Development of an Open Source Web GIS to Improve Water Supply in Zambia

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SUMMARY

The overall goal of the water operator partnership (WOP) between the German utilities (GELSENWASSER AG and Emschergenossenschaft/Lippeverband) and Lukanga Water Supply & Sanitation Company (LgWSC) is Know-how transfer at working level in order to reduce water losses at LgWSC as water supply and sanitation (SDG 6) are key factors for sustainable urban development. Therefore, one main objective is to improve the digital data infrastructure and make the information available to support more efficient operation and maintenance of the distribution network.

A Web GIS based on the open source software QGIS was developed as a central tool that enables employees to view a georeferenced map on their mobile phones, for example to identify leakages and carry out targeted repairs.
A key prerequisite is the successive collection of data using a GNSS equipment for accurate surveying, the digitalization of existing analogue data and integration into the Web GIS. The project strengthens the efficiency and sustainability of the water supply at LgWSC.

ZUSAMMENFASSUNG

Das übergeordnete Ziel der Betreiberpartnerschaft zwischen den deutschen Betreibern (GELSENWASSER AG und Emschergenossenschaft / Lippeverband) und dem sambischen Betreiber Lukanga Water Supply & Sanitation Company (LgWSC) ist der Wissensaufbau, um im Bereich der Wasserversorgung die Wasserverluste bei LgWSC zu reduzieren, da Wasserversorgung und Abwasserentsorgung (SDG 6) Schlüsselfaktoren für eine nachhaltige Entwicklung sind. Ein zentrales Ziel ist die Verbesserung der digitalen Dateninfrastruktur und die Verfügbarmachung der Informationen zur Unterstützung eines effizienteren Betriebs und Unterhaltung der Versorgungsinfrastruktur.

Als zentrales Instrument wurde ein Web GIS, basierend auf der Open-Source-Software QGIS, entwickelt, so dass die Mitarbeiter die Karten mobil abrufen, um beispielsweise beschädigte Leitungen zu identifizieren und Reparaturen zielgerichtet durchzuführen.
Wesentliche Voraussetzung ist die sukzessive Datenerhebung durch ein GNSS zur präzisen Vermessung, die Digitalisierung existierender analoger Daten und Integration in das Web GIS. Das Projekt stärkt die Effizienz und Nachhaltigkeit der Wasserversorgung bei LgWSC.

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1. Introduction and approach

1.1 Background of the project and objectives

Taking the Water Operators' Partnerships of the United Nations as their blueprint, German water utilities, represented by the German Water Partnership's Working Group for Operation and Capacity Development, proposed supporting partnerships between German and international water utilities. The utility platform has been developed together with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Engagement Global with its Service Agency Communities in One World. The project is designed firstly to promote partnerships between German municipal enterprises and water utilities in the partner countries, and secondly to establish long-term structures that in future will underpin the provision of support to partnerships between municipal enterprises worldwide.

The Federal Ministry for Economic Cooperation and Development (BMZ) is providing € 6 million of the household of the German Federal Government for this project in the period 07/2024 to 06/2027. The GIZ is responsible for implementing the Utility Platform. GIZ advises on and supports the initiation and implementation of the partnerships, finances partnership activities via grant agreements, organizes network meetings and offers the partners diverse training measures. The Utility Platform is being implemented and further developed in cooperation with the German Water Partnership, the German Association of Local Utilities (VKU) and Engagement Global with its Service Agency Communities in One World (Utility Platform (2025)). The roles and tasks of the partners are shown in Figure 1.

