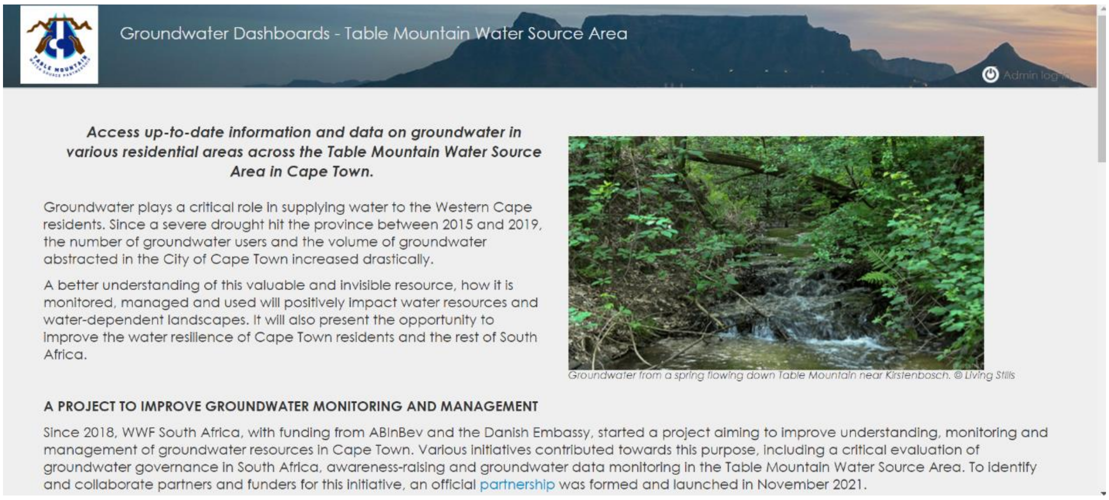
ANNEXURE 4: GROUNDWATER DASHBOARD

Partnering with iComms and Immo Blecher



CONTENTS

DEVELOPING A GROUNDWATER KNOWLEDGE-BASE AND DATABASE FOR THE TABLE MOUNTAIN STRATEGIC WATER SOURCE AREA

by Immo Blecher

1. BACKGROUND

The Day Zero period saw an unprecedented spike in borehole installations across the city. just how many boreholes there are in the city, how much water is being used privately, whether this exceeds the recharge rate, and the impact on ecosystems, remains unclear. greater water use through private and public means is the new norm, and it is pivotal to ensure a sustainable management and utilisation of the resource.

In an effort to mobilise activity in the Table Mountain Water Source Areas, WWF started to involve citizens of cape town in 2018 in a broad-based citizen science monitoring programme that is helping to build a clearer picture of cape town's groundwater use and sustainability over the long term. this groundwater monitoring project currently spans six areas of the city, to build an understanding about the health of the aquifers and how they respond to pumping and rainfall.

The dashboard GROUNDWATER DASHBOARDS - TABLE MOUNTAIN WATER SOURCE AREA (GROUNDWATERINFO.AFRICA) is one of the very tangible and long-lasting outputs of this project. it ties into the filling and addressing of several groundwater management and information gaps. Firstly, it is an information system for residents, providing an added source of awareness raising to the topic of groundwater. the language is specifically tailored to make it accessible to any interested citizen. this in itself is an important output, because groundwater is a technical topic that is not easily communicated. Secondly, the dashboard is a relatively live groundwater data collection site, making this a rare and much needed source of groundwater data, that is often not shared or held in one location. Thirdly, the dashboard is built on previous work by the Water Research Commission (WRC) and Aquabase, using existing structures to a maximum.

The dashboard was officially launched on 24 March 2022 for World Water Day. Its launch was most befitting of the World Water Day theme: "Groundwater, making the invisible, visible".

2. MAIN AIMS FOR DASHBOARD DEVELOPMENT

The development of the groundwater dashboard had five main aims:

1. Identify and implement required changes/additions to an existing web-based mapping system
2. Identify and implement additional requirements from the front-end software and database
3. Identify additional sources of data for the database and load data
4. Determine database and web-server hosting platforms and locations (IT requirements) for the maps/dashboard
5. Determine the sustainability and further development/maintenance of the solution

These activities did not run in series but were often conducted in parallel, as one could not necessarily function or achieve results without work on any of the other. The outcomes of the initial activities are discussed further in the document.

