REPUBLIC OF RWANDA

RWANDA WATER AND FORESTRY AUTHORITY

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Rwanda IWRM Programme:

Ground Water Recharge and Storage Enhancement in Eastern Province

April 2019

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
2	09/11/2018	WE Consult			Implementation of comments from workshop and presentation in addition to initial comments to draft report
3	10/12/2018	WE Consult			Implementation of additional comments after submission Revision 2
4	13/02/2019	WE Consult			Implementation of additional comments, addition of ground water storage.

In order to do good management of water resources, the Government of Rwanda in partnership with the Netherland Kingdom elaborated a program of Integrated Water Resources Management (IWRM) which operated in Rwanda mainly in four demonstration catchments. This was implemented by a consortium of three partners: SHER ingenieurs co s.a, SNV and Euroconsult Mott Mc Donald with well defined responsibilities where Euroconsult McDonald is lead partner. This consortium becomes later Water for Growth Rwanda. However, in certain domains this project intervened at national level. Water for Growth Rwanda is then a platform to promote improved management of Rwanda's water resources. A joint Rwanda-Netherlands initiative, Water for Growth is supported by the IWRM Programme Rwanda.

The Integrated Water Resources Management (IWRM) Programme Rwanda is led by the Government of Rwanda and supported by the Embassy of the Kingdom of the Netherlands (EKN).

EKN Project number: 201501033.062; Mott MacDonald project nr: 348246.

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List of Abbreviations

.csv	Comma Separated File
.shp	Shapefile
.tiff	Tagged Image File Format
ARC	ATSR Reprocessing for Climate
ATSR	Along-Track Scanning Radiometer
BH	Borehole
CDP	Chinese Drilling Programme
CFSR	Climate Forecast System Reanalysis
CN	Curve Number
CRU	Climate Research Unit
DA_RCHG	Recharge to deep aquifer
DEM	Digital Elevation Model
DIVA	Data-Interpolating Variational Analysis
EC	Electro – Conductivity
EPSG	Geodetic Parameter Dataset
ET	Total Evapotranspiration
GIS	Geographic Information System
GPS	Global Positioning System
GWQ	Return flow
HRU	Hydrological Response Unit
ISRIC	International Soil Reference and Information Centre
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
LATQ	Lateral flow
M AMSL	Meters Above Mean Sea Level
m bgl	Meter Below Ground Level
MODIS	Moderate Resolution Imaging Spectroradiometer

NCEP	National Centre for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
OSM	Open Street Map
P	Precipitation
PERC	Percolation past root zone to shallow aquifer
PET	Total Potential Evapotranspiration
Ph	Acidity
REVAP	Water in shallow aquifer returning to unsaturated zone (capillary fringe)
RNRA	Rwanda Natural Resources Authority
RWFA	Rwanda Water and Forestry Authority
SRTM	Shuttle Radar Topography Mission
SURQ	Surface runoff
SWAT	Soil & Water Assessment Tool
SWL	Static Water Level
TRMM	The Tropical Rainfall Measuring Mission
VES	Vertical Electrical Sounding
W4GR	Water for Growth
WASAC	Water and Sanitation Corporation
WGS 84	World Geodetic System 84
WISE	World Inventory of Soil Emissions Potentials
WRM	Water Resources Management
WSL	Water Strike Level (1 for first, 2 for second etc)
ΔSW	Change in soil water

Executive Summary

The overall objective of this report is to inform on: Groundwater, recharge and storage enhancement in the Eastern Province and to identify/confirm main aquifers, understand their hydrodynamic behaviour, potentiality and recharge mechanisms.

Groundwater resources

Quantified sources of groundwater are available in the form of boreholes, which for their production depend on the aquifer they take groundwater from. Alternatively, springs where ground water flows out freely, are available in certain areas but they have not been quantified to the same extend.

Bugesera, Rwamagana and Kirehe have the least number of recorded boreholes. Bugesera in particular seems to also have a great shortage in terms of the borehole yield versus the demand of the district. High yielding boreholes can be found in clusters in Rwamagana, Gatsibo and part of Kayonza. The highest number of recorded boreholes can be found in Nyagatare, where because of the aquifer type, the yield over the district fluctuates between very low and very high yields. While Bugesera is dealing with similar aquifer types, the high yielding boreholes do not match up to the ones found in Nyagatare.

The Eastern Province consists mostly of fractured aquifers which are highly heterogeneous in nature, with possibly little to no relation to surroundings. Calculations for storage, flow and capacity which would apply to more homogeneous and consistent aquifers based on sediments for example, do not work. In order to still provide outputs, generalization needs to be made in order to establish a general picture of the above-mentioned characteristics. Fractured basement aquifers cannot be extrapolated and are much localized. Generalizations will obscure some of the information pertinent to the characterisation of these aquifers but will allow for a starting point to recognize them. All assessments done attempt to provide the highest resolutions with the data, knowledge, observations and understanding available at this point, to be built upon in the future.

Groundwater flow

In terms of ground water flow, little data is available from the boreholes to build upon. Since we are dealing with multiple possible aquifers feeding one borehole, the depths at which the water was found is key to establishing which aquifer the water belongs to. To avoid assigning water levels found in boreholes to aquifers they don’t belong to, borehole data was only used for verification, rather than establishment of the groundwater flow, since water strike levels are not available. This however means that only the upper aquifer on top of the rock can be displayed. Spring levels and surface water levels were used as the basis for creating the contours, creating a flow map that primarily takes into account the topography, rather than borehole data that would have been used.

Ground water flow in fractured aquifers at large scale is difficult if not impossible to establish. Fractured aquifer flow depends on interlinking of fractures and faults, creating conduits. With the data available at this point, flow cannot be established. However, in the future, if enough data is collected and enough boreholes are monitored, localized flow indications for these aquifers, if interlinked, can be mapped. Monitoring is key if this is to be achieved, preferably in production boreholes that are in use so that characteristics and influence on direct environment can be gauged.

Recharge assessment

An attempt has been made to estimate the groundwater recharge based on geological characteristics and mean annual rainfall. Each geological unit was attributed a recharge percentage (%) and for each unit the recharge percentage was converted into sustainably abstractable volumes (in m^3) by multiplying the rainfall with the surface area of the particular formation in the Eastern Province. The recharge percentage attributed varied between 5 and 15%. The total recharge in the province accumulated to, **98,447 m^3/h.**

Additionally, another method was employed using empirical formulas to the same dataset to compare results. The results are similar to the above described method (**112,506 m^3/h**). If little knowledge on the area is present, empirical formulas can provide a good overall estimate on recharge, so long as the resolution does not become too big (zoomed in too close). However, if knowledge is present (and growing) and better resolution is needed, the first method will allow for more refinement and closer approximation.

High accuracy on large scale will rarely be achieved in an area that has as many variations as Eastern Province. However more information will help increase accuracy, taking into account verified faults, fractures and weathered rock, which all influence recharge but are much localized.

Hydrogeology and potential

Different hydrogeological units or aquifer types were distinguished:

- **Granites** (Mainly Bugesera and Nyagatare): overall competent and relies on fractures for recharge and transmissivity.
- **Schists**: considerably less competent than granites and easy to fracture and erode. However, fractures also easily fill up with weathered materials. Overall higher transmissivity and recharge, but lower transmissivity and potential in the fractured areas.
- **Quartzites**: interbedded throughout the less competent schists, it is the most competent aquifer type identified. Where not fractured or faulted, transmissivity and recharge is non-existent. Very high potential and transmissivity in the rare places where the beds of quartzite are crossed by perpendicular valleys, breaking through.
- **Schists/Quartzites**: A combination of the schists and quartzites but more closely interlinked, providing most of the high yielding clusters of boreholes.
- **Consolidated sediments**: Found towards the east, with little to no information available on potential and yields. Largely overlain by alluvium.
- **Alluvium**: overlaying most aquifer types. Overall, the alluvium mostly consists of clayey soils which, even though recharge will be high, will not provide high yielding boreholes because of the constricting transmissivity. In some cases, coarse sediments are deposited, and high potential can be identified. Coarse sediments are more common close to meandering fast flowing rivers.

Potential is based on yields derived from the underlaying aquifer types, in conjunction with features which in turn increase or decrease potential according to their characteristics.

- Lineaments, in the form of faults and fractures were identified through the use of satellite imagery, geological maps and ground verification.
- Water levels derived from boreholes were used to indicate likely areas where the static water level would not reach 50 meters below ground level (meaning that the water strike would in fact be lower). This area is considered low potential, since drilling boreholes here would be cost ineffective and not sustainable.

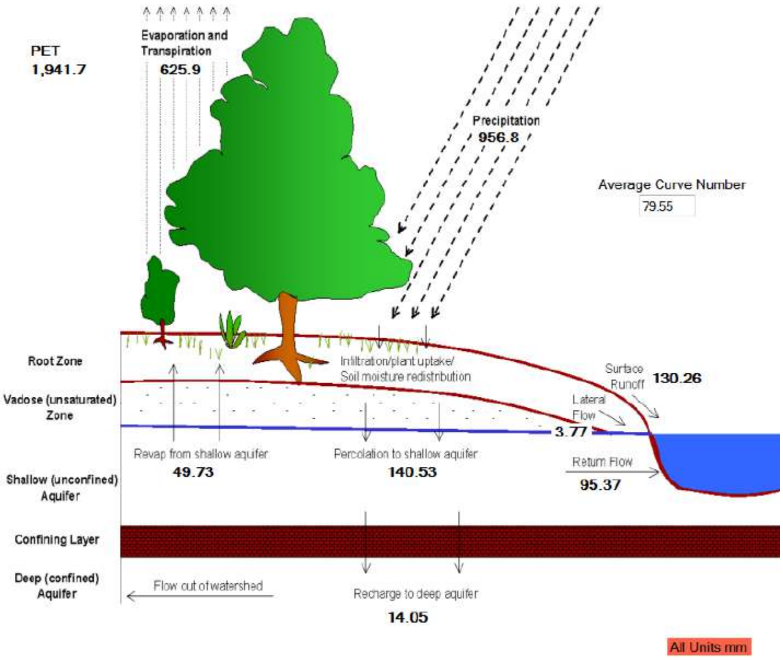
- Spring potential was indicated separately based on spring presence and their apparent connection, to help identify areas where springs in fact provide good potions for water supply.
- Tectonic valleys and depressions in quartzite beds were identified and indicated with very high potential, due to implied faulting. Without tectonic movement it is unlikely for a river to flow perpendicular through a quartzite band.

Potential was indicated for each of the districts separately at higher resolution while also taking into account the apparent demand, current abstraction and potential recharge. This should allow for a first overview on the existing and potential balance of recharge and abstraction. More information supported by monitoring and regulated data collection for water sources should further built on this first overview, to establish greater resolution.

For the Eastern Province, the derived recharge (using the recharge calculations earlier described) lies between 98,447 and 112,506 m^3/h, estimated to decrease to 25% in the driest period. The current abstraction is calculated by adding all boreholes and assuming that they function at 742 m^3/h. Depending on the water use per capita applied (between 20 and 50 litre per day), the demand will fluctuate between 3,069 and 7,672 m^3/h. The calculation is not overly complicated, thus allowing for future inclusion of irrigation projects and population projections based on plans put in place.

Water balance

A water balance was set up using SWAT. SWAT used spatial data of catchment characteristics such as DEM, land use, soil, stream pattern, combined with climate data series and water use to simulate water flow through the catchment. The model was run for 15 years (1999-2013), simulating daily time steps. The results were processed and analysed. The below schematic represents roughly the outputs when applied to the Eastern Province overall.



The SWAT model was developed as a first step to get an understanding of sub-catchment water balance processes in the Eastern Province. The model seems to adequately model the main hydrological situation. Detailed calibration of the model is difficult due to the lack of consistent stream gauging data series with overlap with the model simulation period. For future improvement of the model, several steps can be taken:

- Select separate sub-catchment for detailed model development.
- Collect detailed data of rice irrigation, wetlands and reservoirs.
- Collect any additional stream flow information that might be available and install automatic gauging stations

Groundwater recharge and storage enhancement

A special focus was given to the use of current characteristics of the Eastern Province to enhance the current recharge and storage capacity.

The interventions for enhancement of recharge and storage described in this report are feasible in the Eastern Province; however, not every intervention fits everywhere. Specific applicability depends on local conditions, for which a specific storage and enhancement map was developed taking into account a large number of the variations of variables found in Eastern province, making them context sensitive.

Ground water development

All interventions should be brought under catchment management strategy and specific catchment management plans for each sub-catchment. Within these sub-catchments, micro-catchments can be formed in which local stakeholders are represented. These plans should align with existing policies and practices in Rwanda, including the Rwanda Water Resources Master Plan (NWRMP).

Strategic recommendations

- Transmissivity of aquifers in Eastern Province will not suit large scale irrigation, but can support small scale drip irrigation. Surface water should remain the preferred resource for irrigation.
- Development of groundwater should be more closely coordinated between stakeholders. Implementation of point water sources where systems are already in place should be avoided. Rather, sources should be found that can supplement the existing systems, accelerating water supply through groundwater development.
- There is need for a water supply development master plan at a regional / district / catchment scale.
- Increase the delivery capacity of the piped systems by additional supply of groundwater to the existing storage tanks. For this purpose, well fields need to be identified and developed. The groundwater potential map clearly indicates the target areas where high yielding boreholes can be drilled.
- Groundwater monitoring is of utmost importance for the management of the groundwater resources, both for natural situations and impact of production boreholes. Additionally, there is a need to incorporate abstraction impact monitoring boreholes in areas with large abstraction for town / irrigation water supplies (currently not existing in Eastern Province).
- The following standard procedures are suggested to be developed:
    - Borehole siting
    - Borehole drilling and test pumping
- Groundwater resource management: Although generic estimates can be made on aquifer characteristics such as recharge and potential yields of boreholes, due to the fragmented nature of the hydrogeology, sustainability of abstractions will have to be based on local monitoring of abstractions and custom made licenses for larger abstraction.
- A licensing system needs to be implemented for:
    - Drilling contractors.
    - Groundwater consultants
    - Groundwater abstraction permits

    - Drilling permits
- RWFA should implement a source numbering system. Such a system is not only required to facilitate the various licensing / permits system, but is also required for the implementation of a groundwater database.
- A lot of groundwater related information has been lost in the past 2 decades. Infrastructure has been developed but no investigation, construction and operational data have been collected and/or stored. In addition to the suggestions for enforcement of data collection and submission requirements, RWFA should set up a groundwater database to store, validate, analyse and disseminate the generated information.

1 Introduction

1.1 General background

WE-Consult was commissioned by RWFA through W4GR to carry out a groundwater study in Eastern Province to assess the groundwater potential and recharge enhancement possibilities. The project is part of the Dutch funded IWRM Programme, known as the Water for Growth Rwanda Program. The programme supports the Rwanda Water and Forestry Authority (RWFA) to enhance capacities at national, catchment, and local (district) level about catchment management and IWRM.

Rwanda Water and Forestry Authority is responsible for water resources assessment and monitoring in Rwanda. However, reliable information on water resources availability is scarce, especially with regards to groundwater. Within the framework of the Water for Growth Program, a ground water monitoring network was designed, and its implementation is ongoing. The monitoring information will be more valuable if they can be used in a situation where the ground water resources situation is well understood. This final report for the Ground Water Recharge and Storage Enhancement in Eastern Province, Rwanda, presents the findings of the various components of the project that cover aspects beyond what is expected from the official project title.

The results of the current project shall contribute to the better understanding of the hydrogeology, sustainable groundwater development and a more efficient use of the financial resources for development of groundwater use in the Eastern Province.

1.2 Project objective

According to the Terms of Reference, the objective of the projects is “to carry out a groundwater, recharge and storage enhancement investigation in the Eastern Province and to identify/confirm main aquifers, understand their hydrodynamic behaviour, potentiality and recharge mechanisms.”

During the project, the objective was adapted and the consultant was requested to include; the assessment of potential drill sites for ongoing and future drilling programmes, as well as the assessment of the potential of high yielding boreholes for piped schemes.

1.3 Project activities

The project activities and the periods in which the activities were carried out are given in Table 1.

Table 1: Project Activities

Activity	From	To	Staff involved
Desk study	26/04/2018	30/05/2018	Roel Toonen, Ron Sloots, Reinier Visser
Start-up meeting	07/05/2018	09/05/2018	Roel Toonen, Ron Sloots
Inception workshop	08/06/2018	08/06/2018	Roel Toonen, Ron Sloots, Reinier Visser
Reconnaissance visit	07/06/2018	14/06/2018	Roel Toonen, Ron Sloots, Reinier Visser
Desk study reporting	14/06/2018	30/06/2018	Roel Toonen, Ron Sloots, Reinier Visser
Geophysical fieldwork	12/07/2018	22/08/2018	Roel Toonen, Ron Sloots, Paul Kato, Deborah Ucu, Michael Kazinda

Pumping testfieldwork	29/07/2018	07/09/2018	Roel Toonen, Ron Sloots, Michael Kazinda, Bosco Nsiimire, Elvis Anyii
Analysis and draft reporting	15/08/2018	16/09/2018	Roel Toonen, Ron Sloots, Reinier Visser, Michael Kazinda
Workshop and training	17/10/2018	19/10/2018	Roel Toonen, Ron Sloots, Reinier Visser
Final report submission	19/10/2018	31/10/2018	Roel Toonen, Ron Sloots, Reinier Visser

The output of these activities has been used to prepare the following deliverables, which are all included in this final report:

Deliverable	Explanation
Borehole data and aquifer analysis	In depth analysis given in Chapter 5 page 41 to 80, making use of reconnaissance and desk study results along with the results from the geophysical investigations and the pumping test programme.
Results of geophysical investigations	The method of investigation and previous geophysical results can be found in in Chapter 6 from page 80 to 932. An overview of where the geophysical investigations under this project were conducted can be found on page 88. The specific results from the survey can be found in Annex 2.
Results of a pumping testprogramme	A summarised overview of the pumping test programme can be found in Chapter 7 from page 93 to 965. The specific pumping test results can be found in Annex 3.
Ground water resources, potential and flow assessment	Ground water resources (overview of aquifer types and characteristics) can be found on page 64. Groundwater potential indications can be found on page 69. An assessment on ground water flow can be found on page 52.
Recharge assessment methods and quantification of recharge	An indication of recharge based on geology can be found on page 61. A more detailed overview of recharge in Eastern province can be found as part of the SWAT model
Water balance study and water resources modelling	Explanation of SWAT model principles and outputs can be found in Chapter 8. Due to the size of the Eastern province, 3 catchment areas have been displayed in this report to demonstrate the results. The results of the remaining catchments have been processed and are available in the data attachment in Annex 8
Recommendations for groundwater recharge and storage enhancement	Extensive recommendations for ground water recharge and storage enhancement focussing on land use improvement can be found in Chapter 8 from page 96 to 132. Summarized recommendations can be found on page 140.
Recommendations for groundwater development in Eastern Province	Summarized recommendations can be found on page 1389

Picture 1: Typical valley with agricultural activities in Eastern province

2 Data availability

2.1 Introduction

The project outputs depend on the amount, type and quality of available information, in terms of :

1. Spring location and discharges throughout the year
2. Borehole location, construction data, well logs and pumping testrecords
3. Geological maps/information
4. Satellite images

All collected and generated data and information are included in the data storage device in Annex 8.

2.2 Earlier studies

The consultant has been able to identify the data sets available in the country as listed in Table 2. The availability column indicates whether the data was available for this study. If data was acquired, the corresponding date was recorded.

Table 2: Project data sets

Data set	Source	Available since	Details and comments
VES measurements	WE consult	23/04/2018	107 measurements spread over the province from JICA and other projects
Borehole data	JICA drilling programme	23/04/2018	Location and functionality only
Borehole data	WASAC drilling programme 2017	-	45 finished, to be shared
Spring data	JICA	26/06/2018	All locations of springs included in JICA "The study on improvement of rural water supply in the Eastern Province in the Republic of Rwanda." (2010). Limited yield information.
Spring data	RWFA	25/06/2018	Locations corresponding with locations acquired from JICA. Yield data in current form not usable, clarification required.
Piped Water Supply Kayonza	JICA	11/06/2018	Locations of taps, tanks and water sources. (shapefile)
Piped water other districts shapefile Lists	WASAC	-	To be shared
Piped water supply Eastern Province	JICA	26/06/2018	Data tables describing, taps, tanks and water sources. Little usable qualitative information but sufficient for display purposes.
Land cover dataset	W4GR	-	Initial dataset shared by RWFA. Later additional dataset shared which is incorporated in the stud and report, including the SWAT model and Potential for Storage Recharge enhancement map.
Geophysical data	WASAC drilling programme 2017	-	Geophysical reports for boreholes surveyed under the drilling programme
Satellite data	Landsat	23/04/2018	Satellite imagery used for false colour composites, NDVI and other remote sensing operations.
Administrative	DIVA, OSM and	23/04/2018	Used in the generation of maps, for clarity and

shapefiles	other opensource data sharing instances online		distinction.
Soil data	RWFA	07/05/2018	Soil type shapefiles acquired during initial visit. Used for remote sensing.
Evapotranspiration	MODIS	20/06/2018	Used for remote sensing
Surface water	RWFA	07/05/2018	Shapefiles and monitoring data shared. Stream flow gauging data downloaded from the Rwanda water portal.

The consultant has used the following existing reports for the assessment of the ground water resources in Eastern Province:

1. JICA reports 2009 and 2014 (Preparatory survey report on the project for rural water supply (Phase 3 in Republic of Rwanda March 2014)
2. WE-Consult reports 2009 JICA siting, 2010 Nyabarongo test pumping
3. W4GR Reports
    a. Integrated Water Resources Management Programme Rwanda, 2016, Draft Technical Report - groundwater- Emergency Plan in Umutara, fieldwork and recommendations reports
    b. Integrated Water Resources Management Programme Rwanda, 2017, Draft Technical Report
    c. Ground water resources in the Eastern Province, progress of fieldwork, monitoring and attempt to evaluate GW reserves.
4. Others
    a. Nile Basin Initiative, 2007, Kagera River Basin Monograph
    b. National Water Resources Master Plan (NWRMP)

2.2.1 Borehole and spring data

Borehole data is critical when analysing the ground water resources of an area. Unfortunately, the requirement to submit borehole drilling data has just recently been implemented by RWFA. As such, there is hardly any information available. The consultant was able to collect some borehole information from databases kept by Drill con (drilling company from Uganda), WASAC and RWFA. Only 4 drill logs (drilled by Foraky) are available for boreholes in Eastern Province.

The available data has been processed and imported in an excel database. The results of the analysis of the database are given in chapter 5.2 on page 41.

A spring dataset compiled by JICA was provided to the consultant by RWFA.

2.2.2 Geophysical measurements

The consultant has carried out several projects in Eastern Province (see references) that comprised the execution of geophysical measurements. A total of 107 locations have been subjected to VES measurements and/or resistivity profiling.

2.2.3 Hydrological data

Although gauging stations are present, and gauging data series are present for several streams, no river gauging data series could be obtained by the consultant in the study area. Some point discharge measurements were executed by the consultant during the field assessments. In addition to this, some information on stream flow characteristics was obtained through field interviews and field observations on stream characteristics such as flood marks, stream profiles and stream bed characteristics. These have been used to develop a local understanding of stream and river flow in the Eastern Province.

Furthermore, outputs of earlier studies were reviewed for parameter settings and calibration of outputs. Some hydrological information on the scale of Level 1 catchments is provided in the Rwanda Water Resources Master Plan.

2.3 Rainfall data

Rainfall and climate data from several sources (mentioned below) has been used in the report:

- Daily rainfall (precipitation) records were obtained from TRMM satellite data for the period 1998-2014.
- All other climate parameters are obtained from the Climate Forecast System Reanalysis (CFSR) database, i.e. temperature, wind, relative humidity and solar. The National Centre for Environmental Prediction (NCEP) CFSR was completed over the 36-year period of 1979 through 2014.
- Source of data: CRU CL 2.0 which is described in New, M., Lister, D., Hulme, M. and Makin, I., 2002: A high-resolution data set of surface climate over global land areas. Climate Research 21:1-25 and Aquastat via https://www.samsamwater.com/climate/

2.4 GIS information

GIS was intensively used for data analysis and visual representation. Many existing GIS datasets were used and adapted, and new data was created based on interpretation of different datasets to produce the products presented in this report.
Satellite imagery was an important resource for the assessment of the area and development of detailed thematic maps. Integrated remote sensing and GIS are widely used in groundwater mapping, especially in areas where data is scarce. Remote sensing can provide detailed information of large areas with much less time and effort than classical alternatives. However, there are limitations and the data has to be interpreted by experts based on ground data.
Satellite imagery was used for:

- Elevation maps using a digital elevation model (DEM) and derived products (catchment boundaries, flow accumulation, slope, etc.).
- Geological mapping and geological structure and lineament analysis using multispectral and/or optical images.
- Rainfall and other climatic data.
- Vegetation and land cover.

Used data sources and products are provided in Table 3.

Table 3: Optional data sources for satellite imagery

Data type, analysis and derived products	Data source
Multispectral imagery used for geological mapping and geological structure and lineament analysis, including automatic lineament analysis (PCI Geomatica)	Landsat 8
Digital Elevation Model (DEM), used for hydrological analysis including water balance modelling, and automatic linemant analysis.	SRTM (30m res)
Daily rainfall data used for rainfall analysis and as input for the SWAT model	ARC-2
Daily climate data: temperature, wind, relative humidity and solar. Used as input for the SWAT model	CFSR
Vegetation, NDVI, ET and PET	MODIS, Landsat 8
Pre-processed optical images, used for area reconaissance field work planning, lineament analysis	Google Earth, Bing maps

All data sets and information have been included in Annex 8 and include:

1. .shp shapefile format for conventional shapefile data
2. .tiff for raster data
3. .csv for data sets that can be used in excel for analysis.

During the field work activities and the reconnaissance phase, coordinates were taken using a GPS device in WGS 84 (Projected 36S) (EPSG 32736). Most of the data sources gathered during the desk study where represented either in WGS 84 (unprojected) (EPSG 4326) or WGS 84 36S (EPSG 32736).
However, since RWFA and other institutions in Rwanda are making use of a modified coordinate system with false eastings and northings, all coordinates presented in this report are modified to be represented in said coordinate system. The presentation coordinate system is based on WGS 84 (EPSG 4326) but with the following modifications.

- Projection: Transverse_Mercator
- false_easting: 500000
- false_northing: 5000000
- central_meridian: 30
- scale_factor: 0.9999
- latitude_of_origin: 0.0
- Geographic Coordinate System: GCS_WGS_1984
- Datum: D_WGS_1984
- Prime Meridian: Greenwich
- Angular Unit: Degree

When the data sets of the project are used, it was suggested to save the coordinates to WGS 84 36S (EPSG 32736) since most of the coordinates originated in this system. Whenever the coordinate system is re-projected or changed, small shifts of the datapoints occur and these shifts accumulate over time if many different systems are used. To keep this effect to a minimum it is recommended to use either the presentation projection system or WGS 84 36S (EPSG 32736).

3 Reconnaissance visit

3.1 Project area

The Eastern Province of Rwanda is the largest, most populous and the least densely populated province in the country. It was formed in early January 2006 as part of a government decentralization program that reorganized the country's local government structures. It has seven districts: Bugesera, Gatsibo, Kayonza, Ngoma, Kirehe, Nyagatare and Rwamagana. The capital city of the Eastern Province is Rwamagana. The Eastern Province comprises the former provinces of Kibungo and Umutara, most of Kigali Rural, and part of Byumba.

3.2 Objective of the reconnaissance visit

Physical landscape and climate characteristics determine the potential and limitations of natural resources in an area. Understanding the physical landscape and climate is the basis for water resource development planning. A reconnaissance visit was made to the project area to meet stakeholders, collect data, understand the landscape and perform ground-truthing of maps and data that were already present. This information is being used to acquire a solid understanding of the general water resources in the area and, in particular, the hydrogeological environment in order to develop thematic maps of the area.

3.3 Activities

The project area was visited for ground-truthing, verification and collection of missing data. In addition, a technical review was done for what has already been implemented in the field of water resources management, storage and recharge measures. The preliminary thematic maps developed during the desktop study were updated and completed with data from the field visit. Additionally, the potential of water resources and recharge enhancement was further examined.
The following topics were looked at during the field visit:

1. Physical Landscape: topography, geology, soils and soil management and erosion. Climate data from secondary sources.
2. Water resources: water supply and demand, existing recharge and storage practices, current WRM (Water Resources Management) practices, groundwater resources and surface water.
3. Recharge potential: potential of enhancement of recharge, storage potential for water supply and soil and water conservation.

3.4 Observations

Most of the land, except for protected areas, is deforested with almost all indigenous tree cover has been removed. The land is predominantly used for agricultural processes. Even though most natural forest cover is severely reduced, trees are adopted into agriculture through agroforestry practices; these are mostly exotic species, such as Eucalyptus. Soil and water conservation measures are common practice, and erosion is therefore minimised. These practices include, terracing, contour bunds, mulching, contour ploughing, grass strips, tree strips, slope protection with trees, and wetland protection.

Surface runoff seems to be limited as there are few surface-runoff patterns present. In addition, although floods are present, flash floods in the streams and smaller rivers which have their catchment within the project area seem to be limited based on observations of flood marks and interviews. A large number of springs is present in the hillier areas, and many of the smaller streams have a permanent base flow. Spring and stream discharge estimates were made on many locations together with testing of Electrical-

Conductivity (EC) and acidity (pH). This information, combined with streamflow gauging data, will be used to acquire an understanding of the water system. The SWAT model will be used to quantify this understanding and prepare a water balance calculation.

There are many water storage interventions present in the Eastern Province. Most common are valley dams, of which the storage capacity varies from a few hundred cubic meters to millions of cubic meters. Roof rainwater harvesting is also practiced, but not commonly present throughout the area. Throughout the Province, irrigation is practiced with generally well-functioning irrigation systems. Most of the larger systems are in the valleys, where naturally wetlands or wetter areas are present. These systems are mostly used for rice production.

During the reconnaissance visit, several stream flows were measured; the flows appeared to be quite significant, much higher than the maximum yield of the springs reported in the spring database. The streams are reported to be perennial. A large fraction of the flow is expected to be baseflow[1] and therefore it is expected that more springs / seepage zones with higher yields may occur in specific parts of the province.

Many hand pump boreholes tap stands and storage reservoirs of piped systems in the area were found to be broken down or not in use. The reasons for the breakdowns were not inventoried, but the absence of regular maintenance seems to be the main reason for the hand-pumps, and the lack of water was mentioned as the main reason for the piped systems. Many locations with high groundwater potential based on geological / geomorphological conditions were identified.
Pictures of the reconnaissance survey have been included in Annex 8.

[1] the portion of streamflow that comes from subsurface flow

4 Natural environment

4.1 Rainfall, temperature and evaporation

The annual rainfall in the Eastern Province is between 800 - 1000 mm. It is relatively low in Nyagatare and Bugeresa Province, while Ngoma and the eastern parts of Gatsibo and Kayonza are relatively high (see Figure 1, Figure 2, Figure 3[2] and Figure 4[3]). The rainy season has two peaks from February to April and October-November. The dry season is generally from June to August with almost no rainfall. This rainfall pattern is similar throughout the whole province.

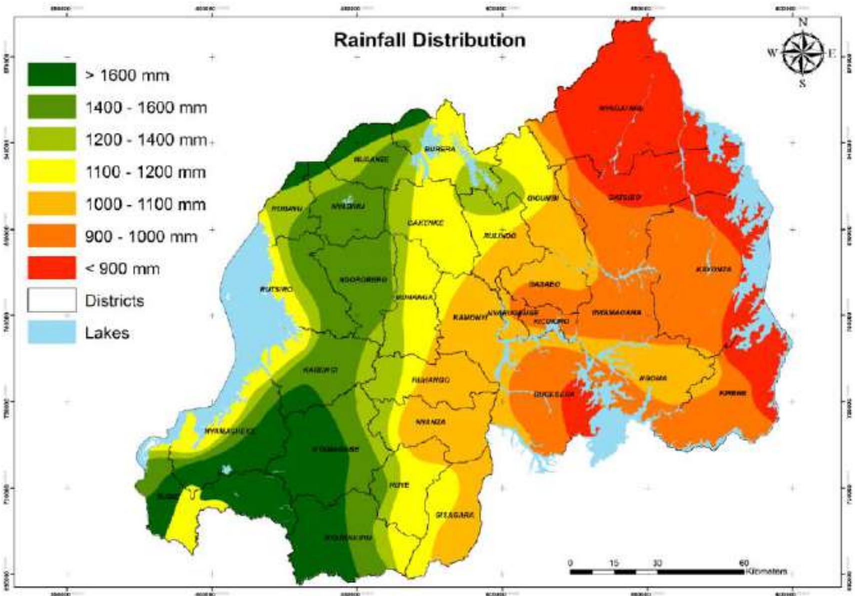
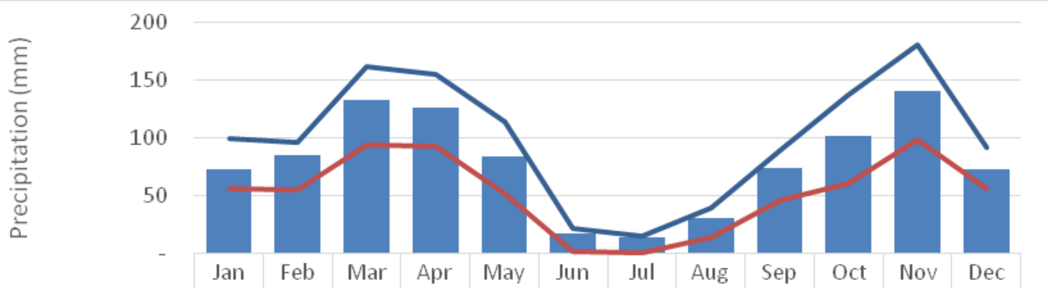


Figure 1: Rainfall distribution in Rwanda (Source: RNRA, 2016)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
average	73.2	84.4	132.6	126.3	83.5	17.2	13.8	30.9	73.8	101.0	139.8	73.0
P=0.8	98.7	95.8	161.8	155.1	114.0	22.1	15.3	39.8	89.2	137.1	179.8	91.0
P=0.2	55.8	54.9	94.0	92.9	51.2	1.9	1.0	13.7	46.0	60.1	98.0	56.0

Figure 2: Monthly precipitation (P) characteristics of the Eastern Province

Daily rainfall (precipitation) records were obtained from TRMM satellite data for the period 1998-2014. Mean annual rainfall in the Eastern Province SWAT 950 mm. Figure 2 provides the average monthly precipitation characteristics of the Eastern Province, with the average, 20th and 80th percentile of monthly precipitation. A percentile is a measure used in statistics indicating the value below which a

[2] (Source: JICA, 2010)

[3] (source: African Journal of Environmental Science and Technology Projections of precipitation, air temperature and potential evapotranspiration in Rwanda under changing climate conditions, Haggag et al, 2015)

given percentage of observations in a group of observations fall. For example, the 20th percentile is the value (or score) below which 20% of the observations may be found.