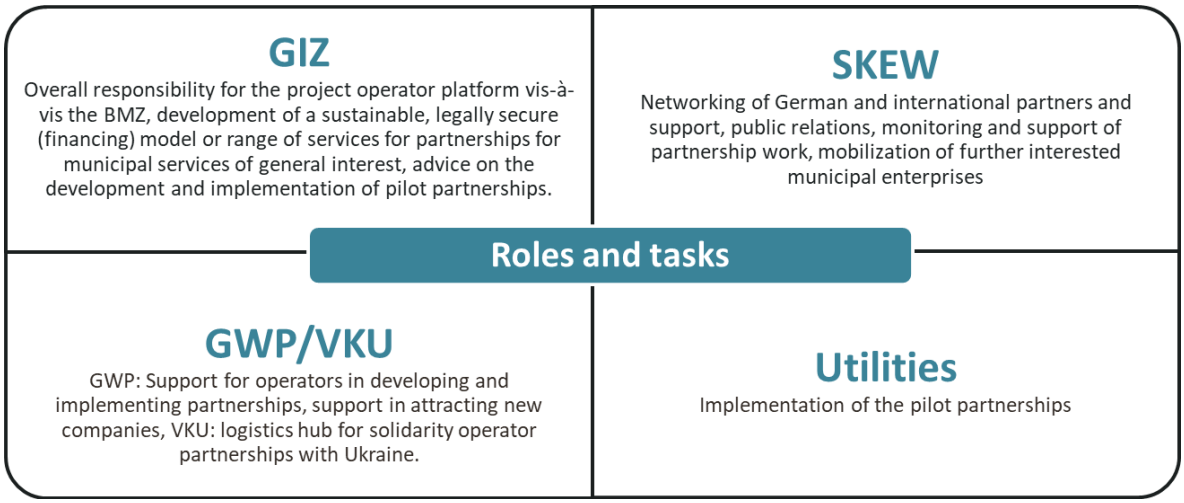

Figure 1: Roles and tasks within the utility platform

The Zambian water company Lukanga Water Supply & Sanitation Company (LgWSC), GELSENWASSER AG and Emschergenossenschaft/Lippeverband have been in a Water Operator Partnership (WOP) for more than three years.

The overall goal of the WOPs is Know-how transfer at working level as water supply and sanitation (SDG 6) are key factors for sustainable urban development. Within the first period of the project, nine missions, four job shadowing visits and one networking event in Germany were undertaken (Figure 2).

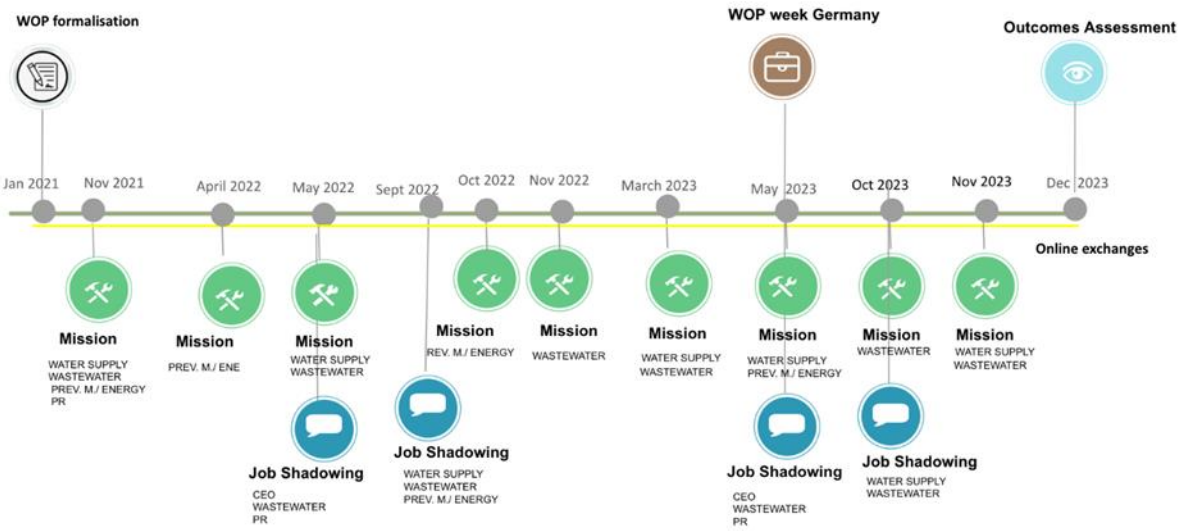

Figure 2: Timeline of activities within the WOP

One specific goal within the partnership is the reduction of water losses (approx. 51 %) and the associated enhancement of the current Geographic Information System (GIS) at LgWSC for documentation and maintenance of the supply infrastructure.

1.2 Lukanga Water Supply & Sanitation Company

Lukanga Water Supply and Sanitation Company Limited is one of the eleven commercial utilities in Zambia formed as part of the Government supported water sub-sector reforms to improve and commercialize water and sanitation service delivery in Zambia. LgWSC was incorporated as a private company in 2006 and is wholly owned by eleven Local Authorities in the central province of Zambia (Figure 3). LgWSC currently serves a population of about 589,000 people within eight districts and has 33,913 water and 14,540 sewerage connections. It has a staff base of 261 employees and a revenue of € millions 2.4 (annual account 2024).

