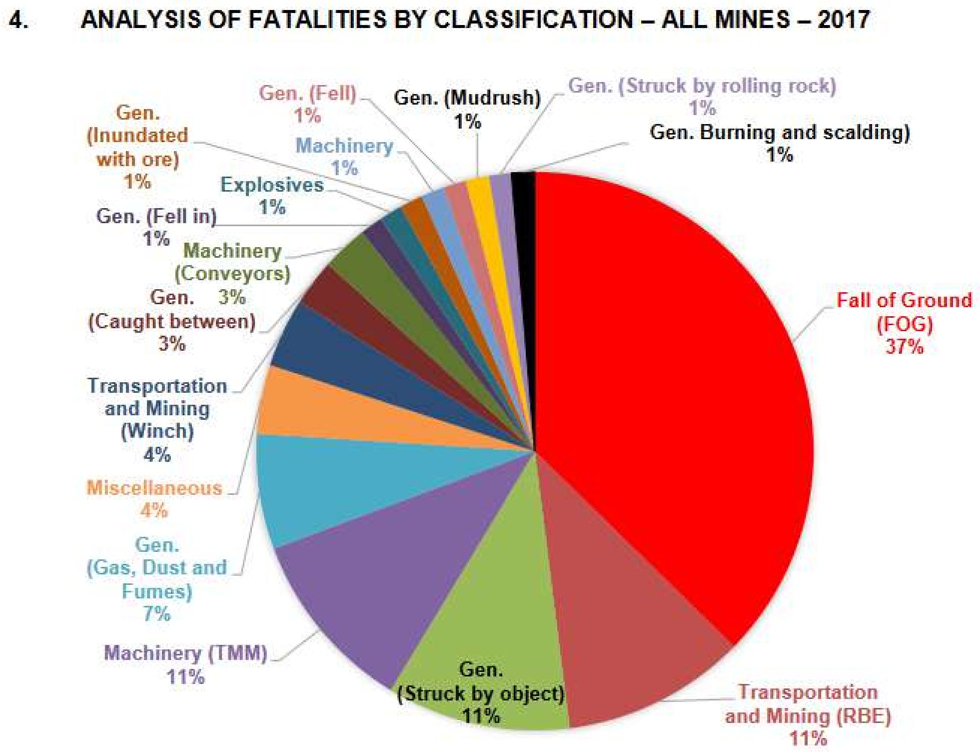
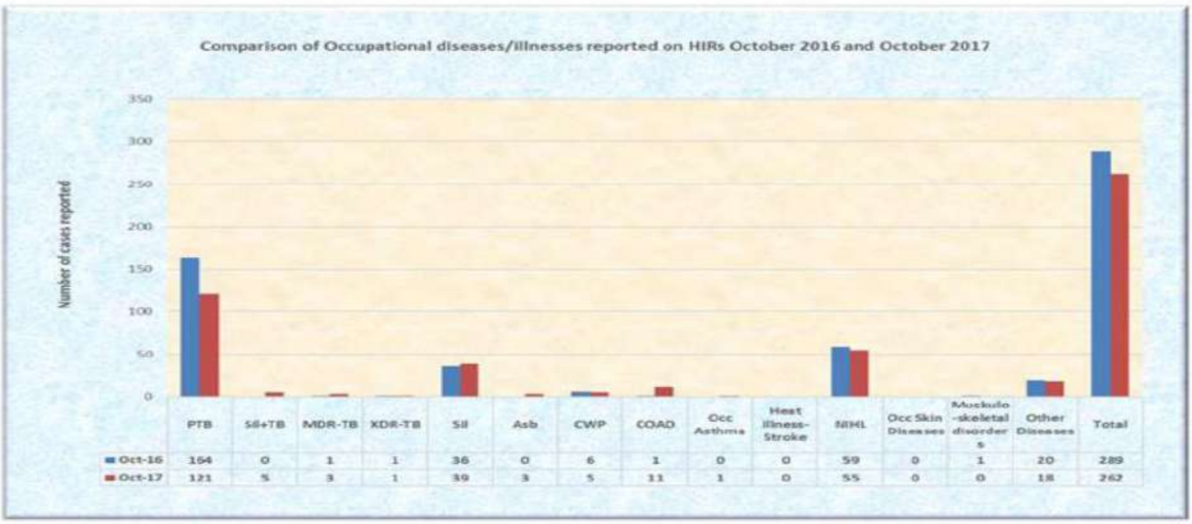


Abbildung 5: Überblick über die Ursachen der Unfälle (Department Mineral Resources, 2017)

Graph 7.3.1 Occupational diseases/illness reported on Health Incident Reports (HIRs) per region: October 2016 and October 2017



	PTB	Sil+TB	MDR-TB	XDR-TB	Sil	Asb	CWP	COAD	Occ Asthma	Heat Illness-Stroke	NIHL	Occ Skin Diseases	Musculo-skeletal disorders	Other Diseases	Total
Oct-16	164	0	1	1	36	0	6	1	0	0	59	0	1	20	289
Oct-17	121	5	3	1	39	3	5	11	1	0	55	0	0	18	262

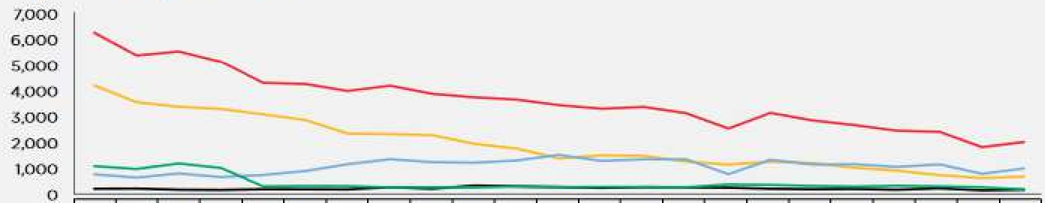
Verification source: Health Incident Reports submitted by regions October 2016 and October 2017

Abbildung 6: In Gesundheitsberichten aufgeführte Berufskrankheiten für Oktober 2016 und 2017 in Süd-Afrika (Department Mineral Resources, 2017)

Gleichzeitig wurden Statistiken über Berufskrankheiten geführt. Im Oktober 2017 wurden 262 solcher Fälle gemeldet. Die häufigsten Krankheiten waren Lungentuberkulose (PTB), Silikose (Sil) und lärmbedingter Gehörverlust (NIHL).

Aktuellere Zahlen listet der Jahresbericht des „Minerals Council South Africa“. Folgende Grafiken sind dem Bericht entnommen (Minerals Council South Africa, 2022a.):

Injuries by commodity: 1993 - 2021

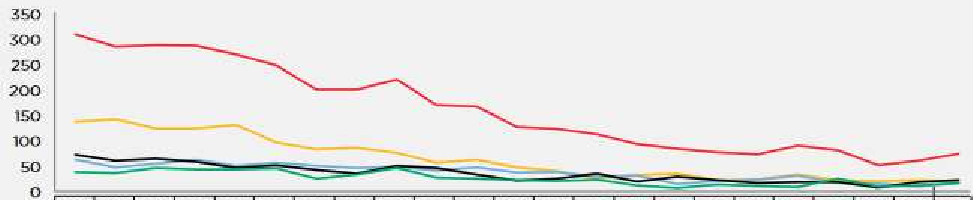


	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gold	4,202	3,549	3,374	3,288	3,079	2,861	2,338	2,318	2,274	1,937	1,760	1,379	1,498	1,477	1,252	1,142	1,249	1,200	1,018	905	732	620	676
Platinum	765	638	797	659	738	892	1,155	1,348	1,233	1,213	1,299	1,515	1,283	1,345	1,344	771	1,328	1,140	1,156	1,049	1,151	782	992
Coal	207	213	170	161	188	187	181	266	205	333	295	273	241	269	263	249	206	189	200	169	224	146	168
Other	1,079	971	1,184	1,008	296	314	309	257	261	255	296	271	277	276	267	372	355	317	290	324	299	266	178
All	6,253	5,371	5,525	5,116	4,301	4,254	3,983	4,189	3,973	3,738	3,650	3,438	3,299	3,367	3,126	2,534	3,138	2,846	2,664	2,447	2,406	1,814	2,014

Source: Department of Mineral Resources and Energy

Abbildung 7: Verletzungen nach Rohstoff zwischen 1993 und 2021 in Süd-Afrika (Minerals Council South Africa, 2022a)

Causes of fatalities: 1999 - 2021



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fall of ground	137	142	124	124	131	96	83	86	76	56	62	47	40	25	32	35	22	24	33	22	20	22	20
Transportation and mining	62	47	54	62	50	56	50	46	48	41	47	37	38	29	31	14	20	23	31	16	15	9	16
General	72	60	64	58	46	51	42	35	50	46	33	21	25	35	19	29	22	16	18	18	7	18	22
Other	38	36	46	43	43	45	25	33	46	27	25	22	20	23	11	6	13	10	8	25	9	11	16
All	309	285	288	287	270	248	200	200	220	170	167	127	123	112	93	84	77	73	90	81	51	60	74

Source: Department of Mineral Resources and Energy

Abbildung 8: Todesursuchen zwischen 1999 und 2021 für den Bergbausektor Süd-Afrikas (Minerals Council South Africa, 2022a)

Cases of non-milestones' pneumoconiosis as per the DMRE: 2019-2020

Diseases	2019	2020
Pneumoconiosis due to coal dust exposure	46	19
Pneumoconiosis due to silica dust exposure	374	271
Pneumoconiosis due to platinum dust exposure	N/A	N/A

Source: Department of Mineral Resources and Energy

Abbildung 9: Fälle von Pneumokoniose für die Jahre 2019 und 2020 für Süd-Afrika (Minerals Council South Africa, 2022a)