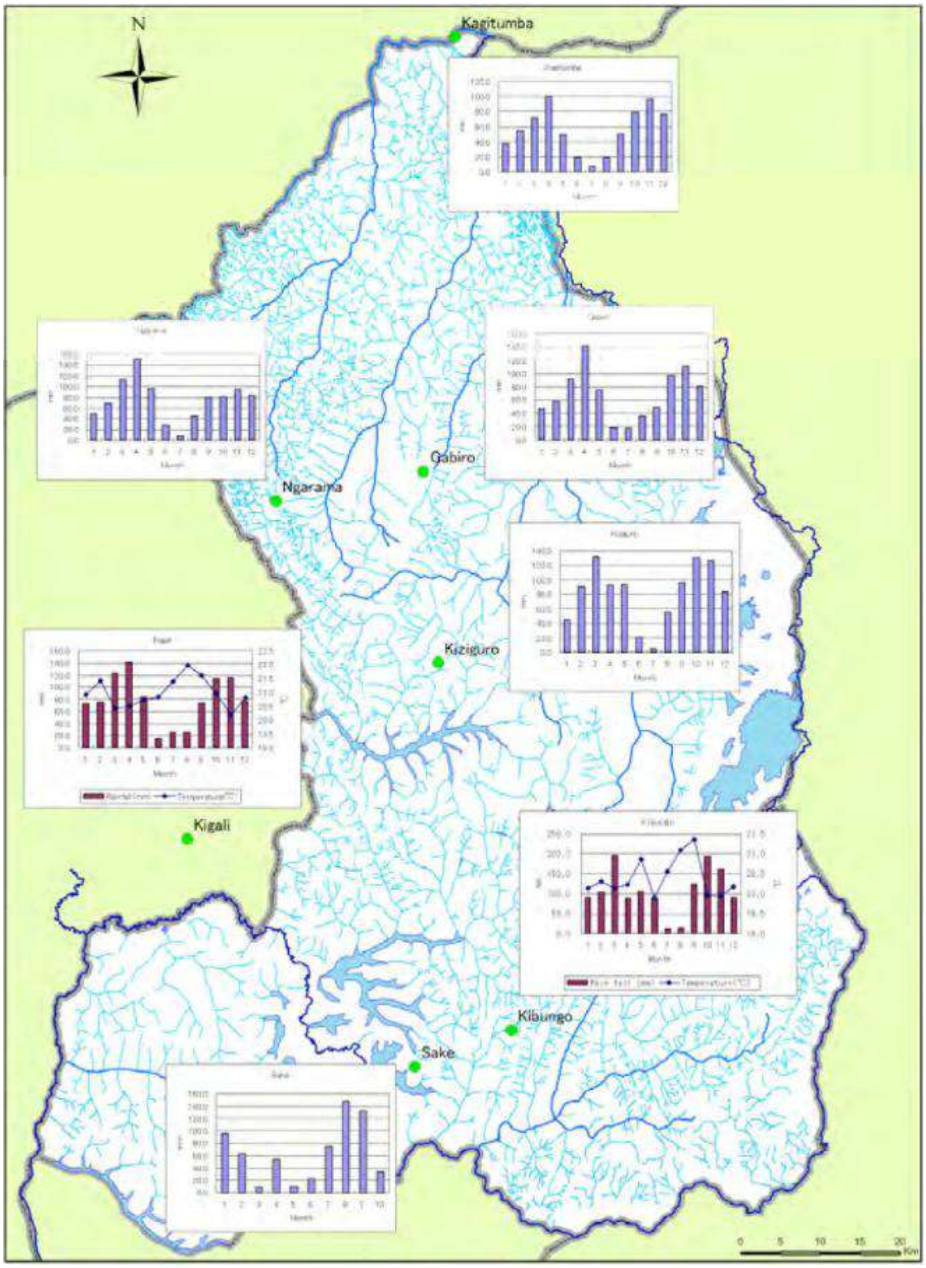


Figure 3: Locations of stations and monthly rainfall graphs

Long term daily rainfall data covering the entire project area, is needed for the SWAT model. CFSR data was reviewed since it is available as pre-processed data format for SWAT. However, the CFSR rainfall data did not match measured rainfall data to satisfaction, so other data sources for rainfall will be considered. The study 'air temperature and potential evapotranspiration in Rwanda under changing climate conditions, (Haggag *et al.,* 2015) indicated a good relation between TRMM data and observed rainfall data.

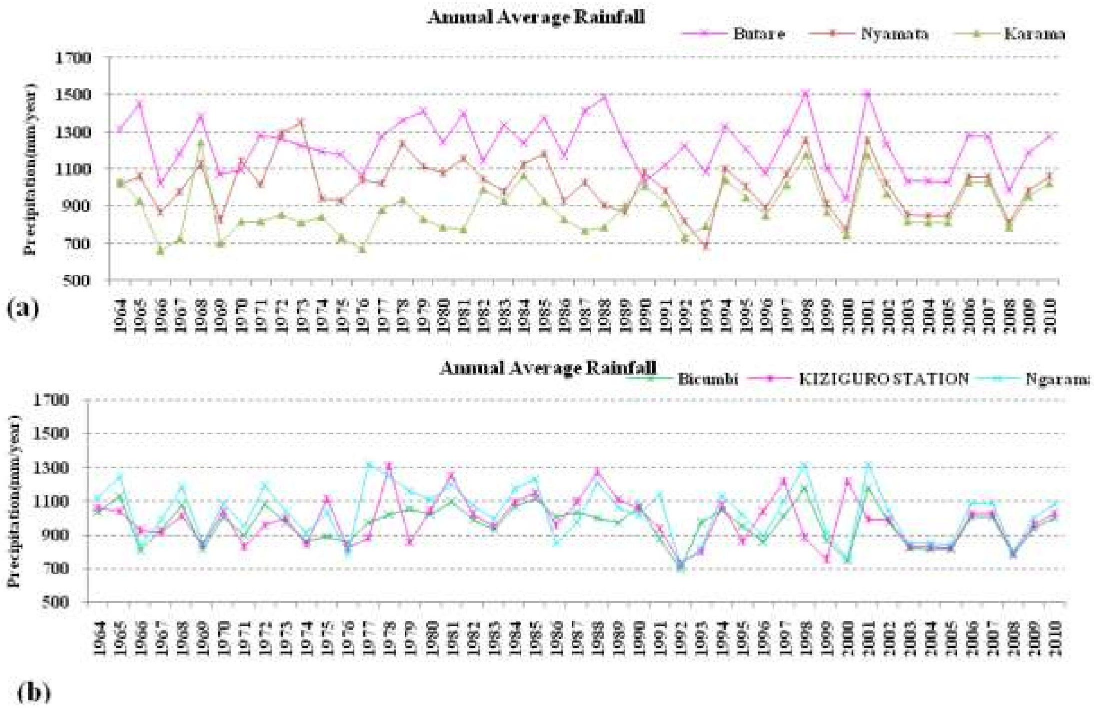


Figure 4: Annual average observed rainfall, for six rainfall stations from 1964 to 2010

Climate data

All other climate parameters are obtained from the CFSR database. The National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) was completed over the 36-year period of 1979 through 2014. The CFSR was designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period. This CFSR data include, precipitation, wind, relative humidity, and solar and can be obtained in SWAT file format for a given location and time period. Table 3 provides the average monthly climate characteristics for Nyagatare area as example.

Table 3: Climate characteristics, for Nyagatare area from CFSR data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Max Temperature (°C)	26.4	27.2	25.9	23.9	23.8	25.3	26.6	27.4	27.7	26.3	24.5
Min Temperature (°C)	13.8	27.2	25.9	23.9	23.8	25.3	26.6	27.4	27.7	26.3	24.5
Wind (Km/hr)	2.4	2.6	2.6	2.9	3.2	3.2	3.3	3.4	3.1	2.8	2.3
Relative Humidity (%)	0.7	0.6	0.7	0.8	0.8	0.6	0.5	0.5	0.5	0.6	0.8
Solar	21.0	22.1	21.5	20.0	19.6	20.7	21.8	22.2	22.0	20.0	18.8

MODIS evapotranspiration and net precipitation

Figure 5 [4]provides the average annual Total Evapotranspiration (ET) and Total Potential Evapotranspiration (PET) based on MODIS (MOD16A2 V006) for the period 2010-2017. The average annual ET image shows a clear distinction between permanent open water (no data value), wetlands, and areas with limited vegetation cover. In the Eastern Province, the mean ET based on MODIS is 706 mm. Net precipitation can be calculated, by deducting ET from precipitation, bringing average annual net precipitation between 200-300 mm. The net precipitation becomes either surface runoff that leaves the area as streamflow or groundwater recharge beyond the root zone. The ET and PET will be used for water balance calculations in SWAT.

[4] Based on MODIS

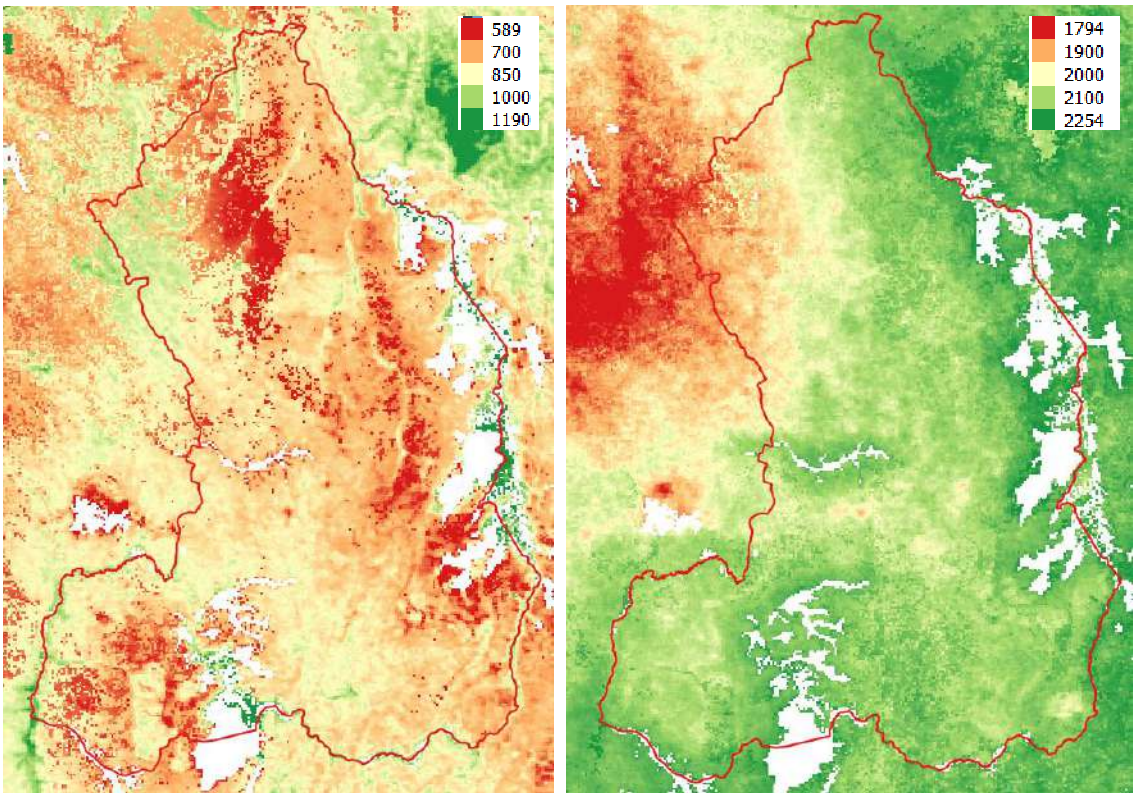


Figure 5: Average Annual Total and Total Potential Evapotranspiration in mm for 2010-2017

4.2 Land use and vegetation

Figure 6 provides the land cover for Eastern Province, from the RWANDA Land Use / Land Cover 2018. The Land Use / Land Cover map of Rwanda, developed by SARMAP contracted by ESRI Rwanda by order of Euroconsult Mott MacDonald / Water for Growth Rwanda 2018, under auspices of Rwanda Water and Forestry Authority. Most of the Eastern Province is covered by cropland.

The Eastern Province is dominated by open grassland and seasonal agriculture, with natural forests/sparse forests being limited to protected areas. Many of the forest areas outside the protected areas are eucalyptus plantations. The central-eastern part has mostly grassland with some trees and shrubs. Large wetland systems are present in the east and south. Throughout the Eastern Province, irrigation is practiced with generally well-functioning irrigation systems for irrigated rice. Most of the larger systems are in the valleys, where naturally wetlands or wetter areas would be present.

The Eastern Province experienced a significant transformation in land use. Most of the land, except for protected areas, is deforested and almost all indigenous tree cover has been removed, and the land is currently, mostly used for agriculture. Even though most natural forest cover is severely reduced, trees are incorporated increasingly into agriculture through agroforestry practices. Within Rwanda, during the period 1990–2016, about 7090.02 km^2 (64.5%) and 1715.26 km^2 (32.1%) of forest and grassland covers were lost, respectively. During this period, the cropland and built-up land areas increased by 135.3% (8503.75 km^2) and 304.3% (355.02 km^2), respectively (Karamage *et al.,* 2017).

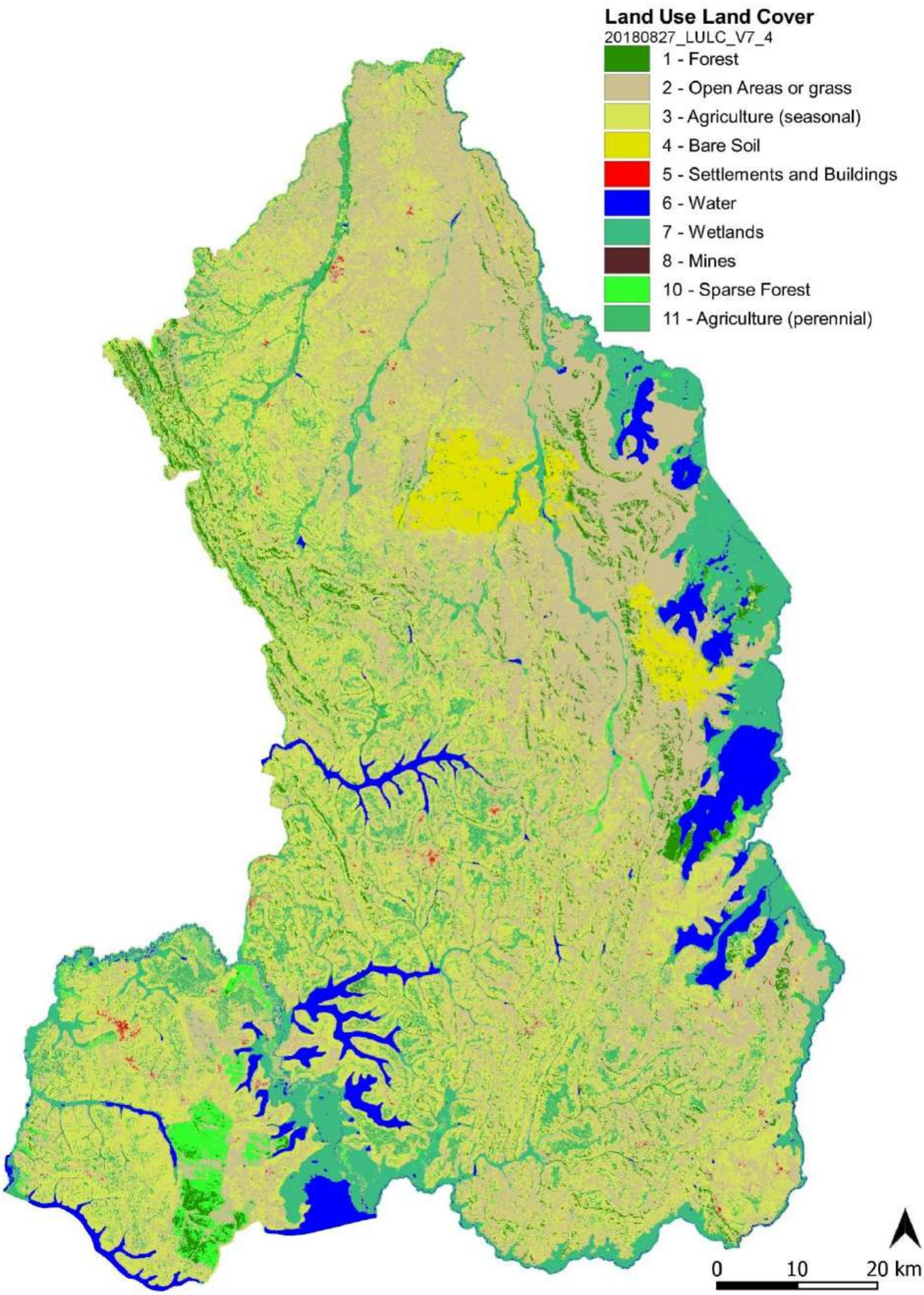


Figure 6: RWANDA Land Use / Land Cover 2018 (Source: RWFA, 2018)

Normalized Difference Vegetation Index (NDVI)

The NDVI provides an insight in vegetation cover in the area. Figure 7 provides a NDVI from a landsat 8 image from 31-08-2016, during a dry period. This image clearly shows open water, permanent areas, and potentially areas where shallow groundwater is available.

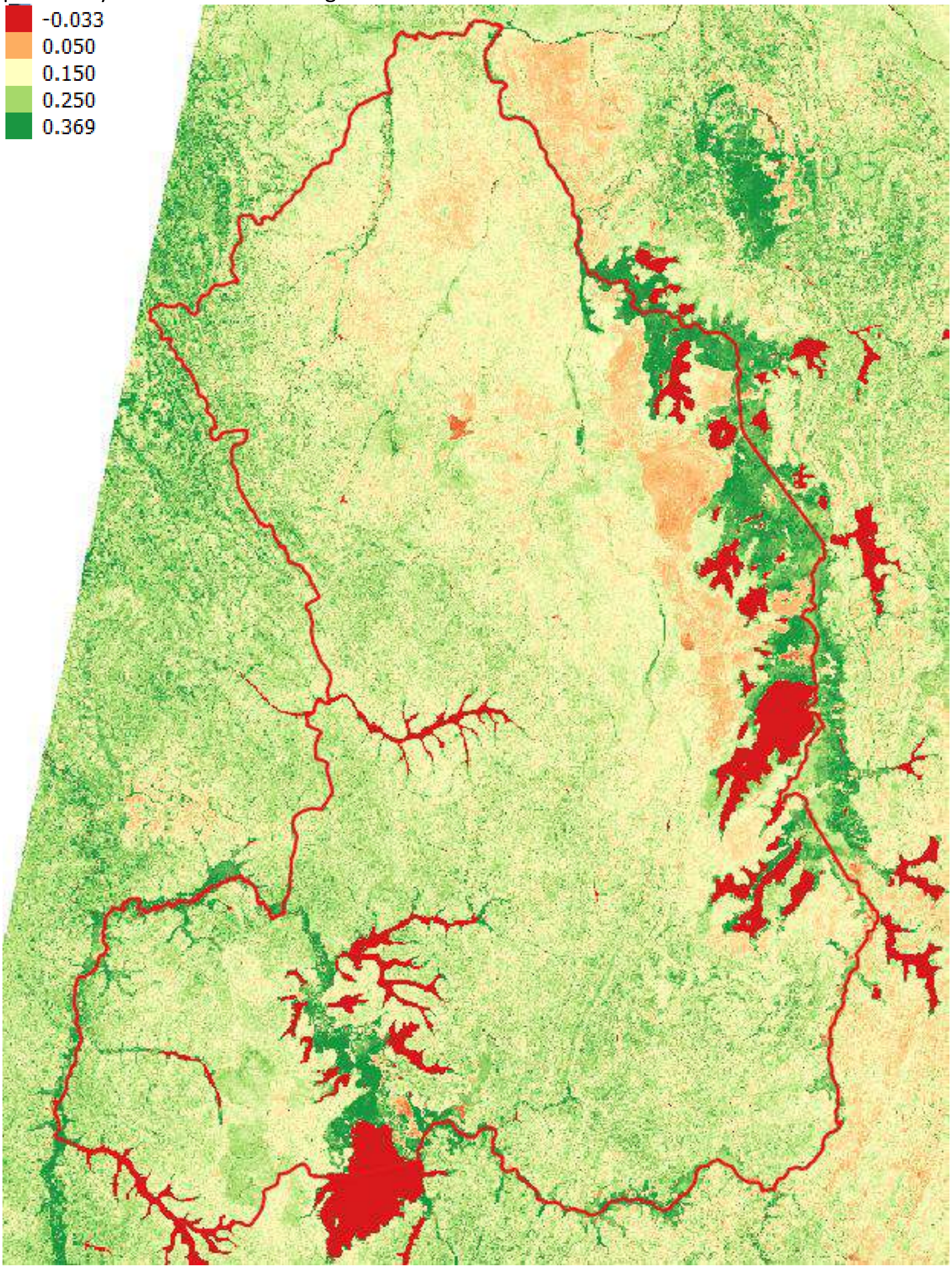


Figure 7: NDVI derived from Landsat 8 image of 31-08-2016

MODIS provides pre-processed NDVI data sets. These are available starting from the year 2001, in a 16 day interval with a 250 m resolution. This allows temporal analysis of vegetation cover, as well as surface water. Figure 8 provides statistics of the MODIS NDVI dataset for the period 2010-2017. The variance image shows a high variance at the boundaries of the lakes, these are most likely the areas of the lake that fall dry during dry periods. These images will be further analysed and where relevant incorporated in the water resources potential maps.

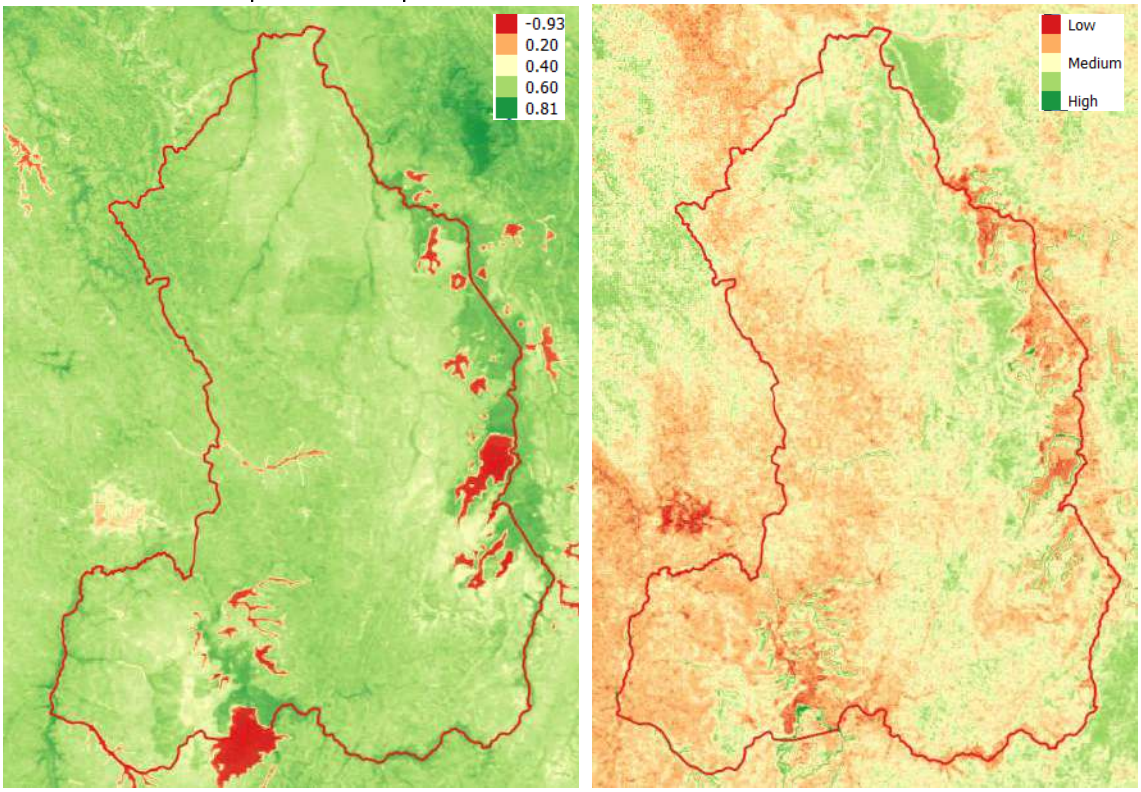


Figure 8: Average MODIS NDVI 2010-2017 (left). MODIS NDVI variance 2010-2017(right)

4.3 Topography and surface water

Rwanda is a landlocked country with an active geological history that formed the rugged topography, with mountains, volcanoes, pronounced valleys, large wetlands and lakes. Figure 10 provides an east-west cross-section of the country. Along the western border with Congo lies the western rift valley which forms part of the African Great Rift Valley. Also present in this area, is Kivu Lake (elevation 1,460 m) formed by the volcanic activities of the rift valley and the Virunga volcanic mountain ranges where the country's highest peak Karisimbi (altitude 4,507 m) can be found. Starting from these volcanic mountain ranges, the Congo-Nile water divide range stretches to the south, with the Kivu Lake water basin to the west and the Akagera river basin to the east, which covers over 80% of the national land. The Akagera river basin spans from the central plateau to the eastern plains, gradually decreasing altitude and the flow of the Akagera River and its tributaries creates topography of the "land of thousand hills" with an average altitude of 1,600 m (JICA, 2010).

The Eastern Province is considered as relatively flat within Rwanda and referred to as the Eastern Plains region. The region has altitudes between 1,000 m - 1,500 m. Nevertheless, steep slopes are present, the western part and the southern part is mountainous and has many undulations. The south-west (Bugesera), northern and eastern parts have gentle slopes, becoming semi-plains (Figure 9). The central southern area is dominated by the wetlands and water bodies of Lake Rweru. Along the southern and eastern border, the Akagera River is present with its many lakes and wetlands, and Akagera national park in the north-east.

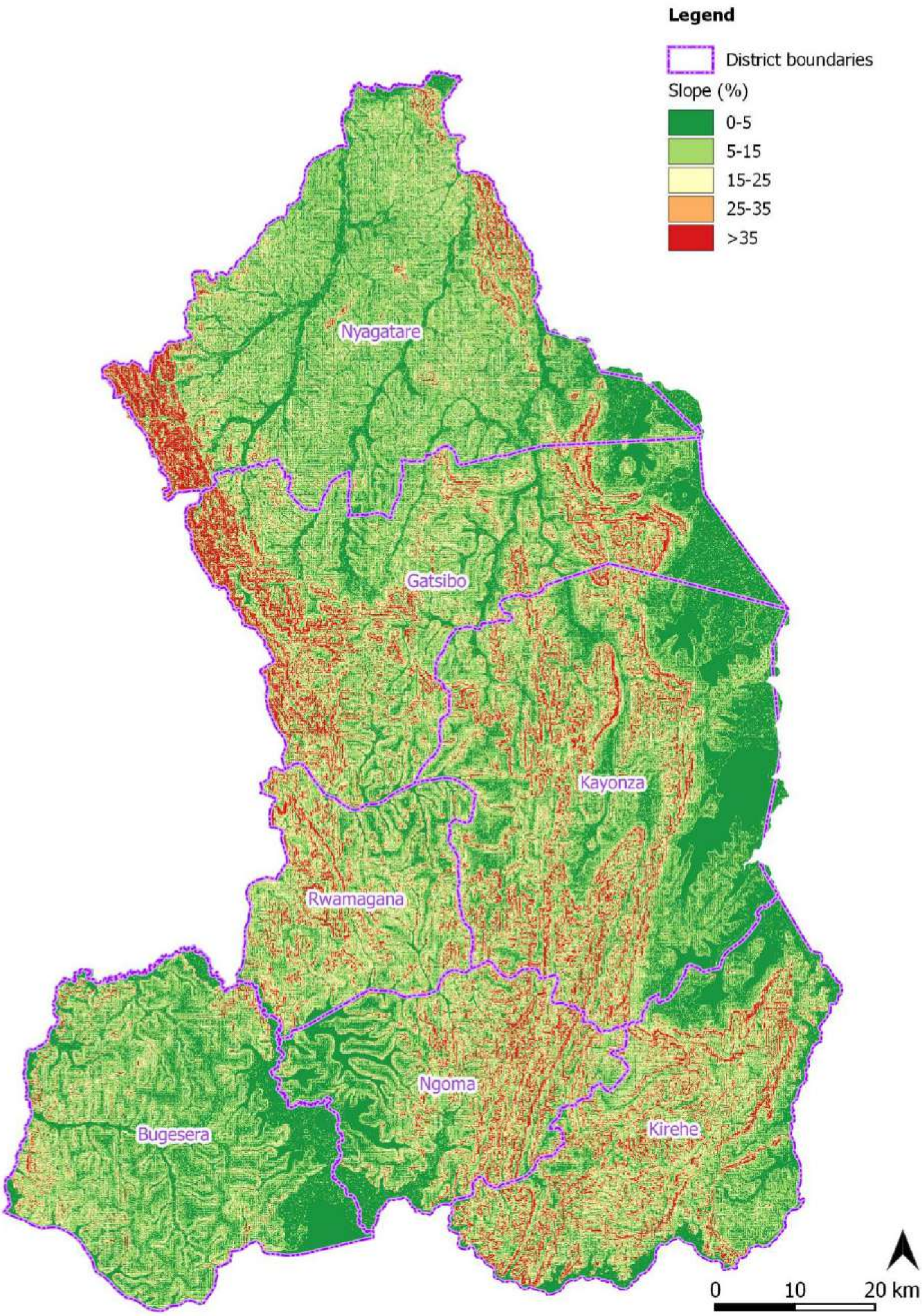


Figure 9: Slopes (%) based on SRTM DEM

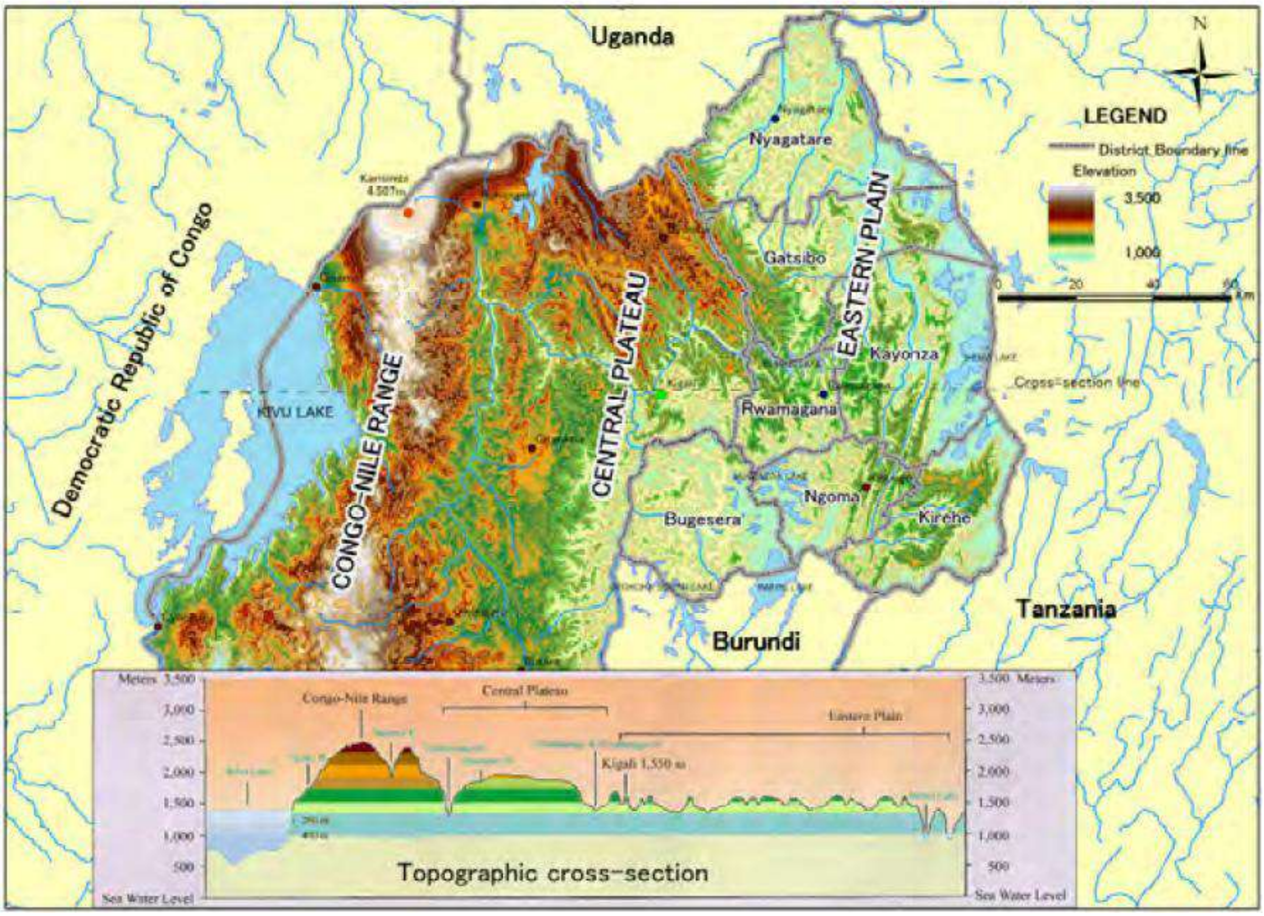


Figure 10: Topographical map and cross-section (Source: JICA, 2010)

4.4 Surface water and catchments

4.4.1 Akagera Basin

The entire Eastern Province is part of the Akagera Basin (Rwandan Nile Basin). It originates in the western mountains of Rwanda, as the Nyabarongo River. It becomes Akagera River where Akanyaru meets Nyabarongo and enters the Eastern Province just south of Kigali where it forms the border of Bugesera District and enters into Lake Rweru. From there, it flows towards the east along the Burundian border and continuous along the Rwanda-Tanzania border all the way to the border with Uganda in the north. From there, its flow direction changes towards the east along the Tanzania-Uganda border until it finally flows into Lake Victoria.

