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Groundwater Data Management by Water Service Providers in Peri-Urban Areas of Lusaka

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Abstract: Groundwater management by water service providers in Lusaka, Zambia, includes borehole siting, drilling and on-going monitoring. Semi-structured interviews were conducted with Lusaka Water and Sewerage Company (LWSC) and devolved Water Trust managers, in order to assess their needs and collect their suggestions to improve data management. The research found that both the Water Trusts and LWSC lacked the capacity to fully utilize hydrogeological information. Prior to the research, none of the ten Water Trusts collected water level data. Four have started to collect data recently and another four have plans to, and they would like to share this data more widely.

Keywords: groundwater; data management; capacity building

1. Introduction

"Halving, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" was one of the targets set by the United Nations Millennium Development Goals. Whilst this goal was met globally, it was not met in Sub-Saharan Africa [1].

Because of its buffer characteristic, groundwater is usually more reliable than surface water, in particular in areas subjected to droughts, and it is also generally of better quality than surface water [2]. However, knowledge of groundwater is usually inadequate, in particular in Africa [2]. As population growth is increasing greatly the demand for water, groundwater resources are likely to be threatened; in addition, it is expected that climate change will exacerbate this situation, as a result of more extreme rainfall events and droughts [3,4]. Consequently, there is a great need to develop our understanding of groundwater and its links with climate variability and demographic changes, in particular through long-term monitoring and the development of integrated models [5].

United Nations Educational, Scientific and Cultural Organization (UNESCO)'s Hydrology for the Environment, Life and Policy Task Force [6] has illustrated a "Paradigm Lock" in which scientists are separated from the managers and stakeholders by the lack of usefulness of their studies, and reciprocally stakeholders are separated from scientists by "accepted practices" which can be outdated. While Acreman [7] argues that there is no real gap, rather a span in research that is more or less applied, Liu *et al.* [8] consider that combining science and decision-making remains one of the main difficulties in environmental management. The key to make research useful is then for it to be based on actual needs derived from practitioners [9]. Siew [10] also emphasises the need for practical and applicable research, and highlights in addition that support systems as well as knowledge management are often required to promote cooperation between researchers and decision-makers. Groundwater is no exception and whilst hydrogeologists have gathered extensive data and have a relatively good understanding of issues related to groundwater, decision-makers usually have limited knowledge on the matter [11]. In particular, Carter [12] identified the need to "translate" and communicate scientific information to make it more understandable to end-users. This has been achieved in Australia [13].

In the water supply sector, these issues have been studied by several within the framework of Integrated Water Resources Management (IWRM). IWRM is a holistic approach that has been used on many projects and in facilitating management involving many stakeholders from various sectors [14–16]. Within IWRM, Water Demand Management (WDM), or water conservation, in particular, is a way to overcome the challenge of urban water supply by focusing on optimisation of current resources rather than the expansion of services [17]. With high unaccounted-for water in many cities of Southern Africa, including Lusaka [18,19], WDM would highly benefit the poorest parts of the population [17]. Capacity building at all levels has been identified as a crucial need in WDM: it is essential that professionals are trained and enabled to transfer their know-how to end-users, and that WDM is conducted mainly at a local level [20,21].