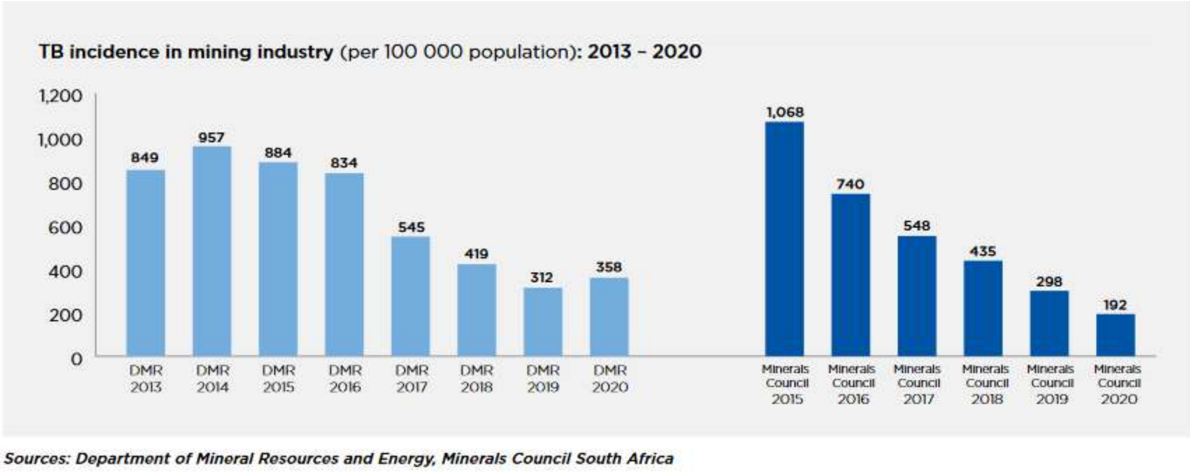


Abbildung 10: Tuberkulose-Inzidenz im Bergbau (pro 100 000 Einwohner): 2013 – 2020 für Süd-Afrika (Minerals Council South Africa, 2022a).

Die Arbeitsbedingungen in Südafrikas Minen sind, obwohl nach Ende der Apartheid, in der die zumeist schwarze Arbeiterklasse systematisch ausgebeutet wurde, signifikante Schritte unternommen wurden, nach wie vor schlecht. Es ergeben sich große Risiken durch unzureichend gesicherte Tunnel, fallende Steine, giftige Dämpfe, hohe Temperaturen und einer hohen Lärmbelastung. Auch die Beschäftigung von Minderjährigen für 12 bis 15 Stunden am Tag bei einem Lohn von umgerechnet weniger als $US 2 ist ein großes Problem (Mining in Africa, 2017).

Eine Kollaboration von 4 NGOs aus dem Jahr 2019 berichtet zudem von gewaltsamen Niederschlägen von Protestbewegungen, die bessere Arbeitsbedingungen forderten. Als Beispiel wird hier die Niederschlagung des Protests von Arbeitern der Lonmin Platin Mine in Marikana, Northwest Province, im August 2012 angeführt. Insgesamt wurden 34 streikende Arbeiter von der Polizei erschossen. Das Ereignis wird auch „Marikana massacre“ genannt (Human Right Watch et al, 2019).

Der „Minerals Council South Africa” führt derweil 6 Herausforderungen für die Sicherheit im Bergbau auf. Darunter (Minerals Council South Africa, 2022b.):

- Organisierte bewaffnete Angriffe auf Minen und Edelmetalleinrichtungen
- Illegaler Bergbau, sowohl in aktiven Bergbaubetrieben als auch in stillgelegten und herrenlosen Bergwerken und Abraumhalden
- Diebstahl von Produkten und Infrastruktur in Bergwerken und von Material auf dem Transportweg
- Manchmal gewalttätige Unruhen in der Gemeinschaft und Störungen des Betriebsablaufes
- Die Auswirkungen von Korruption und Nötigung im Zusammenhang mit der Auftragsvergabe
- Opportunitätskosten für die Ausfallzeit der Infrastruktur im Zusammenhang mit kriminellem Verhalten

Nicht nur für im Bergbau beschäftigte Arbeiter, sondern auch für umliegende Gemeinschaften ist von Auswirkungen des Bergbaus betroffen. Eine Studie teilte Anwohner nach ihrer Exposition anhand der Entfernung zu Goldminen in der Region von Johannesburg in drei Kategorien. Die Gruppe mit hoher Exposition (Haus < 500m entfernt von einer Bergwerkshalde) hatte signifikant erhöhte bereinigte Odds Ratio (aORs) für Symptome der oberen Atemwege (aOR: 2,76, 95% CI: 1,28-5,97), Keuchen in der Brust (aOR: 3,78; 95% CI: 1,60-8,96) und durch Spirometrie diagnostizierte chronisch-obstruktive Lungenerkrankung (COPD) (aOR: 8.17; 95%CI: 1.01–65.85) (Iyaloo et al., 2020).

In einer weiteren Studie wird eine Bewertung der Luftqualität anhand von Ausbreitungsmodellen für windverwehten Staub einer liquidierten Goldmine in der Gauteng Province durchgeführt. Das Oberflächenmaterial der TSF (teilweise sanierte Haldenlager) wurde beprobt und mittels Röntgenfluoreszenz (XRF) und induktiv gekoppelter Plasma-Massenspektrometrie (ICP-MS) auf den Gehalt an Siliziumdioxid und Schwermetallen untersucht. Die Studie kommt zu dem Ergebnis, dass der PM10-Staubniederschlag, der einen hohen Siliziumdioxid- und Urangehalt aufweist, eine potenzielle Gesundheitsgefahr für die umliegende Bevölkerung darstellen könnte. Die Studie zeigt ferner, dass die Staubablagerung in den Monaten Juli bis Oktober am höchsten ist, wobei Staub der TSF6 eine Belästigung darstellt, während Staub von TSF1 aufgrund seiner Partikelgrößenverteilung eine potenzielle Gesundheitsbedrohung für die umliegende Goldminensiedlung darstellt. Zu den potenziellen Empfängern der Luftverschmutzung durch Staub in diesem Untersuchungsgebiet gehören benachbarte Grundstückseigentümer, Geschäftsinhaber eines nahe gelegenen Einkaufszentrums, die Schule und die Klinik. In dieser Studie wird außerdem festgestellt, dass die plötzliche Schließung von Minen aufgrund von Minenauflösungen zu unsanierten Abraumlagern führt, die die Staubablagerung noch verstärken (MPANZA et al., 2020).

Ökologische Probleme

2014 gab es ungefähr 6.000 verlassene Minen, die ihre Umgebung mit saurem Wasser und gelösten Schwermetallen verschmutzt haben. Das saure Grubenwasser aus mehreren aktiven und stillgelegten Kohlebergwerken hat in Verbindung mit unzureichend behandelten Abwässern aus Minen, Industrie und Kläranlagen den Olifants River, der durch die südafrikanischen Provinzen Mpumalanga und Limpopo nach Mosambik fließt, zu einem der am stärksten verschmutzen Flüsse Südafrikas gemacht. Eine Studie unter der Leitung des Rates für wissenschaftliche und industrielle Forschung zur Bewertung von Gesundheitsrisiken im Zusammenhang mit Wasser aus dem Lower Olifants River aus dem Jahr 2014 fand überhöhte Mengen an Antimon, Arsen, Kadmium Quecksilber und Uran in den Proben der Wasserversorgung der Gemeinde. Die aufgeführten Elemente sind giftig und können extrem schädlich für die menschliche Gesundheit und Meeresorganismen sein. Die Quecksilberwerte lagen bei mehr als dem 10-fachen des Wertes, der in der Studie bei einem täglichen Konsum von einem Liter Wasser aus dem Fluss, als unbedenklich angesehen wurde. Die Arsenwerte lagen bei dem 20fachen der sicheren Menge. Die Verschmutzung bedroht das gesamte Ökosystem rund um den Olifant River (Human Rights Watch et al, 2019).

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Botswana

Der Bergbau in Botswana begann im 19. Jahrhundert mit der Förderung von Gold durch Europäer im Tati-Riff, heutiges Gebiet von Francistown. Ein Großteil dieser Aktivität konnte nie nachgewiesen werden, obwohl sie zu jener Zeit einen großen Beitrag zur Wirtschaft leistete. Der moderne Bergbau in Botswana begann 1971 mit dem Abbau von Diamanten in Orapa, gefolgt von der Kupfer-Nickel-Produktion 1973 in Selebi Phikwe. Seit den 1980er Jahren leistet der Bergbau den größten Beitrag zum realen Bruttoinlandsprodukt. Der Anteil variiert zwischen 20 und 50%. Seit der Rezession 2009 liegt der Beitrag allerdings unter 25%. Trotz des großen Beitrags ist der Bergbausektor sehr kapitalintensiv und macht weniger als 5% der Beschäftigumg im Privatsektor aus. Heute werden in Botswana Diamante, Kupferkonzentrate, Gold, Soda, Salze, Silber, Kohle und Kupfer-Nickel-Kobaltstein abgebaut (Statistics Botswana, 2022).

2020 lag das BIP bei US$ 15.781.732.825,89 (https://wits.worldbank.org/CountryProfile/en/BWA).