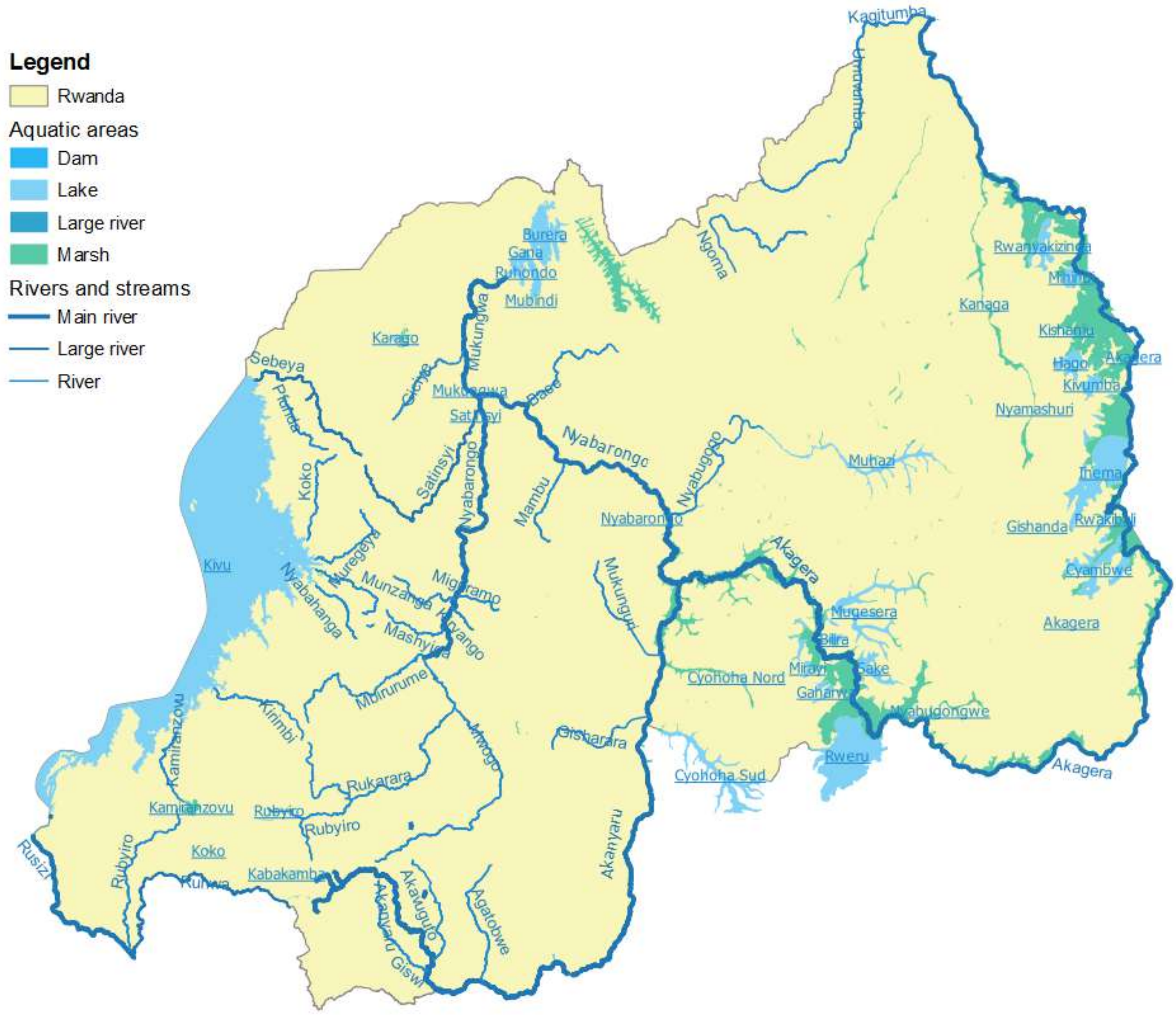


Figure 11: Main surface water bodies

Looking at the Akagera catchment from the point where it leaves Rwanda, the catchment includes most of western Rwanda, and parts are located in Burundi, Tanzania and Uganda. The Level 1 catchment division of Rwanda (NB1) only covers the parts of the catchment within Rwanda, while a number of the catchments have a large transboundary parts (see Figure 12).

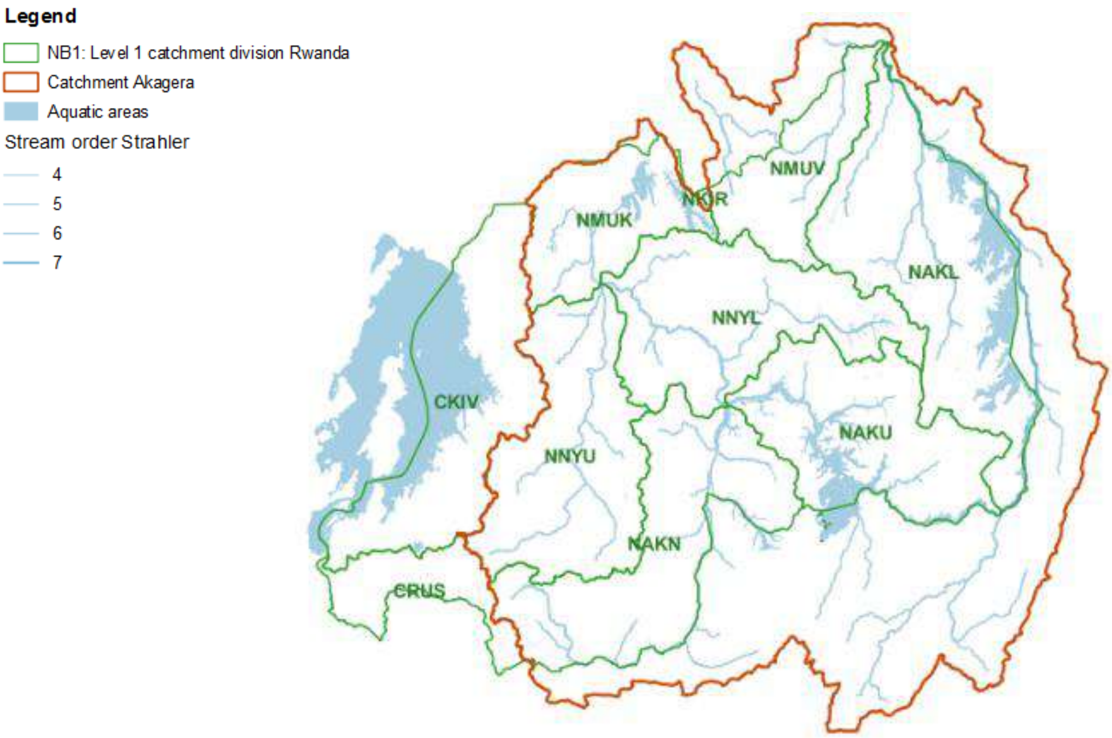


Figure 12: The Akagera catchment (red) from the Rwanda outflow point with sub catchments and the NB Level 1 catchment divisions in Rwanda

4.4.2 Sub-catchments in the Eastern Province

Below are the Level 1 Catchment divisions of eastern Rwanda with the main sub-catchments:

1. Muvumba (NMUV), Ngoma, tributaries: Ngoma, Umuvumba,
1. Lower Akagera (NAKL)
2. Lower Nyabarongo (NNYL), tributary: Nyabugogo
3. Upper Akagera (NAKU), Lake Mugesera
4. Akanyaru (NAKN), tributaries: Gisharara, Akanyaru

The NB2 catchments are almost like NB1 level catchments in the Eastern Province. They combine several sub-catchments into one shape, even though in some cases they are not directly hydrologically connected. This is not preferable for the hydrological analysis. In addition, the catchments in the NWRMP are cut at the Rwandan border, while for catchment assessment the entire sub-catchment has got to be considered. Figure 12 provides the main sub-catchments and river systems in the Eastern Province.

Although the entire Eastern Province falls within the Akagera Basin, there are many sub-catchments that do not have a direct hydrological connection with each other. There are sharp water divides and rivers drain in different directions. Streams were determined based on SRTM data, using flow accumulation.
The geology has a large influence on drainage patterns in the area, valleys and rivers are often along geological folds or fault lines, which create relative straight stream sections and narrow catchments in some cases. Often sharp bends and a sudden change of direction is related to geological structures. The sub-catchments and micro catchments are typically formed by long ridges that form the water divide and in the centre valleys filled with alluvial deposits, where floodplains, marches or irrigated rice fields are located.

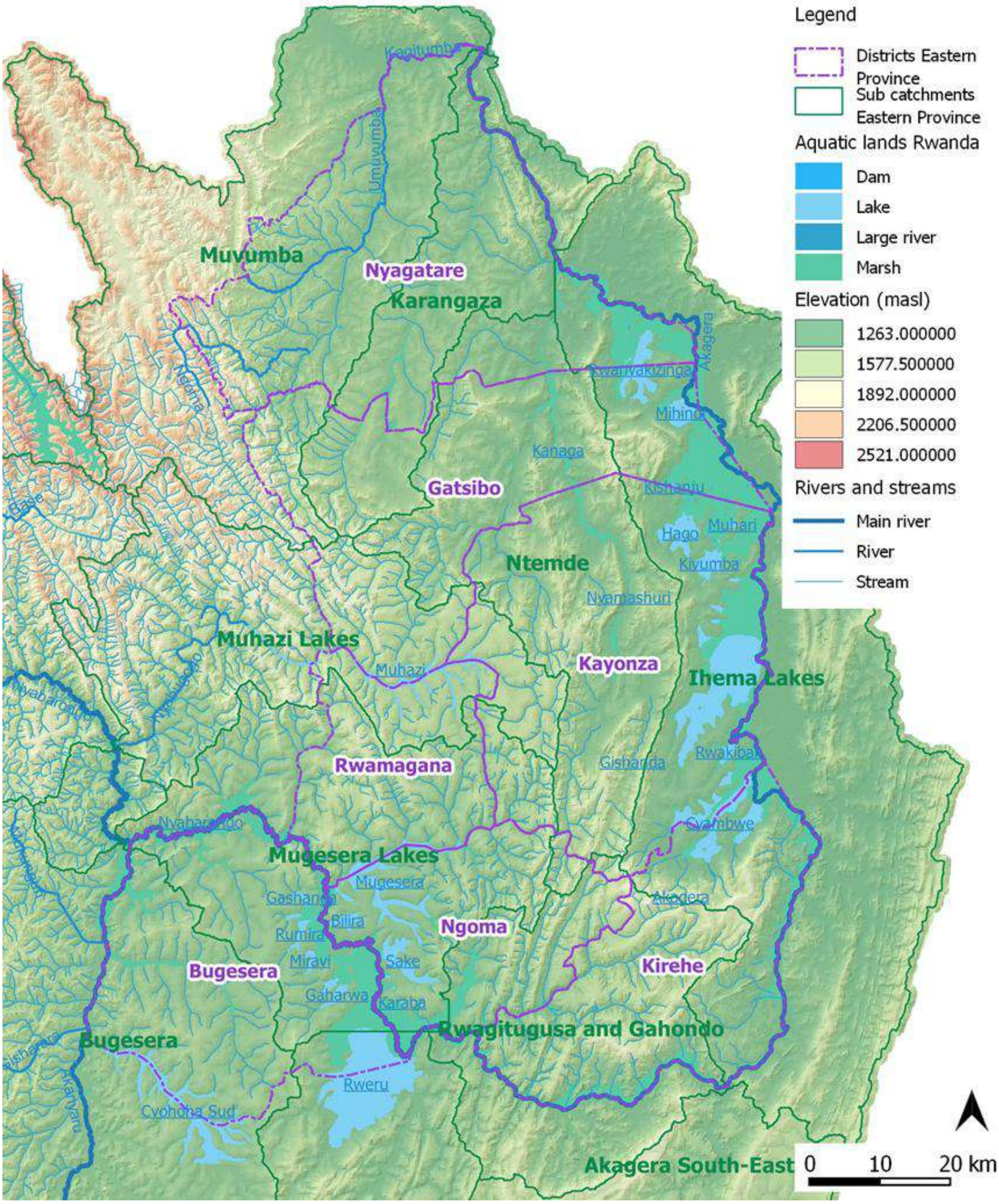


Figure 13: Main river systems and sub-catchments in the Eastern Province

Picture 2: Typical landscape of a smaller tributary in one of the sub-catchments

Although peak flows occur as a result of heavy rainfall, the severity of flash floods is limited, considering the steep slopes in the upper catchments of most rivers. Many of the smaller streams have a permanent flow, even far up in their catchment due to groundwater recharge.

Surface runoff seems to be limited as there are few surface-runoff patterns present and considering the number of perennial springs present and high base flow of streams high up in the catchment, is an indication relative high infiltration rates.

Picture 3: Examples of the many groundwater fed streams in the mountainous zones

4.5 Soils

Figure 14 provides a soil map of the Eastern Province.

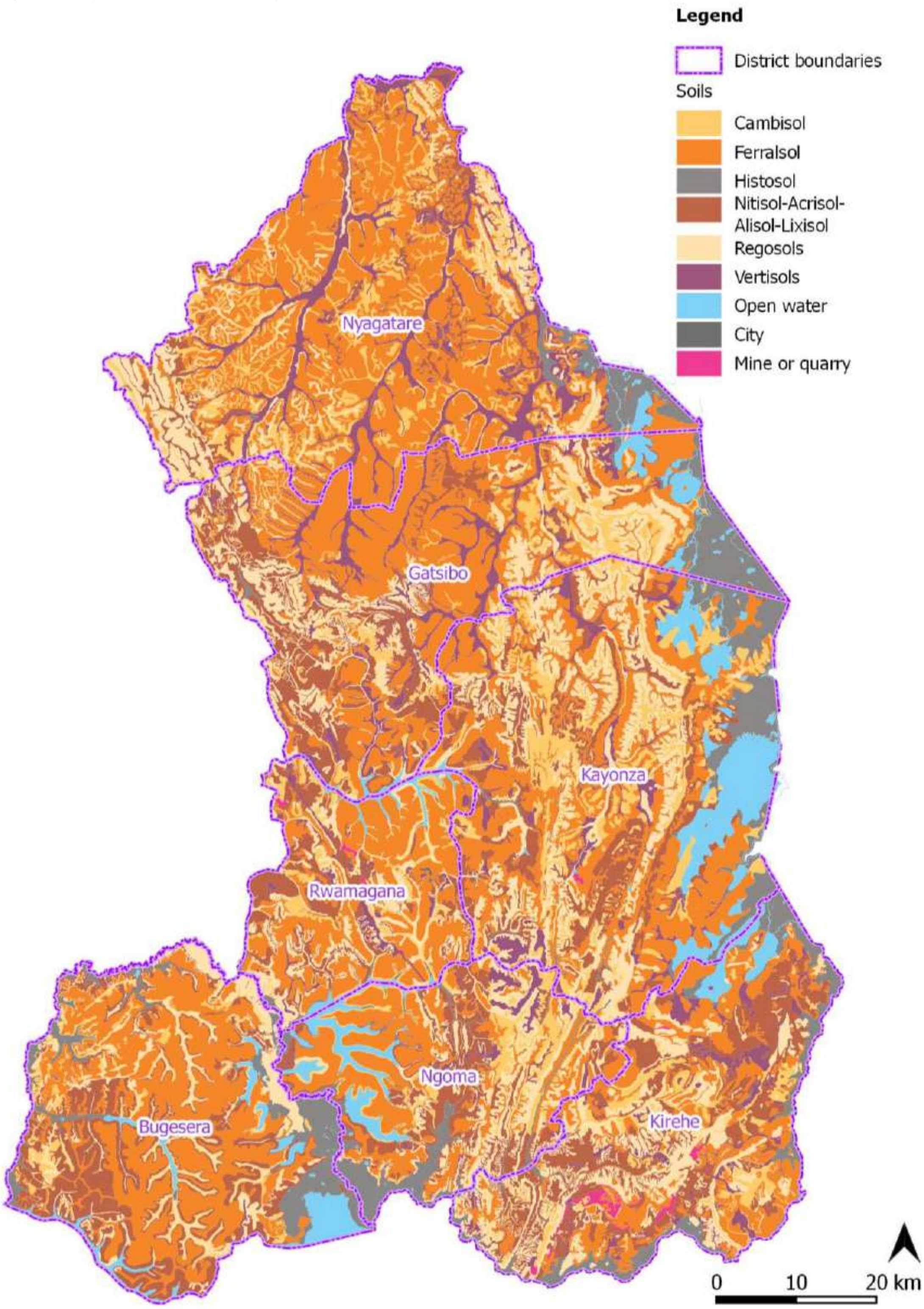


Figure 14: Soils (Source: NWRMP Soil 1:50.000 FAO Classes)

The dominant soils in the Eastern Province are cambisols and regosols. Cambisols are among the better agricultural soils in Africa as they are less depleted of nutrients than other tropical soils and have a sufficiently high nutrient-holding capacity to retain fertilisers and good water holding capacity. In hilly or mountainous areas, cambisols can be sensitive to erosion, especially when the surface is bare. When under cultivation, specific care has to be taken and soil and water conservation is needed. Under steep slope conditions, these soils are best being kept under forest or perennial crops.

Regosols are mainly found on the mountains ridges as shallow sometimes rocky, mineral soils. These soils are weakly developed and are high in nutrients as they occur in young weathering material. Water-holding capacity is often low and water stress is common. They are most feasible for shrub and tree cultivation or left under natural vegetation.

The valleys are filled with clay soils, mainly vertisols (black cotton soils), with swelling and shrinking properties when wet/dry. These can be productive soils, but they need adequate soil moisture management when under production. These soils are highly erodible when exposed.

Other soils that are locally present in the area are nitisols, acrisols, alisols and lixisols.
Figure 15 [5] provides the textural content (a,b,c) and the soil textural classes (d) for Rwanda. Within the Eastern Province, clay and sandy clay loam soils are dominant.

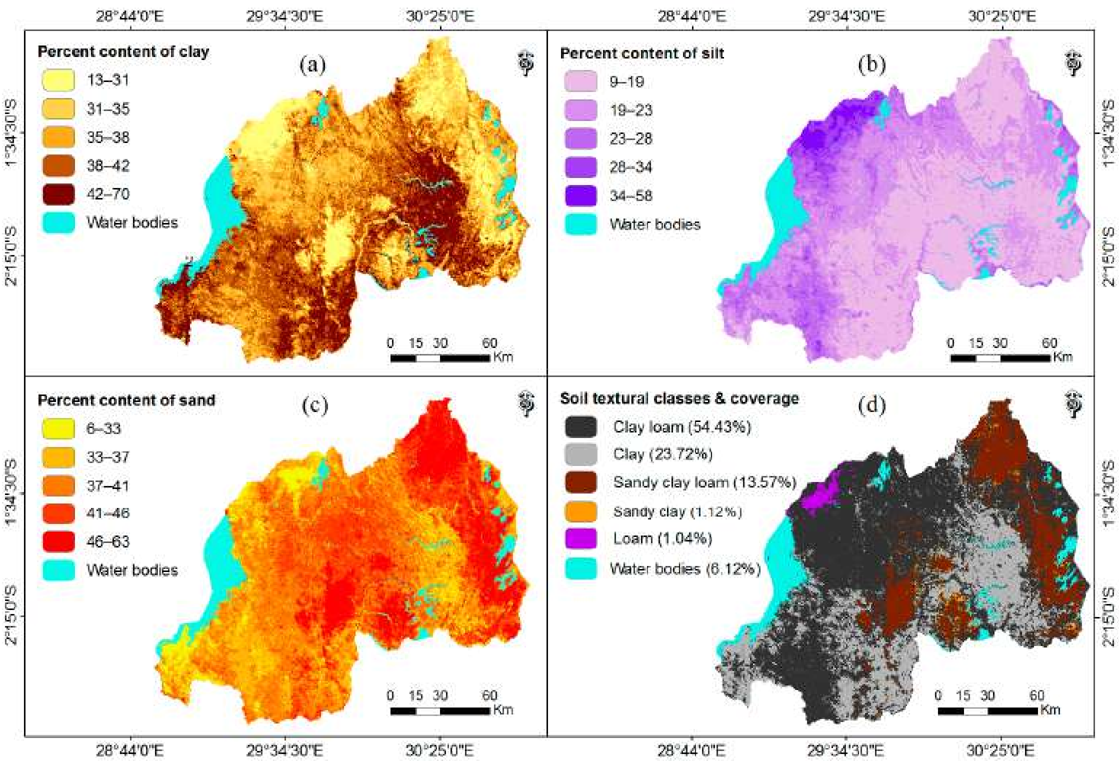


Figure 15: Percent content of: (a) clay; (b) silt; (c) sand and (d) soil textural classes for Rwanda

[5] **(Karamage et al, 2017)**

4.6 Geology

Three versions of the geological map are available; an optimised geological map is produced in the final map, taking into account the analysis of the existing maps and the findings during the reconnaissance and the field work. The following maps have been consulted:

1. Carte Géologique Du Rwanda, Service Géologique, Ministere de l'industrie et d l'Artisanat
2. Low resolution shapefiles derived from: Carte Géologique Du Rwanda, shared by African history museum in Belgium. Current map used by RWFA.
3. Carte des Gîtes Mineraux Du Rwanda, Ministère des Resources Naturelles

Map number 1 has been used in this report, with above mentioned improvements and considerations. The geology of the areas is comprised of three to four distinct formations that have an impact on the topography, hydrogeology and drainage pattern of the area. The geological map indicates the occurrence of the formations.

1. Granitic formation: the granites are often coarse-grained, but few outcrops occur. The granites in Bugesera are labelled granites but could also comprise of gneisses and schists
2. Quartzite formation: These form long ridges / bands in the landscape, sometimes more than 50 km long parallel to the bedding plane of the formation. The ridges are dissected by faults in some places.
3. Schists / phyllites / mudstones: These are the less competent layers of the geological formations in the area and as such, these sequences of soft layers may form valleys with widths that depend on the thickness of the formations.
4. Alluvium: The granitic and metamorphic formations have been dissected by valleys. In many valleys', erosion materials has been deposited. The grain size of the sediments is not always known, but clays, silts and sand have been encountered. The thickness of the sediments is not known.

The units and codes featuring on the map are given in Table 4 .

Table 4: Lithological codes and geological formation description

Colour	Code	Tickness (m)	Formation	Summary description
	Ho		Alluvium	Sand and clays on top of other formations
	Br		Birenga	Schists, silty layers, quarzitic layers
	Kg	100	Kibungo	Quartzites and fine sandstones, black schists
	Nm	1,500	Ndamira	Schists and siltstones some fine sandstones
	Kb	300	Kibanya	Quartzites
	Gi		Gitwe	Quartzite, medium grained sandstones
	Bl	1,300	Buimbi	Sandstones with black schists, some volcanic sediments
	Rr		Rukira	Schists and siltstones some fine sandstones
	Mh	300	Musha	Homogeneous schists, some fine sandstones, thick layers
	Ak		Akagera	Sandy and clayey sediments, no outcrops
	Ng		Nyabugogo	Fine to coarse grained quartzites, some schists
	Bu		Butare Complex	Granites, granitic gneisses, quartzites, meta sediments, amphibolies, many mylonites
	Mu		Muyaga complex	Quartzite with some phyllites
Intrusions				
	TM		Intrusion	Granites with micas
	TB		Intrusion	Probably granites, not confirmed but based on morphology
	TL		Intrusion	Leuco-granites often pegmatic
	D		Basic instrusions	Micro gabbro's, dolerites

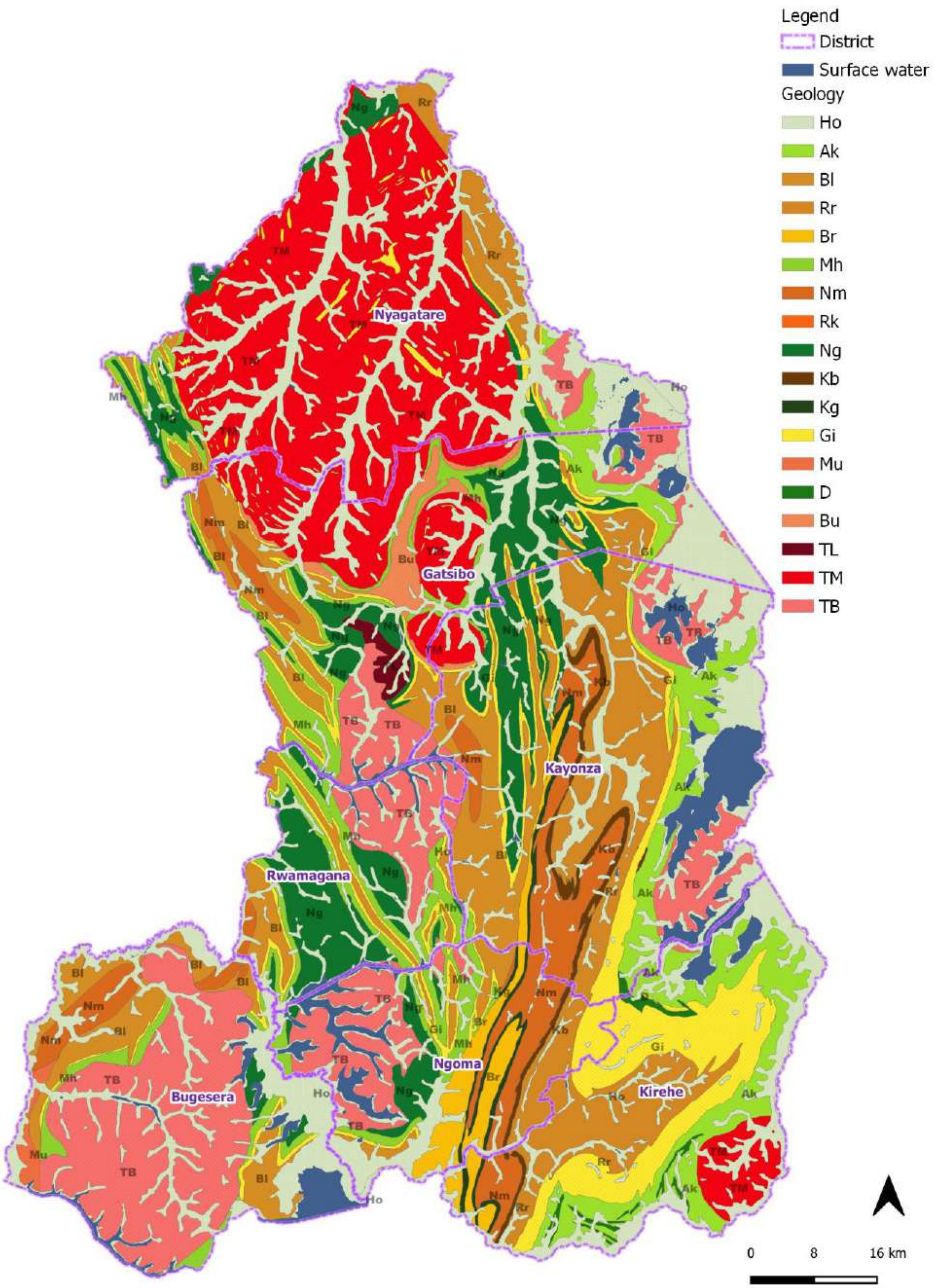


Figure 16 Geological map

Table 5 Geological units in districts

Litho Code	Area (km^2)	Bugesera_Area (km^2)	Gatsibo_Area (km^2)	Kayonza_Area (km^2)	Kirehe_Area (km^2)	Ngoma_Area (km^2)	Nyagatare_Area (km^2)	Rwamagana_Area (km^2)
Ak (sand/siltstones)	454		60	138	231		24	
Bl (sandstone)	652	155	142	214		41	22	78
Br (schists)	141			20	21	99		
Bu (gneiss)	88		84	4	0	0	0	
D (intrusions)	26			3	23			
Gi (quartzite)	684	21	78	130	292	61	57	45
Ho (sand/clays)	2,571	403	394	570	307	213	549	136
Kb (quartzite)	74	0		55	7	12		
Kg (quartzite)	58			19	10	29		
Mh (schists)	389	58	124	5		68	37	99
Mu (quartzite)	22	22						
Ng (quartzite)	716	15	197	154		56	91	202
Nm (schists)	399	65	41	167	34	84	0	8
Rr (schist)	713		39	309	197	60	107	
TB (granite)	1,166	572	129	145	2	156	40	122
TL (granite)	27		27					
TM (granite)	1,414		291	24	71		1028	
Total (km^2)	9,592	1,310	1,605	1,957	1,196	879	1,956	690

Occurrence of mentioned geological formations can be found in Table 5. The alluvial deposits are the most common formation in almost all the districts. These sediments are found on the valley floors and generally have an anticipated thickness between 0 and 20 m in the granitic areas of Bugesera and Nyagatare. In the wider valleys in the schist dominant areas, they may have a thickness or more than 20 m.

Picture 4: Lakes near Kagera River in Kayonza district from quartzite hills (Gi)

Picture 5: Quartzites and sandstone of Kb formation near Kibungo

5 Hydrogeology of the Eastern Province

5.1 General

The groundwater resources of the Eastern Province have not been studied in detail. Some attempts have been made to understand the hydrogeological systems and to quantify the groundwater resources. The analyses of the existing reports have been reviewed and together with the results of the reconnaissance survey have led to some conceptual models and situation analysis described in the sections below. The reliability of the qualification and quantification of hydrogeological parameters is based on the information made available.

5.2 Borehole data

5.2.1 Borehole characteristics

A database of all available data on boreholes in Eastern Province has been prepared. The details are presented in Annex 1.

Table 7 shows the borehole characteristics in the various districts in the Eastern Province. It should be noted that the records only have values for a few fields. It is not yet a habit to collect the borehole data in a systematic way in Rwanda. The JICA project however made an attempt to share the main borehole data on sign posts near the boreholes as can be seen in

Picture 6. Unfortunately, only one such a signpost was encountered in the area.

Picture 6: JICA borehole with signpost with borehole data

Table 6: Borehole characteristics per geological formation

Formation	No. of records	No. records BH depth	Average BH depth (m)	Maximum depth (m)	No. records with Yield	Average of Yield (m3/h)	Max of Yield (m3/h)	Nor of records WSL1	Average WSL1 (m bgl)	Max WSL 1 (mbgl)	No. of records WSL2	Average WSL2 (mbgl)	Max WSL2 (m bgl)
Ak (sand/siltstones)	1	1	40	40	1	4.0	4.0						
Bl (sandstone)	19	19	100	140	19	2.6	7.0						
Bu (gneiss)	1	1	82	82	1	0.8	0.8	1	51	51	1	55	55
Gi (quartzite)	7	7	88	145	7	2.4	4.0	2	75	75	2	91	95
Ho (sand/clays)	88	85	57	122	88	3.8	25.0	14	43	95	11	60	115
Kb (quartzite)	1	1	65	65	1	3.0	3.0						
Kg (quartzite)	1	1	150	150	1	2.0	2.0						
Mh (schists)	1	1	40	40	1	5.0	5.0						
Ng (quartzite)	14	14	71	114	14	4.0	10.8	3	81	90	3	91	110
Nm (schists)	9	9	77	100	9	5.1	12.0	1	55	55	1	80	80
Rr (schist)	15	15	72	105	15	2.9	7.2	3	80	89	2	86	87
TB (granite)	15	15	58	122	15	3.9	8.2						
TM (granite)	55	54	65	140	55	3.0	12.0	18	61	95	18	73	120

Grand Total	227	223	67	150	227	3.5	25.0	42	58	95	38	72	120

WSL1 : First water strike | WSL2: Second water strike | mbgl: meters below ground level | Yield is for most records derived from drillers yield which is yield brought up with compressor which is an indication of actual yield.