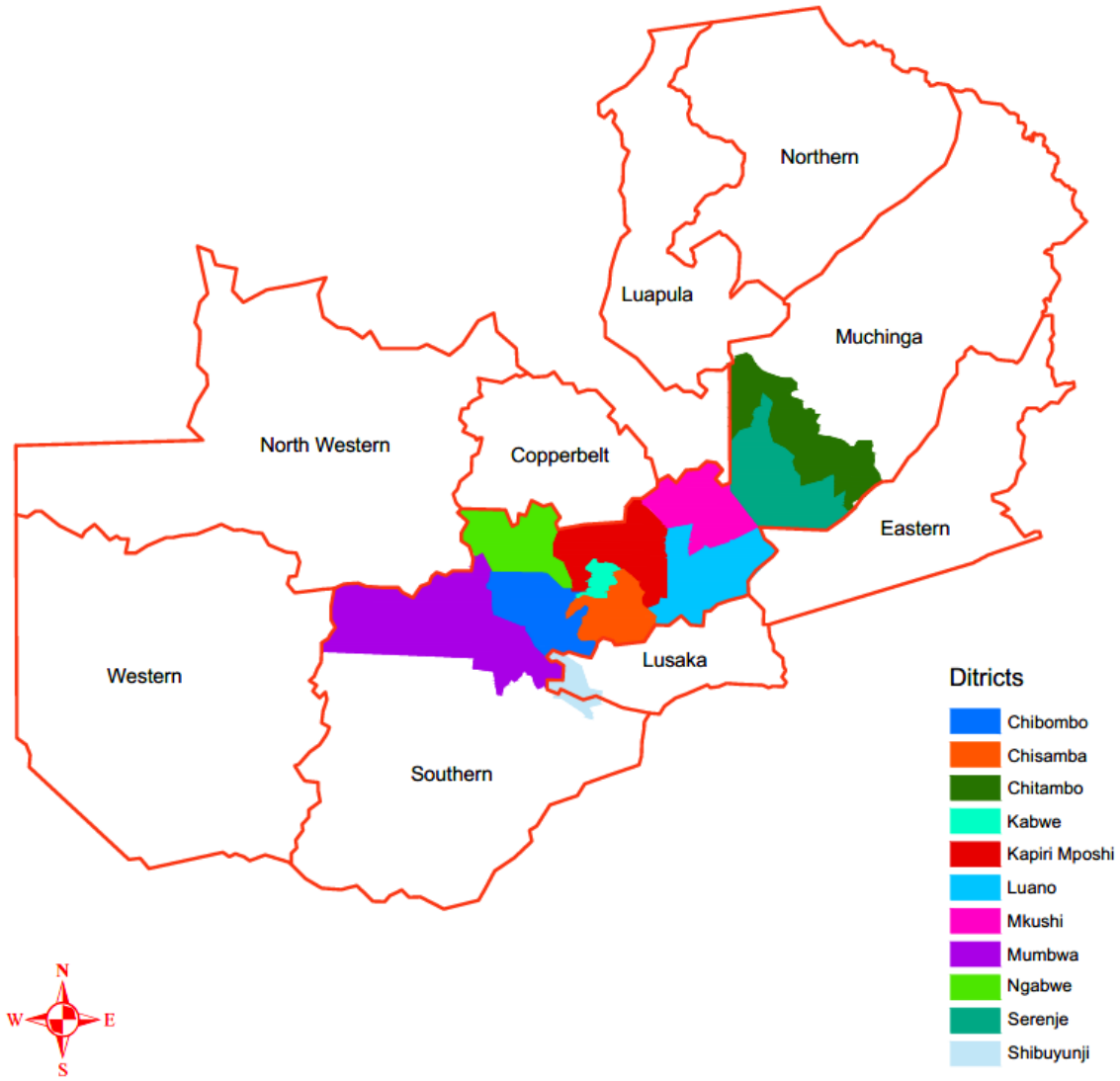

Figure 3: Overview of local authorities within the central district

2. Use of GIS and challenges within the company

2.1 Initial Situation

The distribution network operated by LgWSC is managed by means of a GIS and data is partially stored in a spatial database (geodatabase). It includes, among other things, approximately 400 km of pipelines, hydrants, valves, treatment plants and water kiosks. Approximately 1,500 of around 30,000 house connections are currently documented in the GIS.

