eGROUNWATER
Working paper 2

Participatory Groundwater monitoring using a mobile phone application in South Africa - Potchestroom

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In brief – In this project, researchers develop and test a mobile phone application, which can be used to locate and describe boreholes and monitor groundwater levels over time. Data collected are stored in an online database accessible to users. One of the main innovations of the application lies in the data quality assurance approach, which relies on a dynamic system of user star rating reflecting confidence that can be placed in the data they provide. The App is also designed to provide incentives for consultants to upload the data they collect, through a system of data credit reflecting their contribution to the system and determining how much data they can download in return. The application has been successfully tested on a local pilot study, with a small group of volunteers, but questions remain concerning the possibility to upscale it at regional, basin or national level.

This document should be cited as follows:

R Ouedraogo and JD Rinaudo, 2023, Participatory Groundwater monitoring using a mobile phone application in South Africa – Potchestroom, Egroundwater working paper 2, 7 pages. Available at https://egroundwater.com

eGROUND WATER
This project is part of the PRIMA programme supported by the European Union's Horizon 2020 research and innovation programme
PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA
Horizon 2020 European Union Funding for Research & Innovation

Context and innovation

The national groundwater archive: current situation and main problems

Existing databases operated by Department of Water and Sanitation contain information on boreholes (officially registered only), water levels, water chemical quality and various other information. Data are supplied by (1) boreholes owners, drilling companies or consultants and by (2) public agencies when they conduct specific surveys. The system however suffers from a number of problems.

Gaps in borehole data: many boreholes are not registered; their geographic location is imprecise (inaccurate, false or missing coordinates); water level data are scarce and have a poor temporal resolution. This situation is due to the following factors:

(1) the agency in charge lacks the financial resources to conduct expensive groundwater monitoring programs and even to enter in the database the information they receive (there is a huge backlog of borehole information that still needs to be captured).

(2) Users rarely report the data they have regarding borehole location, water levels and water chemistry. This is particularly true for consultants who prefer keeping the data for themselves as this knowledge give them a comparative advantage for conducting studies.

(3) A high number of domestic boreholes (about 30,000 boreholes around Cape Town) which were drilled as emergency response during the 2015-18 drought were not declared, as they do not require a license[1]. This information, if captured, could significantly improve groundwater knowledge.

Users have no incentives to communicate their data to the Information System Manager, as they may face difficulties in accessing to the database in return. They do not always get an answer when they submit a data query, as agency staff manually process some of those queries.

The trigger for innovation: the 2015-18 drought

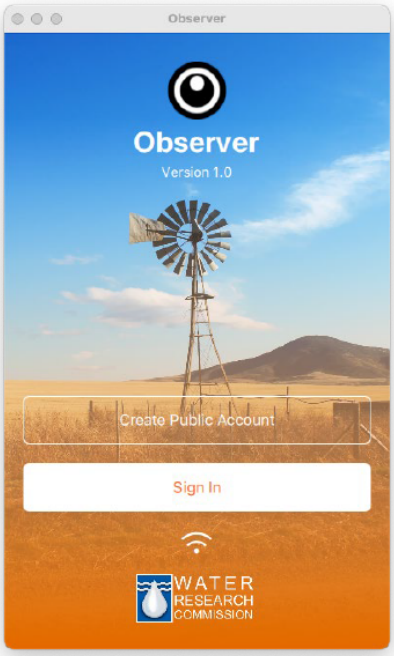
During the drought period, surface water resources dried-up and many communities and users were running out of water, so drilling boreholes became the only alternative. The demand for information about groundwater resources and water levels increased. As a result, citizens spontaneously started to exchange groundwater level information on social network platforms.

This sparked the idea of developing a smartphone application, for general public and professional, which could facilitate groundwater data collection. This mobile app was tested during a pilot project conducted by North-West University researchers and funded by the Water Research Commission of South Africa. The objective of the application is to involve users in (i) the identification of boreholes localities and (ii) the measurements of groundwater levels.

[1] Indeed, these boreholes fall under “Schedule 1 use”: water uses are generally low-volume, low-impact activities that are consistent with domestic use, livestock watering, recreational use and the use of water for emergencies.

Technical characteristics of the innovation

- The mobile phone application



The mobile app. The North-West university team in South Africa decided to develop the App using a commercial solution (ESRI App Studio) with Qt language, rather than developing a customized application. The ESRI App allows creating a geo-enabled cross-platform native application. The database is hosted on an ArcGIS Online Server under a University license. The data can be directly queried from the server, but the buy-in from the official databases, such as NGA (National Groundwater Archive), would be required. However, before start looking how the database can be connected to NGA, a custodian or an owner of the system must be appointed. Moreover, this will make the App available to everyone (via Google Play Store or Apple App Store), as currently the App is only available to those belonging to the University group.