Ho (sediments) is the formation with the highest average yield but it should be noted that this formation consists only of up to 20 m of alluvial material lying on top of one of the other formations in Nyagatare and Bugesera (granite), and 20 to 50 meters in the remaining districts (schists with quartzite). This estimation is derived from the geophysics done in sedimentary formations, with examples displayed in Figure 17.

Since most boreholes are drilled in valleys filled with these sediments, this unit has the highest number of boreholes.

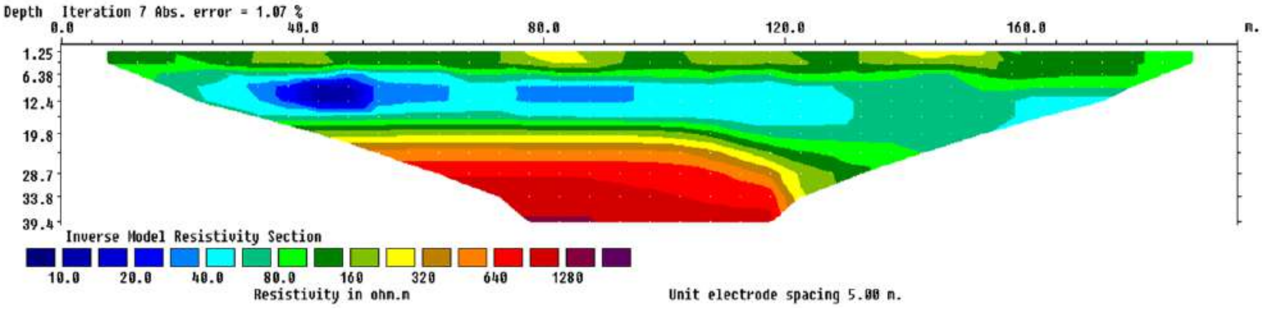


Figure 17 ERT profile in alluvium in Nyagatare, with granite visible at around 20 m

When the alluvial material goes beyond 50 meters in depth it can be considered the main aquifer type for that location, which when viewed in resistivity would look like Figure 18. This however is rare as most alluvium deposits are shallow and consist mostly of clay.

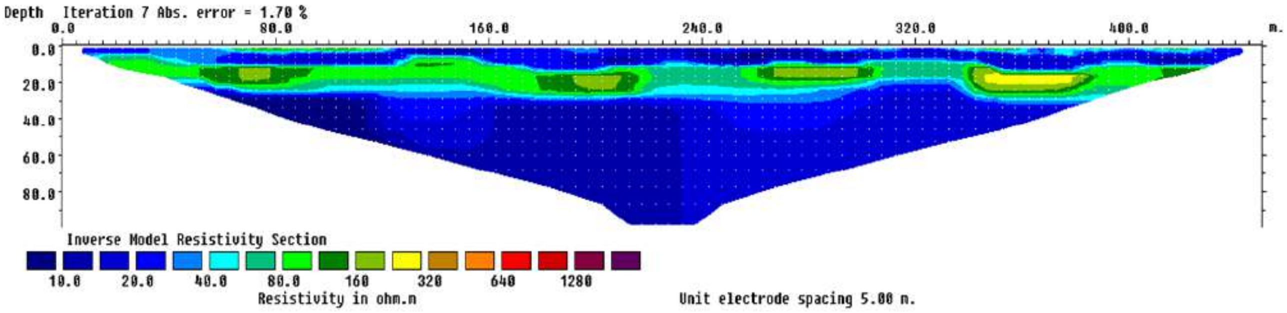


Figure 18 ERT profile in alluvium in Kirehe, with sand deposit from 10 to 20 m and no bedrock visible

Table 7: Borehole characteristics per district

District	No. of records	No. records BH depth	Average BH depth (m)	Maximum depth (m)	No. records with Yield	Average of Yield(m^3/hr)	Maximum Yield (m^3/hr)	Nor of records WSL1	Average WSL1 (m bgl)	Max WSL (mbgl)	No. of records WSL2	Average WSL2 (mbgl)	Max WSL2 (m bgl)
Bugesera	8	8	55	100	8	2.6	5.0						
Gatsibo	50	47	48	90	50	4.3	13.0	1	51	51	1	55	55
Kayonza	51	50	77	145	51	3.7	12.0	1	55	55	1	80	80
Kirehe	7	7	62	150	7	3.0	5.0						

Ngoma	17	17	63	105	17	2.8	5.0						
Nyagatare	87	87	73	140	87	2.8	25.0	40	58	95	36	72	120
Rwamagana	8	8	70	122	8	6.1	10.8						
GrandTotal	228	224	67	150	228	3.5	25.0	42	58	95	38	72	120

WSL1 : First water strike | WSL2: Second water strike | mbgl: meters below ground level | Yield is for most records derived from drillers yield which is yield brought up with compressor which is an indication of actual yield.

Table 8: Borehole characteristics per geological formation per district

District	No. of records	No. records BH depth	Average BH depth (m)	Maximum depth (m)	No. records with Yield	Average of Yield (m3/h)	Max of Yield (m3/h)	Nor of records WSL1	Average WSL1 (m bgl)	Max WSL (mbgl)	No. of records WSL2	Average WSL2 (mbgl)	Max WSL2 (m bgl)
Bugesera	8	8	55	100	8	2.6	5.0						
Bl (sandstone)	2	2	33	35	2	0.9	1.2						
Ho (sand, clay)	3	3	53	95	3	2.6	3.0						
Mh (schists)	1	1	40	40	1	5.0	5.0						
Nm (schists)	1	1	100	100	1	3.0	3.0						
TB (granite)	1	1	75	75	1	3.0	3.0						
Gatsibo	50	47	48	90	50	4.3	13.0	1	51	51	1	55	55
Bu (gneiss)	1	1	82	82	1	0.8	0.8	1	51	51	1	55	55
Gi (quarzite)	1	1	75	75	1	2.0	2.0						
Ho (sand, clay)	23	21	48	90	23	4.4	13.0						
Ng (quarzite)	3	3	69	82	3	2.1	3.0						
TB (granite)	9	9	52	60	9	5.4	8.2						
TM (granite)	13	12	34	70	13	4.2	7.2						
Kayonza	51	50	77	145	51	3.7	12.0	1	55	55	1	80	80
Bl (sandstone)	17	17	108	140	17	2.8	7.0						
Gi (quarzite)	3	3	107	145	3	2.9	4.0						
Ho(sand, clay)	14	13	58	105	14	4.6	12.0						
Ng (quartzite)	3	3	34	51	3	2.8	3.6						
Nm (schists)	5	5	72	90	5	6.9	12.0	1	55	55	1	80	80
Rr (schists)	3	3	49	57	3	3.3	7.2						
TB (granite)	1	1	51	51	1	1.0	1.0						
TM (granite)	5	5	55	63	5	3.4	4.3						
Kirehe	7	7	62	150	7	3.0	5.0						
Ak (sand/siltstone)	1	1	40	40	1	4.0	4.0						
Ho(sand,clay)	2	2	50	60	2	3.5	5.0						
Kg (quartzite)	1	1	150	150	1	2.0	2.0						
Rr (schist)	1	1	60	60	1	3.0	3.0						
TM (granite)	2	2	42	45	2	2.6	4.0						
Ngoma	17	17	63	105	17	2.8	5.0						
Gi (quartzite)	1	1	25	25	1	2.0	2.0						
Ho(sand,clay)	2	2	48	50	2	5.0	5.0						
Kb (quartzite)	1	1	65	65	1	3.0	3.0						
Nm (schists)	3	3	80	95	3	2.7	4.0						
Rr (schists)	7	7	69	105	7	3.1	5.0						
TB (granite)	3	3	54	70	3	1.0	1.0						

District	No. of records	No. records BH depth	Average BH depth (m)	Maximum depth (m)	No. records with Yield	Average of Yield (m3/h)	Max of Yield (m3/h)	Nor of records WSL1	Average WSL1 (m bgl)	Max WSL (mbgl)	No. of records WSL2	Average WSL2 (mbgl)	Max WSL2 (m bgl)
Nyagatare	86	86	73	140	86	2.9	25.0	40	58	95	36	72	120
Gi (quartzite)	2	2	98	105	2	2.2	3.0	2	75	75	2	91	95
Ho (sand/clays)	41	41	63	122	41	3.0	25.0	14	43	95	11	60	115
Ng (quartzite)	4	4	96	114	4	4.6	8.0	3	81	90	3	91	110
Rr (schist)	4	4	97	104	4	2.3	6.0	3	80	89	2	86	87
TM (granite)	35	35	77	140	35	2.6	12.0	18	61	95	18	73	120
Rwamagana	8	8	70	122	8	6.1	10.8						
Ho (sand/clays)	3	3	43	50	3	7.4	9.9						
Ng (quartzite)	4	4	77.3	110	4	5.9	10.8						
TB (granite)	1	1	122	122	1	3.0	3.0						
Grand Total	227	223	66.6	150	227	3.5	25.0	42	58	95	38	72	120

WSL1 : First water strike | WSL2: Second water strike | mbgl: meters below ground level | Yield is for most records derived from drillers yield which is yield brought up with compressor which is an indication of actual yield.

The borehole yield data has been used to make an interpolated yield map. It should be used with care because no groundwater potential should be expected in the higher areas even when they have a good potential colour on the interpolated yield map. The groundwater potential map that is one of the outputs of the current project combines the topography, yields and other aspects. It is presented in paragraph 5.8.9 on page 67.

Picture 7: Elevated tank surface water-based water supply system Bugesera

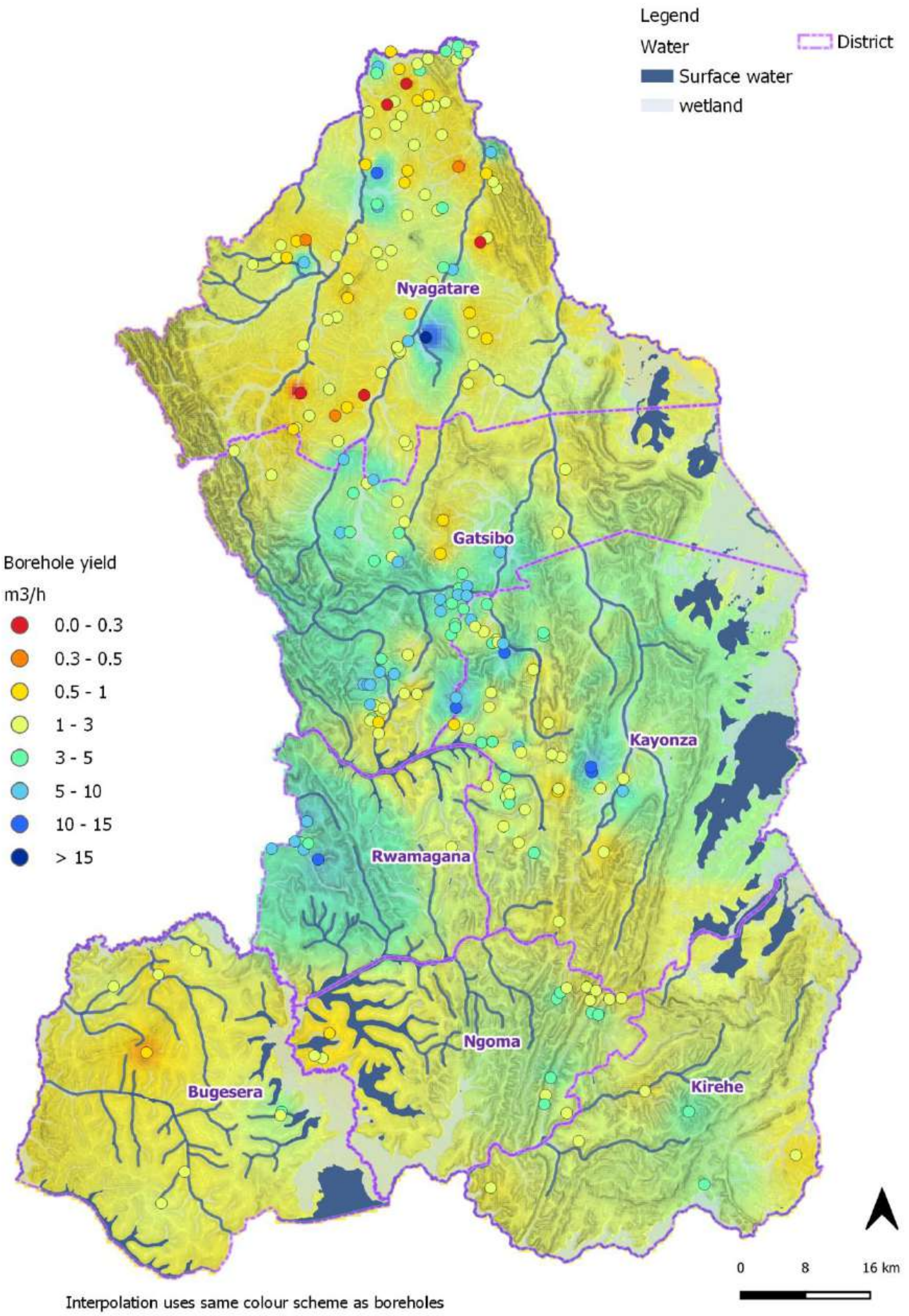


Figure 19: Borehole yield interpolation map

5.2.2 Dry boreholes

One of the datasets obtained also contained the information on dry and low yielding boreholes. The information has been analysed and the results are given in Table 9. It should be noted that it is not representative for the whole region since the projects were focused on Nyagatare, Kayonza and Gatsibo. Most of the dry boreholes have been drilled in the higher areas of the granites and in side valleys of the granites. Moreover, there are also yielding boreholes in those areas but it is clear that success rates are lower in those areas then in other areas like the main valleys that are usually thought to be structurally controlled (see Paragraph 5.6).

Table 9: Dry boreholes topographical location per geological formation

Geology	High slopes	Main valley	Side valley	Grand Total
Bi (sandstone)	5			5
Ng (quarzite)	2		3	5
Rr (schists)	1		2	3
Tb (granite)			2	2
Tm (granite)	11	1	4	16
Grand Total	19	1	11	31

5.2.3 Success rates

The same part of the dataset has been used to calculate a success rate. In this case, a successful borehole is a borehole that gives enough water for it to be equipped with a hand pump. The threshold yield has been set at 500 l/hr. The results are given Table 10. In Gatsibo the groundwater potential for hand pumps is rather good with a success rates are 98% while the potential in Kayonza and Nyagatare is much smaller with success rates of 77% and 79%. Success rates in this case only focuses on successful boreholes drilled giving a minimum quantity of water (>500 l/hr). Water quality is not taken into consideration.

Table 10: Drilling program success rate

District	Contractor	dry	installed	unknown	Grand Total	Success rate
Gatsibo	CGC		6	1	7	100%
	Drillcon	1	4		5	80%
	SABA		32	2	34	100%
Gatsibo Total		1	42	3	46	98%
Kayonza	Drillcon	5	4		9	44%
	SABA	8	43	3	54	84%
Kayonza Total		14	47	3	64	77%
Nyagatare	CGC	19	69		88	78%
	Drillcon	2	12		14	86%
Nyagatare Total		22	81		103	79%
Grand Total		37	170	6	213	82%

Table 11 shows the success rates for the different formation based on the same data set in the three districts. It is remarkable that the most challenging formations are formed by the quartzites and sandstones (Gi). The alluvium formation (Ho) also has many dry boreholes but it should be noted that the Ho formation is only superficial (generally less than 20 m thick in granitic areas and not much thicker in the rest) and therefore it is difficult to say in which formation the dry borehole has been drilled, especially since drilling locations close to the slopes are favoured.

Table 11: Drilling program success rate in different formations

Formation	Sum of Failure	Sum of Success	% success
Bl (sandstone)	3	17	85%
Bu(gneiss)	0	1	100%
Gi (quartzite)	2	6	75%
Ho (sand, clay)	16	78	83%
Ng (quarzite)	1	10	91%
Nm (schist)	0	5	100%
Rr (schist)	0	7	100%
TB (granite)	1	10	91%
TM (granite)	8	53	87%
Grand Total	31	187	86%

5.3 Springs

According to a database made available by JICA the Eastern Province has more than 500 springs. The location of the springs is given in Figure 21. There is a strong relation between springs and topography. Most are in the mountainous areas, and on the (upper) valley break and at the start of the foot of the slope.

Figure 20,

Table 12 and Table 13 gives an overview of the number of springs per geological unit and their flow rates per district and per geological units. It can be clearly seen that the springs are mainly associated to certain formations like the quartzites /schists/ sandstone of the Gi and Bl followed by the Rr, Nm and Ng formation. The Ho formation has most springs but is in fact just a superficial formation overlying other formations.

Table 12 shows the same pattern. The yield information in the same table indicates that the springs with the highest yields can be found in the Nm and Bi formation but the discharge – geological unit relation seems to be weak.

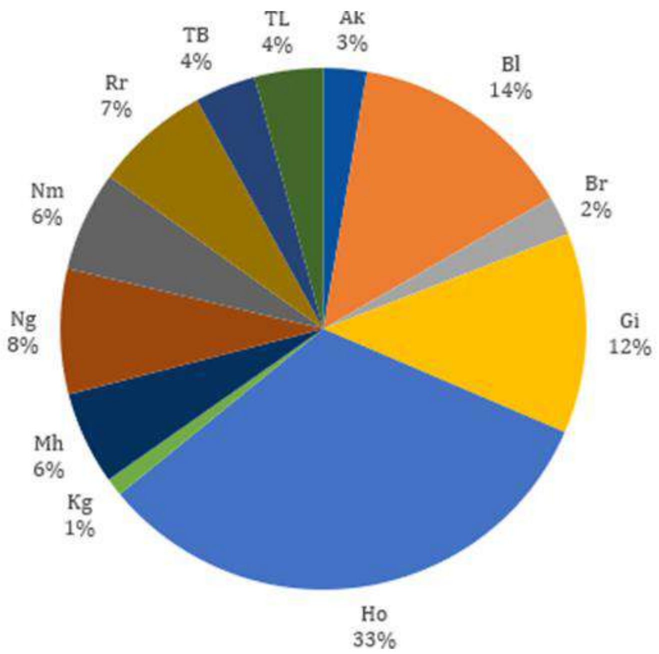


Figure 20: Springs per geological unit

Table 12: Spring yields per geological unit

Lithology	No. of records with yield data	Average of m^3h	StdDev of m^3/h	Max of m^3/h
Ak (sand siltstone)	2	2.6	0.6	3.0
Bl (sandstone)	3	3.3	1.3	4.3
Br (schists)	9	2.3	2.1	7.1
Gi (quartzite)	12	2.0	1.8	6.4
Ho (sand,clay)	37	2.1	1.8	9.0
Kg (quarzite)	1	2.0		2.0
Mh (schist)	11	1.5	1.4	5.2
Ng (quartzite)	11	1.7	1.3	4.6
Nm (schists)	6	3.4	3.4	9.7
Rr (schists)	21	2.1	1.6	6.5
TB (granite)	10	1.8	2.3	7.7
TL (granite)	1	0.9		0.9
Grand Total	124	2.1	1.8	9.7

The district with the highest number of springs is Gatsibo as can be seen in Table 13. By taking into account the number of potential springs in this district and a water supply needed still to be filled, springs do provide a potential solution to said water supply challenge.

Table 13: Number of springs per district

District	No. of springs
Bugesera	11
Gatsibo	201
Kayonza	39
Kirehe	71
Ngoma	104
Nyagatare	29
Rwamagama	29

Grand Total	484

JICA investigated the spring potential in Eastern Province and concluded that some springs do have sustainable yields that are high enough for them to be incorporated in piped schemes. Table 14 shows the flow characteristics of some identified high yielding springs in three districts.

Table 14: High yielding springs JICA 2010

District	Site	Spring name	Spring yield (Q) in m^3/hr								
			APR	MAY	JUN	JUL	AUG	SEP	OCT.	Q Range m^3/hr	Lowest Q Month
Kirehe	Musaza	Kucyizanye-1	7.5	7.7	4.0	3.9	2.7	2.8	2.9	2-8	AUG
		Kucyizanye-2	9.1	10.2	7.7	6.8	5.0	5.0	5.0	5-10	AUG
Ngoma	Rukira	Kabuye	3.7	3.0	3.4	2.8	3.8	4.0	3.7	3-4	JUL
		Akanyirarukima	—	—	11.4	10.6	8.9	8.2	8.5	8-12	SEP
Kayonza	Murama	Gicaca	6.3	6.8	6.0	7.9	7.9	7.4	6.6	6-8	JUN
		Gasake	—	—	7.2	7.3	7.9	7.2	7.4	7-8	JUN
Kayonza	Ruramira	Gitoke	9.3	8.7	7.7	7.7	7.7	7.7	7.7	8-10	JUL
		Nyakariba	5.6	2.9	2.4	2.2	2.0	2.3	2.3	2-6	AUG
		Rubenbezi	2.8	2.7	2.2	2.0	1.9	2.0	2.1	2-3	AUG
Gatsibo	Remera	Nyabukobero	7.0	7.7	6.8	6.1	6.0	6.0	6.0	6-8	AUG

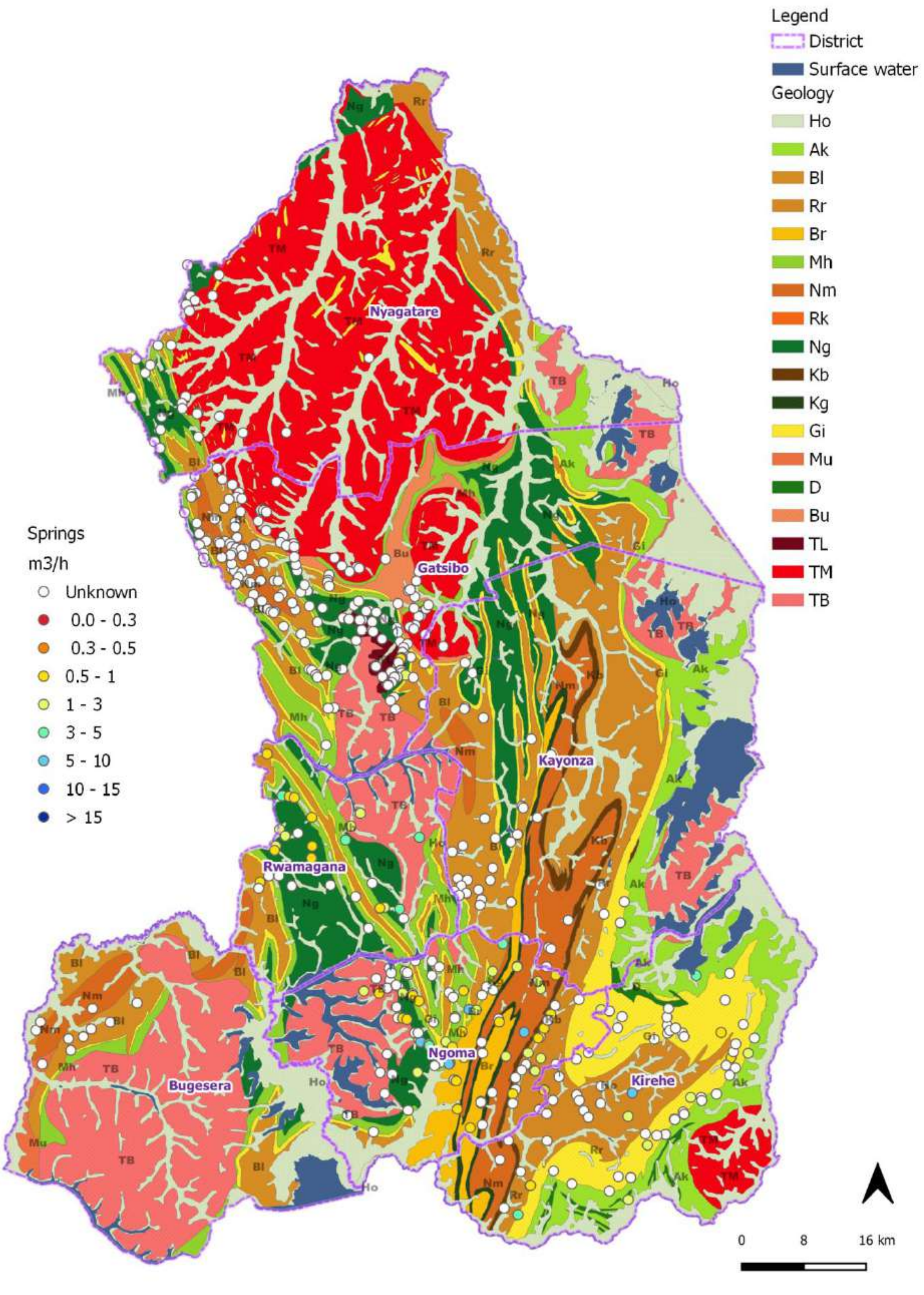


Figure 21: Spring location map

5.4 Groundwater flow

The borehole data, pumping tests data and monitoring data sets have been used to collect the static water level (SWL) of the boreholes. However, without indications on what aquifer the boreholes take the water from, a groundwater flow map would be misguiding. An attempt has been made to make a SWL map of the province (in meters above mean sea level), considering topographical features, surface water bodies and spring locations. The results are presented in Figure 22. For a district specific overview please refer to Annex 7. The map should be considered as a rough indication for the regional groundwater flow considering the following limitations:

If the static water level would be derived from the borehole data, it would present a skewed picture, with ground water flow not considering topographical features at all. Some boreholes may encounter aquifers that are part of a different system and as such, have different piezometric levels. Without detailed borehole data, it is difficult to assess the different systems.

Therefore, the contours are based on the interpolation of surface water levels and springs, creating a set of datapoints that considers topography. General directions and levels remain the same, as with the borehole data, but elevation and catchment boundaries are better displayed and taken into account. Catchment boundaries displayed are derived from the surface water catchments, which represent topographical divides. Ground water divides are almost always offset from the topographical divides, but impossible to determine unless in-depth geophysical investigations along with probing are employed for just that reason. Therefore, the topographical boundaries represent the ground water divides, knowing that there is supposed to be an unknown offset. Figure 24 displays what is meant by said offset.

These contours now do not display the ground water flow in deeper systems, which due to the fractured nature of the aquifers is not feasible, but rather the overburden aquifer system. Ground water flow in deeper systems (fractured aquifers) can be observed on small scale when an interaction between close proximity deep boreholes can be derived, through monitoring only.

The boreholes with static water level data are displayed on the map with their water level in meter below ground level (mbgl). The colour indicates how deep it is below said ground level, with red and orange likely indicating a different aquifer is struck than the overburden aquifer displayed by the contours. The dataset is not big enough yet to justify making contours based on these observations

It is important to note that deep ground water in the fractured aquifers does not necessarily follow the same direction as the shallow ground water displayed. Fractures may or may not be connected and dictate flow direction in fractured rock. This is completely heterogeneous and can therefore not simply be displayed using generalized flow lines. It is expected that the shallow groundwater flow generally follows the topography.

In order to get a general overview on deep ground water flow, water strike levels need to be recorded for all boreholes. If this is not known, a borehole camera can be used to get the location of the screens where likely water strikes took place. Together with an understanding of the lithology, this should provide insight of the different aquifers in play for each borehole. Figure 25 schematically displays a borehole that takes ground water from 2 separate aquifer systems. With the location of the screens known, these aquifers systems can be located.

However, still the data gained from the deeper aquifers can then only be extrapolated to boreholes close by, where a direct relation between ground water levels and pumping influence on each other can be observed. An important tool here will be ground water monitoring, both in boreholes that are not pumping, and boreholes that are. Functional production boreholes give a lot of information on how your aquifer reacts, and in fact which other boreholes are connected.

In summary, the ground water flow map included is a possible representation given with the data availability for this project. Ground water flow will generally follow the topography. However, since most, if not all of the area is fractured basement, there is no correlation between ground water flow on Hydrographic Area (HA) scale. These fractures can work independently, or not, it is not possible to establish at this point. You can establish how ground water behaves in these formations, only after installing a borehole. Monitoring is key here, and based on monitoring information, you will find out how the ground water behaves, on that borehole only. These results can be extrapolated to a nearby borehole, if it is also monitored and a relation found, but not beyond.

5.5 Groundwater quality

During the execution of the project the Electrical Conductivity (EC) of the water of the visited boreholes was measured. These points have been used to prepare a rough EC map.

The boreholes with saline water may be situated in areas where deeper groundwater comes closer to the surface. This water usually has a higher EC. Alternatively the groundwater has passed some layers with more soluble rocks. Figure 23 depicts the EC situation based on available information and measurements done in the field. Higher EC values can typically be found in the granitic areas. However, low values can also be found, with both value ranges in close proximity. Water coming from similar aquifers are unlikely to have EC values that differentiate from each other like this, indicating different aquifers measured according to values, if in proximity.

Figure 23 also shows mineral water quality issues which are typically associated with deep ground water like iron (Fe), manganese (Mn) and fluoride (F) (JICA, 2010) of different boreholes in Eastern Province. Overall iron and fluoride are more common in the granitic areas of Nyagatare, while iron and manganese are more common in the granitic areas of Bugesera and Rwamagana.

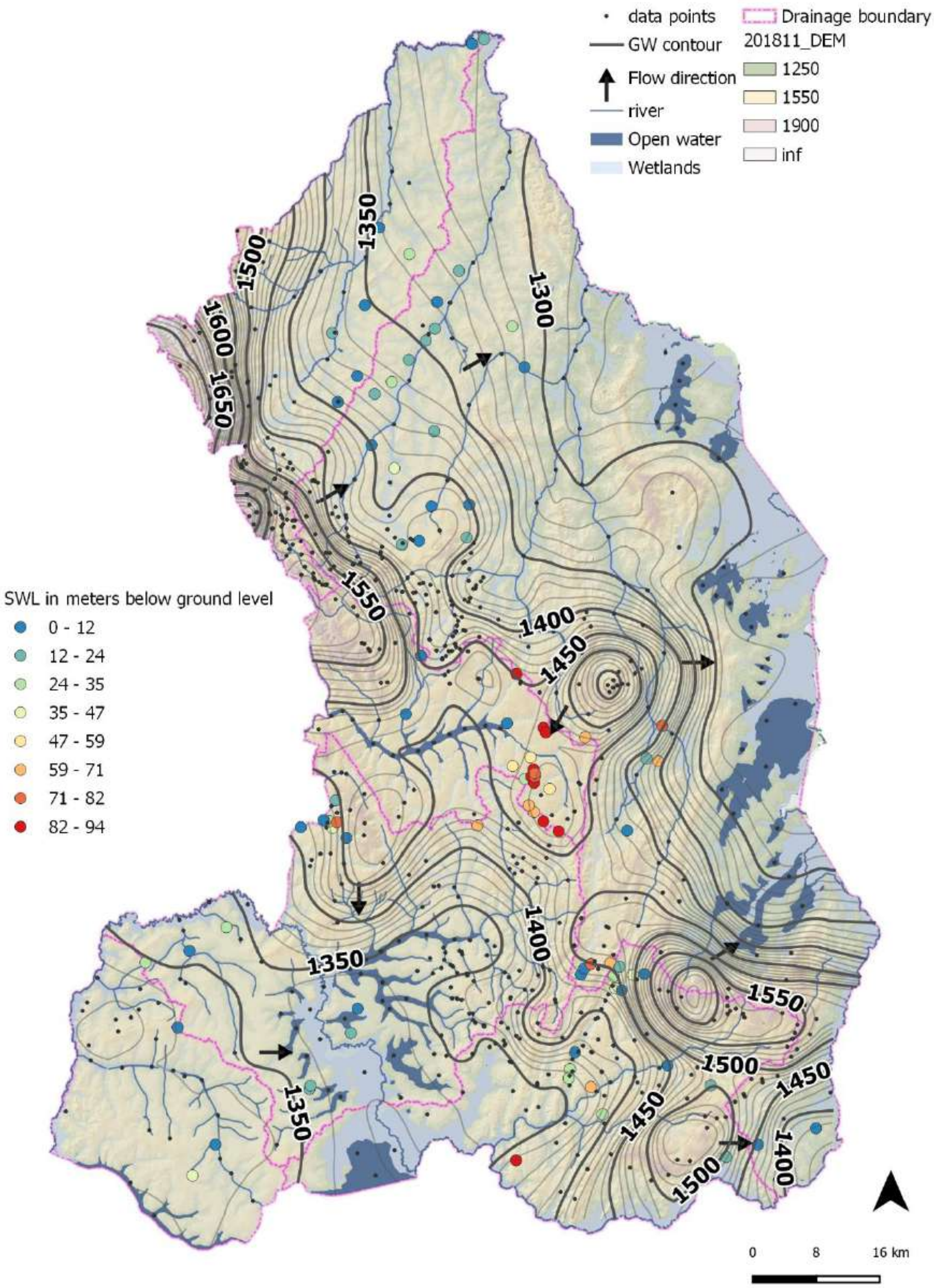


Figure 22: Regional groundwater piezometric map based topography

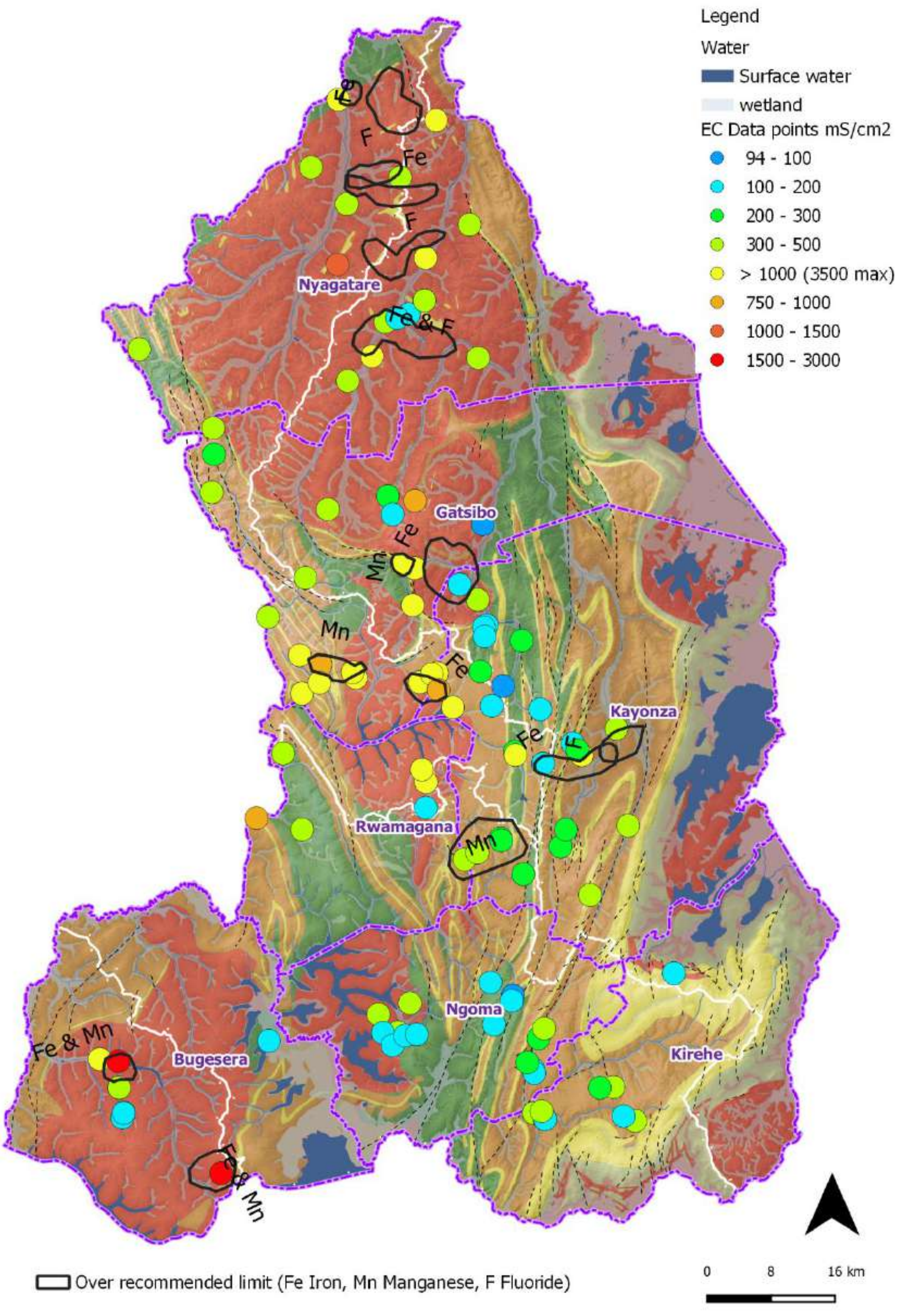


Figure 23 Water quality: EC overview

5.6 Conceptual models

An analysis of the available data, the findings of the reconnaissance visit and knowledge on similar areas elsewhere in the east African region has led to a number of assumptions that have been compiled in a

number of conceptual models and sketched to better understand and depict the conceptual hydrogeological situations in the area.
The general hydro(geo)logical situation is depicted in Figure 27. The higher areas in province act as recharge zones and rainwater infiltrates and flow down to a deep- water table or will generate a sub-surface flow. The shallow groundwater will flow towards the valleys but maybe forced to exfiltrate and form springs in some place.

