Developing a conceptual framework concerning water infrastructure and technology

Multifunctional Strategies for Resilient Water Security in the Eastern Erongo Region (MultiReWaS)

In the initial phase of the MultiReWaS project (01.12.2021 to 28.02.2023) the Research Institute for Water Management and Climate Future at RWTH Aachen e.V. (FiW) and TERRA URBANA Umlandentwicklungsgesellschaft mbH (TUR) as the joint coordinator, in cooperation with the Namibia University of Science and technology (NUST) developed a sustainable region-specific concept that takes into account the cultural, technical and economic requirements for improving access to and use of the highly limited water resources in the eastern Erongo region of Namibia. Embedded in a socio-ecological systems (SES) approach, the project partners based their concept on their theoretical-practical and empirical findings, a comprehensive water audit and the accompanying stakeholder dialogue. The research project focused on the cities of Karibib and Omaruru and the village of Otjimbingwe.

As part of the theory formation phase of the MultiReWaS project, a comprehensive literature review was conducted to collect relevant scientific research and previous projects on context-adapted solutions to address water insecurity in Namibia, with a focus on the Eastern Erongo region. Various scientific papers, reports and projects on water insecurity and possible solutions in the region were searched and analysed.

Based on the findings of this literature review, the project team has identified critical success factors. To ensure the credibility and accuracy of the results, the research outcomes have been verified in close collaboration with the Namibian University of Science and Technology (NUST). The following lessons learned were derived from the former projects in the Erongo region:

- Avoid knowledge loss due to fluctuation of team members by selecting responsible individuals based on motivation rather than other criteria.
- Performance of wide-ranging technical and managerial capacity development which takes account of social skills and is supported by relevant Namibian institutions.
- Performance of a systematic assessment of water supply, sanitation, water treatment and water reuse infrastructure during project planning is essential to close data gaps.
- Focus on community-based approaches can be helpful to lower costs, raise resilience and support the transfer of knowledge and the attendance of training.

To assess the existing policies and strategies implemented by Namibian institutions to address water security challenges, close collaboration with Namibian partners and a comprehensive institutional analysis was conducted.

Water related goals and strategies were found in general and specifically water-related policies on the transnational, national, regional and local level. The following important general transnational and national policies were identified:

- the National Development Plan 5,
- the Harambee Prosperity Plan II,
- the Swapo Party Election Manifesto,

- the Strategic Plan of the Ministry of Agriculture, Water and Land Reform (2017/18 - 2021/22),
- the SADC Regional Water Strategy,
- the Vision 2030.

In most of the general transnational and national policies, the availability of water was identified as essential for the achievement of overarching goals such as economic development or social progress. At the regional and local level, the strategic plans of the Erongo Region and the Karibib Municipality were considered relevant. As the impacts of climate change on water security become more severe, policies such as the National Climate Change Policy of 2011, the NDC Implementation Strategy and Action Plan 2021-2030, and the Disaster Risk Management Act of 2012 were also examined. Finally, various water-related national policies were identified and reviewed for water-related objectives and strategies:

- the Namibia Water Sector Support Program 2020-2025
- the water supply and sanitation policy of 2008
- the water resources management act of 2013
- the Integrated Water resources Management Plan 2010
- the Water Policy for Namibia 200
- the Namibia National Sanitation Strategy 2010/11-2014/15

The identified water-related objectives and strategies were analysed quantitatively by counting their mention in the policies studied (Figure 1).