3. DASHBOARD ARCHITECTURE

The Groundwater Dashboard for the Table Mountain Water Source area consists of five components, which are necessary to set up and maintain:

1. The PostgreSQL database server, that holds the groundwater data and other spatial layer data
2. The Aquabase water resources management software to enter and import groundwater and weather related data into the database and manage what data is available for the display on the maps
3. The QGIS desktop software with the Lizmap plug-in to produce the map projects for online publishing (the Lizmap plug-in configures and prepares the QGIS project for the online display)
4. The QGIS server software, which is normally part of the desktop software, but is installed on the same server as the database as standalone software
5. The Lizmap web client, also on the same database server, which consumes the QGIS projects from the QGIS server and makes them available in the Internet browser

All these are open-source software and under active development. The QGIS projects are normally set up on a laptop or desktop and then transferred to the server via FTP. On the desktop all layers and groundwater data are accessed on the database server directly so that the connections between layers and database are automatically set up. The server should ideally be a Linux (with Apache or nginx web) server and hold the PostgreSQL database, QGIS server and the Lizmap web client.

4. SETUP FOR THE DEVELOPMENT OF GROUNDWATER DASHBOARD

1. Identify and implement required changes/additions to an existing web-based mapping system

a. In order to save on development time and cost it was proposed to use an existing web-based mapping project, which was developed under a previous WRC project, as a basis. This was based on only open-source software: QGIS desktop Geographic Information System for the creation of the maps, Aquabase water resources management software to manage the groundwater data, PostgreSQL as database and QWC2 web client in combination with QGIS server to serve the pages to the Internet. As the QWC2 web client became difficult to maintain, especially with the view of establishing a long-term sustainable project for the Table Mountain Water Source Area Partnership, it was decided to switch to the Lizmap web client, which is a lot easier to set up and maintain. It is also open-source and under active development with new functionality coming out regularly. This switch-over was easily achieved by installing the Lizmap web-client code on the server and adding the same QGIS project used for the previous QWC2 web client as a map repository. The advantage of these web clients is that they display all the map layers with their symbologies exactly as set up with the QGIS desktop software.

b. The groundwater database for displaying borehole and related groundwater information on the map was the existing PostgreSQL database, that was already set up during a Western Cape Government groundwater emergency supply programme with data added during the WRC project. The database contains groundwater data for the entire Western Cape province, which would even make it possible to create similar maps/dashboards for other water source areas in the province. Other mapping projects in the province, which may only be accessible to certain logged-in users, already use the same database for storing and retrieving groundwater data.

c. A new Water Source Areas (WSA) layer was created with three WSAs identified according to the WRC report Le Maitre et al.: *Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater.* Cape Town and surrounding areas fall within two overlapping strategic water source areas – the surface Table Mountain Water Source Area and the groundwater Cape Peninsula and Cape Flats Water Source Area. These areas were delineated by using the secondary quaternary catchment areas and combining them into the three sub-areas in QGIS and adding the layer to the web-based map. With the new layer as focus layer the initial extent of the map for the TMWSA project and possible zoom values were updated.

d. After loading the first monitoring boreholes identified by WWF and GEOSS as long-term monitoring points, two distinct monitoring areas (Newlands and Airport/Epping/Bellville) were identified and added as another layer with roughly outlined polygons. These were adjusted during the course of the project as more data and other monitoring boreholes from other projects became available, also necessitating adding another monitoring area to the south of the Airport/Epping/Bellville area around the Philippi Horticultural area and Lentegeur. All these areas were also formed to include rainfall station locations. More areas will be added during the course of 2022, once more viable borehole/rainfall monitoring areas have been identified. The shape of the individual monitoring areas may also change, depending on available data. Four additional monitoring areas, Kommetjie & Scarborough, Noordhoek, Bergvliet and Brackenfell have been identified to expand the monitoring network. Updated water level data from these additional electronic data loggers will become available on the dashboard as soon as they are downloaded, verified and presented for upload to the dashboard.