The general processes are well described in the JICA study on the improvement of the rural water supply in the Eastern Province and other studies. Figure 24 and Figure 25 show two conceptual models that will approach the hydrogeological environment of the Eastern Province.

In principle, the hills act as recharge areas and water will flow to the valleys either as surface water or as sub-surface flow. In some places, water will infiltrate deeper and will exfiltrate again at the springs that have formed at contacts between permeable and non-permeable layers. The rivers and stream will drain the water to the lakes and ultimately the Kagera River that discharges the water into Lake Victoria.

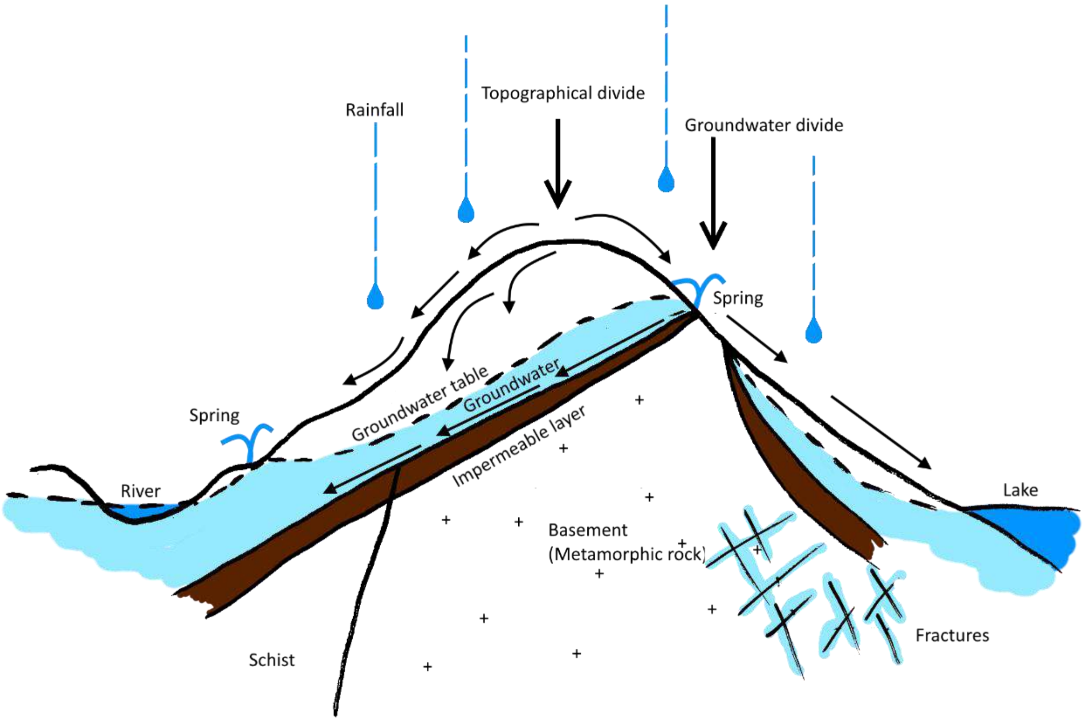


Figure 24 Hydrogeological situation in Eastern Province A

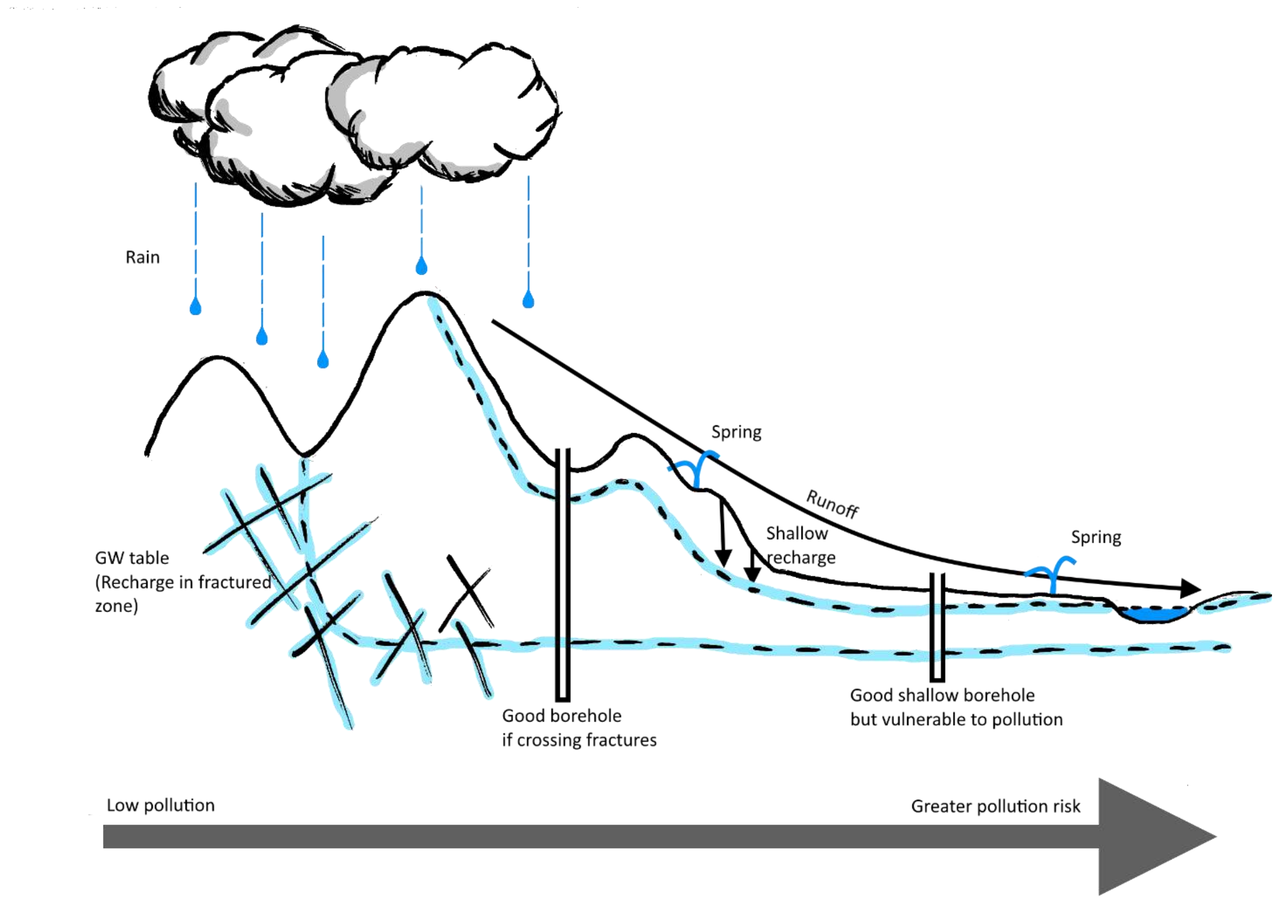


Figure 25 Hydrogeological situation in Eastern Province B

It is obvious that the highest potential is found in the valleys. The JICA study done in 2010 concluded that alluvial plains, developed along valleys have the highest potential for groundwater. Geoelectrical prospecting results confirmed that weathered zones expected to be aquifers are found above basement rock layers with an average layer thickness of 21m and average depths of 24 to 45m. They however also concluded that the thickness and the overburden aquifer presence were difficult to determine by resistivity surveys due to the presence of clays.

Therefore, information on existing borehole drilling and inquiries to contractors were analysed. This information confirmed that successful boreholes are distributed mostly in lowlands along valleys; water is taken from the lower section of highly weathered zones above basement rock. No potential exists in the higher areas of the granite hills and there is a very low potential in the higher areas of the metamorphic formations. The expected situation is depicted in Figure 26.

It should be noted however that some valleys are expected to have a better potential then others. There are three types of valleys:

1. Valleys formed by less resistant layers within a sequence of hard and soft layers of metamorphic rock. They are often filled with thin layers of sediments and are underlain by the soft layers with in the sequence. These valleys are thought to have a low potential.
2. Valleys filled with thin layers of sediments but underlain by faults and fractures. These can be divided in two groups:
   a. Major valleys along wide fractured zones as expected from Google Earth interpretation and/or faults marked on the geological map.
   b. Relatively small valleys that cut through bands of quartzite.

3. Valleys filled with sediments. Depending on the thickness and the character of the sediments these valleys good have a poor to very high potential.

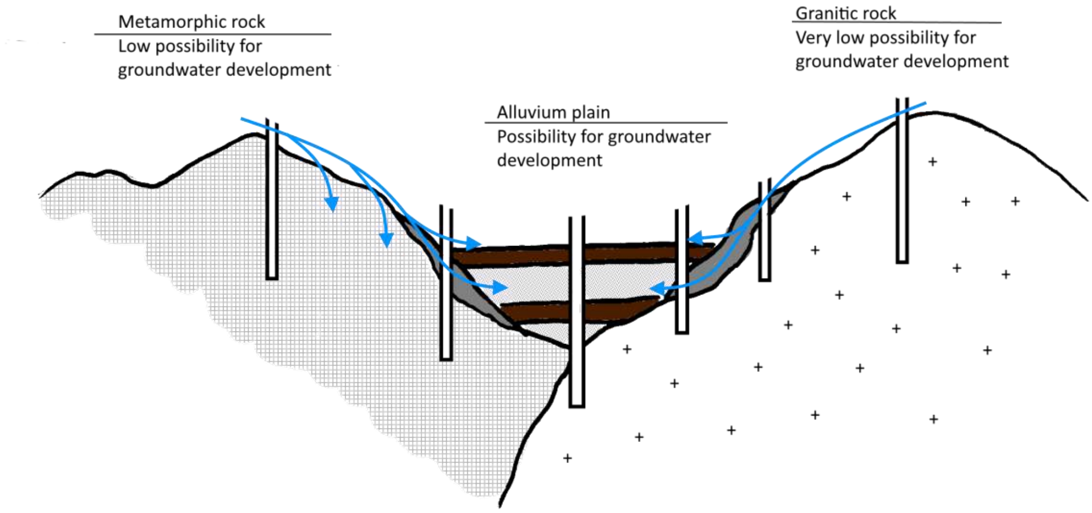


Figure 26: Expected general hydrogeological situation

The situation on the higher grounds depends on the elevation difference between the anticipated groundwater table (generally slightly above the elevation of the valley floor but should be checked with the expected static water level map as well). If the vertical distance between the drill location and the valley floor is more than 50 m then the water table is expected to be too deep for a handpump.

Apart from the elevation, the type of bedrock also plays a role. Compact un-weathered granites and gneisses have no potential, but fractured and fissured sand and siltstone may have a good potential at least for handpumps, even outside the valleys as long as the elevation is not high above the expected groundwater level.

The different situations that can be encountered in the field are depicted in Figure 27 to Figure 31

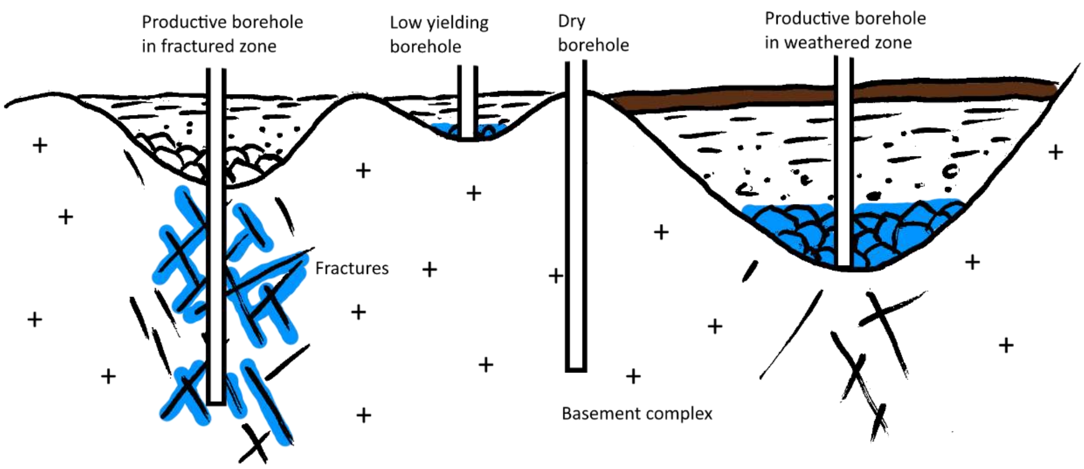


Figure 27:Hard rock borehole yield principles

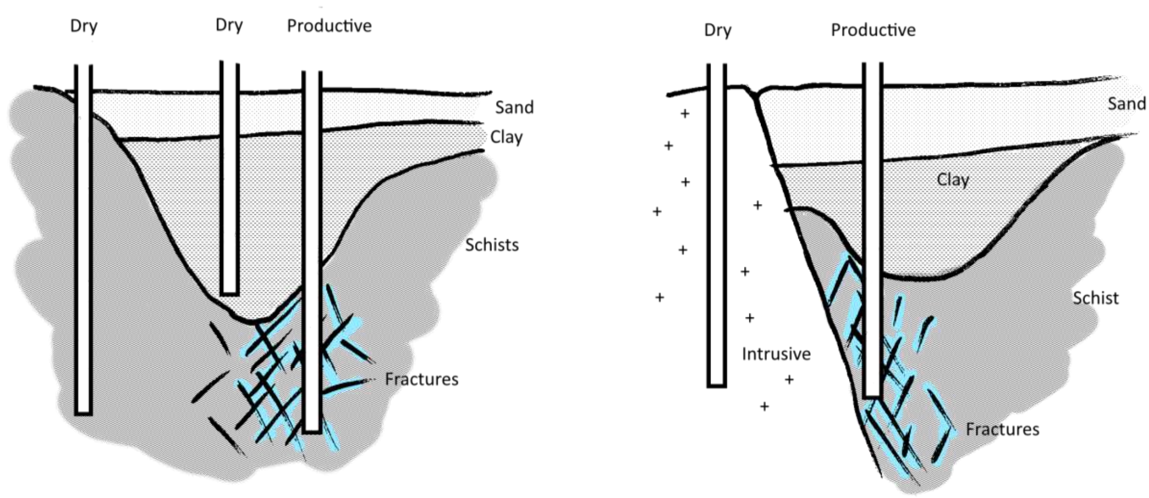


Figure 28: Schist borehole yield principles

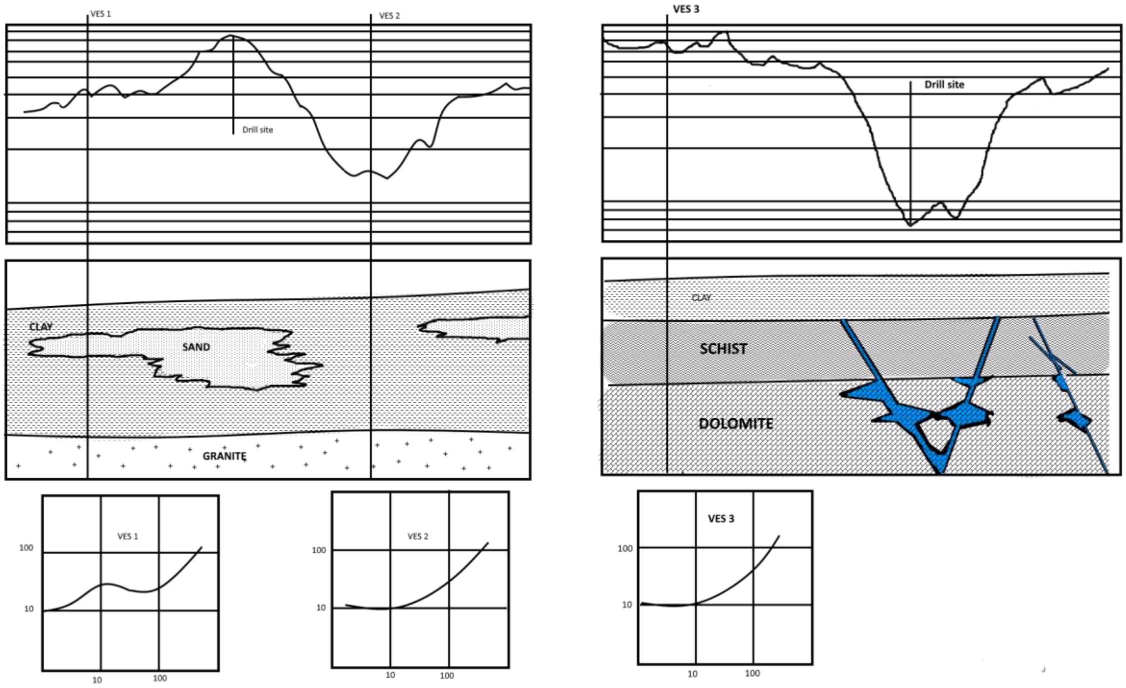


Figure 29: Sediments and hard rock profiling and VES location selection principles

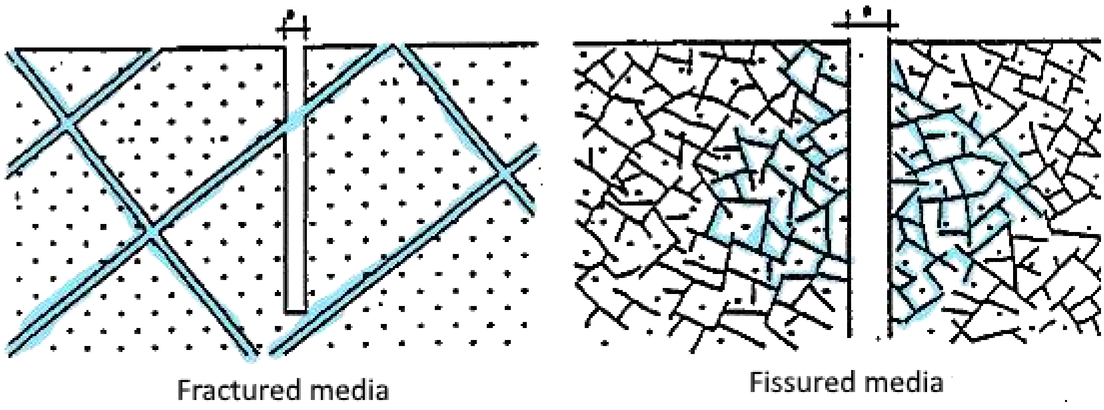


Figure 30: Fractured and fissured issued rock

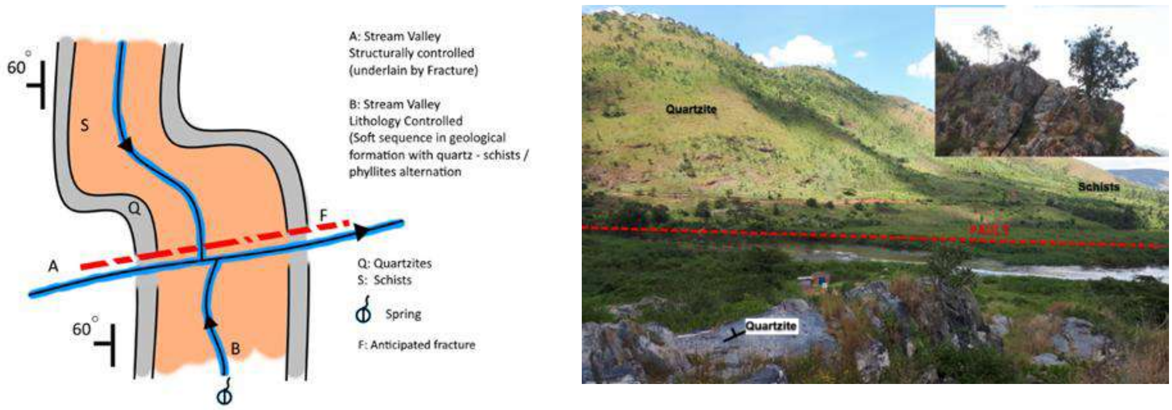


Figure 31: Structurally controlled stream valley principle

5.7 Recharge

An attempt has been made to estimate the groundwater recharge based on geological characteristics and mean annual rainfall. Each geological unit was attributed a recharge percentage and for each unit the recharge percentage was converted into sustainably abstract able volumes (in m^3) by multiplying the rainfall with the surface area of the formation in the Eastern Province. The recharge percentage attributed varied between 5 and 15%.

The sediments normally would have the highest recharge, however many of the sediments overlaying the granitic areas are shallow and in fact rely on granite recharge figures. For this reason, a segregation between sediments underlain by granites and schists (generalisation) has been taken into consideration. The results are given in Table 15.

It should be noted however, that these numbers for large areas are often not very accurate. The amount of water that can be pumped in a sustainable manner largely depend on local conditions and are best determined by managing wellfields and production wells in detail by monitoring production volumes and water levels combined with rainfall series.

Table 15: Recharge calculation based on geological unit and rainfall

		Mean annual rainfall (mm)							
		1045	1041	999	971	979	985	986	1,001
Litho Code	Area (km²)	Recharge rate %	Bugesera (recharge million m³/yr)	Gatsibo (recharge million m³/yr)	Kayonza (recharge million m³/yr)	Kirehe (recharge million m³/yr)	Ngoma (recharge million m³/yr)	Nyagatare (recharge million m³/yr)	Rwamagana (recharge million m³/yr)	Eastern Province (recharge in million m³/yr)
Ak (sand/siltstones)	454	5%	0	3	7	11	0	1	0	22
Bl (sandstone)	652	5%	8	7	11	0	2	1	4	33
Br (schists)	141	5%	0	0	1	1	5	0	0	7
Bu (gneiss)	88	5%	0	4	0	0	0	0	0	5
D (intrusions)	26	10%	0	0	0	2	0	0	0	3
Gi (quartzite)	684	15%	3	12	19	43	9	8	7	102
Ho (sand/clays/Schists)	1,530	15%	6	49	77	45	31	4	17	229
Ho (sand/clays/Granite)	1,052	5%	19	4	3	0	0	26	1	53
Kb (quartzite)	74	15%	0	0	8	1	2	0	0	11
Kg (quartzite)	58	10%	0	0	2	1	3	0	0	6
Mh (schists)	389	10%	6	13	0	0	7	4	10	39
Mu (quartzite)	22	15%	3	0	0	0	0	0	0	3
Ng (quartzite)	716	15%	2	31	23	0	8	14	30	108
Nm (schists)	399	10%	7	4	17	3	8	0	1	40
Rr (schist)	713	10%	0	4	31	19	6	11	0	71
TB (granite)	1,166	5%	30	7	7	0	8	2	6	60
TL (granite)	27	5%	0	1	0	0	0	0	0	1
TM (granite)	1,414	5%	0	15	1	3	0	51	0	70
Total (million m³/yr)			85	156	208	130	88	121	75	862
Total (m³/hr)			9,711	17,760	23,730	14,809	10,089	13,785	8,565	98,447

Another option is to rely on an empirical formula. Chaturvedi (1973) proposed the following empirical relation based on the water level fluctuation and rainfall:

$$R = 2\,(P - 15)^{0.4}$$

However, this formula alone does not consider any relation to geology which will lead to skewed results. For example, the total recharge for Eastern Province would amount to about 1,751 million m^3/yr, which is more than double of most estimates. Geology plays a large part.

If to use an empirical formula, the results can be enhanced by using probability figures to estimate the percentage that would reach the aquifer in the designated lithological layer groundwater in fractured rocks (Sharp, 2007).

Table 16 lithology and recharge probability (%)

Geology - Lithology	Recharge probability (%)
Gneiss	65
Granite	65
Limestone	85
Quartzite	65
Sediments	90
Schists	65
Sedimentary	75
Shale	55

The probabilities used in Table 17 are lower than depicted in Table 16 in order to consider obstructions before permeating into the ground. However, as can be seen, the results are strikingly similar for such a scale to the results depicted in Table 15. These numbers can be refined over and over as more information is gathered and the areas cut into smaller more manageable sizes. On the other hand, the advantage of the method in Table 15 is that adjustments are easily made based on expert judgement.

Table 17 Recharge figures based on empirical formula & consideration of lithology and probability

			Mean annual rainfall (mm)							
			1045	1041	999	971	979	985	986	1,001
Litho Code	Area (km^2)	Recharge probability %	Bugesera (recharge million m^3/yr)	Gatsibo (recharge million m^3/yr)	Kayonza (recharge million m^3/yr)	Kirehe (recharge million m^3/yr)	Ngoma (recharge million m^3/yr)	Nyagatare (recharge million m^3/yr)	Rwamagana (recharge million m^3/yr)	Eastern Province (recharge in million m^3/yr)
Ak (sand/siltstones)	454	55%	0	6	14	23	0	2	0	45
Bl (sandstone)	652	55%	16	15	21	0	4	2	8	66
Br (schists)	141	55%	0	0	2	2	10	0	0	14
Bu (gneiss)	88	55%	0	9	0	0	0	0	0	9
D (intrusions)	26	60%	0	0	0	2	0	0	0	3
Gi (quartzite)	684	50%	2	7	12	26	5	5	4	62
Ho (sand/clays/Schists)	2,571	80%	6	47	75	44	31	4	17	223
Ho (sand/clays/Granite	2,571	50%	34	7	5	0	0	47	2	95
Kb (quartzite)	74	50%	0	0	5	1	1	0	0	7
Kg (quartzite)	58	50%	0	0	2	1	3	0	0	5
Mh (schists)	389	55%	6	13	0	0	7	4	10	39
Mu (quartzite)	22	50%	2	0	0	0	0	0	0	2
Ng (quartzite)	716	50%	1	18	14	0	5	8	18	65
Nm (schists)	399	55%	7	4	17	3	8	0	1	40
Rr (schist)	713	55%	0	4	31	19	6	11	0	71
TB (granite)	1,166	50%	54	12	13	0	14	4	11	108
TL (granite)	27	50%	0	3	0	0	0	0	0	3
TM (granite)	1,414	50%	0	27	2	6	0	93	0	129
Total (million m^3/yr)			128	172	214	128	94	180	70	986
Total (m^3/hr)			14,565	19,670	24,435	14,620	10,694	20,509	8,013	112,506

5.8 Hydrogeology and potential

Figure 32 shows the different aquifer types identified for Eastern Province. The following aquifer types were distinguished:

5.8.1 Granites

Most common in Bugesera and Nyagatare, they are typically characterised by low potential when not weathered or fractured. While elevations differences are typically not as high as found in the schists or quartzites, successful boreholes tend to be found in or near the valleys. This is in small part because some of the boreholes struck, in fact, take water from the overlaying sediments, but for the most part because getting successful boreholes in these formations relies on identifying and confirming underground faulting and fractures. Several valleys in the area will be the direct result from tectonic movement, and a number of valleys will be the result of erosion of softer layers, the latter being less ideal for ground water. Geophysical surveying will distinguish between the types of valleys. Ground water exploration will depend heavily on previous borehole data, previous surveys and identification of lineaments. This aquifer type contains isolated fractured aquifers that do not necessarily have any coherence with neighbouring aquifers. Recharge rate (5 %) and recharge probability (50%) are low since they can only recharge where the rock is fractured or faulted. For hand pump boreholes, valleys should normally provide enough potential, however geophysical surveying is still advised. For production boreholes, extensive geophysical surveying is an absolute must, and can provide high yielding boreholes in the right locations, where transmissivity in the fractures is high.

5.8.2 Schists

These metamorphic rocks are typically a lot softer than granites and quartzites, and have a higher overall transmissivity because of it. They are more prone to fracturing and fissuring (see Figure 30), but fractures and fissures themselves will have lower transmissivity because it is a less competent formation. Erosion is more common and transported particles will bottleneck flow in the fractures, which is less common in the more competent rocks. Valleys in these formations are typically caused by erosion of less competent layers, and not tectonic movement. While it is possible to have valleys caused by tectonic movement, it is not common, and they are difficult to detect using geophysics. Geophysical results in schists are typically homogeneous and difficult to distinguish. Overall, hand pump boreholes can easily be found in the valleys. Overall potential is good, but its homogeneous nature means that excellent (high yielding) boreholes can usually only be found where it interfaces with other formations. Recharge rate (10%) and recharge probability (55%) are higher than with granites, as is overall transmissivity. However, transmissivity for “high” yielding boreholes will be lower because of the fractures filling with less competent formations and the overall more dispersed infiltration.

5.8.3 Quartzites

Overall quartzite is considered to have no ground water potential. It is usually intermitted by less competent schists, where the ground water would infiltrate. In Eastern Province quartzites can be identified as beds surrounded by schists. However solid the quartzites are, there are locations where these beds are forcefully broken through by valleys in perpendicular directions, which can (most of the time) only be caused by tectonic faulting. Because of the density of the quartzite these tectonic movements would have to be considerable and potentially hold high yielding faulted/fractured aquifers. While these faults/fractures also manifest into the schists, they are not easily identified in those formations. Only in those instances which are identified on the potential map, should boreholes be considered in quartzites. Recharge rate (15%) is relatively high compared to recharge probability (50%). This is mainly because many instances of broken quartzite ridges have been identified (where recharge rate would be high) in a relatively small aquifer type (in terms of surface area).

5.8.4 Schists/Quartzites

This aquifer type is a combination of the two above, quartzites and schists but more closely intermingled. Field visits and geophysics should distinguish between the two types in order to get high potential boreholes. Consequently possibly because of the heterogeneity of the aquifer type many high yielding boreholes are found here, most of the time on lineaments that seem to cross quartzites at some point. Besides the high yielding boreholes based on features, also the low to mid-range yielding boreholes, which are more typical for schists, can be found in this aquifer type. As more information becomes available, as more data is stored in databases, this aquifer type will be divided up in the quartzite and schists aquifer types respectively.

5.8.5 Consolidated sediments

Only found in Kirehe and part of Kayonza in the east, these areas are surrounded by surface water and prone to flooding. Evidently underlain by granites, and overlain by sediments, it relies on those respective aquifer types for ground water. Typically flat, it is difficult to identify features that will help find locations for boreholes. A lack of borehole data is restricting estimations of potential in this aquifer type. However, proximity to surface water and sediments does suggest hand pump borehole potential should be there, if verified by geophysics. This aquifer type should be slotted according to potential once more data is available in the future. Typically recharge rates (5%) and recharge probability (50%) are considered low.