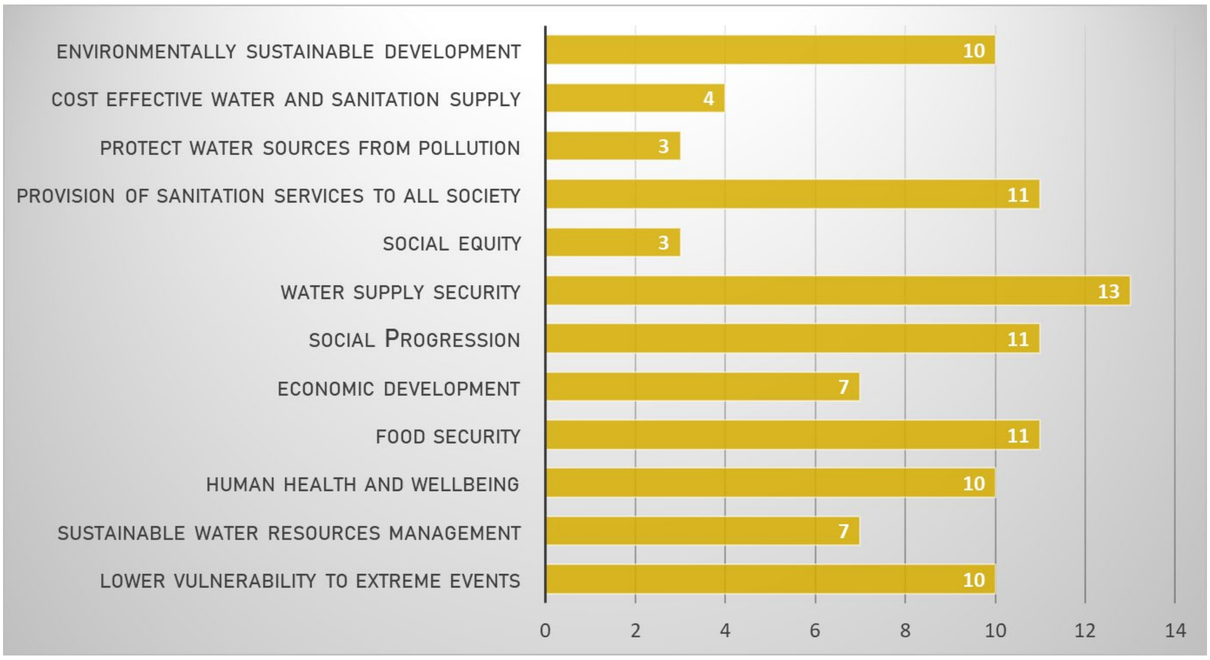

Figure 1: Water-related goals mentioned within the examined policies and number of mentions.

Strategies mentioned to address water security challenges were categorized as water demand and water supply management challenges. Strategies focussing on water demand management included measures such as conservation-oriented pricing, recycling and reuse of water, increased water use efficiency or monitoring of water use. The most frequently mentioned strategy in this context was awareness raising, education and training of Namibia residents. Strategies focussing on water supply management included the extension and updating of purification plants, the development of aquifers, establishment of rain harvest and storage facilities, desalination and the artificial replenishment of groundwater tables. The most mentioned measure was the refurbishment and establishment of modern infrastructure, such as the updating of pipe and sewer systems. Also, regarding the strategies, the Strategic Plan of Erongo Regional Council and Karibib Municipality contained only few water-related strategies. The mentioned strategies mostly deal with the maintenance and refurbishment of infrastructure and the provision of sanitation systems. There is little focus on water demand management within regional and local policies which also applies for the NDP 5 and the Harambee Prosperity Plan. However, the importance of water demand management is highlighted within the Vision 2030 and several water-related policies. Overall, there was a difference in the focus of certain strategies between general and water-related policies. While water-related policies focused more on water demand management, general policies mainly focused on strategies aiming to increase water supply. Considering the expertise of the MultiReWaS project consortium the policies were especially screened for goals and strategies related to the reuse of water, or closed loop systems. Since recycling and reuse of water was mentioned within 50 % of the examined policies it can be considered a political strategy of major importance.

Understanding the existing legal regulations and the organizational setup of the water sector was crucial. In close cooperation with the Namibian partners and through the comprehensive literature review, identified policies were screened for strategies and goals with relation to water security and the findings were quantitatively and qualitatively analysed. The results of the research were verified by the Namibian subcontractor NUST and identified key stakeholders within expert interviews and stakeholder workshops. The confirmed information derived from the policy analysis was considered in the development of the implementation concept to ensure that activities planned in the course of the MultiReWaS project are politically supported.