For successful IWRM, Ashton *et al.* [22] advocate for strong communication and partnerships between scientists, policy-makers and managers. This involves the management and transmission of information and knowledge. In the Indus River Basin, for example Karki *et al.* [22] have identified several issues that include uncoordinated research and a lack of sharing of information. They recommend the implementation of a framework to ensuring systematic data collection and management, and developing a common understanding of data needs among all stakeholders. In that regard, Dungumaro and Madulu [14] insist on the involvement of local communities. In Nairobi, shortages in central utility water supplies mean that many private boreholes are being drilled with no central records kept [23]. Gumbo *et al.* [19] also identified a lack of data and of comprehensive information systems; giving four examples in cities of Southern Africa, they present the benefits of a Management Information System as a tool for good WDM. However, the systems focus only on pipe network related data (e.g., number of connections, non-revenue water, *etc.*) and do not consider hydrological data. Whilst in some parts of the world hydrogeological data management is very advanced (for example in Australasia [24–26], North America [27] and Europe [28]) this is typically not the case in Africa. Various organisations are trying to collate African groundwater data, including the International Water Management Institute, the British Geological Survey and Hydrogeologists without Borders. This study aims at evaluating the relevance of such systematic data management to water utilities in the peri-urban areas of an African city, including usefulness of available hydrogeological primary data, and data collection and sharing. This will be achieved by: (1) identifying the needs in hydrogeological information of water utilities at key decision-points of groundwater abstraction; (2) assessing water utilities' capacity focusing on data collection, management sharing and interpretation; and (3) suggesting ways to improve primary hydrogeological information use and groundwater data management within and between water utilities.

2. Materials and Methods

2.1. Study Area

Lusaka was selected as a study area as around 60 percent of Lusaka's population currently rely on groundwater, while the rest is supplied by the Kafue River [29]. According to Nkhuwa [30], no other sustainable resource than these two is available in the area, and since exploiting groundwater is less expensive than surface water, partly because Kafue River is located 50 km south of Lusaka, groundwater may be the only foreseeable supply for further development. Like much of the continent, data management in Lusaka is poor, but this is being addressed through a Strategic Groundwater Resources (SGwR) Project established by Water and Sanitation for the Urban Poor (WSUP) Zambia, in partnership with Ian Sutton Ltd. This provides a further pragmatic reason for site selection. The SGwR project aimed to improve local groundwater source supply, and realise an effective centralised groundwater data storage system, at a more detailed level than the continent-wide databases described above. The project identified that capacity building and further on-going monitoring were required.

Training of Water Trusts focused on tasks requiring basic skills while specialists were contracted for more complex jobs like borehole drilling [31].

Lusaka has seen its population double since 2000 to reach more than two million inhabitants today, and it is expected that the trend will remain similar, as projections suggest that Zambia's population could increase by around 50 percent between 2013 and 2025 [32].

The official water utility in the city is the Lusaka Water and Sewerage Company (LWSC), which services 87 percent of the population [33]. In order to expand the services to low-income areas, where 70 percent of Lusaka's population reside [29], the LWSC created a Peri-Urban Department in 1995; in addition, with the support of CARE International, Licensed Water Trusts were created and are delegated by the LWSC to supply water to certain peri-urban areas [33]. The trusts' managers are trained by the LWSC while the vendors are employed from the community on a roster [34]. The population is served mostly through water kiosks, to whichpeople bring jerry cans and pay for them to be filled with water. The Water Trusts are often faced with several challenges, which include, but are not limited to: poor organisation and management, inadequate operation and maintenance, a lack of staff with appropriate skills, high capital costs which impact the prices for customers, and few incentives to improve services [35,36]. In addition, because of the illegal status of unplanned settlements, it is not clear whether the main utility—here, the LWSC—is responsible for water and sanitation services. Initially the peri-urban Water Trusts were independent providers, the population served by them did not benefit from the regulator's control [37]. However, this seems to have changed as the Water Trusts are now licensed by the LWSC [29]. In areas that are not served by the LWSC or Water Trusts, people rely on poor-quality shallow wells [31].

The geology under Lusaka is mostly comprised of dolomitic marbles and schists; while the schists have a low permeability, the marbles constitute a karst aquifer that provides a relatively cheap water supply [30]. Its many fractures and the high water table (sometimes as high as 2 m below ground level) make it very vulnerable to contamination [38]. In particular, population growth has been accompanied by an increase in the production of waste, which, coupled with inappropriate solid and human waste disposal, threatens groundwater quality [30]. Health problems as a result of microbiological contamination have already been observed widely in the city and treatment was identified as being insufficient, in particular for the many private boreholes and shallow wells [39]. According to De Waele *et al.* [40], there are 3000–4000 private boreholes in Lusaka, most of which are not submitted to satisfactory monitoring. The water levels are threatened as well, by both over-abstraction following population growth and lack of rainfall; consequently abstraction is exceeding recharge [38,41]. Overall groundwater data has been identified as nonexistent or inadequate, as there is a lack of collaboration between all stakeholders [30]. Over the last years the government of Zambia has collaborated with several international agencies to develop hydrogeological databases. One of the recent collaborations has seen the Federal Institute for Geosciences and Natural Resources, a geoscientific branch of the German government, produce extensive technical reports and maps on groundwater in the Lusaka Province as part of the Groundwater Resources Management Support Programme (GReSP).

