CTCN Zambia Aquifer Mapping Methodology Revision

Summary feedback and comments following the stakeholder engagements in Nyimba.

Overview

Presentations to Zambian stakeholders on the 21st and 23rd August 2023 in the project inception meetings indicated that expectations for the project were strongly aligned with aquifer mapping – understanding the extent of local aquifers and determining basic aquifer parameters, rather than focusing on water balance studies.

Various geophysics methods exist to do intensive aquifer mapping data collection but these are expensive and beyond the scope and size of the current resources of this project. What can be proposed can be fitted into the water balance study paradigm but altering the thrust of the approach. A simple way of perceiving this is to understand, from data, what can be taken out of the groundwater resource more so than what comes in. It is a matter of approach.

The methodology proposed here would be first to understand the extent of the local aquifer(s) in Nyimba through improved hydrogeological mapping and then to determine the recharge estimate. It is important at this point to understand the aquifer characteristics – and extent. This approach broadly meets the objectives of meeting the aquifer mapping expectations. Water balance can be understood in the context of rainfall, recharge, and abstraction.

Updated Hydrogeological Mapping for Nyimba

Based on the stakeholder engagement meetings in Lusaka, the Zambian government indicated that 1:100 000 geological maps were available for the Nyimba area. This represents a significant improvement on the 1: 1 500 000 scale that the current hydrogeological model by BGR and the UPGro Groundwater Atlas (see Fig 1). This mapping approach will need to be mindful of the improved scale mapping by BGS of the Kafue Flats at a scale of 1 : 250 000 in 2007 (Fig 2).

At the stakeholder engagement meeting in Nyimba, it was indicated that certain groundwater resource data was available and that additional data, particularly aquifer parameters, could be collected by the Zambian contingent through their own funding. It is envisaged that this would include a hydrocensus, possible water quality tests, and possible test pumping of existing groundwater resources. The data is

considered to be “scattered” at this point, and effort will need to be invested in collecting as much as possible by both the project technical and the Zambian team. The aim of collecting the groundwater resource data is to be able to run statistics on key parameters in order to refine not only the scale of the current geohydrological mapping initiatives but also improve the classification of aquifers into yield classes, similar to that conducted in South Africa (see Fig 3). It should be noted that the data set is critical to generate a meaningful response.