The analysis of the legal framework and organisational structure of the water industry was an iterative process which started with a comprehensive literature research. In the course of the literature research important institutions, legal regulations and relevant standards were identified. Special focus was put on the nature of Namibia's decentralised government system which was depicted within a graphical overview and verified by the Namibian subcontractors. Based on the results the project consortium was able to derive challenges for the implementation of technical solutions for increased water security connected to Namibia's decentralised government system. In a next step key institutions of the water sector and their corresponding responsibilities were identified. Main information sources were the water resources management act of 2013 and the water supply and sanitation policy of 2008 in which key institutions are legally appointed. However, since the water resources management act is not constituted up to today intensive exchanges with responsible actors were necessary to get a realistic picture of Namibia's water supply sector. Lastly, important standards and regulations relevant for the eligible technological solutions were identified in close cooperation with the responsible executive authority, the Ministry of Agriculture, Water and Land Reform.

Within the overview Namibia's decentralised government system is depicted which is divided into the national, regional and local level. Several challenges connected to the decentralised government system that could possibly influence the planned implementation concept were derived from the literature:

- Weak institutional/human capital capacities and performance at the regional and local level
- Unclear responsibilities and poor coordination among stakeholders
- Limited fiscal decentralisation
- Prevailing deconcentration instead of decentralisation

Overall, the decentralisation process is not completed up to today. Few ministries have started to transfer power and responsibilities to regional and local authorities. The responsibility of rural water supply and sanitation coordination was delegated to local authorities. However, due to limited fiscal decentralisation the majority of intergovernmental transfers are quickly used up for administrative purposes, such as salaries leaving little room for tackling problems connected to water supply.

Namibia's water supply is mainly regulated by the water resources act of 2013 and the water supply and sanitation control policy of 2008. Within these legal regulations important institutions of Namibia's water supply sector are appointed (Figure 1). The institutions found within the regulations were presented to experts of the water sector within the first stakeholder workshop of MultiReWaS. At this occasion important institutions were added like the National Planning Commission, the Ministry of Urban and Rural Development or the technical committee of experts. As a result of comprehensive literature research and verification rounds with key stakeholders a final framework was developed which contains key institutions and their responsibilities and relationships (see following table).

Institutions	Responsibilities
NamWater	Bulk water supply, development and implementation of water schemes
MAWLR – Directorate of Water Resources Management	Overall water resource inventory, monitoring, control, regulation and management
MAWLR – Directorate of Water Supply and Sanitation control	Coordination of implementation of water supply and sanitation control in urbanised areas and rural settlements
Local and Regional Authorities	Water supply and sanitation control in urban and rural areas - if necessary, infrastructure cannot be afforded NamWater jumps in
MAWLR – Basin Support Coordinator	Overall Coordination of Basin Management Committees
MAWLR – Basin Support Officer	Local link between MAWLR and Basin Management Committees
Basin Management Committees	Advisory role on matters of protection, development, conservation management and control of the respective basin’s water resources
Water Point Committees	Management and control of water supply the at a specified water point/rural water supply scheme or part thereof
Water Regulator	Tariff Setting, Determination of fees and charges
Water Advisory Council	Advisory role on political and institutional developments

As for legal standards the Code of Practice for wastewater reuse was identified as highly relevant. It contains regulations and standards for waste water treatment technologies and parameters of water quality that need to be fulfilled for the reuse of treated wastewater. Within the document different utilisation options like industrial or agricultural use are discussed. During exchanges with Namibian experts, it became clear that the Code of Practice only becomes legally binding with the constitution of the water resources act of 2013. Until then the water act constituted in 1956 applies. However, many municipalities that perform water reuse are already complying to the new standards.

Embedded in the SES approach, the empirical phase of the MultiReWaS project was based on a stakeholder dialogue and a water audit.