Folgende Tabelle zu aktiven bzw. geschlossenen Minen (mit [1] markiert) wurde 2022 von der USGS (United States Geological Survey) rückwirkend für 2018 veröffentlicht (Yager, 2022):

Tabelle 6: Überblick über Minen und ihre Betreiber in Botswana 2018, sortiert nach Rohstoff (Yager, 2022)

TABLE 2: BOTSWANA: STRUCTURE OF THE MINERAL INDUSTRY IN 2018

(Metric tons unless otherwise specified)

Commodity		**Major operating companies and major equity owners**	**Location of main facilities**	**Annual capacity**
Aggregates, unspecified		Portland Pretoria Cement Ltd. (PPC)	Quarry at Kgale	830,000.[e]
Do.		do.	Quarry at Francistown	330,000.[e]
Do.		do.	Quarry at Mokolodi	280,000.[e]
Cement		Matsiloje Portland Cement Co.	Plant at Matsiloje, 45 kilometers southeast of Francistown[1]	36,000.
Clay[2]		Makoro Brick and Tile (Pty.) Ltd.	Makoro, 10 kilometers south of Palapye	100,000.[e]
Do.		Lobatse Clay Works (Pty.) Ltd. (Botswana Development Corp. and Interkiln Corp. joint venture)	Lobatse, 70 kilometers south-southwest of Gaborone[1]	70,000.[e]
Coal		Morupule Colliery (Pty) Ltd. [Debswana Diamond Co. (Pty.) Ltd., 100%]	Morupule Mine, 14 kilometers west of Palapye	3,200,000.
Diamond	thousand carats	Debswana Diamond Co. (Pty.) Ltd. (Government, 50%, and De Beers Centenary AG, 50%)	Jwaneng Mine near Jwaneng	30,000.
Do.	do.	do.	Orapa Mine near Orapa	20,000.
Do.	do.	do.	Letlhakane Mine near Letlhakane	1,000.
Do.	do.	do.	Damtshaa Mine, 220 kilometers west of Francistown	670.
Do.	do.	Lucara Diamond Corp.	Karowe Mine in Boteti Sub-District	460.[e]
Do.	do.	Kimberley Diamonds Ltd.	Lerala Mine near Lerala[1]	400.

Commodity		Major operating companies and major equity owners	Location of main facilities	Annual capacity
Do.	do.	Gem Diamonds Ltd.	Ghaghoo Mine[1]	210.
Gemstones, semiprecious	kilograms	Agate Botswana (Pty.) Ltd.	Processing plant at Pilane, 45 kilometers north of Gaborone	70,000.[e]
Do.	do.	Masa Semi-Precious Stones (Pty.) Ltd.	Bobonong, east of Selebi-Phikwe	20,000.[e]
Gold	do.	Galane Gold Ltd.	Mupane Mine, 30 kilometers southeast of Francistown	2,000.
Nickel-copper-cobalt:				
Mine		BCL Ltd. (Government, 100%)	Selebi-Phikwe Mines, 350 kilometers northeast of Gaborone[1]	3,000,000 ore matte content (of which 30,000 nickel, 25,000 copper, 400 cobalt).
Do.		Tati Nickel Mining Co. (Pty.) Ltd. (BCL 100%)	Phoenix and Selkirk Mines, 23 kilometers east of Francistown[1]	5,000,000 ore matte content (of which 21,000 nickel, 12,500 copper, 800 cobalt, 4,400 kilograms palladium, 700 kilograms platinum).
Do.		Cupric Canyon Capital LP (CCC)	Boseto Mine[1]	36,000 copper.
Do.		Cradle Arc plc, 60%	Mowana Mine[1]	10,000[e] copper.
Smelter		BCL Ltd. (Government, 100%)	Selebi-Phikwe Mines, 350 kilometers northeast of Gaborone[1]	30,000 nickel; 25,000 copper; 400 cobalt.
Salt		Botswana Ash (Pty.) Ltd. (BotAsh) (Government, 50%, and Chlor Alkali Holdings, 50%)	Sua Pan near Sowa	650,000.
Silver	kilograms	Cupric Canyon Capital LP (CCC)	Boseto Mine[1]	34,000.
Soda ash		Botswana Ash (Pty.) Ltd. (BotAsh) (Government, 50%, and Chlor Alkali Holdings, 50%)	Sua Pan near Sowa	300,000.

[e] Estimated. Do., do. Ditto. NA Not available.

[1] Not operating at the end of 2018.

[2] For brick and tiles.

Botswana—2017–2018 [ADVANCE RELEASE] 4.7

Disclaimer: Im Folgenden wird nur der Abbau von aktiven Minen erwähnt. Bereits geschlossene Minen sind in obiger Tabelle aufgeführt.

1. Rohstoffe

Diamantabbau

2021 war Botswana mit einem Gewinn von 4656,69 Mio US$ gemessen am Wert der größte Produzent von Diamanten (The Global Economy, 2022). Insgesamt wurden 22.696.000 Karat abgebaut (Statistics Botswana, 2022). Die „Bank of Botswana" gibt den Zugewinn im Zeitraum von September 2020 bis September 2021 mit 15,6% an (Bank of Botswana, 2022).

Debswana Diamond Company (Debswana, 2022):

Die Debswana Diamond Company (Pty) Ltd (Debswana) ist einer der weltweit führenden Diamantenproduzenten der Welt. Das Unternehmen wurde 1969 gegründet und betreibt vier Diamantenminen: Jwaneng-, Orapa-, Letlhakane- und Damtshaa-Mine. Die Jwaeng-Mine befindet sich ca. 120 km westlich der Hauptstadt Gaborone. Die anderern drei Minen (auch als OLDM abgekürzt) sind ca. 240km westlich der Stadt Francistown situiert. 2021 förderte das Unternehmen 22,3 Millionen Karat (2020: 16,6 Mio. Karat), eine Steigerung um 34 %.

Debswana ist eine gleichberechtigte Partnerschaft zwischen der Regierung der Republik Botswana (GRB) und der Unternehmensgruppe De Beers. Die in den vier Minen geförderten Diamanten werden an De Beers und die Okavango Diamond Company verkauft. Debswana leistet den größten Beitrag zur Rohdiamantenproduktion der De Beers-Gruppe.

Lucara Botswana (Lucara, 2022):

Die Firma Lucara Botswana ist eine Tochterfirma der Firma Lucara. Sie betreibt die Karowe-Mine im zentral-nördlichen Botswana, nahe der Stadt Letlhakane. 2021 wurden 369.390 Karat gefördert.

Kupfer- und Silberabbau

Die Abbaumenge von Kupfer in Konzentraten lag 2021 bei 11.742t. Kupfer in Kupfer-Nickel-Verbindungen wurde nicht abgebaut, da sich alle entsprechenden Minen in vorläufiger Liquidation befinden. Daneben wurden 2021 10.383t Silber abgebaut (Statistics Botswana, 2022).

Khoemacau Copper Mining:

2021 begann die Tochterfirma der U.S-amerikanischen Firma „Cupric Canyon Capital LP" den Abbau von Kupfer in der Khoemacau Mine, situiert im Kalahari Kupfer Gürtel im Nordwesten der Republik (Bank of Botswana, 2022). Die Betreiber rechnen bis Ende 2022 mit einer jährlichen Produktion zwischen 60 000 und 65 000 tpa Kupfer sowie 1,8 bis 2 Mozpa Silber. Ein weiteres Expansionsprojekt soll beide Abbaumengen verdoppeln auf 130 ktpa Kupfer und 5 Mozpa Silber (FINE, 2022).

Goldabbau

Die Abbaumenge von Gold wird 2021 mit 649kg angegeben (Statistics Botswana, 2022).

Galane Gold (Galane Gold, 2022):

Die Firma Galane Gold betreibt die Mupane Mine, 30km südöstlich der Stadt Francistown. Insgesamt wurden in 2021 20.906oz Gold abgebaut.

Soda- und Salzabbau

2021 lag die Abbaumenge von Soda bei 261.838t. Außerdem wurden 484.629t Salz abgebaut (Statistics Botswana, 2022).

BotswanaAsh (Botswana Ash, 2021):

Die Firma „Botswana Ash Pty Ltd“ (Botash) ist zu gleichen Teilen im Besitz der Botsuanischen Regierung und der „Chlor Alkali Holdings (CAH) Group“, einer Südafrikanischen Firma. Es werden sowohl Soda als auch Salz in Sua Pan im nordöstlichen Botsuana abgebaut. Der letzte aktuelle Jahresbericht bezieht sich auf 2019. Die jährliche Produktionskapazität liegt für Soda bei ca. 300.000t und für Salz bei 650.00t pro Jahr. Zuletzt stand die Produktion von Salz allerdings bei 420.000t pro Jahr, aufgrund einer geringeren Nachfrage. Insgesamt erwirtschaftete Botswana Ash 2019 umgerechnet US$ 87.877.080.

Kohleabbau

2.021.218t Kohle wurden 2021 abgebaut (Statistics Botswana, 2022).

Morupule Coal Mining:

Die derzeitige Kohleproduktion der Morupule Coal Mine, 14km nordwestlich der Stadt Palapye, liegt bei 2,8 Mio t. Die Mine, die zu 100% von der Firma „Minerals Development Company Botswana“ gehört, möchte diesen Betrag 2027 auf 7,6 Mio t erhöhen (Ramaphane, 2022).

Uraniumabbau

Derzeit findet noch kein Abbau von Uranium statt. Die Firma „A-Cap-Energy“ plant in den kommenden Jahren damit im Rahmen des „Letlhakane Uranium Project“ anzufangen. Die entsprechende Lizenz liegt bereits vor (https://acap.com.au/projects/uranium/).