User profiles. The App is designed for two users' profiles, the general public and water professionals (consultants, drinking water services officials, public organizations). General public users can only enter simple information: coordinates and characteristics of the borehole, such as its status (e.g., dry, in use…), the purpose (e.g., irrigation, water supply, livestock...) and a qualitative assessment of its quality (e.g., drinking quality, for animals only, salty…). Screen shots in Figure 1 provide an illustration of the type of data that can be entered. Professionals are allowed to enter more detailed quantitative data related to (i) borehole construction; (ii) water level measurements and (iii) groundwater chemical analyses (Figure 2).

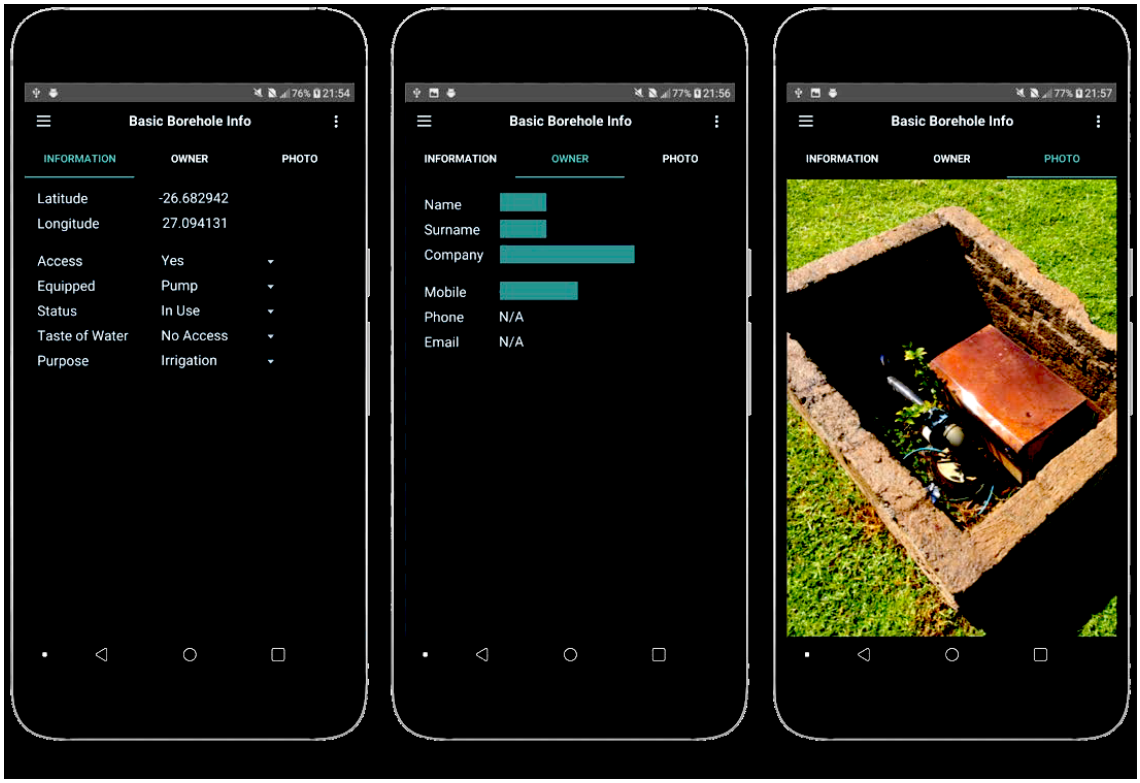


Figure 1. Screen shot of the interface allowing data entry by general public (source: Dennis and Dennis, 2022)