Stakeholder Dialogue

The stakeholder dialogue served to identify the challenges and the appropriate solution strategies in relation to water security. Through the continuous and iterative exchange with different groups of actors, assessments of the relevant stakeholders were obtained, evaluated and compared with each other. In this way, a solid network could be established and so-called "change agents" and "multipliers" could quickly be identified and integrated into the further course of the project. The identification and selection of key actors and decision-makers at regional and local level was done through "influence and power mapping" within the SES approach and through the network of the NUST. Actors from relevant ministries (e.g. MAWLR), sectoral administration (water, agriculture, environment and health, e.g. NamWater), but also formal and informal authorities, i.e. water committees, NGOs, as well as private and academic sector actors were considered.
Based on the results from the SES approach and the continuous the acquisition of knowledge during the theoretical and empirical research, an appropriate "toolbox" (the MultiReWaS approach) with approaches to improve access and utilization of safe, sustainable water resources could be developed and reviewed with regard to stakeholder needs and the hydrological situation.

Water Audit

The project area is situated in a challenging environment with a transition from savannah to dry savannah and Namibia desert. The region experiences very low rainfall, ranging from 100 to 300 millimeters annually, and has high evaporation rates, reaching approximately 3000 millimeters per year. These climatic conditions create a condition of extreme water stress, making water availability a critical concern in the area.

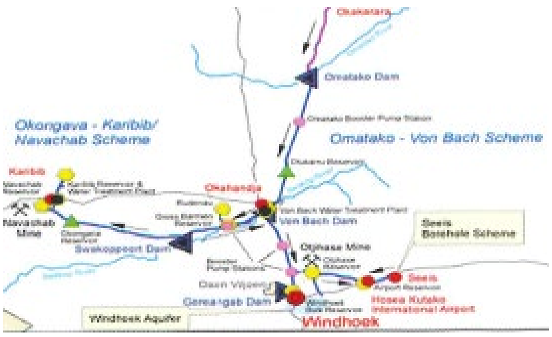

Figure 1: Left: Bulk water distribution system Karibib (source: Groundwater in Namibia, 2020) right: water works Karibib, sedimentation and filtration basins (Foto FiW)

Karibib town relies almost entirely on bulk water supply from the Swakop river dam reservoir, making up nearly 100% of its water source. The bulk water undergoes treatment, which includes processes like flocculation, sedimentation, and filtration, in a water works located at the southern part of the town. Chlorination is then carried out before the water is transferred to a large storage and equalization tank. From this tank, the water is distributed to the municipality to meet the town's water demands.
The estimated monthly water consumption in Karibib ranges between 30,000 and 58,000 m³/month; approximately amounting to 423,000 m³/annually. This calculation includes water consumption recorded by normal meters and prepaid meters.
Additionally, the Navchab mine, along with a new greenhouse area in the west of Karibib, receives semi-purified water from the bulk water supply of the Swakop river dam reservoir.
The water supply of Omaruru is entirely dependent on the water that is infiltrated into the sand bed from the Omaruru river during the short rain season. As the surrounding area has only a small layer of porous material above the rocky underground, the rainwater is mostly collected in the sediment of the river bed. This natural infiltration process is crucial for replenishing the water resources in the region.
To access this water for municipal water supply, wells have been installed in the ephemeral river bed of the Omaruru river (see figure 2). During these periods of flow, water can be extracted from the riverbed through the wells, and it serves as the primary source of water for the town.
In recent years, the water distribution system in Omaruru has been enhanced with the addition of a new concrete tank for the majority of houses and a new steel tank for the informal settlement in the southwestern surroundings.