2. Ökologische und soziale Auswirkungen

Gesundheitliche Probleme

Generell unterscheiden sich die gesundheitlichen Probleme nicht von denen zu Namibia bereits aufgeführten. Eine bereits 1996 veröffentlichten Studie (Steen et al., 1996) befasst sich mit berufsbezogenen Lungenkrankheiten von ehemaligen botsuanischen Minenarbeitern in der Stadt Thamaga, Kweneng district. 26(+- 6)% hatten einen Hintergrund mit Tuberkulose. 23(+-3)% hatten eine berufsbedingte, einschränkende Verletzung. Daneben war auch Pneumokoniose bei 26,6-31% der Befragten festgestellt worden. Viele Fälle waren bis zum Zeitpunkt der Studie unentdeckt geblieben, da die Arbeiter nach ihrem Ausstieg aus der Minenindustrie keinen Zugang mehr zu entsprechenden Gesundheitsüberwachungen hatten. 6-8% hatten eine fortgeschrittene Fibrose. Insgesamt zog die Studie eine ernüchternde Bilanz, da die bestehenden Maßnahmen für den Arbeiterschutz die Arbeiter weder während ihrer Arbeitszeit noch danach erreicht hätten. Nur wenige soziale Kosten wurden demnach von den Unternehmen selbst getragen.

In der 2016 veröffentlichten „Vision 2036“ (The Vision 2016 Presidential Task Team, 2016) verspricht die Regierung Botsuanas genau gegen solche Probleme vorzugehen. Zum Mineral Sektor schreibt sie:

„**We will have a sustainable, vibrant and diversified mineral sector that is integrated into other sectors of the economy.** We will mine and beneficiate mineral resources where viable, and exploit the entire mineral value chain. We will pursue initiatives that ensure continuous social and economic activity in mining areas post mining. Technology will be used to enhance the efficiency and competitiveness of mining and beneficiation activities" (ebd, S.15)

Soziale Probleme

Die Armutsquote in Botsuana liegt bei 17,2% (Stand 2020). 3,5 % sind sehr schwer von Armut betroffen (Republic of Botswana, 2020)

Botsuana gehörte 2022 zu den 10 Ländern mit der höchsten Ungleichheit. Der aktuelle Gini-index liegt bei 54,9 (Stand 2015). Allerdings lag er 2010 noch bei 60,5. Die Senkung um 5,6 Gini-Punkten in 5 Jahren entspricht der höchsten Senkung, verglichen mit anderen Ländern der „Southern Africa Customs Union" (SACU) (THE WORLD BANK, 2022).

Nichtsdestotrotz wird häufig berichtet, dass Botsuana dem „Rohstofffluch" entgehen konnte und große Summen in die Verbesserung der Lebensstandards investiert. Ein Beispiel für so einen Bericht ist der 2013 im Spiegel veröffentlichte Artikel „Diamanten für die Armen" (DÜRR, 2013).

Ökologische Probleme

Botsuana hat mit sehr ähnlichen ökologischen Problemen wie Namibia zu kämpfen. Schwerpunkte der bereits durchgeführten Studien sind dabei vor allem Gesundheitsprobleme, Verlust der Vegetationsdecke und Luft-, Wasser-, und Bodenverschmutzung bzw. Belastung mit Schwermetallen. Weitere Auswirkungen haben die Einleitung und das Versickern von Abwässern aus Abraumhalden und die Verschlechterung der Weideflächen, verursacht durch hohe Abgasemissionen in Form von Schwefeldioxid (Department of Mines, 1995(Quelle leider nur in Zweitquelle gefunden, der ursprüngliche Bericht war für mich nicht zugänglich)).

2008 wurden in der Gegend um die Kohlemine „Morupule Colliery" nahe der Stadt Palapye die Akkumulation von Schwermetallen wie Chrom (13 ppm), Nickel (2,5ppm), Zink (16ppm) und Arsen (5ppm) festgestellt (ZHAI et al, 2008).

In einer weiteren Studie wurden in der Selebhi-Phikwe Region auf der Windseite die momentan geschlossene Kupfer-Nickel Mine 2013 erhöhte Werte von Nickel- (1,15 mg/kg), Kupfer- (2,16 mg/kg), Mangan- (3,55 mg/kg) , Cobalt-(0,22 mg/kg), Blei- (0,34 mg/kg), Zink- (0,66 mg/kg), und Eisenwerte (264 mg/kg) aufgenommen (LIKUKU et al., 2013).

Eine weitere Studie (DARKOH & ASARE, 2001) befasst sich neben sozio-ökonomischen Auswirkungen des Bergbaus vor allem mit der Luftverschmutzung durch freiwerdende Gase wie SO_2. Die Selebhi-Phikwe-Mine war 2001 die größte Quelle von industriellen Luftverschmutzern. Insgesamt wurden 46.850 kg/h SO_2 und 190 kg/h Feinstaub (Department of Mines, 1999 (Quell ebenfalls nicht zugänglich und in gleicher Studie erwähnt)). Es wurden vor allem dann kritische Verschmutzungswerte aufgezeichnet, wenn der Winde von der Abraumhalde in Richtung der nächstgelegenen Stadt wehte. Durch die Luftverschmutzung ergeben sich weitere gesundheitliche Probleme wie Husten, Asthma und Tuberkulose. In der folgenden Tabelle sind totale Anzahl und prozentualer Anteil von ambulanten Besuchen nach Diagnose in 3 besonders durch Bergbau beeinflussten Regionen aufgelistet.

Tabelle 7: Anzahl der ambulanten Besuche nach Diagnose und Bezirk, 1990, 1991 und 1996 (DARKOH & ASARE, 2001)

Table 7. Number of outpatient attendance by diagnosis and district, 1990, 1991 and 1996

Disease	Selebi-Phikwe			Francistown			Serowe/Palapye		
	1990	1991	1996	1990	1991	1996	1990	1991	1996
Tuberculosis	716 (1.7%)	715 (1.9%)	1,852 (5.9%)	1,033 (2.1%)	1238 (2.4%)	2296 (4.3%)	756 (0.8%)	796 (0.8%)	1,598 (3.4%)
Malaria (confirmed)	54 (0.1%)	80 (0.2%)	183 (0.6%)	208 (0.4%)	929 (1.8%)	895 (1.7%)	196 (0.2%)	857 (0.9%)	873 (1.9%)
Malaria (unconfirmed)	-	-	1114 (3.6%)	-	-	4,902 (9.2%)	-	-	6,492 (13.8%)
Asthma	751 (1.8%)	705 (1.9%)	1,785 (5.7%)	1,345 (2.7%)	1417 (2.7%)	2,687 (5.1%)	2371 (2.6%)	2782 (3.1%)	3,679 (7.8%)
Other Respiratory diseases	40,216 (97%)	36,108 (96%)	11,621 (37%)	47,788 (95%)	48,493 (93%)	8,926 (17%)	86,961 (96%)	86,718 (95%)	8,290 (17.6%)
Cough and Cold	-	-	14,593 (47%)	-	-	33,408 (63%)	-	-	33,635 (71.3%)
Total	41,737 (100%)	37,608 (100%)	31,148 (100%)	50,347 (100%)	52,077 (100%)	53,114 (100%)	90,284 (100%)	91,153 (100%)	47,167 (100%)

SOURCE: Central Statistics Office, Health Statistics 1990/91, 1996.

Daneben gibt es eine umfassende Tabelle zu konkreten Auswirkungen bestimmter durch den Bergbau ausgestoßenen Substanzen:

Tabelle 8: Überblick über Auswirkungen auf Gesundheit und Umwelt von wichtigen luftverschmutzenden Schadstoffen (DARKOH & ASARE, 2001)

Table 8. Some health and ecological effects of major air and eater pollutants

Pollutant	Effects on Humans	Effects on Plants	Soil Micro-organisms
Total Suspended Particulate (TSP)	Asthma, cardio-respiratory problems, increase cough and chest discomfort, increase mortality, lungs infection.	Clogs stomates, reducing photosynthesis and growth.	Deposits attached to heavy metals and radionuclides in soil; clogs soil pores; provides possible substrate for decomposers.
Sulphur Dioxide (SO_2)	Aggravates respiratory diseases, reduces lung functions, irritates eyes and respiratory tract.	Injures leaves, reduces growth of tops and roots, increases mortality.	Can inhibit nitrogen fixation in symbiotic bacteria.
Sulphate Particultes (SO_4^{2-})	Effects on human similar to SO2	Corrodes epidermis and leaf tissue, reacts with nutrients from terrestrial plants, increase acidity of water kills diatoms.	Leaches nutrients, change solubility of ions under lower pH, inhibit symbiotic nitrogen-fixing bacteria.
Fluorides (Fl)	Irritates respiratory systems, burns eyes and skin.	Injures leaves, reduces plant growth.	---
Heavy Metals (E.g. Lead, Mercury, Arsenic, Beryllium, Cadmium, Chromium)	Can cause cancer, respiratory impairment, damage to nervous system, anaemia, hyperactivity and neurobehavioral effects, blood enzyme change.	Leaf injury, reduces growth	Depresses decomposition rate by micro-organisms, may inhibit nitrification.

SOURCES: Compiled from Smith 1981; Westman and Lewis 1976; Winner et al. 1965; Dvorak and Lewis 1978; Council on Environmental Quality 1976; Westman 1985; UNEP/GEMS 1991.

Die letzte relevante Tabelle der Studie gibt einen Überblick über die produzierte Menge an Müll, aufgeschlüsselt in produzierte Abwässer und festen Müll der Selebhi-Phikwe Mine.

Tabelle 9: Von BCL erzeugte Abwässer und feste Abfälle, 1998 (DARKOH & ASARE, 2001)

Table 9. Effluent and solid wastes generated by BCL in 1998

Effluent and solid waste type	Quantity in tonnes	Quantity disposed off	Quantity reused
Fissure water*	977	400	300
Tailings water*	300	100	160
Waste rocks	345.833	345,833	None
Slag	833,394	833,394	None

SOURCE: BCL 1999.