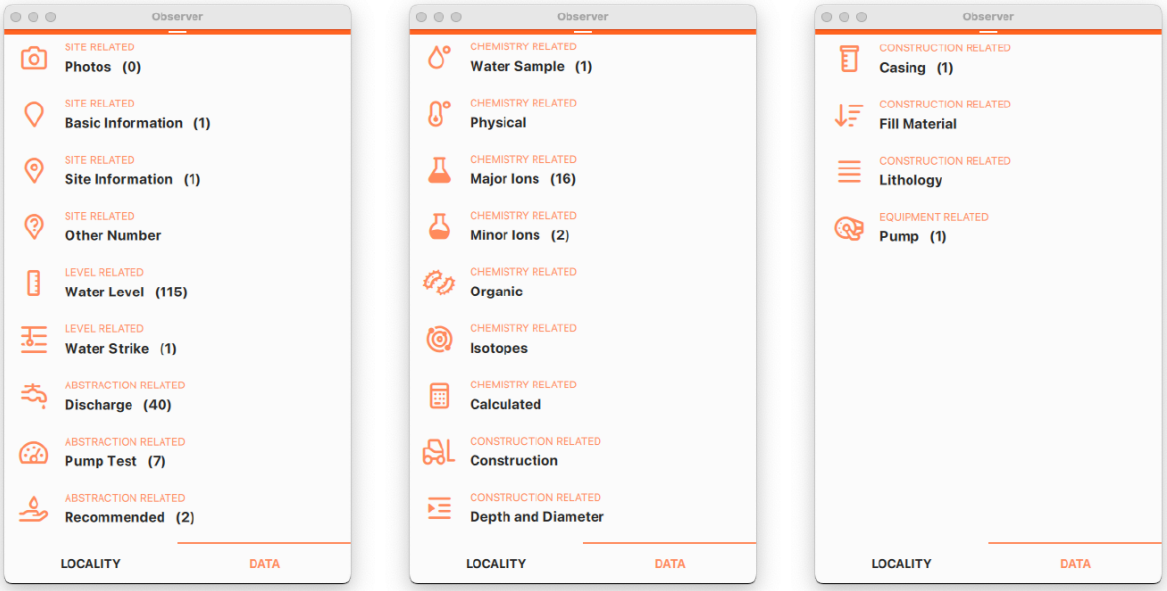


Figure 2. Example of additional information collected by professional (Source: Dennis and Dennis, 2022)

- ### Data verification through users rating

One of the main innovations of the application lies in the data quality assurance approach, which relies on a dynamic system of user star rating reflecting confidence that can be placed in the data they provide. Each new user is initially rated “zero star” on a scale from 0 to 5.

Users considered as professionals and trustworthy will be assigned a five-star rating. And the administrators of the system will receive a 6-star rating. Therefore, data capture by zero star users are considered as low confidence until verified by a user of higher rating. Multiple positive verifications of data produced by a particular user lead to an increase of his/her star rating.

However, to prevent free-rider groups from validating each other’s data quality (in an unjustified manner) just to increase their own star rating, there is a monitoring mechanism based on two criteria: (1) the rating of the user whose data (locality status captured) has been verified by a higher ranting user, will be increased by only half a star; (2) to receive the other half a star, the user has to verify 10 boreholes localities status captured by higher rated users.

- ### Incentives to upload data

The incentive for users to contribute to the database is based on a system of credit reflecting their contribution to the system (amount of data entered) and determining how much data they can download in return. However, even with a zero credit, users can still download some data, as for promoting data sharing the system should not be restrictive.

In addition, users can join an organization to pool their credits and data. The credits are subject to quality verification, so the system will require an administrator that will be able to check on irregular database entries. According to one of the authors: “*the data capture require the user to be within 10 meters of the borehole, so remote data capture via the app is not possible. Consultants and groundwater professionals can register and make use of the desktop app, which will allow bulk uploads remotely, but we can control who these users are*”.

Innovation implementation process: a pilot case study

The mobile app was tested on a pilot study area by making it available to people interested in participating. The user group consisted of ordinary citizens living in Potchefstroom, university students and a local environmental consultant.

Pilot outcomes

At the start of the pilot project, the available data from the official database amounted to 46 boreholes. Most of those boreholes (96%) were historically assigned to the farm centroid at the time (Figure 3 (a)).

The deployment of the application allowed recording the real position of 63 boreholes, bringing the total number of boreholes location to 109 (Figure 3 (b)). The public added 52% of these borehole positions, the rest was provided by students and local consultants. The consultant provided water level readings where the boreholes were not equipped. The public users together with the student group only provided basic information as shown in Figure *1*.

The verification of boreholes location is considered valuable information since locating a borehole in the field for hydro-census purposes is time consuming. Once positions are known, more detailed information can be acquired by professional users.