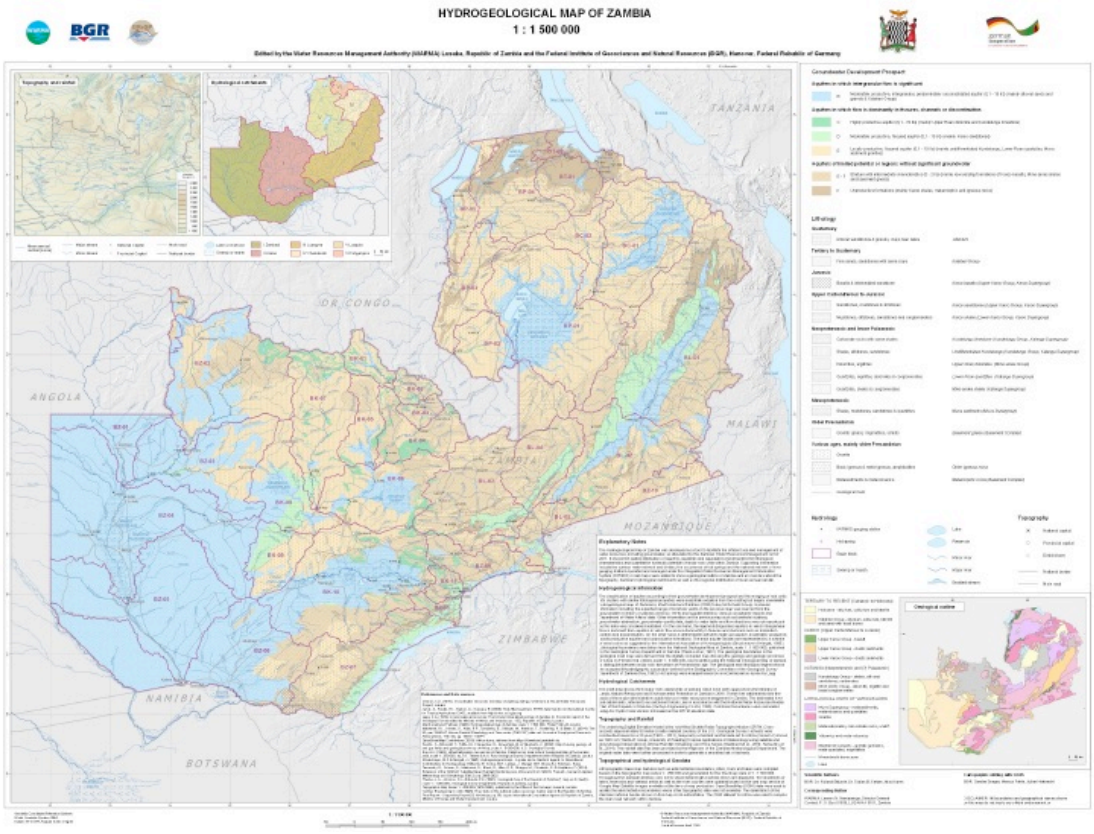

Figure 1 Groundwater map of Zambia by the Federal Institute for Geosciences and Natural Resources [BGR - Bundesanstalt für Geowissenschaften und Rohstoffe].