* Tonnes per hour.

Arbeitssicherheit

Die Khoemacau-Mine berichtete 2022 von zwei Todesfällen während der Arbeit. Entsprechende Untersuchungen zu Hergang des Vorfalles standen zu Zeitpunkt der Medienveröffentlichung noch aus. Die Pressemitteilung ist unter https://www.khoemacau.com/news-media/latest-news/2022 (Stand: 10.01.2023) zu finden.

Eine weitere Mitteilung ist von 2016 und betrifft die damals noch laufende BCl – Kupfer- Mine. Der Unfall ereignete sich in einem der Minenaufzüge. Vier Arbeiter starben, weitere 6 wurden schwer verletzt. Auch hier war die genaue Ursache nicht bekannt. Der Artikel wurde unter https://www.reuters.com/article/uk-botswana-mining-accident-idUKKCN0YL18X veröffentlicht.

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Sambia

Der Abbau von Ressourcen – besonders von Kupfer – hat eine lange Geschichte, geht sie doch bis 1920, damals noch unter britischer Regierung, zurück (ZMERIP, 2022). Die Kupferreserven werden auf insgesamt 21 Mio t. geschätzt. 2020 war Sambia nach der Demokratischen Republik Kongo (DR Kongo) der zweit-größte Kupferproduzent Afrikas und der 8-größte Kupferproduzent weltweit. Neben Kupfer werden auch andere Minerale wie Kobalt, Gold, Mangan, Eisen, Smaragde und eine Reihe weiterer Edelsteine sowie Industrie- und Energieminerale abgebaut (ZEITI, 2022).

Historisch gesehen, konzentrierte sich der Abbau auf die Gegend der Copperbelt Provinz, bekannt für ihre hochwertigen Lagerstätten. Heute sind Minen auch in allen anderen 9 Provinzen Sambias verteilt. Die Hauptverteilungsgebiete liegen in der „North-Western" Provinz (oft auch als `neuer Copperbelt´ bezeichnet), der „Southern" Provinz, der „Luapula" Provinz, der „Central" Provinz und der „Eastern" Provinz (ZEITI, 2022). Eine detailliertere Karte der Minenverteilung gibt es dazu unter: https://portals.landfolio.com/zambia/.

Im Zuge der Privatisierung von Minen im Jahr 2000 wurde das ehemals halbstaatliche Unternehmen „Zambia Consolidated Copper Mines" zur Anlagegesellschaft „Zambia Consolidated Copper Mines Investment Holdings (ZCCM-IH) transformiert. ZCCM-IH behält Minderheitsanteile in den meisten großskaligen Abbauprojekten. Nichtsdestotrotz sind diese Projekte, sowie der Großteil der für den Bergbau in Aussicht stehender Grundstücke in privater Hand (ZEITI, 2022).

Neben den bereits aufgeführten Mineralen gibt es in Sambia auch Erdöl und -gasvorkommen. Stand 2020 gibt es 38 bereits abgegrenzte Flächen, die für den Abbau durch den privaten Sektor zur Verfügung stehen (ZEITI, 2022).

Sambias GDP lag 2021 bei 22,15 Milliarden US$ (retrieved from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=ZM). Die Wachstumsrate lag damit bei 3,6% im Vergleich zu 2020. Der Bergbausektor schrumpfte allerdings um 6,3%. Gründe hierfür waren vor allem exzessive Regenfälle, der Ausfall von Ausrüstung, und in manchen Minen geringere Erzgehalte. Die Produktion von Kupfer ist 2021 auf 800.696t von 837.996t im Vorjahr zurückgegangen (Bank of Zambia, 2022).

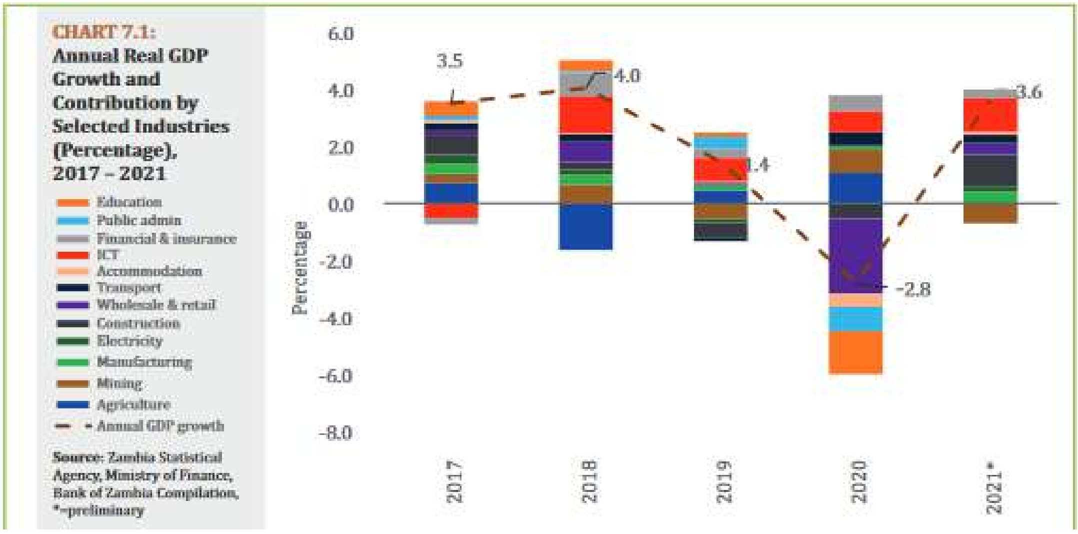

Abbildung 11: Jährliches reales GDP-Wachstum für Sambia und Beitrag ausgewählter Branchen 2017-2021 (Bank of Zambia, 2022)

2020 hat der Rohstoffsektor 11,1% zum GDP, 79,5% zu den Exporten, 31,4% zu den Staatseinnahmen und 2% zur Beschäftigung beigetragen (ZEITI, 2022):

Tabelle 10: Beitrag des Bergbausektors zur sambischen Wirtschaft (ZEITI, 2022)

Table 5: Contribution of the extractive sector to Zambia economy

	2020	2019	Var
GDP	11.1%	9.9%	1.2%
Exports	79.5%	77.0%	2.5%
Revenues	31.4%	27.8%	3.6%
Employment	2.0%	2.4%	-0.4%

Auf den folgenden Seiten sind die zusammenfassenden Tabellen aus dem Bericht von BARRY & PLAZA-TOLEDO (2022) zu den produzierten Mengen (Tabelle 11) beziehungsweise zur Übersicht über die Lage der Minen (Tabelle 12) gelistet.

Tabelle 11: Überblick über die Menge an geförderten Rohstoffen für Sambia 2014 – 2018 (BARRY & PLAZA-TOLEDO, 2022)

TABLE 1

ZAMBIA: PRODUCTION OF MINERAL COMMODITIES[1]

(Metric tons, gross weight, unless otherwise specified)

Commodity[2]		2014	2015	2016	2017	2018
METALS						
Bismuth, refinery, Bi content[3]		180	40	--	--	--
Cobalt:						
Mine, Co content[4]		2,300 [r, e]	1,700 [e]	600 [e]	990	897
Refinery, metal[5]		4,317	2,997	4,725	2,520	1,613
Copper:						
Mine, concentrates, Cu content		517,100	558,600	595,500 [r]	628,400	677,300
Refinery:						
Primary:						
Electrowon		190,000	158,700	167,300 [r]	165,700	176,800
Other		288,800	312,800	230,600 [r]	264,800	248,200
Total		478,800	471,500	397,900	430,500	425,000
Smelter, primary, includes low-grade electrowon		525,800	648,800	698,100 [r]	787,900	828,700
Gold, mine, Au content	kilograms	4,803	4,238	4,610	4,565	3,899
Iron and steel, raw steel		86,400 [r]	52,000 [r]	45,000 [r]	54,000 [e]	75,000 [e]
Manganese, mine:						
Gross weight		130,000 [e]	130,000 [e]	120,000 [e]	98,220	87,997
Mn content[6]		45,000	45,000	40,000	37,000	29,000
Silver, mine, Ag content	kilograms	15,000	15,000	15,000	15,000	15,000
INDUSTRIAL MINERALS						
Cement, hydraulic		1,900,000 [r, e]	1,800,000 [r, e]	2,000,000 [r, e]	2,210,307	2,751,073
Gemstones:						
Amethyst	kilograms	1,150,000	992,000 [r]	964,548	749,425	546,821
Beryl[6]	do.	11,000	17,000	26,000	21,000	6,600
Emerald[6]	do.	18,000	36,000	49,000	38,000	12,000
Tourmaline	do.	19,000	18,000	18,000	18,000 [e]	6,000 [e]
Lime, calcined[6]	thousand metric tons	280 [r]	280 [r]	300 [r]	310	320
Stone, crushed, limestone	do.	2,900 [e]	3,000 [e]	3,100 [e]	4,122	3,413
Sulfur, compounds, sulfuric acid:						
Gross weight		612,598 [r]	481,364 [r]	523,906 [r]	594,533	593,983
S content, 32.6% S		199,707 [r]	156,925 [r]	170,793 [r]	193,818	193,638
MINERAL FUELS AND RELATED MATERIALS						
Coal, bituminous		153,151	103,439	129,470 [r]	208,608	344,717
Petroleum, refinery	thousand 42-gallon barrels	4,825	4,431	4,500 [e]	4,000	6,800 [e]

[e]Estimated. [r]Revised. do. Ditto. -- Zero.

[1]Table includes data available through November 20, 2019. All data are reported unless otherwise noted. Estimated data are rounded to no more than three significant digits.