2.2. Methodology Selection

In order to address the objectives listed above, a formative approach was chosen. Formative research is often used prior to or in the early stage of a programme to identify the needs from a target audience [42]. This study was indirectly part of the SGwR project and attempted to identify the hydrogeological information needs of the target audience, *i.e.*, the water utilities in peri-urban areas of Lusaka. It also looked at their current practices in groundwater data management and collected their suggestions to improve the use and sharing of information; this was expected to help shape the SGwR project, in particular its goal to establish a groundwater database. Used at several stages of a programme implementation, formative research is a way to evaluate the effectiveness of a programme [43]. Therefore this study is one step in the evaluation of the SGwR programme, and monitoring and feedback from the target audience should be used during the whole project implementation.

Formative research is not a methodology in itself, but relies on a wide range of accepted methods [44]. A qualitative approach was then used in order to get an understanding of the data management in peri-urban areas of Lusaka. It was adopted as it focuses on the participants' opinions, lays importance on the context of each participant and the influence the context has on the participant's answers, and allows for reflection on the researcher's involvement [45].

2.3. Data Collection

Semi-structured interviews were used to collect the data. They were approximately 30 min long and relied on a list of questions as a basis for discussion. Two main topics were addressed that cover key decision-points, based on the aspects identified by Mpamba *et al.* [41]: (1) borehole siting and drilling; and (2) on-going water levels and quality monitoring. The questions were targeted at characterising the participant's background, his/her understanding of information required for groundwater management, what information sources were used, what data was collected and what improvements the participant would like to see. The participant's opinion on data sharing between the LWSC and the Water Trusts was also asked. With participants from the LWSC, only relevant questions were asked as roles are clearly defined in protocols for borehole exploitation. For example, the chemist was not asked how data was recorded after borehole completion, allowing more time to be spent on on-going monitoring aspects. The answers were expected to lead to recommendations to be made to the LWSC, the Water Trusts and WSUP concerning groundwater data management.

Semi-structured interviews ensured the systematic but conversational exploration of a range of subjects: in particular, both open- and close-ended questions were asked, and probing encouraged participants to elaborate. While such a method can lead respondents to try and give the answer they think the interviewer is expecting [44], it has the benefit to be flexible and allows the researcher to adapt, to a certain extent, the discussion to the interviewee [45]. A clear explanation of the role of the researcher can help mitigate against this.

In order to ensure confidentiality to participants, they were asked to give informed consent before participating in the study, by signing a consent form which explained the purpose of the research, how data was to be used and how results would be shared. It guaranteed in particular that participants would remain anonymous.

2.4. Sample Selection

The participants were selected by convenience sampling. Five participants from the LWSC were identified based on the previous work of the SGwR project. All ten Water Trusts agreed to take part in the study, providing a robust sample. In the four LWSC departments (Water Supply Department, Peri-Urban Department, Projects Implementation Unit and Assets Department), senior engineers were chosen, as were the managers from the Water Trusts since their roles gave them an overview of the strengths and struggles of their respective teams. A chemist from the LWSC laboratory was also interviewed as water quality was an important component of the study. In total, 15 people with a role in water management were interviewed. Interviews were scheduled during July 2014 by a staff member of WSUP. Even if the researcher was alone with participants during the interviews, he was accompanied to the interview location, and often introduced to the participants, by a staff member of WSUP. It should therefore be noted that the interviewees will have perceived a link to WSUP's SGwR project and there was a risk of bias, especially with questions related to this project, as interviewees may have wanted to give a positive impression of the project in order to receive more support.