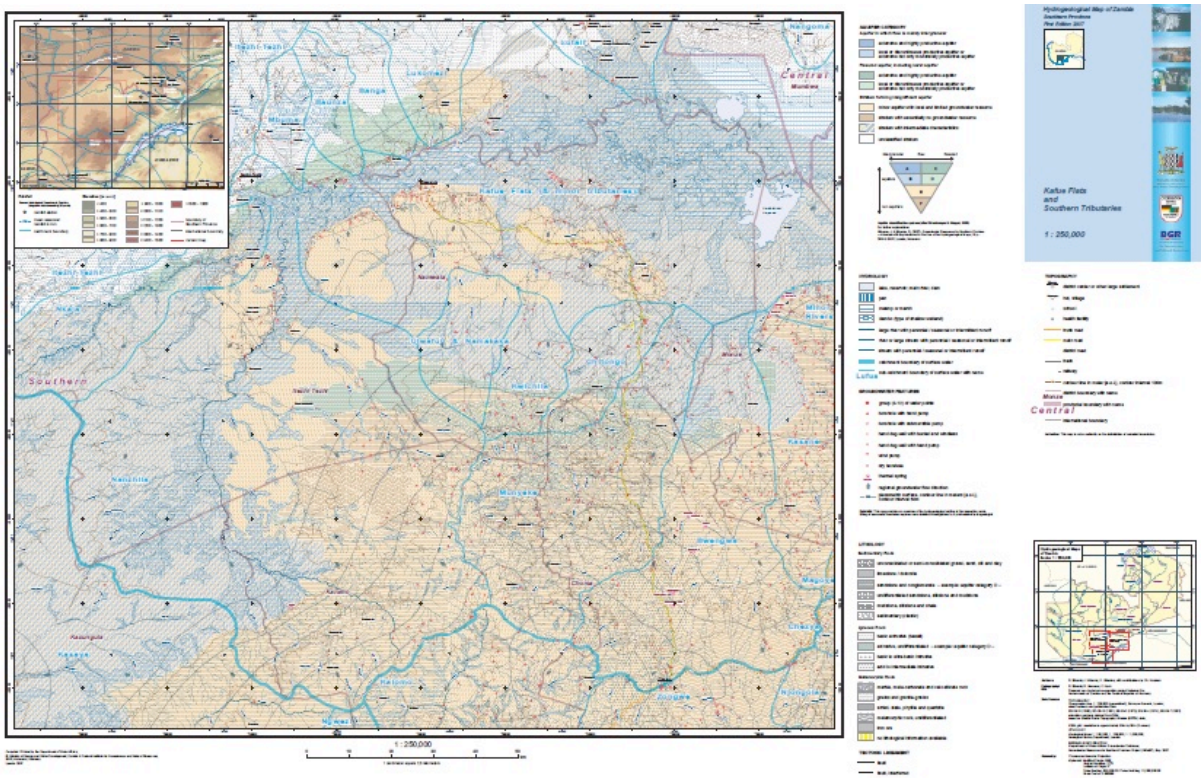

Figure 2 An example of BGS mapping of the Kafue Flats

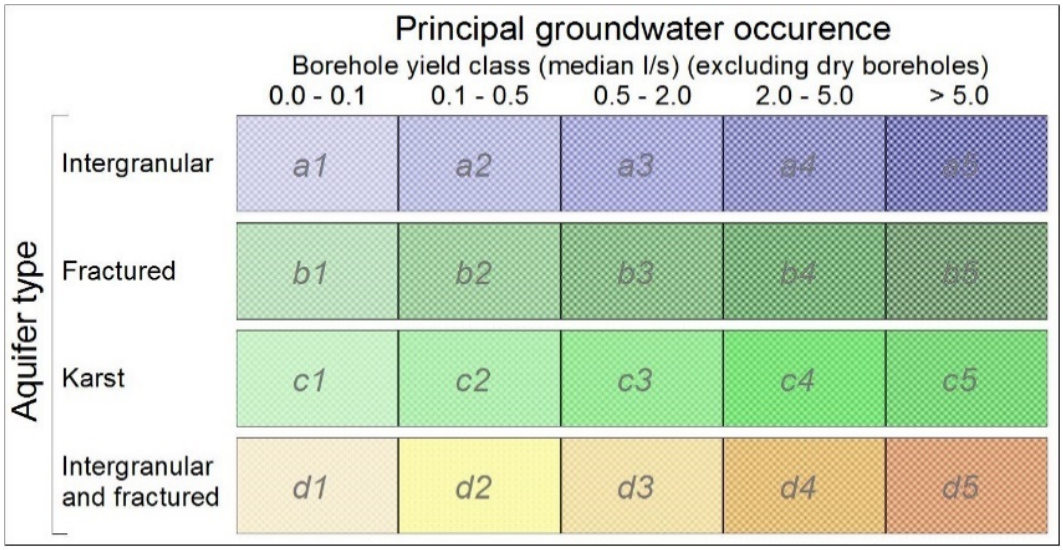

Figure 3 An example of the South African aquifer yield classes used for mapping aquifers.

Development of Recharge Tool

A programme to estimate recharge was developed by Gerrit Von Tonder and Yongxin Xu in 2000 under the guidance of Eddie Van Wyk to apply various methodologies to estimating recharge. This is typically project or area-specific and has allowance for the following methods:

- Chloride Method
- Isotopes
- Saturated Volume Fluctuation (SVF)
- Cumulative Rainfall Departure (CRD)
- EARTH Model
- Baseflow
- Qualified Guess

The Chloride, Isotope, SVF, CRD and Earth model are all methodology specific and directly transferable to the Zambian context. It is also unlikely that there will be sufficient data to run these more data hungry methodologies.

The Qualified guess and baseflow methods are both spatially dependant and present the most achievable assessment of recharge but will need to be adapted where possible to the Zambian context. In addition to the listed methodologies, a desktop review of the Thornwaite, Aplis, and other new methodologies (post 2000) will be considered for compatibility. The WHYMAP recharge mapping will also be considered for applicability. (Possible data source includes HydroATLAS-Zambia - Home (weebly.com))

It is proposed that the necessary permissions are sought to adapt this tool to the Zambian context, particularly of relevance is the qualified guess approach, which allows for informed estimates in data-scarce settings.

Relevant to the tool adaption, the data that would be beneficial from the Zambian government would be geology, soil maps, topography, and rainfall if available. In the event that rainfall is not available, then satellite remote sensing could be considered. This recharge approach can then be considered in the water balance determination.

Determining basic aquifer parameters

Please note – this subsection is to be undertaken by the Department of Water Resources Development at national level and from Nyimba. It has no financial implications for this project. It is included here because it is integral to the progress of the project.