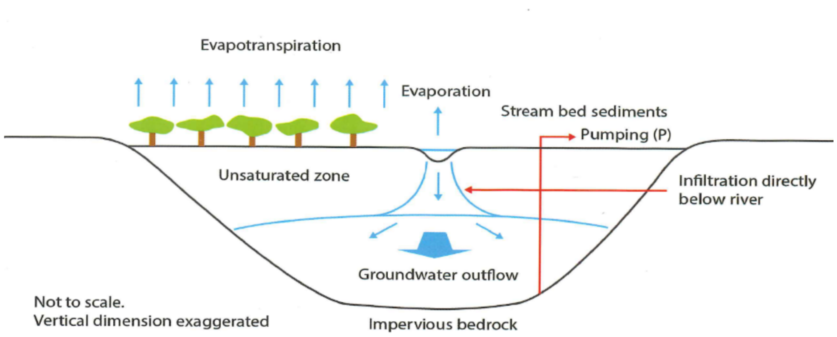

Figure 2: Principle of water accumulation in river bed sediments and view to the well in the middle of Omaruru river (source: Report Groundwater in Namibia, foto FiW)

The water demand for Omaruru consists of the consumption and system losses, both together has an amount of approx. 884.000 m³/a. The sustainable water extraction for Omaruru including one year drought was calculated by 1.250.000 m³/a. That means in case of full exploitation of all rights the municipality Omaruru has to save approx. 294.000 m³/a by different measures to avoid over exploitation of their groundwater resources.

A 50 km long above-ground pipeline conveys water from the water treatment plant in Karibib to Otjimbingwe. This water supplements the partly ground-water-based water supply in Otjimbingwe and the surrounding area. However, the above-ground installation of the pipeline poses a risk of water quality degradation due to bacterial growth caused by high water temperatures. Additionally, a significant amount of energy is required to pump the water over the mountains to reach consumers in Otjimbingwe. Prior to the construction of this pipeline, Otjimbingwe relied solely on water from wells in the Omusema river bed near the Swakop river (see figure 3).

Figure 3: Wells partly out of operation in the Omusema river bed (Foto FiW)

To address the water situation, residents in Otjimbingwe and the responsible engineer in Omaruru have proposed the idea of increasing subsurface storage capacity by building subsurface dams in the riverbed constrictions. Both the Swakop river near Otjimbingwe and the Omaruru river at the road bridge in Omaruru have natural constrictions created by rocks in the underground.

Estimating the amount of wastewater generated in the project area is challenging due to the lack of measurements. However, based on experiences in other dry countries, it is estimated that only a portion of the consumed water, typically between 50% to 70%, reaches the existing wastewater treatment plants. This suggests that a significant amount of wastewater remains uncollected and untreated, particularly in informal settlements.
The three municipalities or towns in the project area have wastewater treatment systems in place, but they vary significantly in their conditions. All three systems are non-aerated pond systems.

In Omaruru, the wastewater system is divided into two separate systems due to its geographical layout. In the northern part of Omaruru, which is the main area, many houses rely on septic tanks for wastewater treatment. The content of these septic tanks is periodically sucked off and transported to the ponds located in the northwestern part of the town (see figure). Apart from the septic tank waste, a portion of the wastewater from houses that are connected to the sewer system is pumped to the same ponds in the northern area.

In the southern part of Omaruru, most of the wastewater is directed to a pond system through gravity flow. Additionally, one pump station feeds wastewater from a longer road in the south to the ponds. The current condition of the ponds in Omaruru is concerning, as both ponds are highly filled with sludge, and vegetation, including trees, is growing inside the ponds. In the northern pond, the sludge accumulation is significant, and the vegetation is thriving within the pond. The insufficient treated waste water flows over in the countryside, evaporates or infiltrates in the underground. The trees in the surrounding adsorb a significant part of the water.

Figure 4: Sludge treatment pond of north part (left) and non-aerated pond in the south of Omaruru (right figure) (Source: Foto FiW)

The town of Karibib has a large pond system, which comprises two lines. Currently, mostly only one line is operational (see figure 5). Despite facing challenges such as a destroyed screen and a high amount of plastic waste in the inlet and anaerobic pond, the pond system continues to function. A critical point in the system is the pump station located in the northwest of Karibib. The two pumps at this station are sensitive to clogging, particularly due to the presence of coarse matter like bottles, waste, and stones.