e. A new buffer zone of approximately 10km around the TMWSA polygons (secondary quaternary catchments), but including these polygons, was created and saved to the database. All geosite (boreholes/springs/weather stations) queries on the database were then set up to only extract boreholes/springs/weather stations and other spatial layers etc. within this buffer zone to reduce server load and query time (make the display of the map faster).

f. Some layers from the previous WRC project were also removed as they were not really relevant for the TMWSA area. Some of the boreholes, springs and weather station layers were grouped into "Monitoring" and "Other" groups to make it easier for map users to distinguish layers relevant to them.

g. Over and above that the Lizmap web-client charting tool (Dataviz) was activated and populated with dashboard-like information blocks to display statistics and charts of various groundwater and weather parameters. For these the data had to be extracted from the database with database views to convert the date and time fields (which are string fields) into date/time fields and make e.g. the water levels negative to reflect metres below ground level [mbgl]. Water level charts are displayed as line charts and rainfall charts as bar charts. Both use the entire date range as extracted for one or more records from the database. Initially these statistics were also supposed to display chemistry over time but this could not be achieved due to the lack of sufficient data to produce sensible statistics for the monitoring areas.

h. A landing page was created as an introduction to the project. At the bottom of the landing page there are two map illustrations (as links to opening the maps) that represent two different versions of the dashboard maps, which are shortly explained on the page.

i. It was decided to present two versions of the dashboard maps, which would be specifically designed for two types of users: 1.) a "Quick view" map for users who for example want to know the average groundwater levels in their area or for curious students or learners, or users who would like to learn about the fascinating world of groundwater; 2.) a "Deep dive" map for practitioners or environmental scientists familiar with groundwater resource data and who are comfortable using mapping software and interfaces. The two maps do not have the same number of layers and the "Deep dive" also has more scientific information and layer naming.

j. Several links to other pages of the dashboard have also been created in various areas of the landing page, pop-ups and the maps, which include links to the Table Mountain Water Source Partnership page and links to the "Quick view" How to navigate page and the "Deep dive" How to navigate page, which provide a guide on using the different map components, and a Disclaimer/Terms of use page.

2. Identify and implement additional requirements from the front-end software and database

a. In order to make a dashboard with "live" data many of the database date fields had to be updated with database triggers and default values to reflect relevant "Date of Entry" and "Date updated" values so that these can be queried by the dashboard/web-based map. Very often users would not bother to import these and that is why they are now updated automatically within the database. Other fields had to be adjusted to insert default values, if values for the fields were not supplied during data entry or import, as otherwise data queries would result in incorrect results and therefore erroneous data or charts on the maps.
b. The import routines for the table import (free format) and the logger data import had to be adapted to new/different output formats from the loggers to make importing of data easier. The table import routine was changed to a more efficient import, especially when dealing with cloud-based databases, to allow data editing/adding while the import is running. The logger-import routine was also further improved to provide for the import of certain records only, e.g. hourly or daily etc., regardless of logger sampling frequency. In addition, a logger-import template spreadsheet was created to simplify the copy/paste/format import process, which has become part of the standard Aquabase tools available to the user.
c. The data import for Water Management System (WMS) from Department of Water and Sanitation (DWS) chemistry data was improved with an option to use existing sample numbers which are already on the system to match with the new import file. This speeds up the import process of new data into existing sites as often site numbers on the WMS do not match with numbers from the National Groundwater Archive.
d. A new tool for the import of "Audited & Reduced Water Levels" from the DWS National Groundwater Archive (NGA) was developed to easily import the downloaded files. This involves a NGA account to log onto the website and search for the old or new *Hydrological Station Number*, which is also stored on the Aquabase database. This import is only necessary if there are more than a couple of water level records as typing in the latest water levels as retrieved from the website may be faster.
e. A data flagging tool was developed and the groundwater database changed to include a flag field in most of the tables. The flag can be used to filter the data to be used for the display on the maps or in the charts, i.e. only the data that is flagged is extracted from the database to be displayed.
f. In order to speed up the display of the maps the data flow between the web client, the QGIS server and the database had to be optimised. For this a number of database views have been created, which extract only the necessary fields and flagged data from the database. The QGIS projects then use the views, instead of the whole table, to work with the reduced data only. For some mapping functions, like the water level statistics in the "Statistics" panel, this could be even further optimised by using so-called *materialised views*, which update only at certain intervals, because the data queried does not actually change that often, as compared to normal views, which are executed as required by the map. Tweaking of the views required a considerable amount of time to make sure that the Lizmap web client can actually produce the charts and statistics.