Key activities will include determining basic aquifer parameters, to be developed in conjunction with this project:

- A groundwater hydrocensus (location of all boreholes, users and uses)
- Pump test measurements (helps define basic aquifer parameters)

- Water quality measurements

Water Balance:

The water balance approach can then be undertaken by developing an assessment of inputs and outputs to the groundwater store. The basic water balance approach remains:

Inflow = Outflow + Δ Storage

Or a combination of these variables.

Estimates of inflow (to the aquifer) can be developed by evaluating rainfall and recharge. Outflows can be evaluated by obtaining data on groundwater abstraction. The change in storage can then be determined, also verified / calibrated against water level changes in the aquifer.

Rainfall

Given the paucity of measured rainfall data in Zambia and especially more remote sites such as Nyimba, remote sensing by satellite provides the most tractable means of obtaining rainfall inputs. We propose using the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) datasets. ChIRPS is a 35+ year quasi-global rainfall data set. Spanning 50°S-50°N (and all longitudes) and ranging from 1981 to near-present, CHIRPS has a resolution of 0.05° and is quite suitable for an application at Nyimba. Fig 4 gives a large-scale example for Africa at a 5-day accumulated value.

Team colleagues at the University of Zambia and stakeholder representation also suggest the TAMSAT series, which gives a similar product but specifically for Africa.

Outflows

These will be determined by borehole pump data, obtained by local stakeholders at Nyimba.

The critical assumption here is that such data exists in various formats, that it can be collated and made available to the project within the time scope of this project and this component of the project will be funded by the Zambian stakeholders (Department of Water Resources and Development). This was the gist of the outcomes of stakeholder meetings in Lusaka and Nyimba (21 – 23 August 2023).

Change in Storage

Similar to the approach above for outflows, the change in storage in the aquifer can be obtained from pump data and water level data, such as it exists. From such data, basic aquifer parameters can be determined.

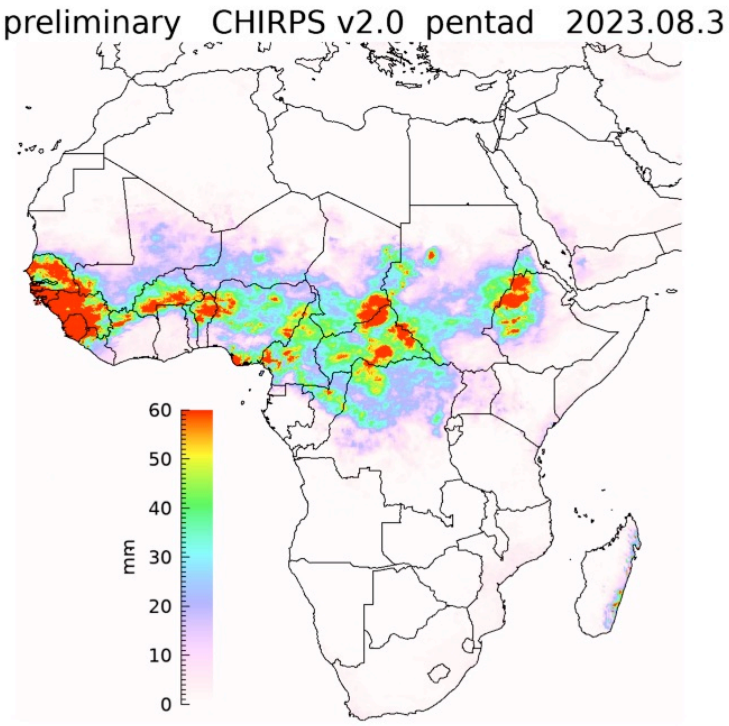

Figure 4 An image of a pentad (5-days) accumulated rainfall for Africa from the CHIRPS remotely sensed data (Source: Climate Hazards Center, University of Santa Barbera, California).

Summary and Conclusions

The Government of Zambia wants and expects methodologies for aquifer mapping that have wide applicability to other areas of Zambia (also strongly articulated feedback from the Lusaka workshop). We believe the above approach attempts to meet the needs of the stakeholders, has practicability, especially regarding the resources required for aquifer mapping, and achieves outcomes for a water balance approach. Key risks include the availability of borehole, groundwater and pump test data from Zambia and Nyimba, with government commitments to fund and undertake that component of the study.