The data was primarily collected from consultants' reports and was available in CAD formats (.dxf), which was later uploaded to the GIS software ESRI ArcGIS and digitized into shapefiles (.shp) of water supply pipelines (transmission and distribution network), valves,

hydrants, meters (bulk meters and domestic meters at customer properties) and customer connections.
The georeference of the documented data is WGS84/UTM35S (epsg-code 32735), while geospatial data originating from authorities, such as the Ministry of Lands, have a different geodetic datum (Arc 1950).

2.1 Challenges

LgWSC had outdated or obsolete maps on which some of the network pipelines were not marked, making it difficult to locate network fittings in the ground, especially when a shutdown was required to repair leaks instead of shutting down the plant completely. Thus, a particular network line could be isolated to pave the way for repair works by use of closing a valve. However, these fittings were not recorded in the GIS database.

Further challenges faced by LgWSC are as well organizational as technical in nature.

The documentation is currently being carried out by one person, who is at the same time the GIS expert as a network engineer.

From the technical point of view the whole data is stored on only one personal computer. Sharing the data with others is implemented so far by distributing pdf files, showing different aspects of the network to interested colleagues. However, empowering LgWSC with company-wide visibility of the water distribution network and its corresponding assets has been considered a key factor for achieving enhanced operational efficiency and more sustainable and reliable water management.

3. Development of an adapted solution

3.1 Web GIS solution

Due to the described challenges, it was intensively worked on the development of a lightweight web-based GIS (Web GIS) solution, which already went live in November 2023.

Alongside HTML and Cascading Style Sheets (CSS), open-source software such as the free and comprehensive desktop GIS QGIS and Leaflet, a JavaScript library primarily used to control interactive behaviour in web pages, helped to create a customized Web GIS that meets the company's requirements (Figure 4). Another important component is a hosting service like GitHub Pages, on which the Web GIS can be published and operated free of charge. Being able to view a georeferenced map on a mobile phone or PC at any time is already a real added value for LgWSC, e.g. when repairing pipe damage, as staff in the field can effectively identify and locate assets or address other operational challenges.