g. The acquisition of rainfall data in South Africa generally is difficult and expensive, e.g. from the South African Weather Service (SAWS). There are, however, a few national and international websites, where up-to-date rainfall and other meteorological data can be downloaded for most of the weather stations in South Africa, that are often also registered with the World Meteorological Organization (WMO). Two import routines were therefore developed within the project to import data directly from these online resources with web-scraping technologies.

3. Identify additional sources of data for the database and load data

a. The initial monitoring network dataset from GEOSS had to be processed through data entry and import. The process involves the data entry of the sites from a PDF document first (this takes most of the time as there are several Aquabase entry forms, but also inconsistencies between some of the data in the PDF and in the logger-import Excel file). Then the logger data was converted (copy/paste) to a one-page spreadsheet (one site at a time) in which a couple of columns are additionally created to fulfil database integrity requirements. The spreadsheet is then reduced to hourly readings from the original 10 minute readings to reduce almost similar readings. These were then imported into the cloud database with the table import tool. The logger import was conducted about three times for the Newlands boreholes and twice for Airport/Epping/Bellville boreholes as new data was retrieved from the loggers.
b. Another borehole dataset from a hydrocensus in the Kommetjie area consisted of basic borehole information from a simple census form given to the residents. Datasets from the most recent borehole surveys in the Bergvliet, Noordhoek and Brackenfell areas were not available at the time of writing this report. Some of the boreholes confirmed during the survey will become monitoring boreholes with the residents' consent.
c. A borehole dataset from previously obtained datasets from the City of Cape Town was also imported. These were monitoring boreholes at cemeteries, which would have some chemistry data attached to them. These chemistry records and maybe other chemistry monitoring data will still need to be obtained.
d. A chemistry dataset from the Water Management System was requested from the Department of Water and Sanitation for all data after June 2018 and promptly received. This data was imported into the database, but included only 2018 sampled data. A query regarding data after 2018 confirmed that there was no data after 2018 and the advice to contact the municipalities directly for more recent chemistry data.
e. A Department of Water and Sanitation (DWS) HYDSTRA dataset from the NGA ("Export Audited & Reduced Water Levels" from oldest available to most recent date) was downloaded and imported into the groundwater database. In order to have the most recent data for testing the dashboard this process was done three times during the course of the project. A gap in the data between the beginning and the end of the 1990's was noticed and emails sent to relevant DWS personnel to inquire about the "missing" data, but to no avail ("it is just not there").
f. A number of data logger files for several monitoring boreholes drilled during the Western Cape Government Water Business Continuity Programme were received from Roger Parsons with permission from the Western Cape Government. Most of these boreholes lying inside the identified monitoring areas have already been

mothballed (monitoring ended around the third quarter of 2021), but their historical water level data is still valuable for the long-term trend observations. These logger files were in the form of spreadsheets, which had to be adjusted to conform with database requirements and then converted to CSV files for import.

g. The last data received were several data logger files from the City of Cape Town for the Cape Flats and Atlantis monitoring programmes conducted by Umvoto Africa for the City. These logger files with the most recent measurements in the fourth quarter of 2021 and starting at the beginning of 2019 were in the form of spreadsheets, which had to be adjusted to conform with database requirements and then converted to CSV files for import. The latest data until April 2022 still needs to be downloaded and received and it would also be beneficial to import data from these loggers from before 2019. These boreholes lie mostly in the Cape Flats area and form part of the Airport/Epping/Bellville and Philippi/Lentegeur monitoring areas. Data was so far only imported for boreholes falling into these areas, but other Cape Flats and the Atlantis monitoring data will subsequently also be imported for the sake of completeness.
h. Rainfall data was obtained from several online websites by using the new Aquabase import routines, which use web-scraping technology to read data from the web and then import it directly into the correct Aquabase tables. For some weather stations data was imported from the 1950s, but these often do not have a continuous record until recent, others have only data available from 2018, but those that are registered on the World Meteorological Organization (WMO) network have data from 2000. Overall this provides a good record for most of the rainfall stations in the monitoring areas, but more recent data for some of the stations is still required for better statistics.