[2]In addition to the commodities listed, bismuth, clay, lead, palladium, platinum, pyrite ore, sand and gravel (construction), and selenium may have been produced, but available information was inadequate to make reliable estimates of output.

[3]Bismuth recovered from smoke at the Chambishi copper smelter.

[4]Estimated production of mined cobalt was revised downward based on an analysis of available information, including reports from Darton Commodities Ltd.

[5]Production reported by the Cobalt Institute (formerly Cobalt Development Institute).

44.4 [ADVANCE RELEASE] U.S. GEOLOGICAL SURVEY MINERALS YEARBOOK—2017–2018

Tabelle 12: Überblick über Minen und ihre Betreiber in Sambia 2018, sortiert nach Rohstoff (Barry & Plaza-Toledo, 2022)

TABLE 2
ZAMBIA: STRUCTURE OF THE MINERAL INDUSTRY IN 2018

(Metric tons unless otherwise specified)

Commodity	Major operating companies and major equity owners	Location of main facilities	Annual capacity
Bismuth	Chambishi Copper Smelter, Ltd. [China Nonferrous Metal Mining (Group) Co. Ltd., 60%, and Yunnan Copper Industry (Group) Co. Ltd., 40%]	Chambishi copper smelter, 75 kilometers northwest of Ndola	NA.
Cement	Dangote Industries (Zambia) Ltd. (Dangote Cement Plc, 100%)	Plant in Ndola, Copperbelt Province	1,500,000.
Do.	Lafarge Zambia Plc (Pan African Cement Ltd., 50%, and Financiere Lafarge S.A., 34%)	Chilanga II plant, about 15 kilometers south of Lusaka	830,000.
Do.	do.	Ndola, Copperbelt Province	450,000.
Do.	do.	Chilanga I plant, about 15 kilometers south of Lusaka	200,000.
Do.	Scirocco Enterprises Ltd.	About 18 kilometers southwest of Lusaka	100,000.
Do.	Zambezi Portland Cement Ltd.	Ndola, Copperbelt Province	510,000.
Coal, bituminous	Maamba Collieries Ltd. [Nava Bharat consortium, 65%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 35%]	Siankondobo coalfield, 350 kilometers south of Lusaka, Sinazongwe District	400,000.
Do.	Nkandabwe Coal Mine Ltd. [Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 100%]	Kandabwe Mine, near Sinazongwe[1]	240,000.
Copper and cobalt:			
Ore and concentrate	Lubambe Copper Mine Ltd. [EMR Capital, 80%; Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20%]	Lubambe copper mine, near Chililabombwe	2,500,000 ore, which yields about 45,000 copper in concentrate.
Do.	Jin Tuo Investments Ltd. (Jinchuan Group International Resources Co. Ltd., 100%)	Munali nickel mine,[1] about 60 kilometers south of Lusaka	1,200,000 ore, which yields about 1,700 copper and 500 cobalt coproduct.
Do.	Chibuluma Mines plc [Metorex Ltd.(Jinchuan Group International Resources Co. Ltd., 100%), 85%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 15%]	Chibuluma South Mine, about 12 kilometers west of Kitwe	600,000 ore, which yields about 19,000 copper in concentrate.
Do.	CNMC Luanshya Copper Mines PLC. [NFC Africa Mining plc, 80%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20%]	Baluba Center underground mine[1]	1,500,000 ore.
Do.	do.	Luanshya North Mine, Luanshya	4,500,000 ore.
Do.	do.	Luanshya slag recovery, Luanshya	500,000 slag, which yeilds 3,500 copper in concentrate.
Do.	Kansanshi Mining plc [First Quantum Minerals Ltd., 80.0%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20%]	Kansanshi Mine, north of Solwezi, Northwestern Province	12,000,000 sulfide ore, 8,800,000 oxide ore, 8,600,000 mixed ore.
Do.	do.	Sentinel Mine, Northwestern Province	NA.
Do.	Konkola Copper Mines plc (KCM) [Vedanta Resources plc., 80%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20%]	Chingola open pit A and Nchanga open pit, Chingola	4,500,000 ore.
Do.	do.	Nchanga underground mine, Chingola	2,800,000 ore.
Do.	do.	Konkola Mine, Chililabombwe	2,400,000 ore.
Do.	do.	Fitwaola open pit, Chingola	NA.
Do.	do.	Reprocessing material from the TD3a, the TD3b, the TD5, and the TD7 tailings dams, Chingola	NA.
Do.	Lumwana Mining Company Ltd. (Barrick Gold Corp., 100%)	Lumwana Mine (Chimiwungo and Malundwe pits), 20 kilometers west of Chingola	21,000,000 ore.

See footnotes at end of table.

TABLE 2—Continued
ZAMBIA: STRUCTURE OF THE MINERAL INDUSTRY IN 2018

(Metric tons unless otherwise specified)

Commodity	Major operating companies and major equity owners	Location of main facilities	Annual capacity
Copper and cobalt—Continued:			
Ore and concentrate—Continued	Mkushi Copper Joint Venture Ltd. (Saringa Mining Ltd., 51%, and Katanga Resources Ltd., 49%)	Mkushi heap leach	NA.
Do.	Mopani Copper Mines plc [Glencore plc, 73.1%, First Quantum Minerals Ltd., 16.9%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 10%]	Nkana Mine, includes the Central, the Mindola North, the Mindola Sub-Vertical, and the South Ore Body shafts for underground operations, and the Area A, the Area E, and the Mindola open pits, southwest of Kitwe	5,500,000 ore.
Do.	do.	Mufulira Mine	2,500,000 ore.
Do.	NFC Africa Mining plc [China Nonferrous Metal Mining (Group) Co. Ltd., 85%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 15%]	Chambishi Main Mine, 75 kilometers northwest of Ndola	2,145,000 ore, which yields about 50,000 copper in concentrate.
Do.	do.	Chambishi West Mine, 75 kilometers northwest of Ndola	990,000 ore.
Metal	Chambishi Metals Plc [Eurasian Resources Group, S.a.r.l. (ERG), 90%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 10%]	Chambishi cobalt plant, 75 kilometers northwest of Ndola	27,000 copper cathode, 5,500 cobalt metal.
Do.	Chambishi Copper Smelter Company, Ltd. [China Nonferrous Metal Mining (Group) Co. Ltd., 60%, and Yunnan Copper Industry (Group) Co. Ltd., 40%]	Chambishi copper smelter	250,000 copper anode (blister copper).
Do.	CNMC Luanshya Copper Mines PLC. (NFC Africa Mining plc, 100%)	Muliashi leach plant, Luanshya	40,000 copper cathode.
Do.	First Quantum Mining and Operations Ltd. (First Quantum Minerals Ltd., 100%)	Bwana Mkubwa solvent extraction–electrowinning plant	52,000 copper cathode.
Do.	Kansanshi Mining plc [First Quantum Minerals Ltd., 80.0%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20%]	Kansanshi smelter, Northwestern Province	340,000 copper cathode.
Do.	Konkola Copper Mines plc [Vedanta Resources plc, 79.4%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20.6%]	Nchanga tailings leach plant at Chingola	80,000 copper cathode.
Do.	do.	Nchanga copper smelter, Chingola	311,000 copper anode (blister copper), 3,000 copper-cobalt alloy.
Do.	do.	Nkana copper refinery, Kitwe	300,000 copper cathode.
Do.	Mopani Copper Mines plc [Glencore plc; 73.1%, First Quantum Minerals Ltd., 16.9%; Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 10%]	Mufulira West heap-leach facility	NA.
Do.	do.	Mufulira (ISASMELT) smelter	200,000 copper anode.
Do.	do.	Mufulira refinery	275,000 copper cathode.
Do.	do.	Nkana solvent extraction plant, southwest of Kitwe	15,000 copper cathode.
Do.	do.	Nkana cobalt plant, southwest of Kitwe[1]	2,800 cobalt metal.
Do.	Sable Zinc Kabwe Ltd. (Glencore plc, 100%)	Sable copper leach and electrowinning plant[1] at Kabwe	14,000 copper cathode, 600 cobalt carbonate.
Do.	Sino-Metals Leach Zambia Ltd. [China Nonferrous Metals Mining (Group) Co. Ltd., Sino-Africa Mining Investments Ltd., NFC Africa Mining plc, China Hainan Construction Co. Ltd.]	Chambishi	8,000 copper cathode.
Do.	do.	Muambashi Mine, Kalulushi, Copperbelt	600,000.

See footnotes at end of table.