Figure 5: View to the anaerobic pond (left) with layer of floating material and plastic bottles and the facultative pond (right), (Foto FiW)

The pond system in Karibib is designed for wastewater evaporation, allowing the treated wastewater to be lost through natural evaporation. The surface area of all ponds is sufficient to facilitate this evaporation process. During a visit, the flow of wastewater was roughly estimated to be around 5 to 7 liters per second. A significant portion of the wastewater flow infiltrates into the underground rather than being solely lost through evaporation.

The municipality of Otjimbingwe has made improvements to their pond system by adding a new large pond, which has been constructed with sealing using plastic foil (see figure 6). The salt deposition observed on the surface of this relatively large pond indicates that evaporation is taking place. Despite being situated in a very dry area, the municipality of Otjimbingwe is not currently engaged in water reuse practices.

The existing sewer systems and treatment plants in the three municipalities (Omaruru, Karibib, and Otjimbingwe) provide a theoretically suitable basis for improving water reuse practices. However, the conditions for water reuse in Omaruru are not very favorable, as the current wastewater treatment plants require significant renovation or new construction.

Figure 6: Improved pond in Otjimbingwe, white “belt” = salt deposit at the sealing foil due to evaporation. (Foto FiW)

The wastewater treatment plant (WWTP) in Karibib holds significant potential for improvement. Its current size allows for enhancing the cleaning performance and implementing post-treatment steps to achieve the desired reuse quality, aiming for at least a general standard and ideally a special standard. To realize this potential, several upgrades and modifications are essential. The maturation/evaporation pond needs to be transformed into a tertiary treatment step, with a preference for Nature-based solutions. Improving the pumping station is crucial to avoid clogging due to coarse matter, ensuring smooth wastewater flow through the system.

Figure 7: left: Plots near the pond system Karibib which are principle suited for agricultural utilisation (Foto FiW).

Moreover, connecting the informal settlement in the east of Karibib town to the sewer system could increase the amount of wastewater flowing into the WWTP and potentially increase the availability of reuse water. The proximity of agricultural plots near the ponds in Karibib (figure 7) offers an opportunity for water reuse in agricultural production (fodder, citrus trees, vegetables in case of special standard)

The Twin Hills gold mine, located near Karibib, is showing interest in reusing water from the improved pond system in Karibib. The potential for water reuse in Karibib is estimated to be roughly between 250 and 400 m³/d, depending on the amount of wastewater entering the improved pond system.

The pond system in Otjimbingwe presents excellent preconditions for implementing water reuse practices. The size of the ponds is more than sufficient, and a tertiary treatment step, such as Nature-based solutions (NBS), can easily be incorporated into the existing large pond. The treated water can then be utilized in a large garden area located near the wastewater treatment plant (WWTP) which is within the river floodplain (figure 8).

Figure 8: Gardening area in the Swakop river floodplain near Otjimbingwe (Foto FiW).

Transporting the treated water to the garden area can be achieved by gravity, minimizing operational costs and making the process more cost-effective. Additionally, the treated wastewater, when used in the garden area, can also serve as a valuable source of nutrients and act as a natural fertilizer, benefiting the plants and crops. The water reuse could be one pillar for more self-sustaining in food production of Otjimbingwe's residents.

However, preconditions for decentralised water reuse in Namibia are compliance with quite strict effluent requirements, which are currently not met by any of the pond wastewater treatment plants. On the other hand, smaller municipalities are not in a position to finance and manage sophisticated technologies for advanced wastewater treatment. An overview of the requirements and the possible reuse options depending on the water quality shows the following diagram (figure 9). Especially for high quality reuse options, a special standard is essential. (Code of practise Volume 6, wastewater reuse) The Namibian Code of practice Volume 6, wastewater reuse summarises a lot of wastewater treatment technologies suited for water reuse and the expected / required effluent concentrations. The effluent concentrations have to meet with a very high level of statistical relevance (95 percentile). In this guideline only "technical" solutions are listed, so-called nature-based solutions (NBS) are not approved in Namibia until now. The expected effluent concentrations of NBS for tertiary treatment are in a similar range compared to advanced technical solutions including filtration.