2.5. Analysis

During interviews, notes were made by the researcher. The answers were then compiled in a spreadsheet and coded so as to identify trends in participants' answers. In particular, segment labelling and colour coding were used to highlight key themes. The spreadsheet is provided as Supplemental Material Table S1.

3. Results

While all participants are involved in groundwater abstraction in Lusaka, there are many differences between their roles, as well as in their respective backgrounds and capacities.

The five participants from the LWSC are working in four different departments that are all involved in the siting, drilling and exploitation of any borehole, directly in peri-urban areas supplied by the LWSC and indirectly where Water Trusts are the suppliers. First, the Peri-Urban Department is responsible for the choice of a broad site where hydrogeological surveys are to be conducted, or to advise the Water Trust that makes the choice. The Project Implementation Unit is then responsible for contracting the geophysical survey and the drilling, sometimes on behalf of Water Trusts with limited capacity. After completion, it hands over the water quality monitoring to the Water Supply Department (WSD), also responsible where Water Trusts are the suppliers, and the technical and electrical maintenance to the Assets Department. During one of the interviews, the suggestion was made that a unique borehole unit—or not more than two departments—that would handle the whole process would be "of great value".

There are also important differences between the Water Trusts: while some are serving several tens of thousands of inhabitants with one or two boreholes and a few employees, others are supplying water to populations of several hundreds of thousands with up to six major boreholes and as many as ninety full-time employees. In addition, the hydrogeological context is also very different depending on the area, resulting in one Water Trust manager saying that abundant groundwater is found wherever they drill in their area, while others have to get water by drilling outside the area they serve.

Therefore, the context in which each participant works is unique. The results from the interviews take this into account, but are still able to identify some trends, which are presented here.

3.1. Educational Background

Of high importance to evaluate the participants' understanding of and needs for hydrogeological information was their educational background. Among the LWSC senior engineers, none had specialised in water management. Some of them took short courses, for example in IWRM, and most received additional training through workshops like the ones organised by WSUP through their SGwR project. Out of the ten Water Trust scheme managers, only two were engineers with a focus on water management. Of the others, five had a background in accountancy, one in marketing, one in management and one was a plumber that then studied management. Again, most of the additional training that they received was provided during WSUP's SGwR project. Of their many employees, only a few had been trained in water management and most of these were plumbers. Overall, several participants from both the LWSC and Water Trusts acknowledged that training in water management, let alone in hydrogeology, was basic.

3.2. Borehole Siting and Drilling

The questions went on to assess what the participants thought their needs in hydrogeological information were in order to site a borehole, what information sources they used, and what data they saved after borehole completion.

The main piece of information that participants identified as required to site a borehole was the general geology, *i.e.*, whether the rock formation is of high yielding potential. This was mentioned by all respondents, though not always as the most important information. Then vulnerability to contamination was mentioned by six participants, who were most concerned with latrine run-off, followed by land availability highlighted four times. While one Water Trust had been able to secure land for further development, others expressed the difficulty to find available land. On that first aspect, one participant said that while they know what information should be used as a priority to site a borehole, they feel sometimes pressured by the local authorities to use cheaply available land even if the underlying aquifer is not suitable. Although the more precise siting of a borehole is usually delegated to contractors and advice is sought from local consultants, five out of fifteen—and four of them after probing—said that they also tried to look at lineaments, faults and fractures; however, they often lacked access to this information, as they did for recharge areas and current borehole locations.

Most of the information that participants were using to suggest a broad area for borehole siting comes from a map produced within the GReSP project and provided during workshops organised by WSUP; it shows hydrogeology in Lusaka and surroundings at a scale of 1:75,000. One participant said he did not have this map but used instead a vulnerability map from the same project, also at a scale of 1:75,000. The Zambian Department of Water Affairs, which collaborated in the GReSP programme, was also cited a few times as an information source. Maps on the Internet, including on the software Quantum Geographic Information System (QGIS) and on Google Earth, were mentioned a couple of times; they had been used after the workshops with WSUP. Consultant companies Azurite Water Resources Ltd. and Rankin Engineering Consultants were named once each. Finally, two Water Trust managers identified local knowledge as their main source of information.