TABLE 2—Continued
ZAMBIA: STRUCTURE OF THE MINERAL INDUSTRY IN 2018

(Metric tons unless otherwise specified)

Commodity		Major operating companies and major equity owners	Location of main facilities	Annual capacity
Gemstones:				
Amethyst		Kariba Minerals Ltd. (Gemfields PLC, 50%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 50%)	Kariba Mine, Mapatizya area, Kolomo District, Southern Province	1,100.
Beryl and emerald	kilograms	Kagem Mining Ltd. (Hagura Mining Ltd. (Gemfields PLC, 100%), 75%, and Government of Zambia, 25%)	Kagem Mine, Ndola District, Copperbelt Province	6,600.
Tourmaline	do.	Artisanal miners	Various locations	NA.
Gold, Au content of ore	do.	do.	Various locations including: Luano District, Central Province; Mumbwa District, Central Province; Petauke District, Eastern Province; Rufunsa District, Lusaka Province; and Vubwi District, Eastern Province	NA.
Do.		Kansanshi Mining plc [First Quantum Minerals Ltd., 80.0%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20%]	Kansanshi Mine, north of Solwezi, Northwestern Province	5,300.
Iron and steel, crude steel		Universal Mining and Chemical Industries Ltd. (Trade Kings Group)	Kafue	100,000.
Lead, metal, secondary		Pagrik Zambia Ltd.	Lusaka	1,000.
Lime, quicklime		Ndola Lime Company Ltd. [Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 100%]	Ndola	300,000.[2]
Do.		Neelkanth Lime Ltd.	NA	144,000.[3]
Manganese		Kaboko Mining Ltd.	Mansa area, Luapula Province	120,000.
Do.		Primarily small-scale miners	Mansa area, Luapula Province, and Mkushi area, Central Province	120,000.
Nickel, Ni content of ore		Jin Tuo Investments Ltd. (Jinchuan Group International Resources Co. Ltd., 100%)	Munali Mine, about 60 kilometers south of Lusaka[1, 4]	10,500.
Petroleum, refined	42-gallon barrels	Indeni Petroleum Refinery Ltd. (Government, 100%)	Indeni refinery at Ndola	10,000,000.
Sulfur:				
Pyrite ore, gross weight		Konkola Copper Mines plc [Vedanta Resources plc, 79.4%, and Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM–IH), 20.6%]	Nampundwe Mine, 48 kilometers west of Lusaka	300,000.
Sulfuric acid		do.	Nchanga acid plant	675,000.
Do.		Chambishi Copper Smelter Company, Ltd. [China Nonferrous Metal Mining (Group) Co. Ltd., 60%, and Yunnan Copper Industry (Group) Co. Ltd., 40%]	Chambishi copper smelter, 75 kilometers northwest of Ndola	600,000.
Do.		Kansanshi Mining plc [First Quantum Minerals Ltd., 80.0%, and Zambia Consolidated Copper Mines Investments	Kansanshi smelter, north of Solwezi, Northwestern Province	NA.
Do.		Holdings Plc (ZCCM–IH), 20%]	Kansanshi smelter, north of Solwezi	1,000,000.

Do., do. Ditto. NA Not available.

[1]Operations suspended. Facility on care-and-maintenance status.

[2]Plant had the capacity to produce up to 5,000 metric tons per year of hydrated lime (slaked) from quicklime.

[3]Plant had the capacity to produce up to 27,000 metric tons per year of hydrated lime.

[4]Operated by Mabiza Resources Ltd. (Consolidated Nickel Mines Ltd., 100%) through a lease agreement with listed owners.

1. Rohstoffe

Ergänzend zu den umfangreichen Auflistungen aus Barry & Plaza-Toledo (2022) finden sich im Bericht der „Zambia Extractive Industries Transparency Initiative (ZEITI)“ (2022) aktuellere Erhebungen zu Abbaumengen und vor allem Produktionswerten:

Kupfer- und Goldabbau

Tabelle 13: Produktionsmenge von Gold und Kupfer 2020 für Sambia (ZEITI, 2022); Zu beachten ist, dass die angegebene Menge für die Kupferproduktion leicht von der Angabe der Bank of Zambia (2022) abweicht.

Table 41: Production of base and precious metals 2020

Commodity	Unit	Production Quantity	Unit Value (US $) (*)	Production Value (US $ million)
Copper	Metric tonne (Mt)	837,003.6	6,168.47	5,163.03
Gold	Kg	3,672	56,692	208.17

(*) The value of production has been calculated on the basis of the average LME monthly prices as provided by MMMD

Tabelle 14: Übersicht über die Produktionsmenge von Gold und Kupfer nach Unternehmen 2020 für Sambia (ZEITI, 2022)

Table 42: Breakdown by company of the production of base and precious metals 2020

Commodity	Company	Unit	Production Quantity	Production Value (US $ million)
Copper	KALUMBILA MINERALS LIMITED	Metric tonne (MT)	251,175.36	1,549.37
	KANSANSHI MINING PLC	Metric tonne (MT)	221,487.44	1,366.24
	LUMWANA MINING COMPANY LIMITED	Metric tonne (MT)	124,969.86	770.87
	KONKOLA COPPER MINES PLC	Metric tonne (MT)	63,027.71	388.78
	LUANSHYA COPPER MINE	Metric tonne (MT)	56,612.06	349.21
	NFC AFRICA MINING PLC	Metric tonne (MT)	48,883.47	301.54
	MOPANI COPPER MINES PLC	Metric tonne (MT)	34,479.89	212.69
	LUBAMBE COPPER MINE LTD	Metric tonne (MT)	21,062.13	129.92
	SINO METALS	Metric tonne (MT)	13,087.30	80.73
	CHIBULUMA MINES PLC	Metric tonne (MT)	2,218.38	13.68
Gold	KANSANSHI MINING PLC	Kg	3,578.81	202.89
	ZAMBIA GOLD COMPANY LTD	Kg	93.6	5.31

(*) the production of CCS consists of toll treated concentrates already declared as production by other operations

Abbau von Industriemineralen

Tabelle 15: Produktionsmenge von verschiedenen Industriemineralen 2020 für Sambia (ZEITI, 2022);

Table 43: Production of industrial metals 2020

Commodity	Unit	Production Quantity	Unit Value (US $)	Production Value (US $ million)
Coal (***)	Metric tonne (Mt)	448,821.4	53.76	23.99
Emerald and Beryl (****)	Kg	9,783.41		10.9
Mn Manganese Ores (*)	Metric tonne (Mt)	28,409	1,693.32	48.1
Cobalt (*)	Metric tonne (Mt)	316	33,985.80	10.7
Cement	Metric Tonnes	2, 796,896.35	124	346.82

Tabelle 16: Übersicht über die Produktionsmenge von verschiedenen Industriemineralen nach Unternehmen 2020 für Sambia (ZEITI, 2022)

Table 44: Breakdown by company of the production of industrial metals 2020

Commodity	Company	Unit	Production Quantity	Unit Value (US $)	Production Value (US $ million)
Coal	COLLUM COAL MINING INDUSTRIES LTD	Metric tonne (MT)	265,677	53.76	14.28
	MAAMBA COLLIERIES LIMITED	Metric tonne (MT)	183,144	53.76	9.85
Emerald and Beryl	Grizzly Mining	Kg	7,653.24	N/A	N/A
	Kagem Mining Limited	Kg	2,130.17	N/A	N/A
Mn Manganese Ores	Champion Minerals	Metric tonne (Mt)	950	1,693	1.61
	SAN HE (ZAMBIA) LIMITED	Metric tonne (Mt)	9,157	1,693	15.51
	DANTONG Industries Corp	Metric tonne (Mt)	2400	1,693	4.06
	Other	Metric tonne (Mt)	15,902	1,693	26.93
Cement	Lafarge	Metric tonne (MT)	816,014.00	124	96.45
	Dangote	Metric tonne (MT)	777,803.00	124	82.96
	Mphande limestone limited	Metric tonne (MT)	669,064.00	124	56.38
	Zambezi Portland	Metric tonne (MT)	454,667.26	124	5.20
	Baudot	Metric tonne (MT)	41,960.61	124	4.64
	Scirrocco	Metric tonne (MT)	37,387.48	124	96.45
Cobalt	Konkola Copper Mines Plc	Metric tonne (MT)	94	32,233.99	375,205.65

Für die Minen, die anteilig zu der „Zambia Consolidated Copper Mines Investment Holdings (ZCCM-IH)“ gehören liegt ein Jahresbericht, ebenfalls für das Jahr 2020 vor. Daraus gehen folgende Gewinne bzw. Verluste hervor:

Bei den Angaben handelt es sich um die Nettoumsätze nach Abzug von Steuern. Absolute Gewinne sind im Originalbericht ebenfalls zu finden. Die Umsätze sind in ZWA und $US angegeben. Lag keine Umrechnung im Bericht vor, wurde der entsprechende Gegenwert in $US mit Hilfe der Seite https://www.finanzen.net/waehrungsrechner/kwacha_us-dollar abgeschätzt.

Tabelle 17: Übersicht zu Gewinnen von verschiedenen Unternehmen im Bergbausektor 2022 für Sambia (ZCCM-IH, 2022)

Firma	**Gewinn nach ZCCM-IH, 2022**
Zambia Gold Company Limited	ZMW 32,02mio (entspricht US$ 1,68mio; Stand 04.02.2023)
Ndola Lime Company Limited ➔ Insolvenzerklärung am 31.08.2020	ZMW 1,152mio (entspricht US$ 0,060 mio; Stand 04.02.2023)
Limestone Resources Limited ➔ Übernahme von Ndola Lime Company am 01.09.2020	Verlust von ZMW 3,7 mio (entspricht US$ 0,19 mio; Stand 04.02.2023)
Kariba Minerals ➔ Abbau von Amethysten	Verlust von ZMW 11,19 mio (entspricht US$ 0,59 mio; Stand 04.02.2023)
Kabundi Resources Limited ➔ Abbau von Manganerzen	Verlust von ZMW 958.000 (entspricht US$ 50.000; Stand 04.02.2023)
Maamba Collieries Limited	ZMW 1.466,08 mio; US$ 78.69 mio
Konkola Copper Mines	k.A.
Kansanshi Mining PCL	ZMW 4.274,67 mio; US$ 229,45 mio
Consolidated Gold Company of Zambia Limited	Verlust von ZMW 19,16 mio (entspricht US$ 1,00 mio; Stand 04.02.2023)
Copperbelt Energy Corporation Plc	ZMW 104,5 mio; US$ 5,61 mio
Lubambe Copper Mine Limited	Verlust von ZMW 1.580,03 mio; US$ 28,34
CNMC Luanshya Copper Mines Plc	ZMW 784,97 mio; US$ 42,13 mio
Mopani Copper Mines Plc	Hier wurde ich aus folgender Formulierung nicht schlau, ob das Unternehmen nun insgesamt Gewinn oder Verlust gemacht hat: “During the financial year to 31 December 2020, Mopani Copper Mines (MCM) recorded net revenue of ZMW4.93 billion (US$ 714.44 million. The net loss for the period under review was ZMW9.31 billion (US$ 474.56 million).” (S.21)
NFC Africa Mining Plc	ZMW 171,48 mio; US$ 19,30 mio
Chibuluma Mines Plc	Betrieb derzeit unter “care and maintainance”
Chambishi Metals Plc	Betrieb derzeit unter “care and maintainance”

2. Ökologische und soziale Auswirkungen

Soziale Probleme

Table 1	2021
Population, million	18.9
GDP, current US$ billion	19.3
GDP per capita, current US$	1019.1
International poverty rate ($2.15)[a]	61.4
Lower middle-income poverty rate ($3.65)[a]	77.5
Upper middle-income poverty rate ($6.85)[a]	90.7
Gini index[a]	57.1
School enrollment, primary (% gross)[b]	98.7
Life expectancy at birth, years[b]	64.2
Total GHG emissions (mtCO2e)	93.1

Source: WDI, Macro Poverty Outlook, and official data.
a/ Most recent value (2015), 2017 PPPs.
b/ WDI for School enrollment (2017); Life expectancy (2020).