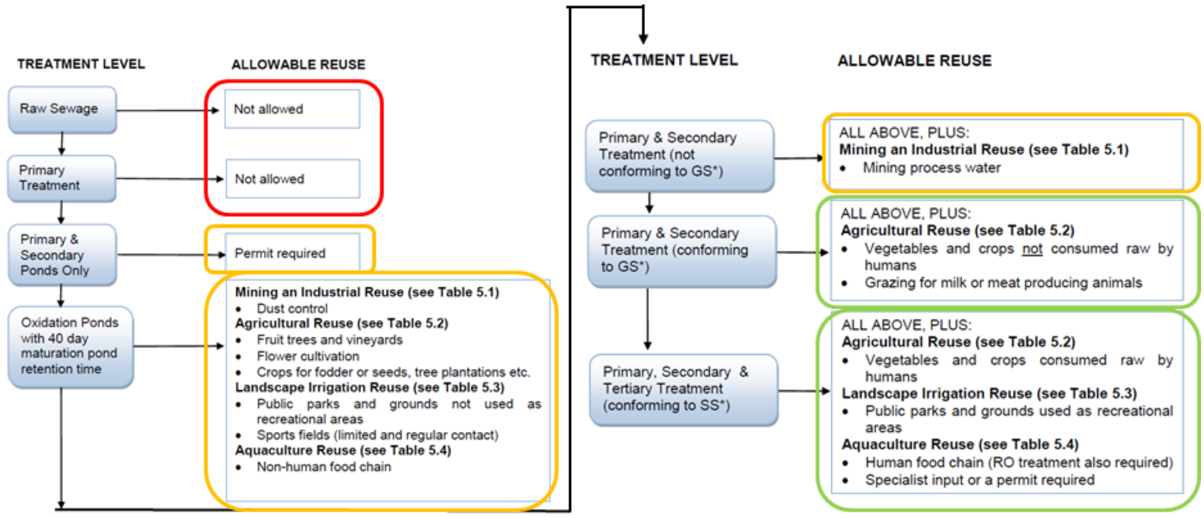

Figure 9: Requirements and the possible reuse options depending on the water quality (Code of practise Volume 6, wastewater reuse).

The implementation of Nature Based Solutions (NBS) is seen as a suited way out of this dilemma of high effluent quality, lack of qualified staff and high costs.
Indeed, Nature-based solutions (NBS) have demonstrated their effectiveness and benefits in various regions worldwide, including Europe, North Africa, and beyond. NBS offer innovative and sustainable approaches to address environmental challenges, especially in improving the quality of insufficiently treated municipal wastewater. The approach of using Nature-based solutions (NBS) for wastewater treatment in Karibib aims to achieve the necessary water quality, with a focus on minimizing energy, maintenance, and operational costs. The exchange and discussions with the city of Karibib, MAWLR, SASSCAL, KfW, and local engineering firms has led to discussions and confirmation of this sustainable approach.
An approach for implementation of NBS in the existing ponds in Karibib shows the following figure 10.