Asked about ways to make those sources more relevant to them, participants expressed a general need for more comprehensive information (although when asked to provide examples their answer remained general) and specifically for more precise maps, in particular that would allow them to site boreholes based on identification of faults and fractures. A few also said that their use of a software like QGIS could be enhanced by a simplification of the tool, further training and off-line access, as their Internet connection is not reliable. One participant said he did not see how to improve the information sources he used, yet that he still depends on consultants to understand it.

On borehole completion, the hard copy reports provided by the contractors are kept but usually not shared outside the LWSC department/Water Trust. Some participants only reported that the borehole depth and yield were recorded, while others included description of pump tests, geological logs, casing details and technical equipment, therefore showing the inconsistency between these reports. One participant said that they were not produced by all contractors.

3.3. Water Levels and Quality Monitoring

A second part in the interviews aimed at identifying what data was already monitored and at which frequency, and what additional data collection participants thought was required.

While water levels have been neglected in the last years [40], they are currently monitored by four Water Trusts, of which one has been recording them twice daily for less than a month, two have been recording them weekly since recent borehole completion and one measures them weekly with a dipper provided during the previous year. Another four Water Trusts have identified water level monitoring as a necessity. Under the SGwR project, the Water Trusts are being provided with nine 50-m dippers and the LWSC received one 150-m dipper. While some are recording or are planning to record water levels on a weekly or even daily basis, others would opt for recording them every month or three months. One participant suggested starting with a high frequency and to reduce it if the levels were not changing.

In terms of water quality, all Water Trusts are measuring only chlorine residues between twice a week and twice daily. Three of the largest Water Trusts are also bringing water samples for microbiological testing to the University of Zambia a few times a year. The WSD is conducting tests every day over different parts of the city—including areas served by Water Trusts—for physical parameters (including pH, turbidity, conductivity, and colour), as well as total and faecal coliforms. Nitrates are tested monthly and samples are brought to the Zambian Bureau of Standards quarterly for heavy metals analysis. The mentioned frequency of the testing for each borehole varied a lot between the Water Trust managers; it seems though that it is a matter of months in the dry season and of weeks in the rainy season as more cholera outbreaks are expected. Three participants reported that borehole abstraction was also measured on a regular basis via meter readings at the water kiosks. Most of the data is kept on hard copy and not shared outside the LWSC department/Water Trust. In particular, the WSD has an Access database only accessible to WSD staff.

Participants identified additional data they thought would be relevant to collect. This included vulnerability to industrial contamination, microbiology, iron content, pesticides and hydrocarbons (in particular near filling stations). In addition the WSD laboratory would like to see its capacity increased to be able to analyse samples for heavy metals directly. Two participants also mentioned the need to give an estimate of the borehole lifespan.

3.4. Relationship between the LWSC and the Water Trusts

Participants were then asked for their opinion about data sharing between the LWSC and the Water Trusts as it is at the moment, and whether they had any suggestion for improvement.

Water Trusts were overall grateful to the LWSC for the training and technical assistance provided; a few participants were happy with the current exchange of information. Several ideas for improvement were still shared. First, eight participants expressed that the WSD only provides feedback on the water samples when they are not complying with the Zambian standards; they wish they could get feedback even when everything is in order. A participant also expressed that they would like the Water Trusts to provide more information to the LWSC; paradoxically, one of the Water Trust managers said they had stopped sending their monthly reports to the LWSC, because "nobody seemed to be interested in them" or was providing feedback. Several participants see the need for improved data exchange, and more technical support from the LWSC. One participant was warning that they felt it was turning into a "competition" between the LWSC and the Water Trusts—in particular the large ones—as LWSC started to charge the Water Trusts for every piece of information or advice. Suggestions were made by two participants that regular meetings with all the Water Trust managers and representatives of LWSC departments would improve communication and data sharing. The use of new technologies, including an online database, was also mentioned.