Abbildung 12: Überblick über die wichtigsten armutbeschreibenden Parameter in Sambia (World Bank Group, 2022).

In Folge zahlreicher sozialer Krisen wie der Covid-19-Pandemie oder des russischen Angriffskrieges auf die Ukraine stieg die Armutsrate in Sambia. Damit rutschte Sambia erstmals seit 2011 wieder aus der „Middle-income“- in die „Low-income“- Kategorie (World Bank Group, 2022).

Der Gini -Index als Richtwert für die Einkommensungleichheit in Zambia liegt bei einem Wert von 57,1% (Stand 2015 aus World Bank, 2023) und ist damit nur minimal niedriger als der in Namibia.

Arbeitssicherheit

Im Folgenden sind einige Meldungen zu Unfall- und Todesfällen chronologisch aufgelistet:

Juni 2018: Nach einem Kollaps einer Mine in der Stadt Kitwe sind 10 Personen gestorben. Mindestens 10 weitere wurden verletzt. Bei der Mine handelte es sich um die Abraumhalde einer nahe gelegenen Kupfermine. Solche illegalen Minen sind weit verbreitet und ähnliche Unfälle haben sich bereits in den vorherigen Jahren ereignet. https://www.ctif.org/news/lethal-accidents-common-zambia-copper-mines-10-dead-and-least-10-injured-illegal-waste

November 2019: In der Nacht vom 14.09.2019 kam es in der „Nchanga-Mine“ der „Konkola Copper Mines“ zu einem Zwischenfall, bei dem Schwefeldioxid aus der Schwefelbrennerkomponente der Säureanlage getreten ist. In Folge wurden über 200 Schüler der nahe gelegenen „Nchanga Trust Secondary school“ und 43 Arbeiter ins Krankenhaus in Chingola eingewiesen. 53 Arbeiter wurden wegen Überlastung ins Krankenhaus in Chililabombwe gebracht. Es gab keine Todesfälle. https://www.business-humanrights.org/en/latest-news/zambia-mines-urged-to-ensure-safety-of-workers-and-communities-after-sulphur-dioxide-leak-and-mining-plant/

https://www.business-humanrights.org/en/latest-news/zambia-vedanta-says-that-it-has-not-had-access-to-cite-of-sulphur-dioxide-leak-incident-for-6-months/

Jahr 2021: Insgesamt wurden 11 Todesfälle festgestellt. 10 davon in Minen in chinesischem Besitz. https://www.lusakatimes.com/2022/01/08/10-of-the-11-minie/

März 2022: Ein Arbeiter der „Zambia`s Mopani Copper Mines“ starb nach einem Sturz durch das Dach eines Lagerschuppens für Kupferkonzentrat. Es war bereits der zweite tödliche Unfall in 3 Tagen. https://www.mining.com/web/another-accident-disrupts-zambias-mopani-copper-mines/

August, 2022: Der Bergbausektor in Sambia verzeichnete bis zum 31. August 14 Todesfälle und 35 meldepflichtige oder gefährliche Unfälle. Die Zahl lag damit höher als im gleichen Zeitraum für 2021. https://frontlineszambia.com/archives/39751

Dezember, 2022: Mehr als 80 Bergleute aus der „North-Western-Province“ sollen aus medizinischen Gründen von der Arbeit entlassen werden, nachdem sie durch das Bedienen großer Maschinen unter Rückenschmerzen leiden. Der stellvertretende Vorsitzende des Zambia National Congress of Trade Union (ZCTU), Joseph Chewe, bestätigt zudem, dass im vorausgegangenen Jahr etwa 80 Personen aufgrund von Arbeitsunfällen entlassen worden sind. https://www.lusakatimes.com/2022/12/22/80-miners-risk-losing-their-jobs-in-northwestern-province/

Januar, 2023: 3 Personen starben bei einem Minenunfall in der „Kasenga B Area“ im „Chongwe District“, Lusaka Provinz nach einem unterirdischem Steinrutsch. 2 weitere Personen wurden verletzt. https://zambianeye.com/3-die-in-a-mine-accident/

Februar 2023: Ein Arbeiter der „Trident Operations“ der Firma „First Quantum Minerals Ltd“ starb bei einem Verkehrsunfall zwischen einem Muldenkipper und einem Kleinfahrzeug. Ein weiterer wurde verletzt. https://www.reuters.com/world/africa/first-quantum-minerals-worker-dies-trident-operations-zambia-2023-02-02/

Insgesamt wird immer wieder von illegalen Abbauaktivitäten berichtet. Als Beispiel ist hier eine Pressemitteilung der „Zambia Chamber of Mines“ anzuführen. Aus ihr geht hervor, dass Hunderte Zivilisten, einige davon erst 10 Jahre alt, in die Tagebaue der „CNMC Luanshya Copper Mines“, namentlich „Roan Extension West“ und „Baluba East“, eindringen und illegal Rohstoffe abbauen. Aufgrund von früheren unterirdischen Abbauarbeiten seien diese strukturell empfindlich. Die Gefahr bestünde, dass der Boden währen der unprofessionell angelegten Grabungen einstürze. Neben der Gefahr für die dort aktiven Menschen, verkürze der illegale Bergbaubetrieb die Lebensdauer des Bergwerkes und erhöhe die Sanierungskosten für die Schließung der Mine, wie sie nach dem „environment act“ erforderlich sei (Zambia Chamber of Mines, 2021).

Ökologische Probleme

Bei Beginn des Rohstoffabbaus in Sambia lagen bis zur sambischen Unabhängigkeitserklärung im Jahr 1964 die Rechte in der Hand der „British South African Company (BSAC). Die Rechte waren allein an Gewinnmaximierung ausgelegt und berücksichtigten keinerlei abbaubedingte Umweltbeeinträchtigungen. In Folge entstanden mehrere unbeaufsichtigte Abraumhalden, die eine Quelle für zahlreiche Umweltverschmutzungen darstellen und insbesondere die in der Nähe lebenden Gemeinden schädigen. Um diesen Umweltschäden entsprechend zu begegnen, gründete die Regierung Sambias mit Finanzhilfen der „World Bank“ das „Zambia Mining Environmental Remediation and Improvement Project. Dieses soll die die Umwelt- und Gesundheitsschäden in kritisch verschmutzten Bergbaugebieten, wie nahe den Städten Chingola, Kabwe, Kitwe und Mufulira, vermindern (ZMERIP, 2022). Das Projekt besteht aus 3 großen Säulen:

1) Sanierung der kontaminierten Hotspots und Verbesserung der Umweltinfrastruktur. Hierbei stehen besonders folgende Projekte im Fokus:

- Sanierung der kontaminierten Hotspots und Verbesserung der Umweltinfrastruktur in Kabwe
- Sanierung der Abraumhalden und Schließung der Minen in der Copperbelt-Provinz

2) Stärkung der institutionellen Kapazitäten für Umweltmanagement und Einhaltung der Vorschriften

3) Verringerung der umweltbedingten Gesundheitsrisiken durch lokale Maßnahmen (ZMERIP, 2022).

Eine Studie beschäftigt sich mit den Auswirkungen und den sozialen Kosten der Bleiverschmutzung des ehemaligen Minenstandortes in Kabwe, die durch zurückgelassene Bergbauabfälle in der Nähe von Wohngebieten verursacht wurde. Unter den Annahmen, dass Bleiverschmutzungen zu mehreren tödlichen Krankheiten führen und die Exposition mit Blei in der frühen Kindheit einen lebenslangen IQ-Verlust verursacht, berechnet sie die sozialen Kosten auf US$ 224-593 mio (YAMADA et al, 2022).

Eine weitere Studie befasst sich mit der Charakterisierung von Boden und Schwermetallen auf sambischen Abraumhalden. Diese untersuchte drei verschiedene Bergbauhalden in der Copperbelt Provinz. Leider war nur der „Abstract“ verfügbar. Aus diesem geht hervor, dass die vorläufigen Ergebnisse Konzentrationsbereiche von 42 ppm bis 164,88 ppm für Kupfer, 0,02 ppm bis 7,18 ppm für Eisen, 0,12 ppm bis 9,24 ppm für Mangan und 0,06 ppm bis 84,2 ppm für Zink zeigten. Die festgestellten Schwermetallkonzentrationen unterschieden sich von denen anderer Studien (LOGAN et al., 2023).

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