5.8.6 Alluvium

Overlaying most of the other aquifer types and in terms of surface area the largest of the aquifer types, alluvium deposits are constricted to the valleys. Overall the alluvium mostly consists of clayey soils which, even though recharge will be high, will not provide high yielding boreholes because of the constricting transmissivity. To get high yielding boreholes in this aquifer type, sandy sediments need to be found (see Figure 29), which have a high transmissivity and can make use of the typically high recharge rate. These sandy sediments are scarce in Eastern Province but can be recognised by meandering surface water (where these sediments are deposited). However, sediments found in granites, near meandering rivers, are typically shallow and hardly store any ground water at all. In the granites, the higher potential can be found in the wider valleys, but the problem is going to be to subtract the water because of the clays. In granites, this aquifer type is mostly in fact feeding the underlaying aquifer type (if fractured). Outside of the granites, meandering rivers typically can be high yielding aquifers, as found north of Bugesera and in Kirehe, south of the quartzite bank. More groundwater can typically be subtracted from the other valley aquifers since here they are thicker. However, outside of the sand lenses found around meandering rivers, transmissivity is going to be a problem, and while much ground water might be present, getting it out will be an issue, resulting in typically hand pump borehole potential. Recharge rate (5 to 15% depending on location) and recharge probability (50 to 80%) is among the highest, but areas of high transmissivity need to be found outside of the clays to make use of it.

5.8.7 Groundwater divide

The ground water divide is represented by the topographical divide. While they are not the same, they are similar and closely related as described in Figure 24. It will allow a rough indication of in which direction water will flow as it infiltrates.

5.8.8 Hydrogeological map

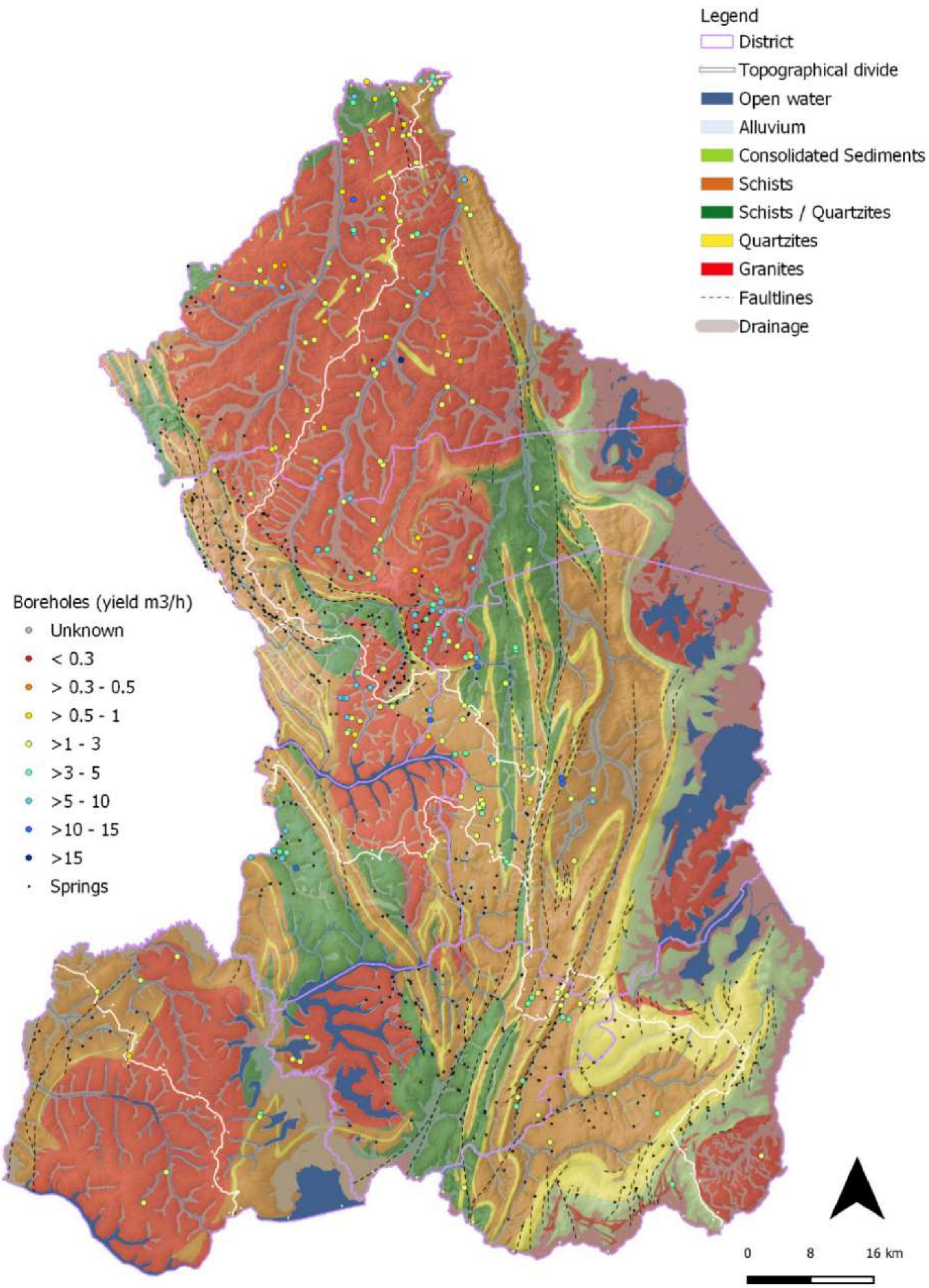


Figure 32 Hydrogeology: Aquifer types

5.8.9 Groundwater potential

An overall groundwater potential map has been prepared based on the information as presented in the earlier chapters. The map is shown in Figure 33. The borehole yields were interpolated to create a base-map that can be used for planning. It should be noted that interpolated borehole yields should be used with care and only serves a planning purpose. Yield differences can be within ranges of a few meters and are mainly caused by linear features. If colours (yield indications) change suddenly and most of the time of the same line, these are cause by indications of structural differences which will indicate an increase in estimated potential yield.

The interpolated yield of boreholes is indicated in 3 classes:

- Low potential: 1 to 3 m^3/h. More typical for the granite and consolidated sediment aquifer types, unless something significant happens that increases potential.
- Medium potential: 3 to 5 m^3/h. More typical for the schist aquifer types. Less likely to have significant changes (not impossible in conjunction with quartzite aquifer type) but higher over the board potential compared to granite aquifer type.
- High potential: 5 to 10 m^3/h. More typical for the quartzite/schist aquifer type. This aquifer type is most heterogeneous resulting in the highest number of clustered high yielding boreholes, giving this interpolation result. Not interpolated class 2 targets also have the high potential standing. These are based on valleys suspected to be caused by tectonic movements.

The following classes were not based on interpolation, but rather on observations and identification of features:

- Major potential: Surpassing 10 m^3/h. Otherwise referred to as a class 1 target. These are areas identified in the quartzite ridges where a valley breaks through the quartzite band in perpendicular fashion as described in Figure 31. These areas have the highest potential found in Eastern Province, but need to be identified with pinpoint accuracy using geophysics, since missing the feature puts you in the next category.,
- Very low potential: less than 0.5m^3/h. These are signified by the quartzite ridges that are not broken. Since there is no transmissivity and recharge, there is no potential. The difference in result between yield in solid quartzite and broken quartzite is significant. Differentiating between the two using geophysics and in the field, is delicate work.

The following layers were then also added to further differentiate in potential:

- On the higher grounds the water table is deep (> 50 m) and it is difficult to identify (highly) productive aquifers with geophysical measurements. These areas have been marked as low potential area and have been indicated in brown.
- Spring potential: areas with spring potential have been rasterized on the map. Some areas (Gatsibo) have a considerable number of springs, suggesting that water supply from springs is a very valid option to consider.
- Alluvial aquifers have a good groundwater potential if they contain coarse material that are hydraulically connected to the current river course. Geophysical measurements in the sediments of the Nyabarongo River indicate the presence of coarse deposits between 2 and 20 m. Boreholes drilled in coarse grained deposits of the same river near Kigali yielded 50 m^3/hr on average from a depth of less than 20 m. The sediments near the Akagera river along the south eastern and eastern border of the Eastern Province could also have a higher groundwater potential. For the rest, the potential is typically high enough across the board to justify a handpump. Verify with geophysics to know what level of potential is on location.

The last layers added are the lineaments which signify subsurface heterogeneity which can result in an increase in potential:

- Lineaments: are identified by studying elevation patterns, satellite imagery and identification during reconnaissance. Typically, these lineaments signify possible faulting which leads to an increase in ground water potential. Their location and direction should however always be verified using geophysics before assuming the attached potential. (5 to 10 m^3/h)
- Faultlines: are identified from the geological map, and more often than not, coinciding with identified lineaments. Same as with other lineaments, their location and direction should however always be verified using geophysics before assuming the attached potential. (5 to 10 m^3/h)
- Highlighted valleys: Some valleys overall seem to coincide with major lineaments or are moving in a way typical for tectonic valleys. Same as with other lineaments, their location and direction should however always be verified using geophysics before assuming the attached potential. (5 to 10 m^3/h)

Figure 35 combines the major and high potential targets and combines it with current water supply (boreholes and springs only) and population density.

Many of the lineaments and targets are in scarcely populated areas, where water supply is low or non-existent (Bugesera, part of Kayonza). Spring potential seems to be high in many of the densely populated areas, where water supply systems are likely already present, and can be combined with high yielding springs.

Figure 36 to Figure 42 give district specific ground water potential maps with more detail for more considered target selection. For A3 size representations of the maps please refer to Annex 7. They also indicate figures that provide overview on the possibilities for additional abstraction in terms of available ground water:

- Derived recharge: This takes the recharge figures computed by using recharge rate and recharge probability as presented in Table 15 and Table 17.
- Dry recharge: this is to represent the driest period. It takes 25% of the derived recharge to represent the month(s) during which the recharge is expected to diminish considerably.
- Current abstraction: This is a collection of all borehole yields collected in an area. Take note that not all boreholes have their yields recorded (especially hand pumps) and the percentage of functionality is expected to be low. Functionality is not considered, presenting a view on total yield if all boreholes were working, and used to their maximum (reported) potential.
- Demand: This represents the population in an area with their daily water demand between 20 and 50 litre per capita per day (l/c/d). This is then divided by 12 to represent likely hours during which they would use the water. The demand assumes only ground water is used to meet the demand.
- Ground water for irrigation is project, plot and crop dependent, and therefore not considered.
- Knowledge on large abstraction and future high demand projects can be added to the numbers presented for each district. These figures serve as a starting point.

In terms of utilizing potential for production borehole planning, do not make use of general zones, but rather identified structures, such as lineaments and major potential targets. The difference between high and low yield, failure and success, relies on identification and confirmation of structures. For this reason, they play a major role in ground water potential and can stipulate changes in potential (if confirmed).

Derived recharge: 98,447 – 112,506 m3/h

Dry recharge: 24,612 – 28,127 m3/h

Current abstraction: 742 m3/h

Demand: 3,069 – 7,672 m3/h

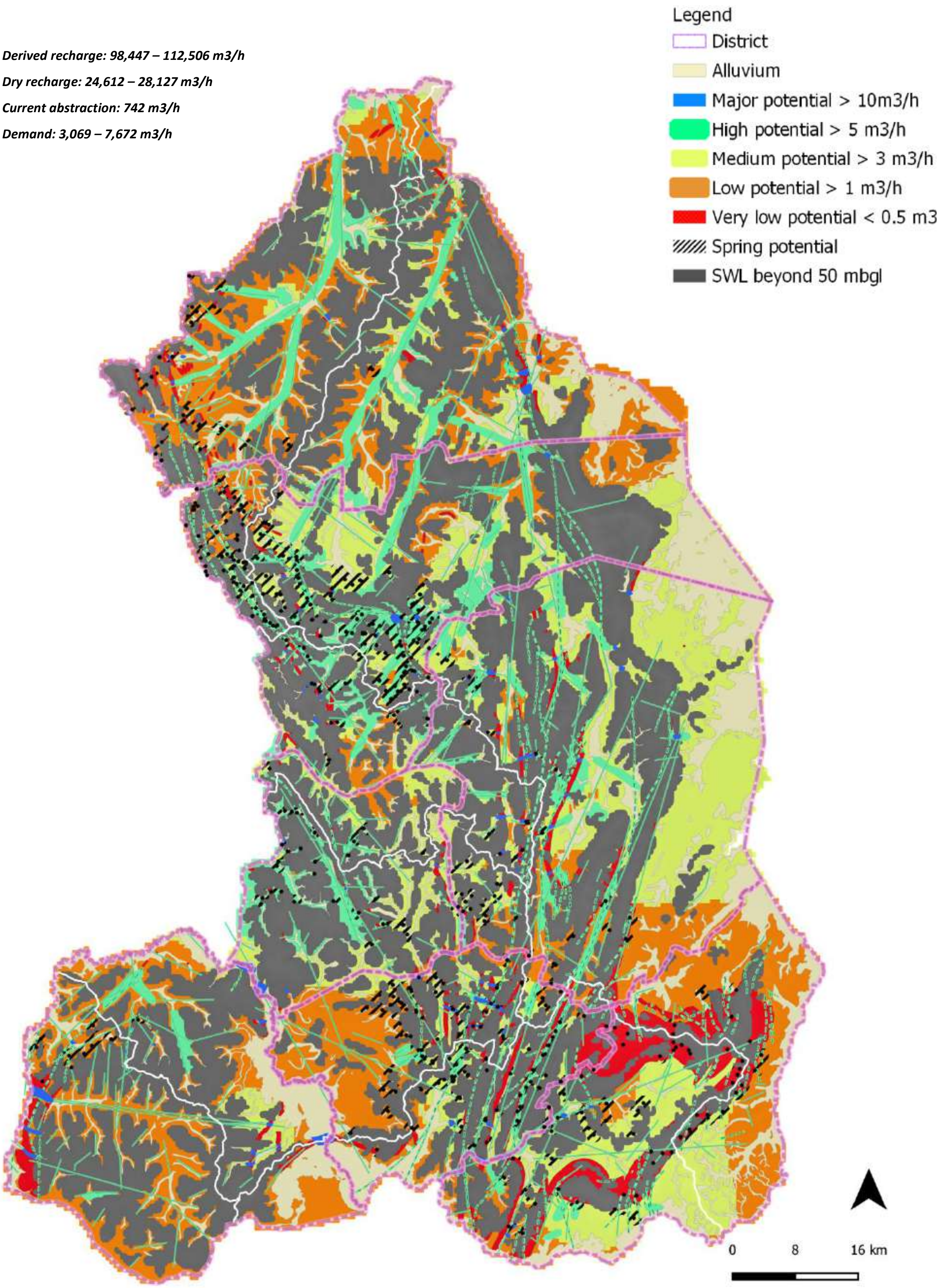


Figure 33: Groundwater potential map – overview

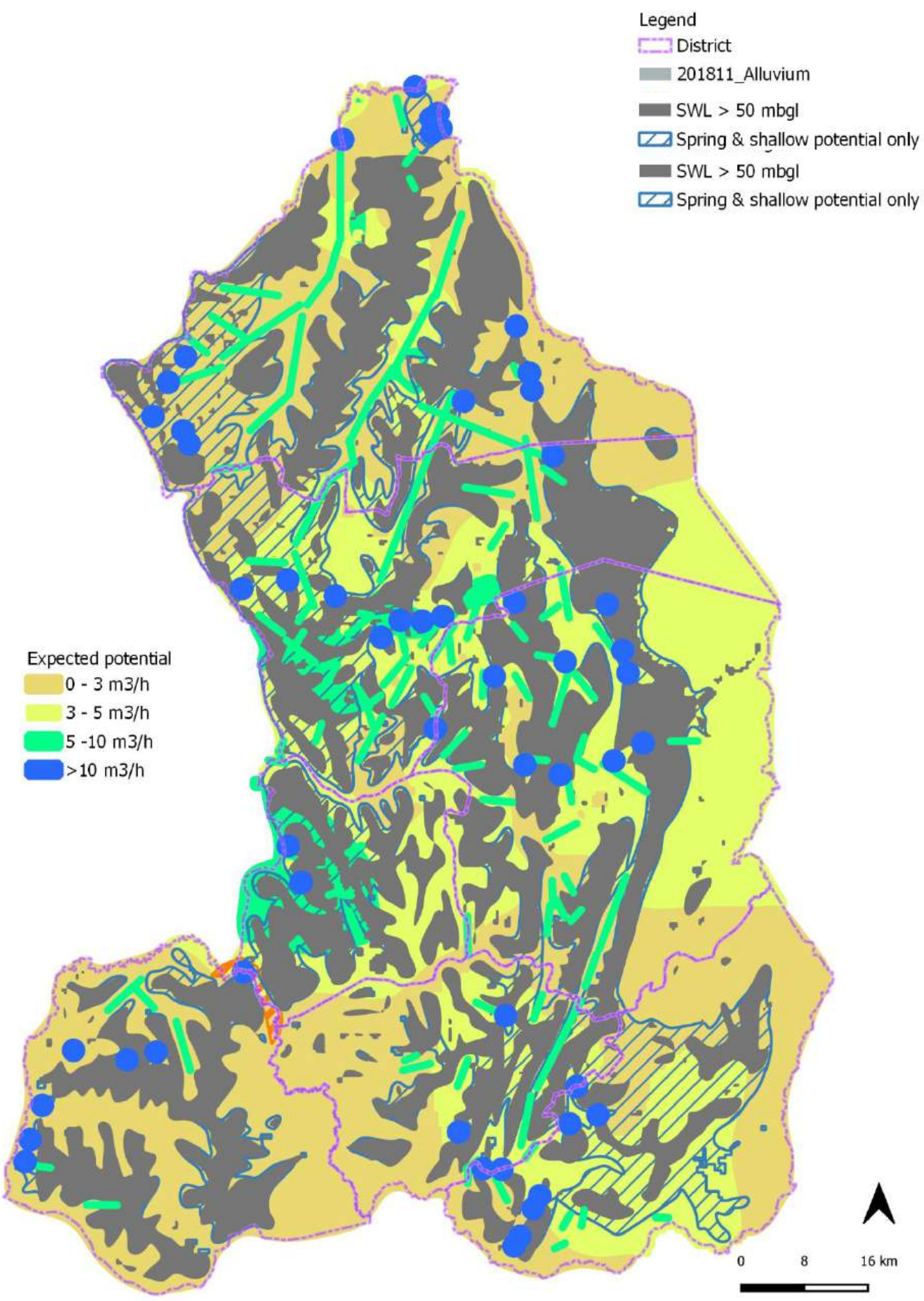


Figure 34 Ground water potential - simplified

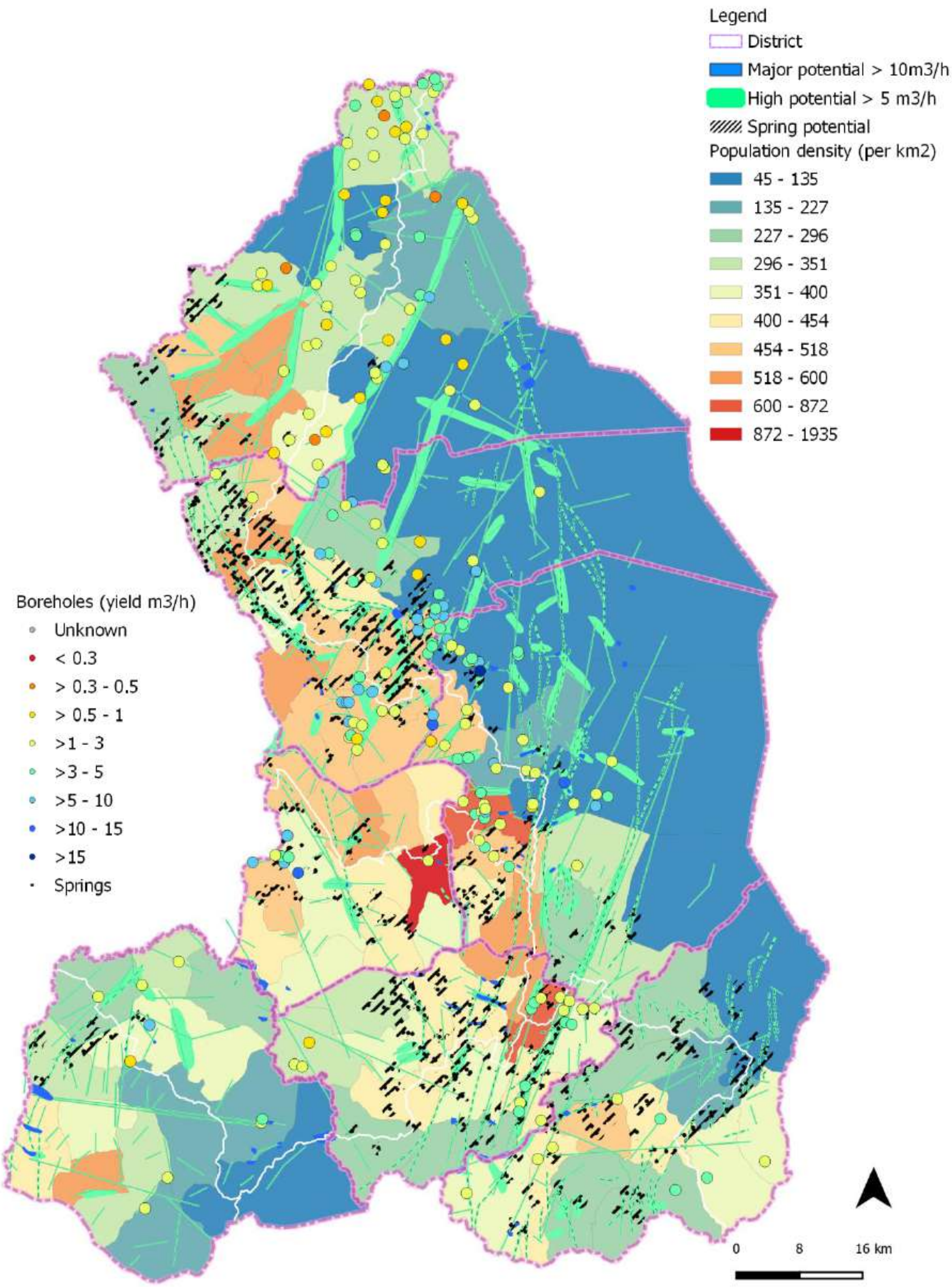
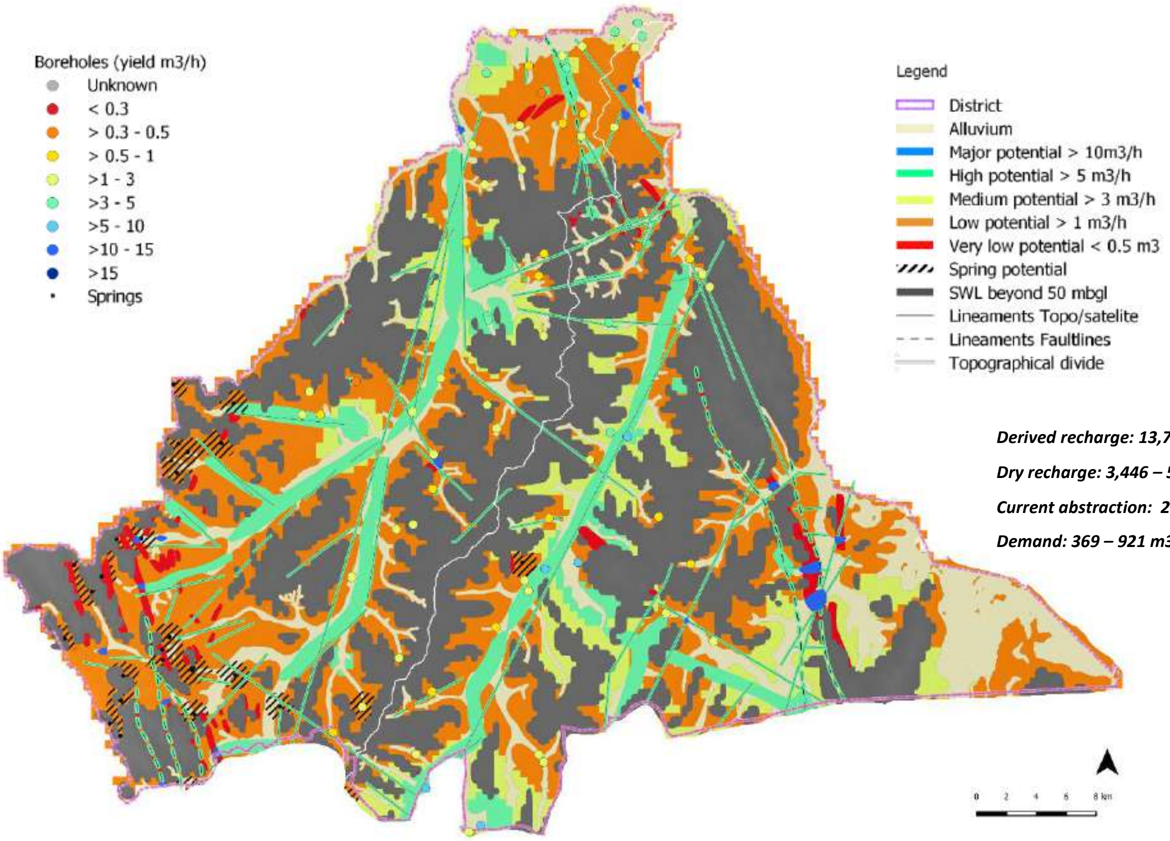