4. Determine database and web-server hosting platforms and locations (IT requirements) for the maps/dashboard

a. For the final hosting of the Groundwater Dashboards it was decided to move the previous web-mapping setup from a home-office Linux server to a more permanent international Linode cloud server at Geotel, Somerset West. For that purpose, the PostgreSQL database server software (version 13 at the time of writing the report) and the QGIS web-server software (version 3.16 at the time of writing the report) had to be installed and set up. This cloud server option was the preferred one at the time of setup as there was little red-tape for the setup of additional software and administration of services required, like FTP. The existing PostgreSQL database was then “dumped” from the home-office server and restored to the Geotel server and made available for access from the Internet. This enabled access by Aquabase software users with relevant permissions to add data into and edit data directly in the database so that there is no synchronisation process involved between different parties contributing data to the database. Over and above that the database is directly accessible by the mapping projects on the same server (QGIS server) reducing loading times for the display of the groundwater layers.
b. As the groundwater database typically has tables (about 83) for storing point data with chemistry, time or depth-dependent data attached to them, another PostgreSQL database was created on the server to hold the other polygon and line data like the water source areas, monitoring areas, rivers/streams, suburbs etc. This made sure that all data displayed on the maps is stored in databases with high integrity and

directly accessible in the cloud from the mapping components. If changes are made to any of the features in any of the databases, these will be immediately showing on the maps. The “non-groundwater” layers in the cloud can also be edited with the QGIS desktop software by users with read/write permissions.

c. The setup of the web-based maps (existing and new ones) on the new server also required the registration of a new domain https://www.groundwaterinfo.africa, which initially was used to host all previous and the new TMWSA projects, until a decision was made to register a new domain or create a sub-domain for the TMWSA project. The sub-domain https://tablemountain.groundwaterinfo.africa was subsequently set up on the server, not necessitating domain registration again and additional cost. For the TMWSA project another instance of the Lizmap web client (version 3.5.1 at the time of writing the report) had to be installed separate from the original Lizmap installation for the other mapping projects on the same server, and which now also has to be updated separately, if required, as newer versions of the software become available.
d. It was also found that some of the wording of the map tool components were not easy enough to understand by the potential website users and therefore a few configuration and language files had to be edited on the server directly. But this also means that using the maps in browsers set to any other language, e.g. in other countries, the wording will default back to the original as installed for that language. These changes could also become a potential issue with future upgrades which may override the changes made.
e. In order to make the hosting environment and server sustainable for the continuation of the project after this project ends, a user with certain admin rights has been created for access via ftp and ssh. This is needed for uploading of project data and files and the update of the services used for the online maps. This includes the regular update of the web-server software (QGIS server and the Lizmap web-client), which requires the use the latest features that become available with the constant open-source developments. The ftp access is used for the upload of the QGIS project, which is normally setup and changed on local desktop or laptop and then uploaded for use by the QGIS server and Lizmap.
f. All database access by the online map and the dashboard projects is specifically done by the read-only user *qgis*, which was created right at the beginning of the map setups. Other users, that have worked on the project and might possibly be involved in the ongoing upload of data have read-write access to the databases.

5. Determine the sustainability and further development / maintenance of the solution

As the groundwater dashboards developed under this project were designed to present the most recent data on the maps to the users the sustainability is one of the most important parts of the solution created. Nobody will use the dashboards if they only have outdated water levels and/or rainfall. There are already many mapping solutions of groundwater data on the Internet, but most of these are static and only have historical information that is several years old.

In order to keep the database, and with it the maps and statistics updated, the following is required:

a. A consultant needs to be appointed and take over the responsibility of the upkeep of the databases and mapping projects (website). This consultant should typically have access to the Aquabase and QGIS software and must have one or more users registered for read-write access to the databases and the QGIS project folder on the server for the FTP transfers. If changes on the server files are required, then a user must also have ssh access to edit certain parameters like headings or menu items that are displayed on the maps. This may not be necessary, but may become important if updates to the QGIS server and/or Lizmap software is required due to security reasons or new functionality.