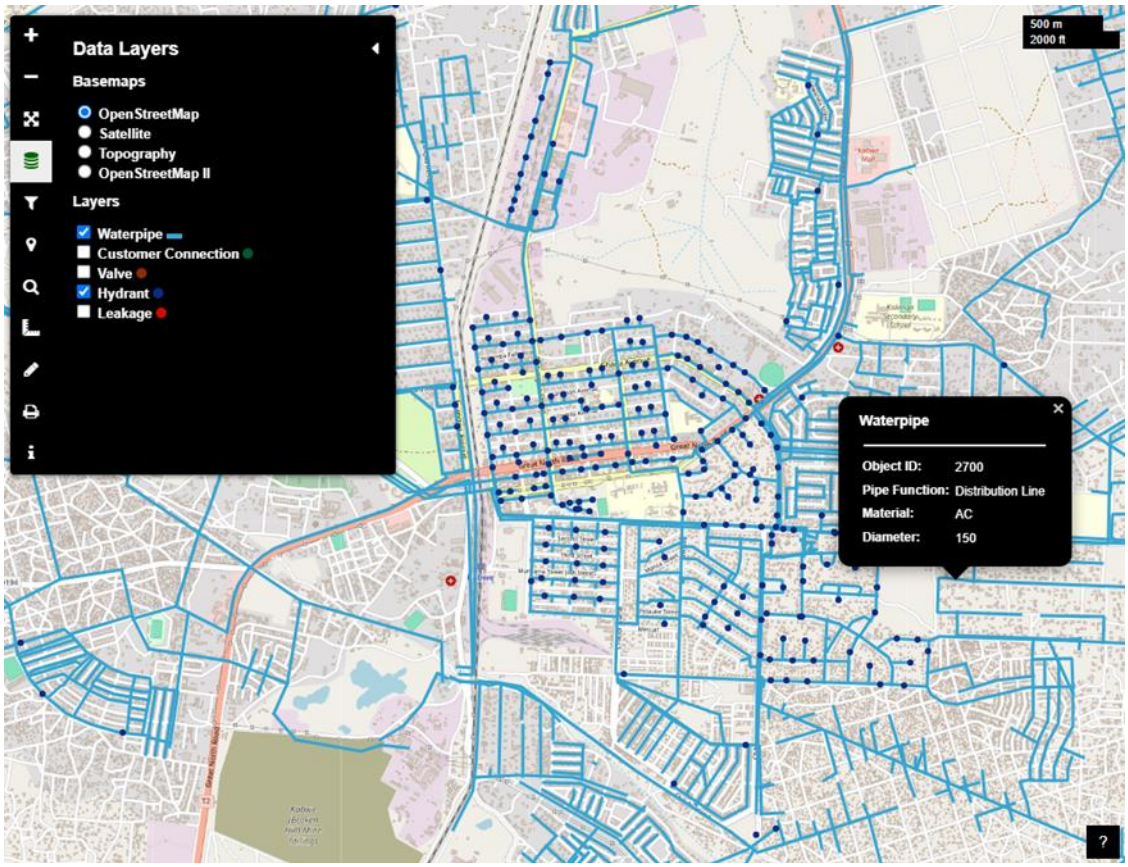

Figure 4: Pipes and hydrants displayed in the map view of the Web GIS

During a further visit in November 2023 the proper use of the Web GIS in the field has been trained (Figure 5). Updating the content of the Web GIS is a manual task. However, a clear procedure has been prepared by Gelsenwasser, empowering the GIS engineer of LgWSC to update the GIS features within a little time.


Figure 5: Training in the field

3.2 Grade of completeness of the GIS documentation

Increasing the completeness of geospatial data to ensure a reliable basis for asset management and supporting decision-making. Different data collection processes have already started. In May 2023 the analogue map archive was searched for relevant maps. These analogue plans, which were scanned by Gelsenwasser's geomatics trainees in Germany, have been later used by the Zambian colleague for completing the digital data.

Additionally, the collection of new GIS data sets for incomplete areas took place during the last visit to Zambia with specialists from LgWSC and Gelsenwasser (Figure 6).


Figure 6: Data collection from analogue maps in Zambia

In areas where according to the Web GIS no pipe network is available, the presence of large puddles caused by pipe leaks revealed areas where the GIS database is currently incomplete. This also showed how the Web GIS can effectively help find missing pipes to be documented in the geodatabase.

Furthermore, high-resolution satellite images were used to update the GIS data. With the help of printed paper plans, the network pipelines were traced, and the existing infrastructure was marked on the plans and later inserted as new data set into the Web GIS. This process required the full commitment of the employees involved in the network installation and the new connection, as well as the zonal managers.

3.3 Capturing data using Global Navigation Satellite Systems (GNSS)

Since April 2024 LgWSC possesses a FOIF A90 Real-time kinematic (RTK) GNSS (Guangdong fllantennagroup Antenna (2025)) consisting of a base and rover unit. During the last visit in October 2024, some test measurements were done (Figure 7). Due to the lack of WGS84 control points, the resulting point coordinates could only be compared to Arc1950 coordinates. Therefore, the results have not been satisfactory.

In Germany, various correction services can be used for differential GNSS measurements, e.g. SAPOS or the services of companies such as Leica, Trimble or Topcon. The use of a correction service enables precise coordinate determination in the sub-centimeter range.

Figure 7: Test measurements with RTK GNSS

The situation in Zambia is, with regard to correction services, not that comfortable. However, a newly built network of Constantly Operating Reference Stations (CORS) for Zambia with WGS84 as the geodetic datum might be the future solution.

4. Outlook

In the future, surveying using GNSS may also become an issue. Specialists from both companies are currently working on the use of this technology and are conducting test in GNSS correction services and methods, as well as RTK positioning, with the goal of achieving accuracies of a few centimeters.

To improve the current situation, the next steps therefore are:

- Equipping LgWSC with both theoretical knowledge and hands-on expertise in GNSS operation, data management, and GIS integration, enabling efficient geospatial data collection and application in water and sanitation infrastructure management.
- Purchasing a tribrach for the base station.
- Establishing control points at key locations around Kabwe.

Once, such control point in the desired coordinate reference system WGS84/UTM35S are in place and the LgWSC staff is trained in the proper use of the GNSS equipment. With the help of the GNSS equipment missing network elements such as pipe or house connections can be surveyed, and data can be captured easily and effectively.

Another issue is the step-by-step digitalization of the entire infrastructure operated by LgWSC (water supply and wastewater disposal) in the database, thus a structured rehabilitation planning can be carried out in the future.

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