Figure 35 Potential targets/current supply/demand



Derived recharge: 13,785 – 20,509 m3/h

Dry recharge: 3,446 – 5,127 m3/h

Current abstraction: 230 m3/h

Demand: 369 – 921 m3/h

Figure 36 Nyagatare ground water potential

Derived recharge: 23,730 – 24,435 m3/h

Dry recharge: 5,933 – 6,109 m3/h

Current abstraction: 198 m3/h

Demand: 333 – 832 m3/h

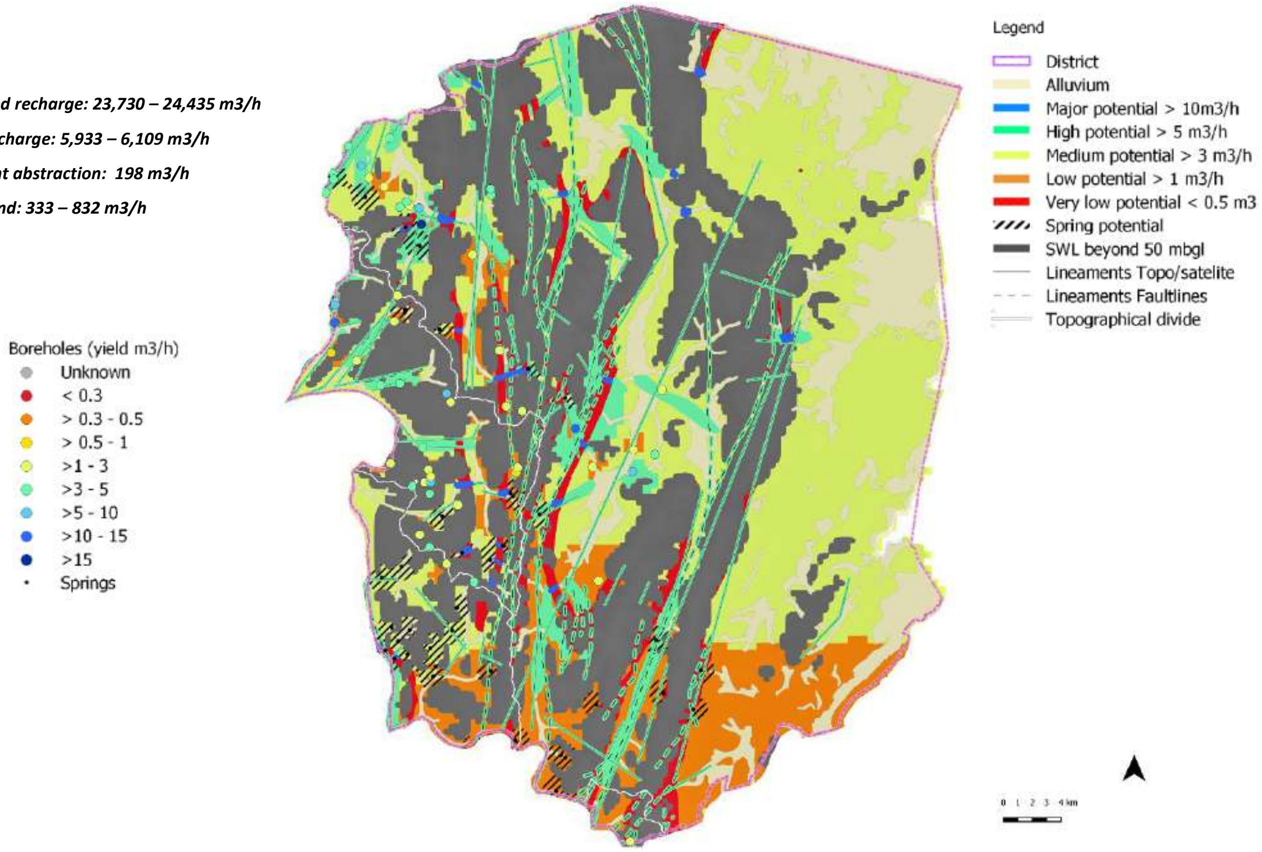


Figure 37 Kayonza ground water potential

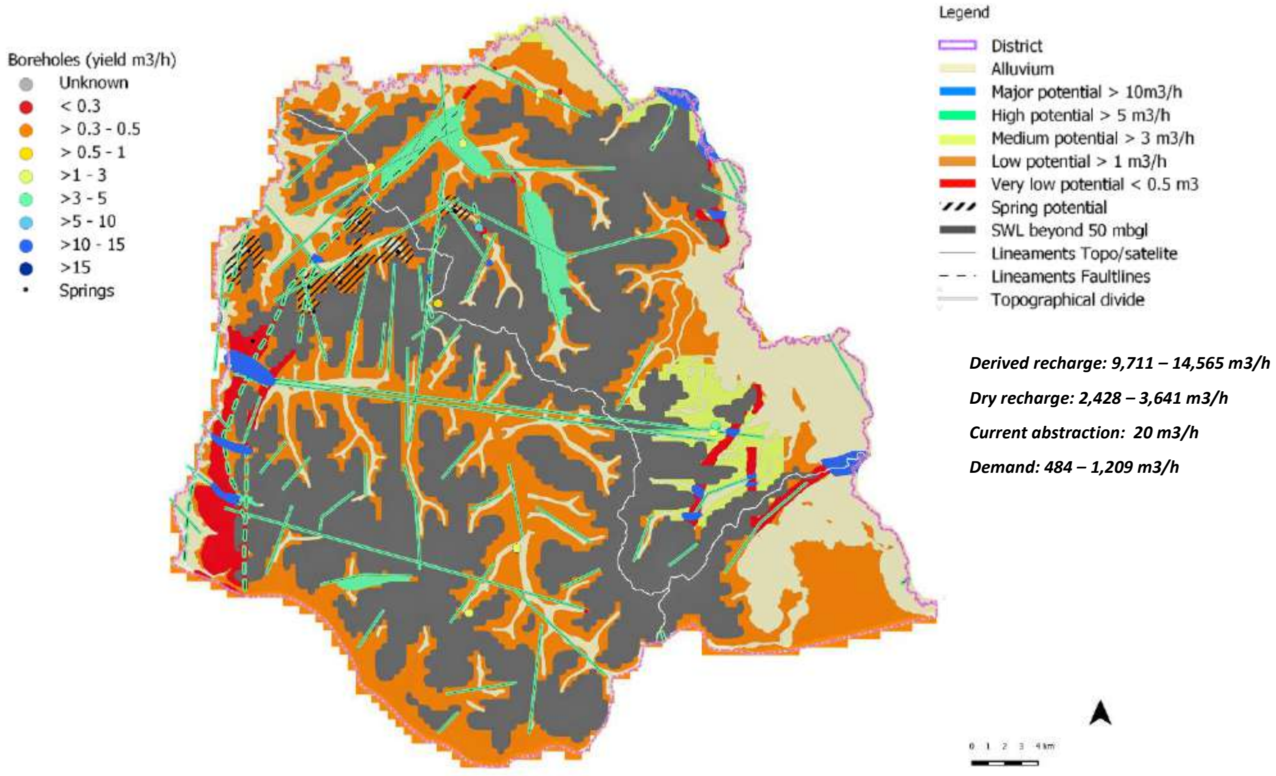


Figure 38 Bugesera Ground water potential

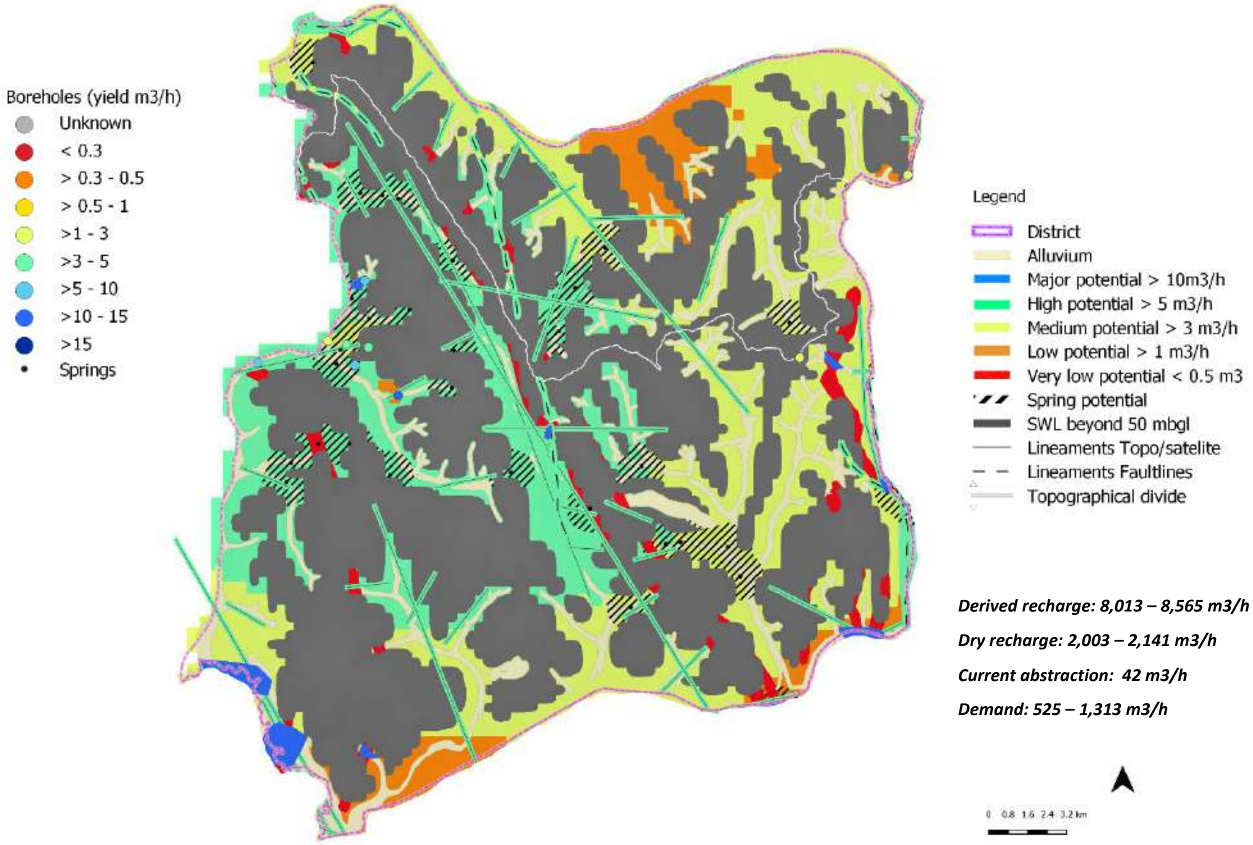


Figure 39 Rwamagana ground water potential

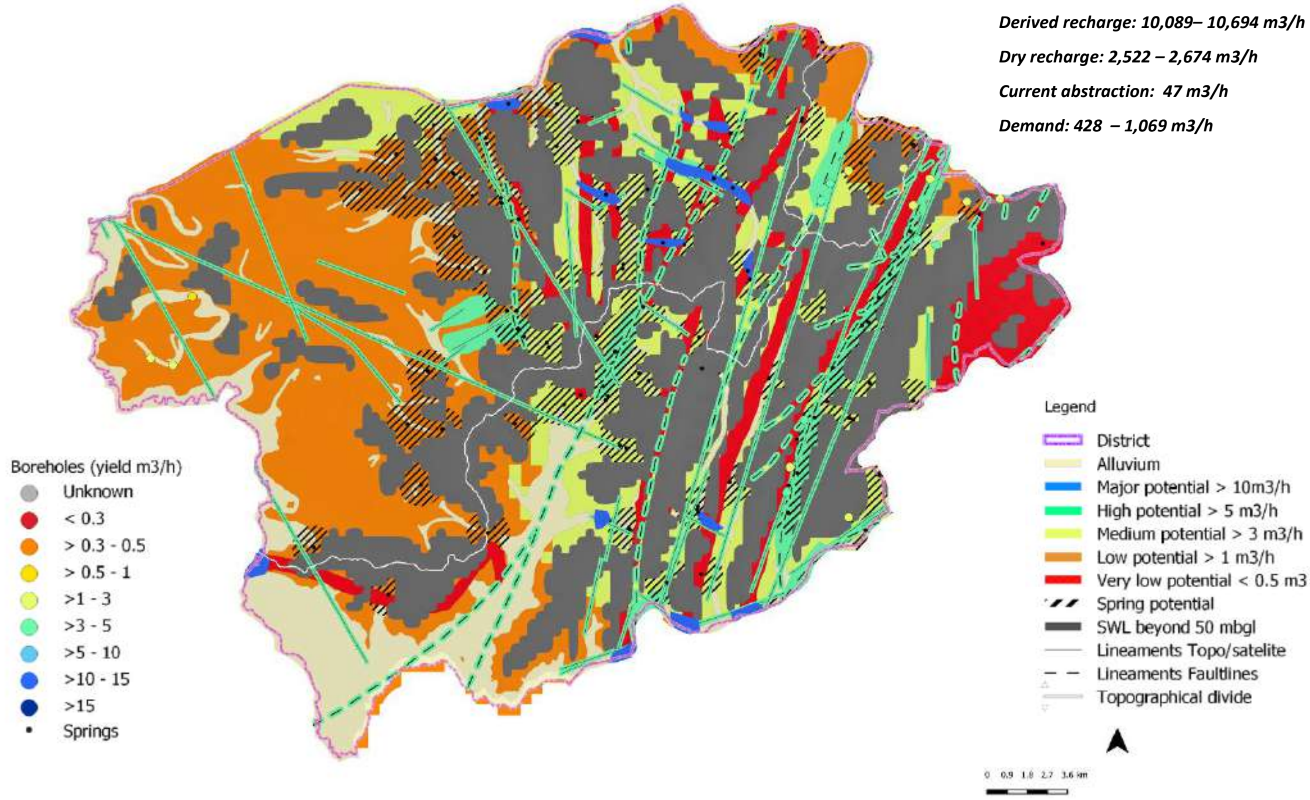


Figure 40 Ngoma ground water potential

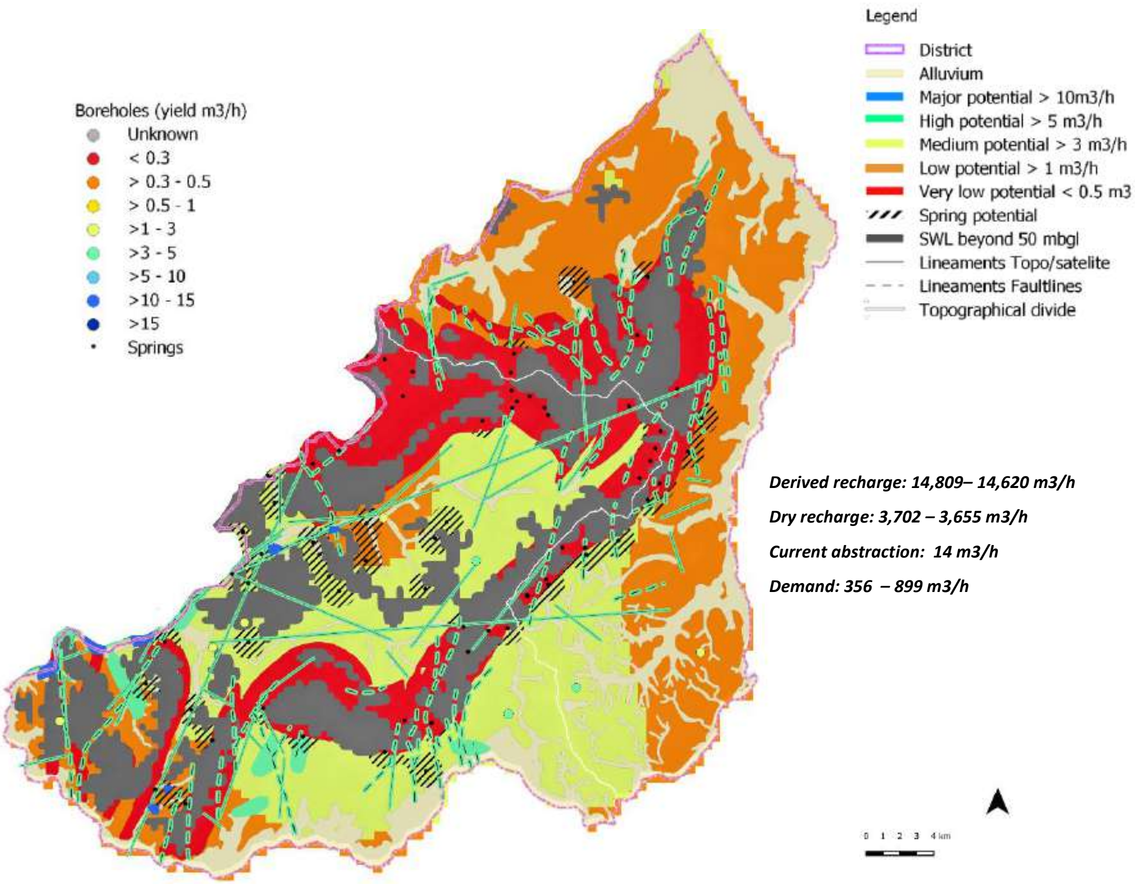


Figure 41 Kirehe ground water potential

Derived recharge: 17,760 19,670 m3/h

Dry recharge: 4,440 – 4,981 m3/h

Current abstraction: 192 m3/h

Demand: 575 – 1438 m3/h

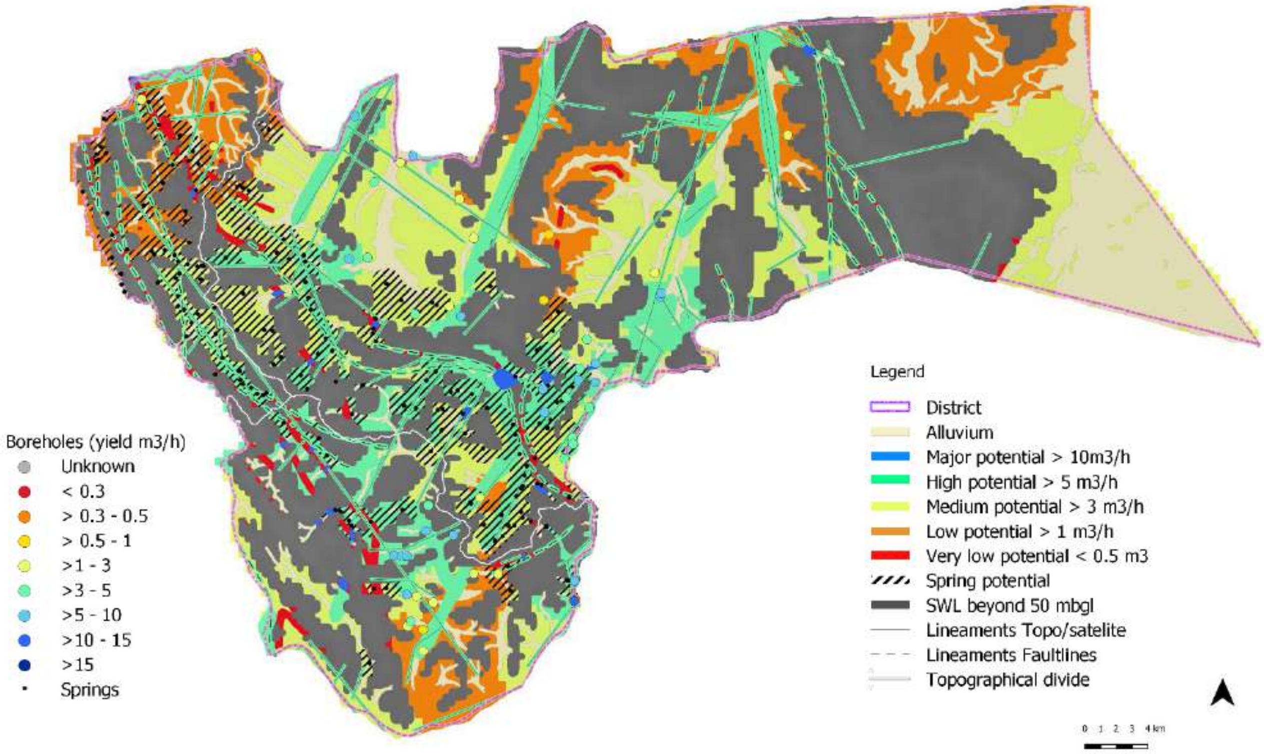


Figure 42 Gatsibo ground water potential

5.8.10 Ground water abstraction potential

Another indicator that is useful for planning purposes is the ground water storage capacity. However because Eastern Province consists mainly of fractured aquifers, ground water storage is not easily calculated. Due to the fractured nature of the rock where the ground water would be stored, the storage would in fact be highly heterogeneous throughout a similar geological unit. Granite for example is quite impervious, except where it is fractured. Whenever fractured however, it is still not clear to what extend (how wide and how deep).

Taking into account the above, an indication of ground water storage can be construed when taking into account annual recharge, using the estimates presented in Table 15 on page 62. These estimates apply a percentage or rate of recharge to a certain geological unit. For this method one needs to take into account the surface area of that unit, its recharge rate and the rainfall for the district it is based in. Using that information it is possible to estimate how much recharge a specific single geological unit would receive during a year. This can then be an indicator for the ground water storage present in that unit, which can be referred to as ground water abstraction potential.

As indicated before most geological units are highly heterogeneous in transmissivity and in fact recharge potential due to their fractured nature, or lack thereof. The above described method assumes the geological units to be homogenous in transmissivity and potential throughout, while this is in fact not the case. This is not so much of impact to the recharge capacity but more a hindrance to the access of the stored ground water. For that purpose the class 1 and class 2 [(6)] targets as described in groundwater

[6] Class 1: potential ground water access points caused by major tectonic movements causing fractures in mainly quartzite beds; Class 2: potential ground water access in valleys likely caused by tectonic movements.

potential, as well as lineaments and fault lines are included to show points where the stored water can be accessed.

Combining the above, a ground water abstraction potential map for geology based on annual ground water recharge is produced. Figure 43 displays potential ground water storage per year in million cubic meters per square kilometre. Because of the potential size difference of the geological units, a map with ground water storage per year without aggregating it over surface would make the map unreadable (small surface areas show nothing while all focus will be on major surfaces. Ground water storage density (m3/year/km2) shows you how much storage there should be per square kilometre. In the map clear distinctions can be seen on the borders of the districts, this is due to the different rainfall figures for each district, which affect recharge.

Many geological units are large, cut across districts and catchments. This means that planning becomes difficult when focussing on smaller areas. For this purpose results derived for the recharge storage from the geological units was aggregated to 3rd level sub-catchment areas (NB3). The results are displayed in Figure 44.

Since the surface areas of the sub catchments are smaller and more equally divided than the geological units it is also possible to show total storage per sub catchment without dividing it over surface area, as shown in Figure 45. District specific maps can be found in Annex 7. Especially the district specific maps can be used as a planning tool. By combining knowledge on current abstraction by boreholes and available recharge per year, it is possible to recognize whether additional boreholes would in fact be sustainable. Specific steps to follow are indicated in the maps in Annex 7.

Calculating remaining abstraction potential:

- Select area on map where your borehole is to be located,
- Add up the yield of all current boreholes in that area (m3/h)
- (unknown yields are likely hand pump boreholes @ 0.6 m3/h)
- Multiply by hours per day (likely 20) and days per year (365)
- Compare with abstraction potential figure from map (divide by 1 million to get million m3/year).
- If numbers approximate it means you are close to using your entire recharge

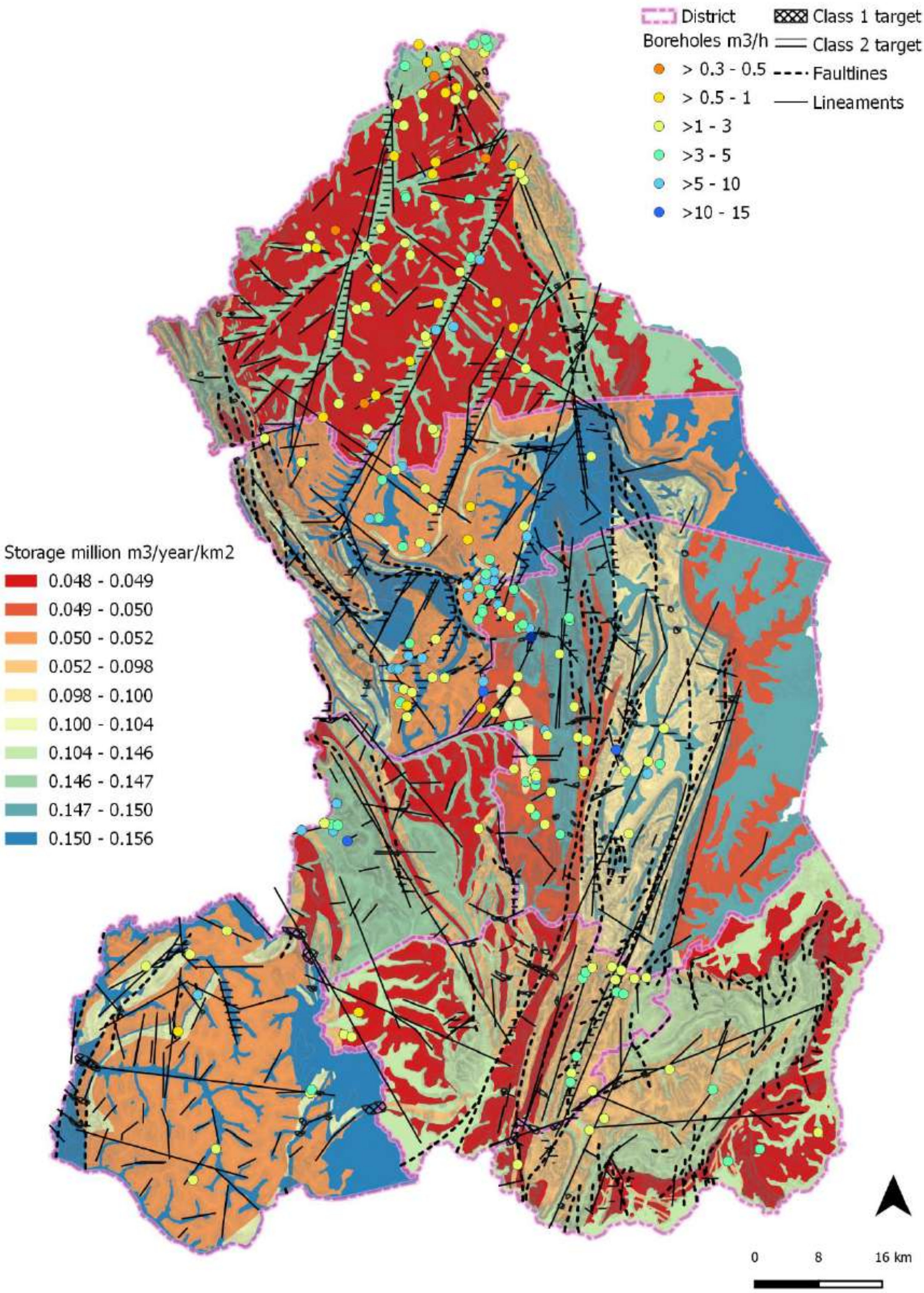


Figure 43 Ground water abstraction potential per geological unit (million m3/year/km2)

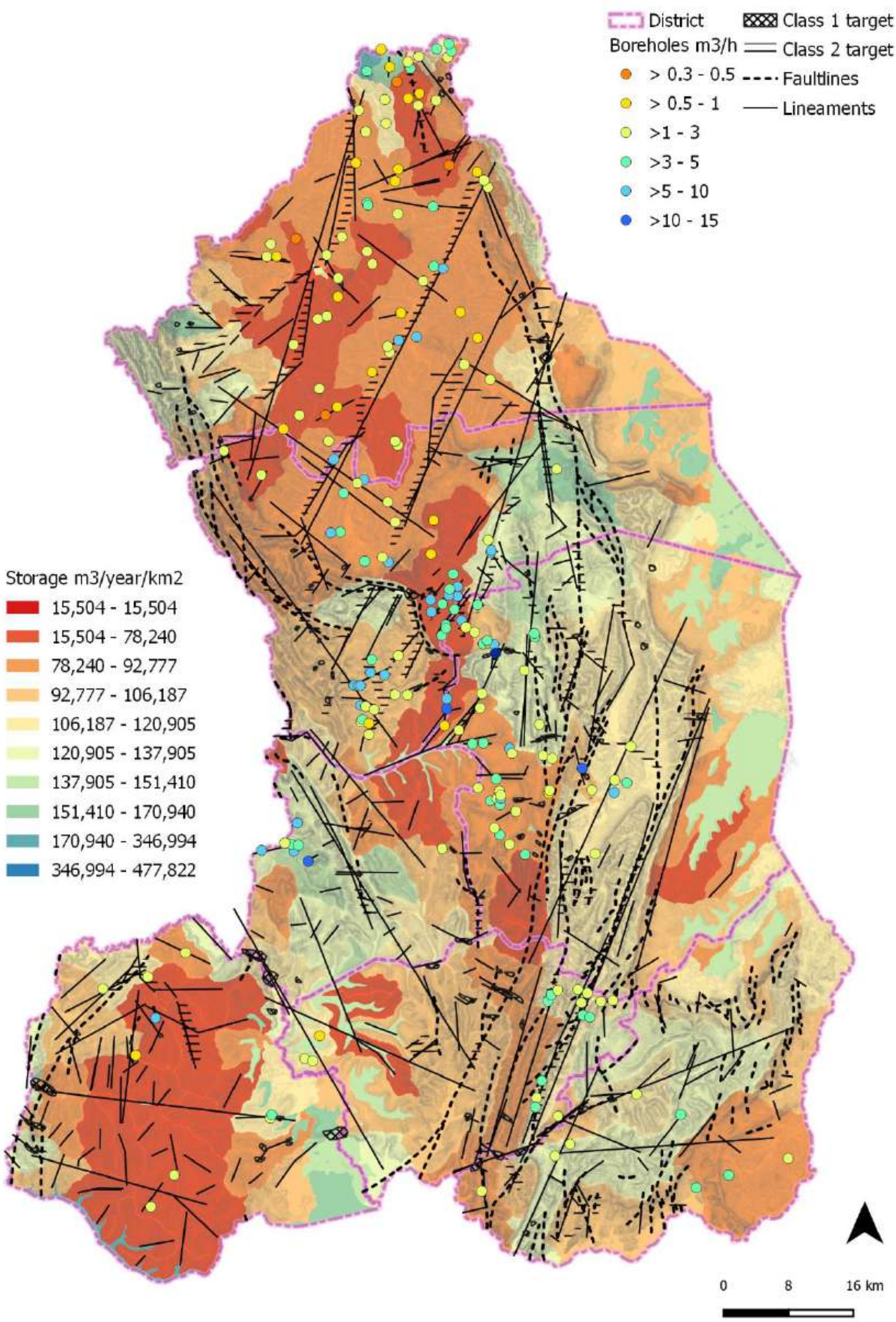


Figure 44 Ground water abstraction potential per level 3 Sub Catchment (m3/year/km2)

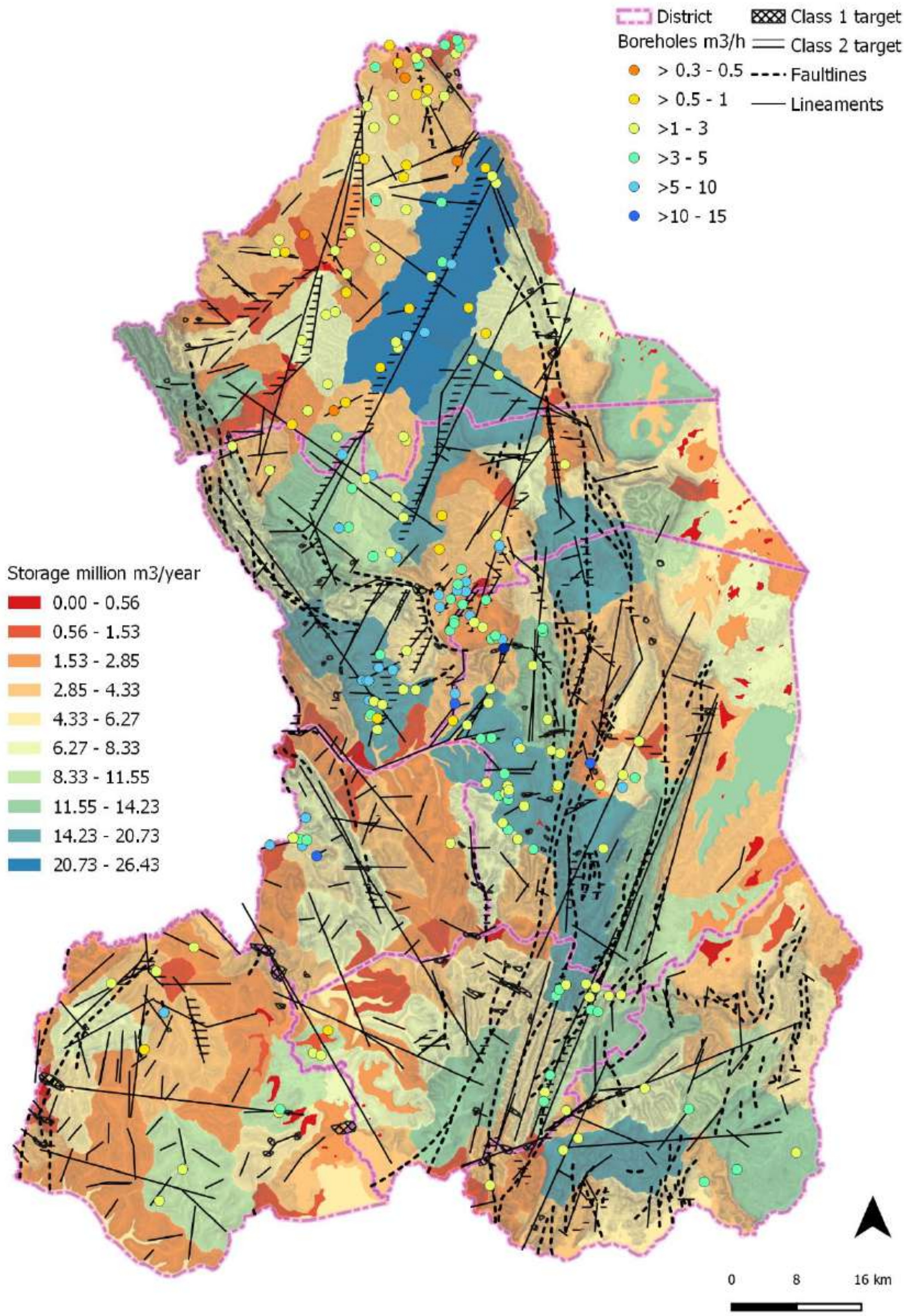


Figure 45 Ground water abstraction potential per level 3 sub catchment (million m3/year)

6 Geophysical measurements

6.1 Introduction

Generally geophysical measurements need to be carried out before a borehole is drilled since in many areas, they will decrease the chance of drilling a dry borehole and increase the chance of getting higher yields.

Geophysical measurements need to be carried out in areas with some groundwater potential to render these measurements useful. Blindly carrying out measurements at random sites (or at sites indicated by clients alone) is not recommended. The target areas for geophysical measurements need to be identified during a detailed desk study. The desk study needs to be carried out by an experienced hydrogeologist and needs to comprise the following:

1. Plotting of the client's preferred sites
2. Analysis of existing borehole data, geological maps, topographical maps, DEM, hill-shade maps and satellite images (Google Earth and others), leading to target sites for geophysical measurements based on the identification of lineaments and/or valleys and/or areas with high potential based on the data of existing boreholes. Lineaments can be underlain by fractured rock and appear as lines on the maps.
3. Lineaments need to be crossed by geophysical profiling. The lineaments may show up as anomalies. Parallel profiles can be done and orientation between anomalies could confirm the existence of a lineament if the orientations are similar. While profiling results in values at one depth in different locations along the profile, Vertical Electrical Soundings (VES) gives values at one point but at different depths.
4. Reconnaissance visit to the preferred sites and the target sites identified during the desk study. The final start and end-locations of the planned profiles may be adapted during the reconnaissance survey.

If the client has prepared the communities of what will happen in their areas the geophysical teams can carry out their surveys effectively and efficiently. The interpretation of the geophysical results will lead to recommended drill sites.

It should be noted that the interpretations are an indication, however, nobody can give a 100% guarantee on the amount, depth and quality of the water. More details on the activities to be carried out and procedures to be followed are given in Annex 4 on page 150.

6.2 Types of resistivity methods

The consultant will use the resistivity method for the characterisation of the hydraulic properties of the rocks underlying the Eastern Province. The method uses four electrodes (two potential and two current electrodes) to measure the resistivity of the sub-surface using an electric current. The setup of the electrodes and the type of the sub-surface determines the depth of penetration.

It should be noted however that there is no conclusive relation between the geophysical results and the hydraulic properties of the geological formations. The geophysical results need to be combined with information on geology, hydrogeology (borehole data) and / or remote sensing information for them to become useful. The best approach for a hydrogeological study is given in Annex 4.

The type of measurement / electrode setup to apply depends on the target. The targets could be formed by permeable layers that are approximately horizontal or by hard rock fractures that are approximately vertical. The methods that are useful to locate one of these may not be appropriate for the other. Hence the importance of a reasonably clear conceptual model.

Three different methods are used in the project. A VES gives the vertical build-up of the underground at one particular spot, while with resistivity profiles give the geophysical properties at a specific depth. The Electro-Resistivity Traverse (ERT) profiling are in fact numerous VES along a line and the geophysical properties of numerous depths along the profile are done.

Profiles are normally carried out perpendicular to the anticipated target. A VES is usually carried out perpendicular to the profile and parallel to the anticipated fracture / fault.

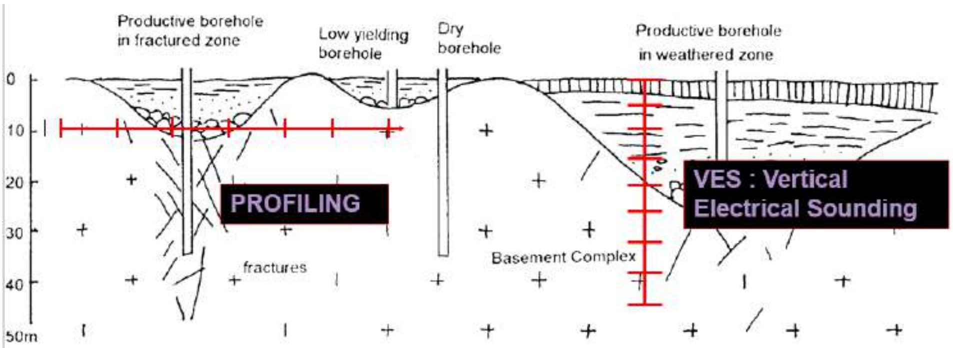


Figure 46: 1D geophysical siting principles

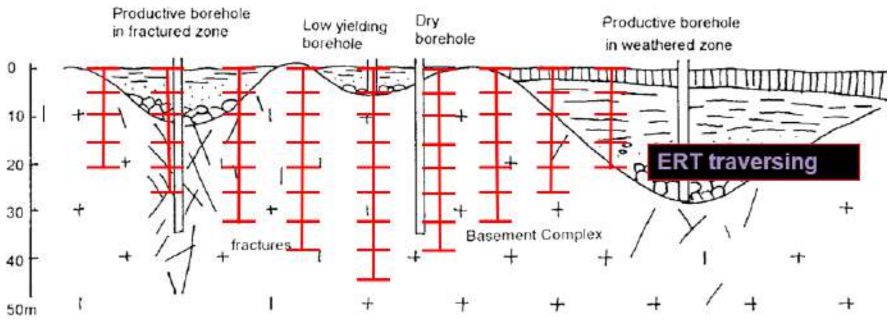


Figure 47: 2D / ERT geophysical siting principle

6.3 Earlier geophysical surveys

The consultant has collected the results of geophysical measurements carried out during earlier project. All information is included in the data drive presented in Annex 8. Unfortunately, the measurements are not accompanied with the results of any drilling carried out at the location. Nevertheless, the measurements, mainly VES, give an idea on the resistivity characteristics of the sub-surface in 107 locations (JICA and other projects) in the Eastern Province. The locations are given in Figure 48 while the information is summarised in Table 20.