In the end, most Water Trusts were expressing their lack of capacity and understanding, but several expressed their strong desire to be trained. One participant said that they needed things that are not done well to be highlighted in order to improve. Many participants had not heard yet about WSUP's project to establish a database common to all Water Trusts and the LWSC, but the reactions were all positive to the idea.

4. Discussion

4.1. Adaptation of Hydrogeological Information

Focusing first on how primary sources of hydrogeological information could be made more relevant to water utilities, the findings highlighted a few potential adaptations: maps at a smaller scale showing the most important faults and fractures would help the water utilities in the siting of boreholes. Maps could also provide additional information that was not currently used, such as recharge areas. Indeed, most of the participants had no idea of the location of recharge areas, and as one of the participants stated, they are of importance as urbanisation is currently leading to their decrease. The use of a GIS software, like the open source QGIS, which was already used by some Water Trusts, would allow different maps to be stored and displayed, at different scales. Further training would however be required. Google Earth was also found to be useful, in particular as it allows zooming to relevant scales and is relatively easy to use. However, it requires an Internet connection to run, unlike QGIS once downloaded.

While it appeared that many participants needed assistance to effectively use hydrogeological information, they were still overall happy with the format it took; it was then not so much the primary information that needed improvement but the participants' understanding. Several of them gave an example when a local consultant had taken the time to explain to them a monitoring procedure and how this was still applied. Therefore, while the need to "translate" information to practitioners highlighted by Carter [12] is still present and it is worth looking at adaptations of hydrogeological information, it seems providing know-how with the reasoning behind would prove more useful in peri-urban areas of Lusaka.

4.2. Lack of Training and Capacity

Overall, backgrounds showed that participants and employees have little expertise; even the two Water Trust managers who were water engineers expressed their need for capacity building. As a result they depend on contractors; but since these consultants do not systematically provide satisfying reports, water utilities need to be equipped to assess whether a geophysical survey or borehole drilling was well done and whether reports are complete and relevant. In addition, as data storage after borehole completion is often incomplete, there is missing information to site the next boreholes. Monitoring is also poor, not only because of limited equipment, but also because water utilities do not always see the point, in particular to record water levels, as a few participants considered that if the levels did not change, it was not necessary to keep monitoring them. This lack of capacity is therefore the greatest barrier to efficient groundwater data management. This is consistent with the findings from Mwendera *et al.* [20] within the WDM framework; but unlike that study, which highlights a lack of commitment to implement WDM guidelines, participants, certain Water Trust managers in particular, were found to have a strong desire to be trained and improve. This was also the case in a study by Gumbo *et al.* [19], who found that demand for WDM training in Southern Africa was high, including among experienced water professionals.

There are thus opportunities for interventions from local consultants and external organisations. The workshops led by WSUP were well received by the participants and seemed fruitful as several participants mentioned they had started to include certain pieces of information in borehole siting or to monitor certain parameters after these workshops. Several asked for similar short-term trainings. Such workshops allow for personalised explanations and demonstrations. While this can be necessary for topics that vary greatly between participants, there is also a need for guidance on siting, drilling, supervision and contract management [12]. This guidance might take the form of short and simple guidelines.

More specifically, on-going monitoring requires that staff involved have an idea of the significance of the different values and, in case of a change from the usual values, the degree of urgency required for an intervention. That is why Water Trusts need to be able to compare their water quality levels to the national drinking standards, both when these are above the thresholds, but also when they are under; the LWSC should systematically share the results of the water quality tests with the concerned Water Trusts, regardless of whether they meet the standards. As for the water levels, they vary greatly between boreholes, so that it is difficult to provide a simple idea of what to expect. This is why water levels need to be measured regularly for each borehole, ideally every day. Pumping rates also need to be recorded as they allow for interpreting dynamic water levels and the relationship of abstraction and recharge to water levels.