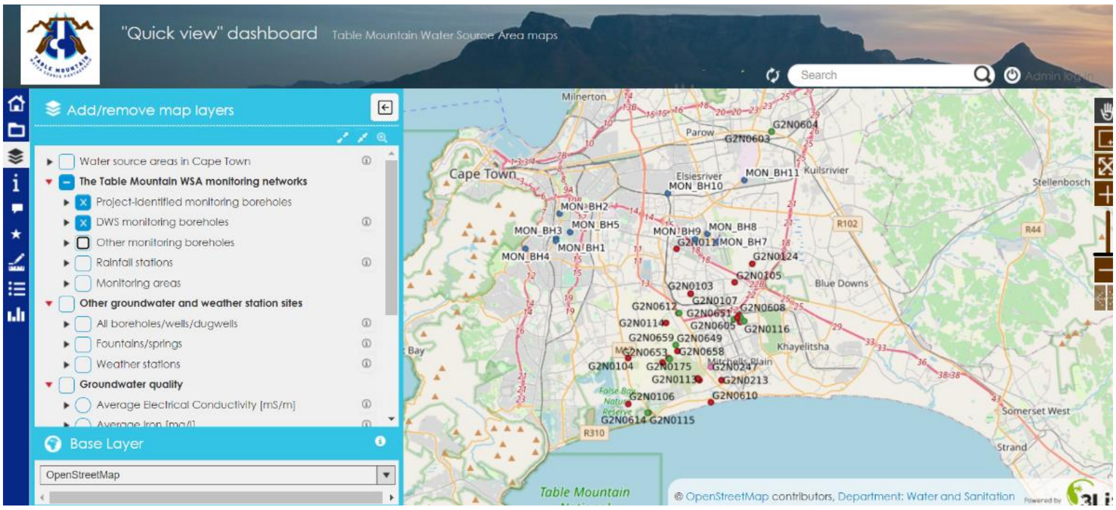
b. Data needs to be obtained from various contributors on a regular basis (at least quarterly), especially for the monitoring boreholes that were identified during this project and the other monitoring networks, like the ones of the City of Cape Town or the DWS HYDSTRA monitoring network.
c. This data needs to be checked for integrity and then imported with the Aquabase supplied tools that were developed or improved during this project. This can be done by the consultants responsible for the collection of the data already.
d. The data then needs to be imported with the logger-import tool or the more general table import tool in Aquabase. The logger-import tool is the preferred tool over the table/spreadsheets import as it can drastically reduce the processing time of the import process.
e. The data in the database then needs to be flagged with the Aquabase flagging tool for display on the maps and the charts, thereby also making them available for the statistics calculations and display. Once the newly imported data is flagged it will automatically be shown on the maps after the views and materialised database views have been refreshed. This can be done by a registered database user manually or will happen periodically automatically.
f. Rainfall data also needs to be imported regularly with the Aquabase tools developed during this project. This will then automatically update the charts and statistics on the maps.
g. In addition, identified monitoring boreholes need to be added to the database and flagged to show on the relevant layers. Once data loggers have been installed in these the data generated will have to be uploaded to the database as well. This would also mean that the monitoring areas need to be adjusted or new monitoring areas created to include these new boreholes for the statistics and charts.

As can be concluded from the above process the update of groundwater and rainfall data is the most important contributing factor to the success of the newly created dashboards. The biggest challenge in this process is the acquisition of data from various sources, including the Table Mountain Water Source Partnership members like the City of Cape Town (e.g. logger data through Umvoto) and Department of Water and Sanitation (National Groundwater Archive). Furthermore, consultants working in the area could also be motivated to contribute to the upkeep of the database by submitting their data either to the appointed consultant or upload the data themselves, which would shorten the turn-around time and updated maps considerably.