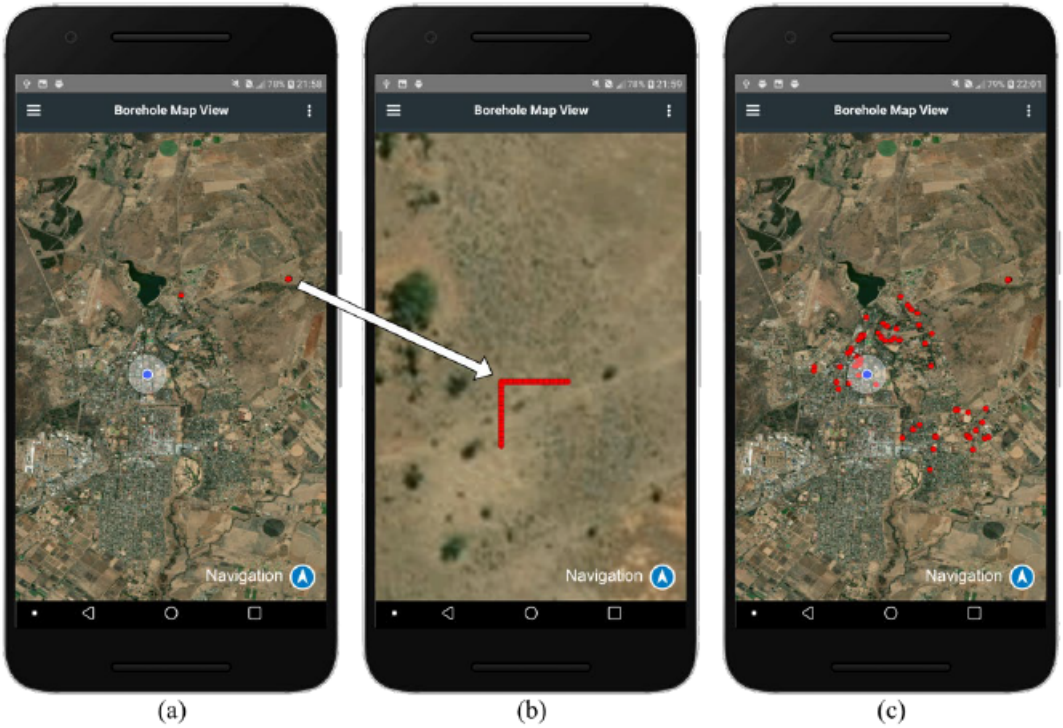


Figure 3 : Location of boreholes at the beginning of the pilot project (a) and at the end (c). The center screen (b) shows two boreholes that were initially assigned to the same location. Source : Denis and Dennis (2022)

Factors hindering the adoption of innovation

A workshop was conducted with several types of stakeholders (e.g., groundwater consultants, an ex-municipality member, farmers, students…). This workshop allowed identifying factors likely to hinder innovation uptake. For example, farmers were reluctant to publish information about the precise location of their borehole, because that would increase the risk of theft of their equipment (e.g., motor pumps…). Their recommendation was to make certain data visible only for trusted users with a high star rating. Similarly, unregistered

boreholes owners were opposed to full transparency as this light force them to apply for a license. Mining industries are also not willing to make their monitoring data public.

A major challenge remains to keep the public motivated to actively make use of the mobile application. As highlighted by Rainer : "*a borehole is not an interesting object to study and if there is no immediate threat of limited water supply to users, monitoring is not a priority for them; Various app exits where citizen science is used to gather data e.g., logging information about frogs and people find this exiting. The problem with a borehole is that the public might not find it as exciting as chasing frogs.*"

The strategy developed by the research team consisted in enlarging the scope of the application to increase public interest. Rainfall data were included in the application – with possibility for users to enter their own data and visualize those collected by others. The hope is that people will target the app to also log rainfall data and once they see the benefit of that also log borehole information for proper management purposes.

Upscaling

The up-scaling of the innovation from the pilot area to higher level, such as province or state, has not yet taken place. This will first require appointing a custodian and an owner of the system, in charge of maintaining the application and the database. At this time, the Water Research Commission is exploring the possibilities of which institution will take over the development and implementation of the app at different scales.

A database administrator will handle the majority of technical issues, but a software developer will be needed to update the app. The financial aspects that the "owner" of the system will support are the ArcGIS online server license and the App hosting on the Google Play and Apple App Store. However, the vision of the project is to keep the mobile app free to motivate users to share data.

References

Dennis S.R, Dennis I (2022) Mobile App for Hydrocensus and Groundwater Monitoring. Final report to the Water Research Commission. Centre for Water Sciences & Management, North West University. Project No. K5/2827 – July 2022.

Acknowledgments

We warmly thank Dr Stefanus Rainier Dennis (Hydrogeologist at Centre for Water Sciences & Management, North West University) for sharing information and illustrations with us on this project. Support from Dr Shafick Adams and Mr Yazeed Van Wyk from the Water Research Commission is also acknowledged.