4.3. Collaboration between Utilities

Data sharing between the utilities was found to be poor, as a lack of coordination and of sharing of results was identified; Karki *et al.* [16] have identified similarly that the lack of coordination between stakeholders resulted in inadequate data sharing, which was in turn a constraint to research program development. At the moment, the relationship between the utilities is mainly between the different LWSC departments and between the LWSC and the Water Trusts. It would still be beneficial for both sides if a two-way relationship was further established, with regular reports from the Water Trusts submitted to the LWSC, on which the latter should systematically provide feedback. In addition, regular consultation should be established between the LWSC and the Water Trusts that require technical assistance. Besides this, the Water Trusts would also benefit from sharing more between them: as some managers are more experienced than others, they can provide examples of good practice and ideas to each other. This is already partly taking place during quarterly forums, but could still be improved according to several managers. The LWSC should play a central part in inter-Water Trust relationships as the coordinator of the water services in Lusaka.

The sharing of data would be greatly improved by first standardising the reports produced on borehole completion to make sure they are consistent across the water utilities. The reports should then systematically be shared with the LWSC by the Water Trusts so that a database is established. Electronic copies should also be made on top of the hard copies. Similarly to Gumbo *et al.* [18], a comprehensive Management Information System (MIS) is lacking and would be of great use. For example, the WSD's Access database could be used as a starting point, and access granted to all LWSC departments and Water Trusts via a password. Such an online database would: facilitate coordination between the different stakeholders involved in borehole exploitation, build up a strong water quality and levels database, and increase transparency. The success of MIS has been shown by Gumbo *et al.* [18] who compared four case studies. The main limitation might be access to the Internet, as highlighted by one of the participants. Other technologies could be explored, for example using phones to enter data to the database while in the field; the start-up mWater provides applications that could be useful in that regard, although they do not solve the issue of accessing the Internet.

Finally, as Jongman and Padovani [15] insisted on the importance not to underestimate local knowledge, it is interesting to notice that the only two participants who mentioned local knowledge were also the two most qualified. While any conclusion on this should be taken with care, it would still be worth investigating ways to integrate and share local knowledge.

It would be interesting to extend the study by involving other stakeholders, for example local authorities as they undoubtedly play a role in borehole siting through land prioritisation for example. It would also have been interesting to look at the many private boreholes in Lusaka, as mentioned in introduction, which were also the concern of one respondent and other authors like Chakava [23].

5. Conclusions

Water utilities in Lusaka are faced with an increasing demand for water and a limited resource available, mainly groundwater. There is thus a need for careful borehole siting, drilling and on-going monitoring. Using a formative approach in the form of fifteen semi-structured interviews with water utility professionals in peri-urban areas of Lusaka, this study has assessed whether hydrogeological information corresponds to their needs, and how data collection and sharing could be improved. A few points can be drawn out of it. First, even though a few adaptations could be made, it was found that primary hydrogeological information sources were overall answering the utilities' needs, although there was a need for maps at a smaller scale showing faults and fractures. The main obstacle to efficient data management was then identified as the lack of capacity and equipment. For example, there is a need to be able to interpret monitoring data and understand the significance of any changes. There is a need for external support by local consultants and international organisations like WSUP, for example by presenting workshops and producing guidelines. Finally, collaboration between the utilities and the establishment of an electronic database to which all have access (internet connection permitting) would greatly enhance data collection, storage and sharing. This would contribute to the improvement of water supply in peri-urban areas of Lusaka.

Supplementary Materials: The following are available online at www.mdpi.com/2073-4441/8/4/135/s1, Coded spreadsheet of interview notes.

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Abbreviations

The following abbreviations are used in this manuscript:

GIS	Graphical Information System
GReSP	Groundwater Resources Management Support Programme
IWRM	Integrated Water Resources Management
LWSC	Lusaka Water and Sewerage Company
MIS	Management Information System
SGwR	Strategic Groundwater Resources
WDM	Water Demand Management
WSD	Water Supply Department
WSUP	Water and Sanitation for the Urban Poor

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