5. APPENDICES

The appendices listed below can be accessed from the Appendices landing page:
www.wwf.org.za/annexures/table_mountain_water_source_area_partnership

APPENDIX A	APPENDIX B
Thematic analysis results for the WWF citizen science groundwater project in Cape Town – iCOMMS	WWF Groundwater platform: Usability Testing Report – iCOMMS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DWS monitoring boreholes
Other monitoring boreholes
Rainfall stations
Monitoring areas
Other groundwater and weather station sites
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Weather stations
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Base Layer
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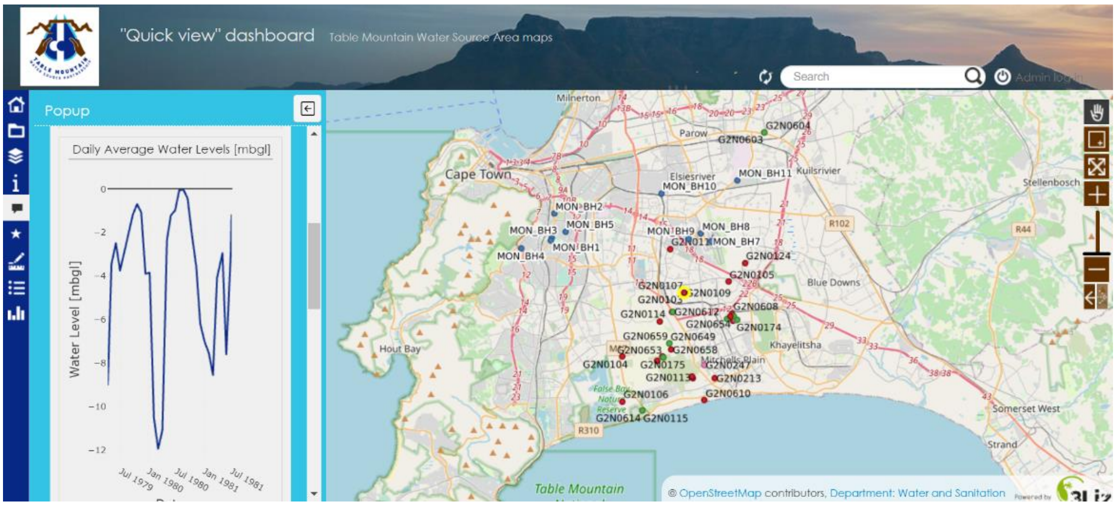
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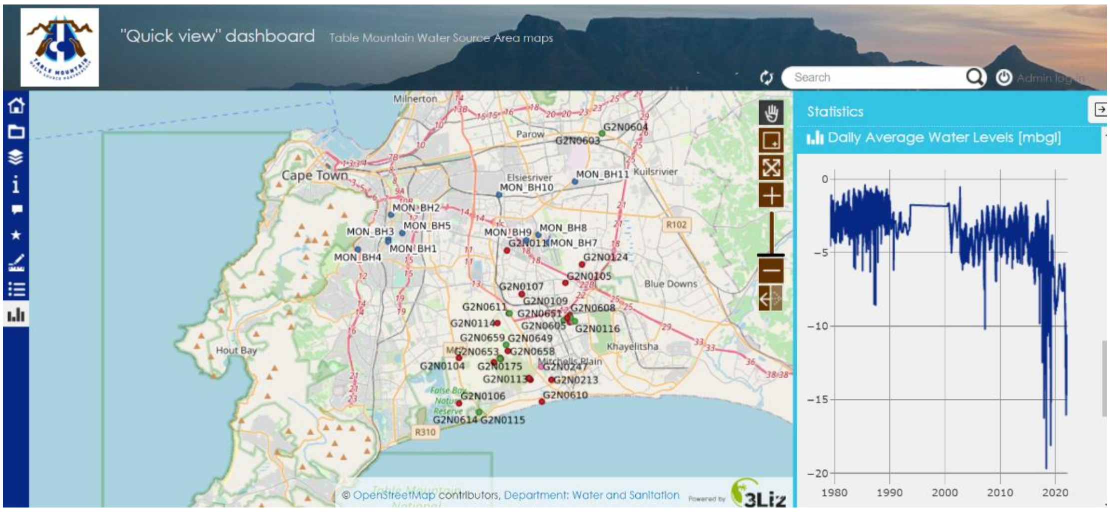
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