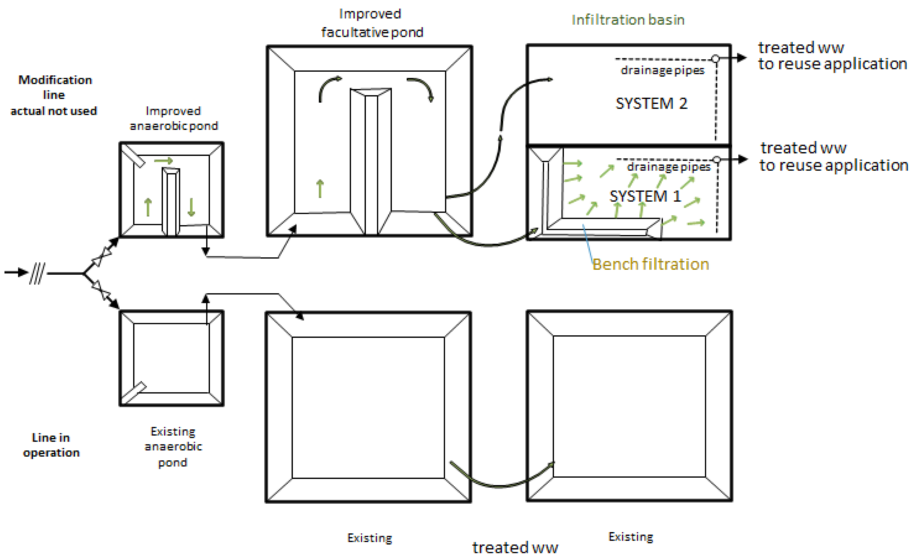

Figure 10: Implementation of NBS in the existing ponds in Karibib.

The research approach consists of two different NBS solutions adapted to the local conditions and available materials. This solution creats a post treatment system after improvement of existing pond structure. The selected scale allows the generation of reuse water for full scale agricultural production.

As part of the project, the issue of water losses and leakage detection was addressed, particularly with the Karibib town council. Identifying and addressing leaks and water losses in the distribution system is vital for conserving water resources and reducing wastage.

The development of the upgraded wastewater treatment plant as a facility for training and demonstration purposes as a basis for related vocational training and local capacity building is additionally a main pillar for the whole concept for Karibib and eastern Erongo.

Stakeholder Dialogue

Establishing an extensive exchange with various stakeholders during the project period was a valuable and vital approach. By engaging with a diverse range of stakeholders, the team gained a better understanding of the options and potential. Also, the project gained valuable insights, fostered new collaborations, and enhanced the overall impact and effectiveness.

The engagement with private sector companies like Aquarius and Aqua Services allowed for valuable industry expertise and perspectives. The involvement of the public sector, including SASSCAL, Karibib Town Council, and NUST Vocational Center, provided an opportunity for policy alignment, government support, integration of local knowledge, community needs, and academic insights into the project's strategies and outcomes. Additionally, the engagement with various organizational and investment institutions, such as KfW, provided access to get to know other funding opportunities and expertise in water-related projects.

Maintaining close and ongoing communication with relevant stakeholders on-site regarding new information, changes and data updates is very important for the success and smooth implementation of upcoming potential phases.

In a first step relevant stakeholders were collected in a list and categorised regarding their type (public institution, research institution, private business etc..) and scope (global, national, regional, local). Based on their feedback additional relevant stakeholders were added and the categorization of the stakeholder map was changed. A new map was developed in which stakeholders are depicted within the categories: water suppliers, decision makers, innovators/advisors and user groups. Other relevant stakeholders identified in the course of stakeholder workshops and exchanges were continuously added to the graphic illustration.

The feedback dynamics between the social, ecological but also economical levels allowed the project team to quickly capture an overview on the realities of water resources management and security and to identify entry points and possible implementation strategies. Through the stakeholder process, the continuous and iterative exchange with various groups of actors, perceptions of the relevant stakeholders could be obtained, evaluated and checked against each other. In this way a good network could be established and so-called 'change agents' or 'multipliers' could quickly be identified and integrated in the further course of the project.

In the context of the ‘MultiReWaS’ system, early definition of system boundaries and rapid focus on promising solution approaches were an important component in reducing the complexity of the system perspective. The previously defined ‘MultiReWaS’ solution approaches (‘toolbox’) have been cross-checked with the on-site realities, the results of the water audit and the stakeholders' assessments. In this way, the project consortium was able to discard some of the initial ideas and identify suitable solutions to implement sustainable solutions in the main phase.