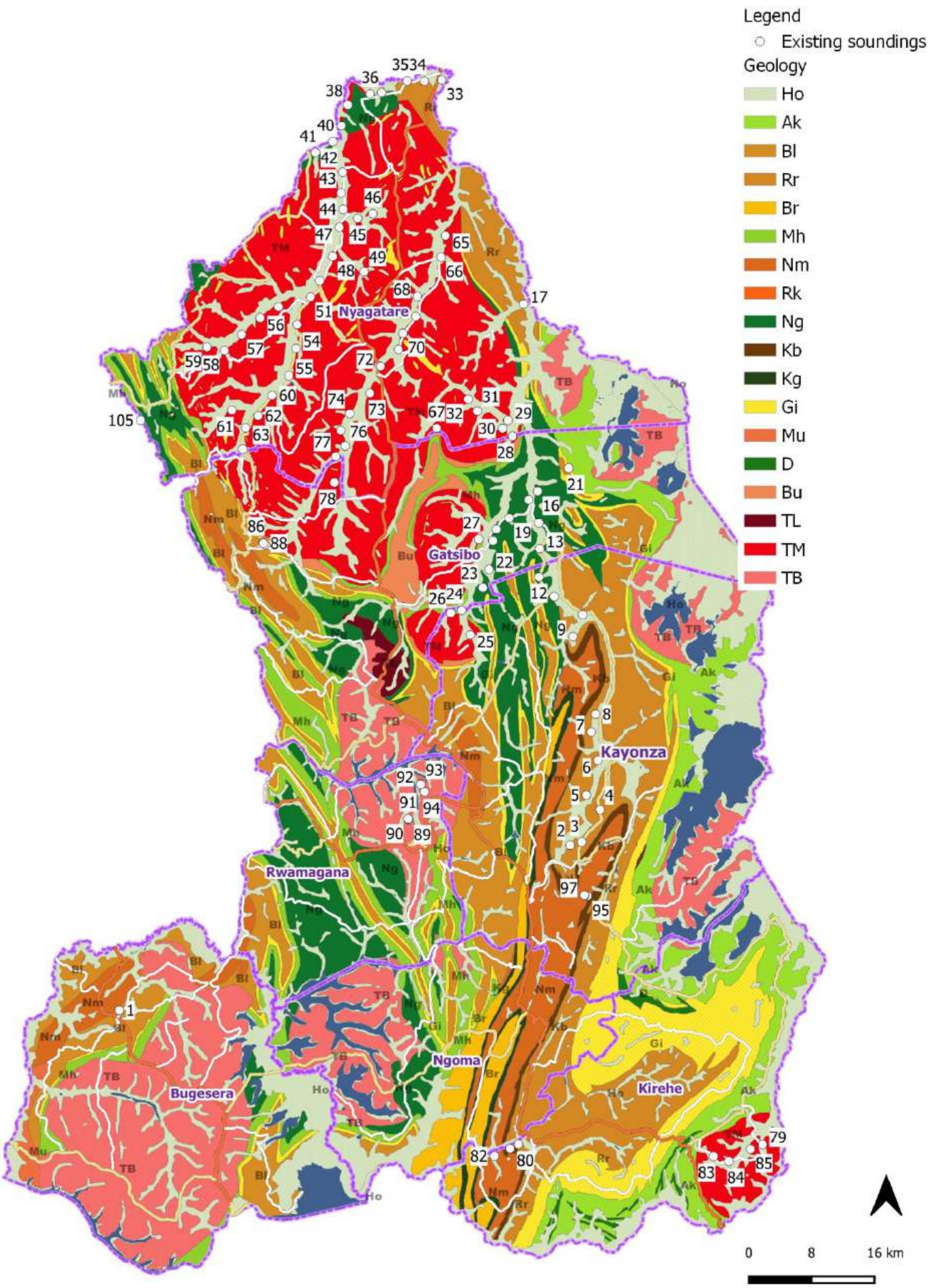


Figure 48: Distribution of earlier geophysical measurements

6.3.1 JICA survey

The survey has been carried out at 84 locations in 18 sectors in four districts. The locations of the villages are given in the maps in Figure 48. The approach used during that project has been summarized in Box 1 below and is followed by a review.

Box 1: Approach for VES analysis JICA project

The results of the hydrogeological survey and the geological maps indicated the presence of sediments (valley fills), schists / phyllites, quartzites and granites. Three general type of graphs could be identified.

1. ***A typical graph expected in areas underlain by sediments starts at low or high resistivity values (coarse or fine river sediments / valley fill sediments) followed by a range of fluctuating resistivity values caused by alternating coarse and fine materials. The curves usually flatten at the higher A values.***
2. ***The typical graph for a quartzite/granite will result in a graph with a slope of 45 degrees at higher A values***
3. ***A graph for a phyllites /schists usually starts with low apparent resistivity values (clayey weathering material), then increases and flattens at higher A values.***

For each different graph a different initial model has been used during the interpretation with WINSEV software. The starting value ranges for the deepest three layers in the model are indicated in Table 18.

Table 18: Resistivity ranges for assumed type curves

Graph	Deepest layer (bedrock) resistivity (ohmm)	Pre-bedrock resistivity (ohmm)	Clay layer (ohmm)
1	100-1000	100-1000	5-100
2	5000	150	5-50
3	200-800	not fixed	5-30

After introducing assumed depths based on curve shape, the software fitted the curve to the model. If the fit was not possible then some of the earlier fixed values would be left free to allow the software to come up with a better fit.

In the granites / quartzites the most promising sites are believed to result in VES with high values for the A distance at which the curve starts rising 45 degrees. In the phyllites / schist formation it is difficult to identify the most promising VES. Only when numerous boreholes would have been drilled then it would have been possible to calibrate the soundings with the geological logs of the boreholes and promising VES could be identified. In the sediments the most promising sites are expected to be those sites which have some layers with resistivities of between 50 and 150 ohmm believed to be representing medium to coarse sand layers saturated with water. Again, it is very difficult to allocate a groundwater potential to a single VES without having been able to calibrate VES measurements with existing borehole information.

The results of the survey are summarised in the main text below and are presented in more detail in the digital report in Annex 8. The results include interpretation of the graphs with the WINSEV software and are based on the expected geology as indicated by the geological map of Rwanda. The following resistivity ranges have been used in the interpretation. In some cases the resistivity curves did not indicate the bedrock below the sediments but then still the bedrock type is indicated in the curve. Another challenge in the interpretations is the fact that the characteristic resistivities of the

formations have large overlaps and it is difficult to know whether some layers should be interpreted as sediment or as a schist or sandstone.

Table 19: Resistivity ranges used during interpretation JICA project

Rock	Ohm			Rock	ohmm		
top soils	100	-	2000	quartzites	60	-	10000
clays	5	-	100	limestones	300	-	50000
dry sands	100	-	5000	phyllites / schists	100	-	800
wet sands	40	-	100	granites / gneisses	1000	-	10000
gravels	90	-	5000	weathered granites	50	-	300
sandstones	35	-	4000				

Electric resistivities (Parasnis 1997, and others)

The project gave the groundwater potential of the sites with regards to the implementation of hand pump boreholes. It should be noted however, that this potential should be used with great care because a single sounding alone cannot reveal the groundwater potential of an area. It is believed that the potential attributed was mainly based on topographic location.

There is a high chance that VESes carried out in valleys are disturbed by the masking effect. This is caused by the very low resistivity sediments near the surface in the valleys (black cotton soils which have a high clay content). For these VESes it is not possible to determine how thick the sediments are and what type of bedrock is underlying the sediments, especially when the VES stops at 100 or 120 m. In the JICA project 36 out of 84 VESes were affected by the masking effect. The sites are marked in Table 20.

For the VESes not hindered by the masking problem the type of bedrock could well be ascertained. Whether a site has good potential can best be done by carrying out resistivity profiling.

Table 20: Results of reinterpretation of the JICA field works

Formation	VES numbers
Masked	5,6,7,8,9,12,15,16,18,19,21,22,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,49,51,52,53,54,55,57,58,61,62,63,64,66,67,68,72,79
schists	1,2,3,4,6,7,10,13,14,17,32,37,41,43,50,52,56,59,60,69,70,71,73,79,80,81,82,84, 25
Quartzite	11, 34
Granite	18,22,23,24, 34,47,48,65,74,77,78,83,84
Ak	20
Saline water?	75,76

6.3.2 Other surveys

WE-consult carried out some other geophysical surveys in Rwanda. Only for the survey for a borehole for the refugee camp in Kivumbi, Ngarama, Gatsibo District, borehole results are known. The borehole drilled in the valley below the camp had an airlift yield of more than 10 m^3/hr and a test yield of 6.0 m^3/hr.

All survey results are given in Annex 5. Airlift yield refers to the yield achieved using a compressor just after finalization of drilling. Test yield refers to the sustainable yield achieved during test pumping.

6.3.3 Observations

An analysis of the earlier survey information indicated the following:

1. The granite / gneiss formations in Nyagatare also comprise of schists and phyllites. This can be seen in the VES curves carried out in the area. In many cases the curves flatten at larger 1/2AB distances indicating that the bedrock is made up of a rock with apparent resistivities of less than 1,000 Ωm.
2. VES carried out in areas with clayey top soils do not yield as much information as VES carried out in valleys without clays at the surface. VESes are point measurements only.

1D Resistivity profiles are better tools to identify points of better potential. Profiles can be used to identify lateral differences in the underlying rocks.

6.4 Target areas

The purpose of the geophysical fieldwork was to collect information on the geophysical properties of the geological formations, in order to get a better understanding of the geological units. The geophysical response is not conclusive and therefore it is important that measurements are carried out near boreholes with known characteristics and/or to confirm the potential drill sites with actual drilling.
Unfortunately, there are no boreholes with well logs and the airlift yield is often the only recorded borehole characteristic. The actual drilling is not part of the current project, but two drilling programmes are soon to start. It was decided to target the demand areas that form part of the two programmes.

The consultant had selected a large number of locations for geophysical measurements. The areas are believed to be representative for the various hydrogeological settings in the Eastern Province. The target areas selection is based on:

1. Geological setting: the target locations are distributed over the various geological units and formations to assess the type of response in each of the geological formations.
2. Hydrogeological setting: The hydrogeological setting (average water quality, average yield, conceptual models) of the areas have been considered and the areas where high potential is expected are prioritised.
3. Focal areas: The three main areas are the three districts of Nyagatare, Bugesera and Kayonza. In addition, future drilling programme locations are also considered as focal areas. All the focal areas are given in Figure 49.
4. Existing boreholes with known yields and lithology: boreholes with information on yield and lithology are targeted for geophysical measurements (calibration measurements).

Handpumps will not be sustainable when static water levels are beyond 50 m below ground level. The pressure needed to operate the hand pump at that depth would cause the pump to wear down quickly. For production wells, high potential locations are considered, and these are usually found in the valleys. As a result, most target locations are in the valleys. Some measurements have been done in the higher grounds in order to get an idea on the resistivity values of rocks of the various formations.

6.5 Types of surveys

6.5.1 Calibration survey near existing boreholes:

The execution of VESes and profiles near existing boreholes with known information is recommended since they provide the link between the geophysical response and the yield of the borehole and/or the geological layers penetrated by the borehole. These measurements are called calibration measurements. A significant number of calibration measurements have been carried out.

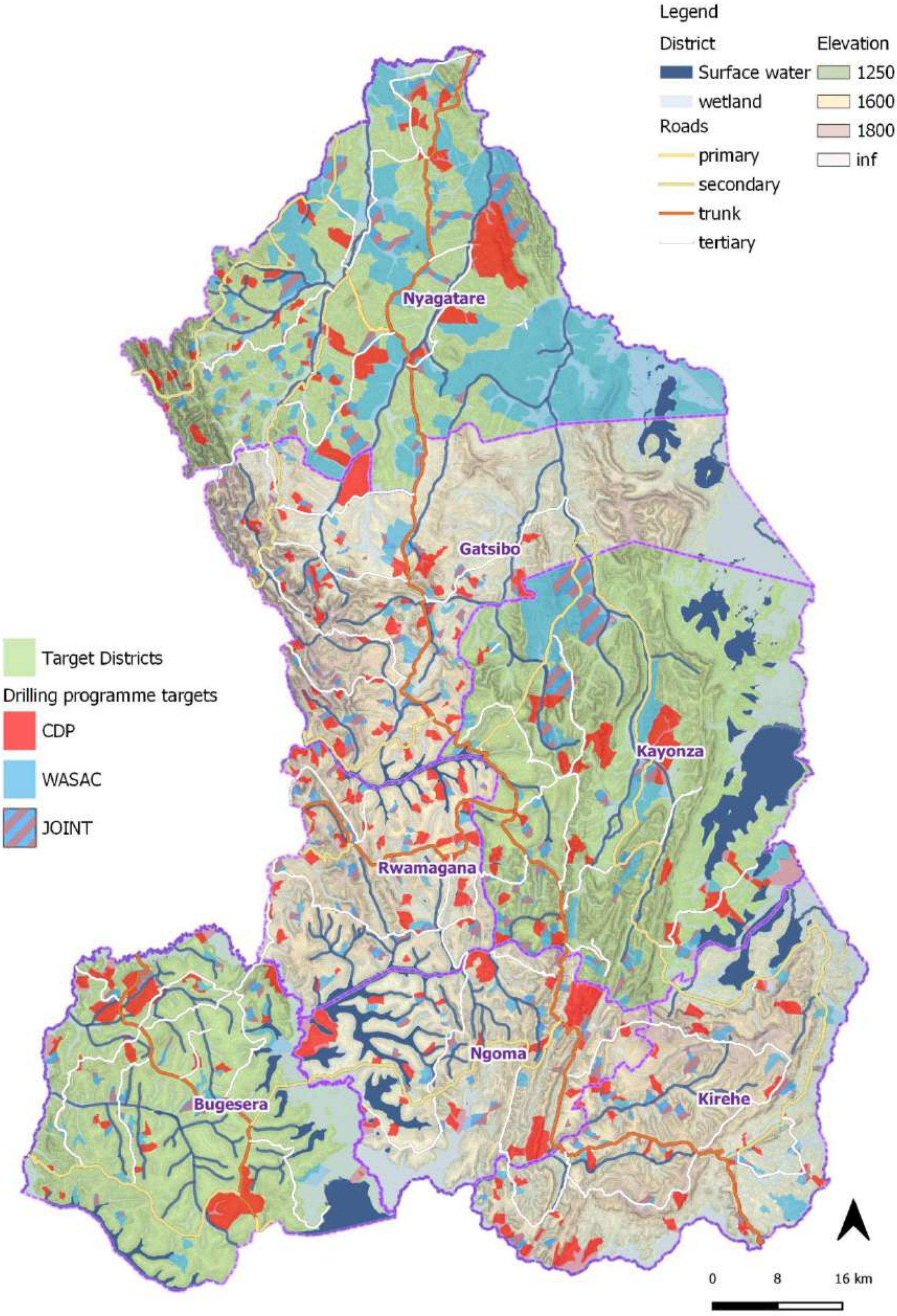


Figure 49: Eastern Province focal areas

6.5.2 Confirmation surveys

Confirmation measurements are based on assumed hydrogeological conceptual models. There are six types of aquifers anticipated in the area. The aquifers in the area expected to be formed by:

1. The streams in the area have deposited sediments along the river course. The sediments consist of fine-grained material (fine sands and clays) with some intercalations of sandy layers. Where the sandy layers are thick enough and in contact with the current streams, they may form good aquifers. These are expected to occur along the banks of the current rivers. They are horizontal layers and can best be identified by carrying out ERT measurements
2. By weathered basement rocks (horizontal layers at the interface between the hard rock and the overburden, see Figure 27). The thick overburden can be identified using VESes and/or profiling.
3. Vertical fractures in the granitic, quarzitic and gneissic hard rock (see Figure 27). Fractured zones that are favourable for groundwater abstraction can be localized through resistivity profiling. In the formations occurring in the Eastern Province, situations occur where bedding planes of hard quartzites are cut by valleys. It is expected that these types of valleys are underlain by faults and therefore are expected to have a better potential than the valleys that have formed in the less competent layers of the geological formation. This situation is depicted in Figure 31: Structurally controlled stream valley principle.
4. Vertical fractures in schists and phyllites can be localised using resistivity profiling.
5. Horizontal and vertical fractured and fissured bedrock in siltstones and mudstones. These can be identified by using VES and /or resistivity profiling but more easily by analyses of borehole logs and field assessments.
6. Spring aquifers: these aquifers are not assessed using geophysical measurements but need to be assessed by field identification, yield assessment and yield monitoring.

6.5.3 Exploration survey

Exploration measurements were carried out to identify the potential in areas with missing relevant hydrogeological information. In some areas of the Eastern Province it is not obvious which geological formation or which section of the geological formation is found in the sub-surface. In these areas, the consultant will carry out exploration measurements which will, when combined with other geophysical and hydrogeological information, allow the assessment of type of rock underlying the target area.

6.5.4 Summary of sites

During the desk study the consultant had identified 105 sites for geophysical measurements, taking into account the considerations for focal areas and target areas as earlier discussed. During the project the objectives slightly changed and actual measurements were carried out at 83 sites. The sites have been lumped into 36 areas that are depicted in Figure 50. The map shows the clusters of investigation areas as well as the individual locations of the profiles and VES measurements.

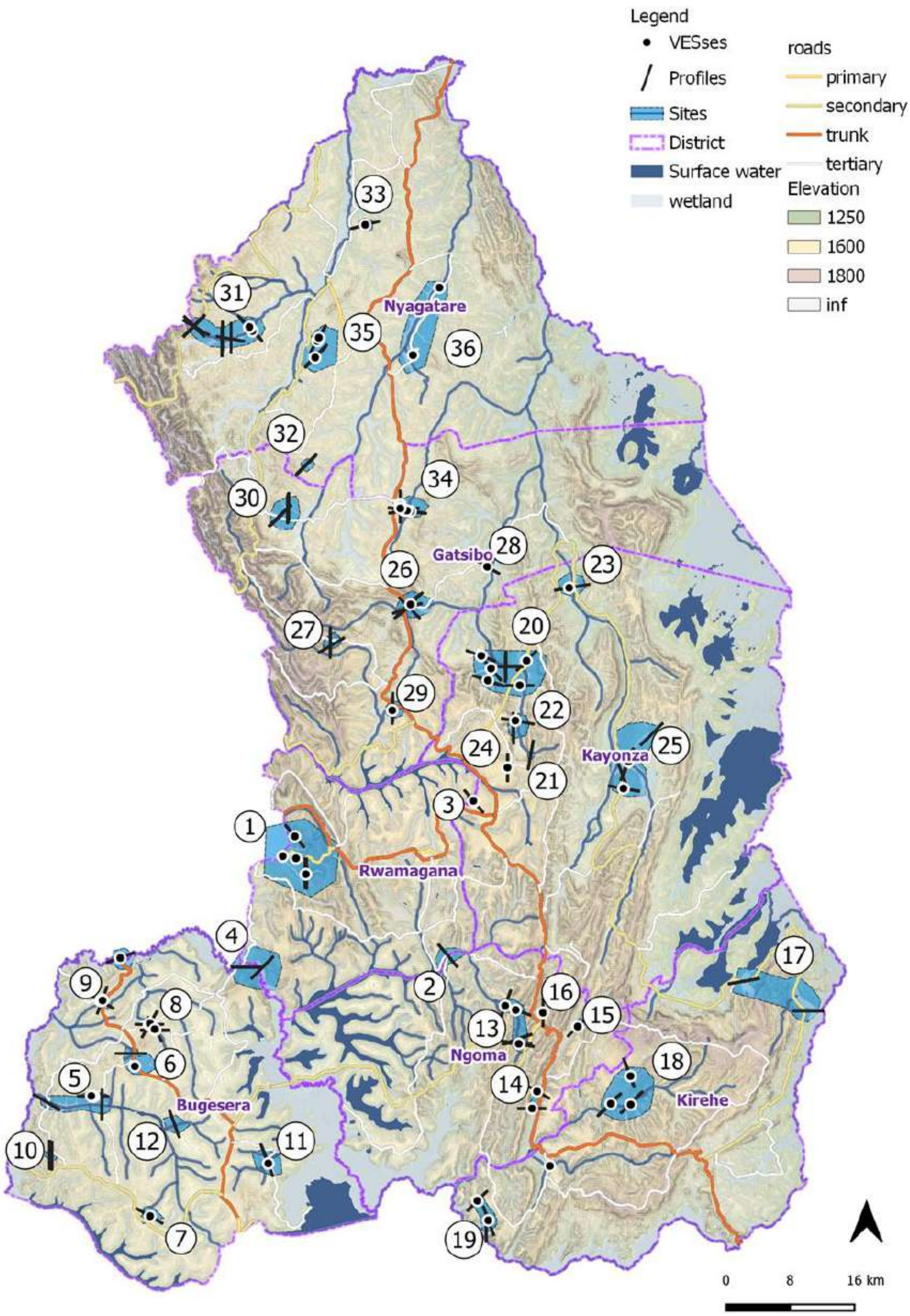


Figure 50: Location of investigated areas

6.6 Results of measurements

The detailed results of the measurements are given in Annex 2.The first page of the Annex also shows the geological formations that have been subjected to geophysical measurements.

A total of 36 areas have been investigated by carrying out 11.6 km of ERT profiles, 21.9 km of 1D profiling and 68 VESes. The distribution of the measurements over the districts is given in Table 21. For each of the areas a description is given in the annex explaining the purpose of the measurements. The measurement graphs are included as well as a map with the locations. Recommendations for future activities are also given wherever these are appropriate.

The measurements also targeted certain possible drill sites in existing drilling projects in pipelines..

Table 22 shows the distribution of these potential drill sites over the various districts. A total of 19 areas with ground water potential have been identified.

The measurements were carried on specific hydrogeological targets as well. The targets are described in paragraph 5.8 and the number measurements carried out on specific targets is given in
Table 23.

The locations where actual measurements have been carried out, changed slightly from the original plan because of time constraints and change of objectives. The following should be noted:

1. The survey was never meant to be a detailed borehole siting programme for boreholes to be drilled based on exact locations identified during the surveys.
2. The survey locations however have been carried out in or close to areas identified for the future drilling programme.
3. No pegs have been placed in the field during the project and that in case boreholes will be drilled it is highly recommended to carry out a confirmation survey before the borehole is drilled.

Table 21: Number and lengths of geophysical measurements per district

District	ERT profiles (m)	1D prof (m)	No. of VES
Bugesera	2,505	4,100	13
Gatsibo	2,670	4,420	12
Kayonza	2,150	5,440	11
Kirehe	1,440	1,950	5
Ngoma	304	2,360	7
Nyagatare	1,795	3,380	14
Rwamagana	810	250	6
Grand Total	11,674	21,900	68

Table 22 Target areas for Districts

District	No. of CDP sites	No. of WASAC sites	No of combined sites
Bugesera	2	0	2
Gatsibo	1	0	2
Kayonza	2	3	1
Kirehe	2	2	1
Ngoma	1	1	2
Nyagatare	3	0	1
Rwamagana	2	0	0
Grand Total	13	6	9

Table 23 Hydrogeological targets for geophysical measurements

District	No. of Target 1 type Quartzite ridge valley	No. of Target 2 type Major valley	No . of other areas	No. of existing boreholes
Bugesera	2	2	3	4
Gatsibo	0	1	4	0
Kayonza	4	5	0	6
Kirehe	1	0	1	2
Ngoma	3	2	0	4
Nyagatare	0	6	1	4
Rwamagana	2	0	0	5
Grand Total	12	16	9	25

6.7 Observations

It is evident that the resistivity method is an appropriate method for the identification of the groundwater in areas identified through a detailed desk study. It is however not always possible to identify the exact location of the fractures in these valleys based on the geophysical results, especially not when the valley floors are covered with clays. The ERT method seems to give slightly better results in these circumstances than the 1D profiling.

Measurements general:

1. Accessibility: the relief is quite pronounced and areas with steep slopes where drilling rigs cannot reach should be avoided for geophysical measurements.
2. Black cotton soils and other clays at the surface hinder the reliable interpretation of layers below the clays (masking) especially for VES measurements.
3. In areas with outcrops, the contact between the electrodes and the soil is often poor leading to unstable measurements

On higher areas: In the quartzite, sandstone and schists formations, usually, the groundwater table is too deep and it is not possible to identify the aquifer with geophysical techniques. Boreholes drilled on the higher grounds of the granite areas may yield some water. VESes can be used to measure the depth to the bedrock, and profiles can be run to identify zones of increased weathering that may yield some water.

Minor valleys: in the fissured siltstones, sandstones the minor valleys form areas with good potential since they are expected to be structurally controlled. In granite, gneiss and schist areas, they are often formed by less competent layers and are usually underlain by clayey weathered bedrock and hence may not always yield a lot of water.

Major valleys: underlain by less resistant layers of geological formations (usually schists, siltstones, and other pellitic rocks) that have been eroded do usually not have a good potential.

Valley underlain by fracture cutting through quartzite ridge: these valleys are almost always structurally controlled. They can be easily identified in the field and on maps where valleys cut straight through a band of quartzites. The target in the valley is the fractured quartzites and less competent, more clayey levels in the formations should not be targeted for drilling.

The lower slopes and middle slopes of the granites and the gneisses can still be considered for handpump boreholes. Boreholes drilled at anomalies are expected to yield between 0.5 and 3 m^3/hr with success rates of around 75%. The more fractured and fissured areas of the schist / siltstones / sandstone formations are expected to yield between 1 and 5 m^3/hr with success rates of approximately 85%.
It should be noted that anticipated success rates and yields are based on limited information available and experiences in similar areas elsewhere.

The results that will emerge out of the drilling programmes will be used to further evaluate the best approach for the geophysical measurements and can also be used to update the groundwater potential map.

Picture 8: ERT measurement across valley

7 Pump tests

7.1 Target areas for test pumping

During the inception phase it was agreed that the main purpose of the pumping testprogramme is the assessment of the transmissivity of the aquifers penetrated by existing boreholes in the different geological units, to enable a better understanding of the range of the transmissivities and the capacity of boreholes drilled in such aquifers. The pumping test will consist of a step test and a 24-hour test. The test results can also be used to identify the installation depth and capacity of a handpump and a submersible pump.

The current project did not foresee in the deployment of a service rig and as such boreholes that are expected to have been blocked by external materials and/or broken pipes cannot be considered selected unless the client can arrange for this.

Therefore, only operational boreholes have been targeted. The client was expected to inform the population about the temporary shut-down of the borehole. In fact, the shut-down will only be during the extraction and installation of the pump and the recovery test. During the test itself the population can use the water being pumped. In many cases however, it was not easy to convince the population and some delays were caused by this.

7.2 Results of test pumping

The results of the pumping tests are given in

Table 24. Three out of the ten boreholes test pumped have sustainable yields of less than 3 m^3/hr. The remaining seven boreholes have tested or calculated sustainable yields between 3.5 and more than 20 m^3/hr. The transmissivity values of the 10 boreholes varies between 3.6 and 166 m^3/day.

Picture 9: Test pumping-team in Eastern Province

Table 24:Pumping test results

BH	Q - Constant test (m^3/hr)	S – recovery test (m)	S – constant rate test (m)	T - rec (m^2/d)	T - con (m^2/d)	Average T (m^2/d)	Q - Sustainable yield (m^3/hr)	Geology	Remarks
1	7.0	0.63	3.30	48.5	9.32	28.9	7.0		
2	2.6	2.78	1.89	4.11	6.05	5.08	2.5		T values for recovery are reliable. T values for CR test are less reliable
3	10.0	0.22	11.94	199		101	10.0		Aquifer limited by extent. T values before hydraulic barrier very low but probably more reliable, T values from rec. test very high and misleading. Check for losses. Longer duration test needed
4	4.6	6.02	5.10	3.36	3.96	3.66	3.5		
5	27.0	2.03	2.66	58.4	44.6	51.5	20.0		could be pumped at >20 m^3/hr but 4" casing
6	2.5	2.40	1.65	4.57	6.66	5.61	2.0		
7	7.0	8.86	8.86	3.47	3.74	3.60	7.0		
8	5.0	3.35	12.31	6.55	1.78	4.17	2.5		
9	5.7	1.92	1.75	13.0	14.3	13.7	7.0		
10	8.0	0.23	0.20	155	177.	166	20.0		can be pumped at >20 m^3/hr actually but it's a 4" casing hole

7.3 Observations

The pumping test exercise has confirmed that many high yielding boreholes are not used to their full capacity. The seven highest yielding boreholes could be used as production boreholes to supply nearby storage tanks of existing piped systems or could be sued for new piped systems. For detailed pumping test results refer to Annex 3.

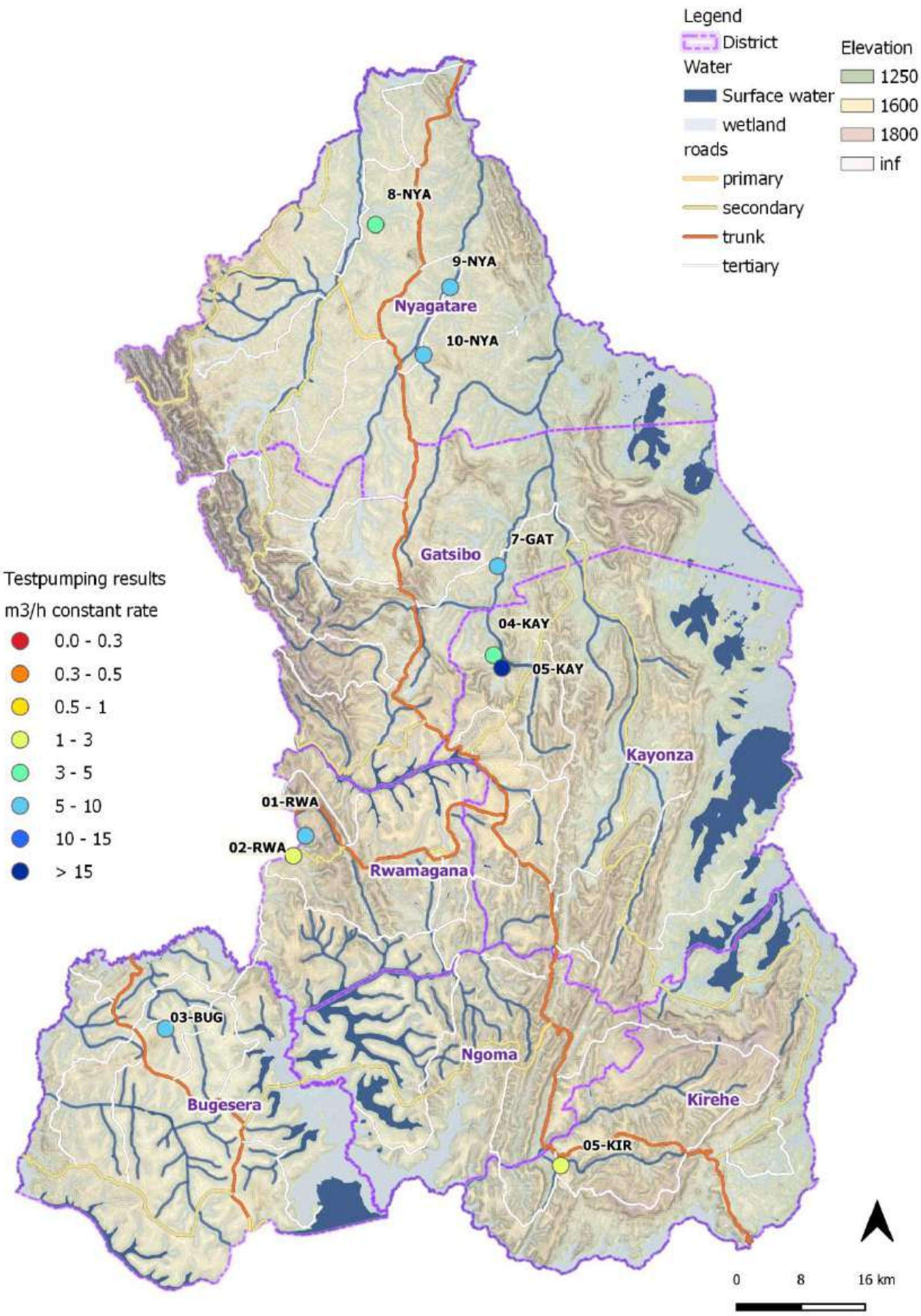


Figure 51: Location of pumping tests

8 Water balance modelling

8.1 Objective of the model

The hydrological model is prepared to develop a better qualitative understanding of the water balance and quantify this understanding to prepare a water balance calculation. The purpose of the model is to acquire an insight in the surface processes and shallow groundwater processes, including, rainfall, surface runoff, infiltration, sub-catchment stream flow, the unsaturated zone and shallow groundwater phase of the water balance. The in-stream processes of the rivers and lake systems are not included in detail in this hydrological model, because of time considerations and because of the purpose of the model, which is to understand the rainfall-runoff and recharge in the catchment.

8.2 SWAT model set-up

A hydrological model was developed for the catchment to create insight in the water balance of the catchment, using the open source modelling tool Soil & Water Assessment Tool (SWAT). The purpose of the model is to acquire an insight in the surface processes and shallow groundwater processes, including, rainfall, surface runoff, infiltration, stream flow, the unsaturated zone and shallow groundwater phase of the water balance. SWAT is developed to predict the impact of land management practices on the water balance in large complex watersheds with varying soils, land use and land management conditions over long periods of time.

8.2.1 Data inputs

SWAT uses spatial data of catchment characteristics (DEM, land use, soil, stream pattern), combined with climate data series and water use to simulate water flow through the catchment. The input data is generated using remote sensing, open source data and the results of the field surveys. Rainfall was obtained from the TRMM satellite data and all other climate parameters from the CFSR database. The model combines land use and soil data into SWAT curve numbers (CNs). High curve numbers indicate high runoff ratios. SWAT operates on a daily time step.

The driving force behind SWAT is made up of the hydrologic-response units (HRUs), each with its own unique combination of soil, land use and slope (Figure 52). The calculations in SWAT are based on these HRUs. SWAT determines the HRUs per sub-catchment, these HRUs will later be summed up together as one result. The starting point in SWAT is the static-input DEM (Digital Elevation Model). The SRTM DEM with a resolution of 30 meter was prepared for the project area was used to delineate the main catchment and its sub-catchments and watercourses. The remaining static inputs are land use and soil layers.

The dynamic inputs of SWAT are measured daily in weather stations. These dynamic inputs are as follows: rainfall, temperature, relative humidity, solar radiation and wind speed. The dynamic input precipitation is the driving force of the in-stationary model. The remaining dynamic inputs (temperature, relative humidity, solar radiation and wind speed) are used to calculate evaporation and transpiration (ET). The dynamic inputs were obtained from CFSR the National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) was completed over the 36-year period of 1979 through 2014. The CFSR was designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period. This CFSR data can be obtained in SWAT file format for a given location and time period.

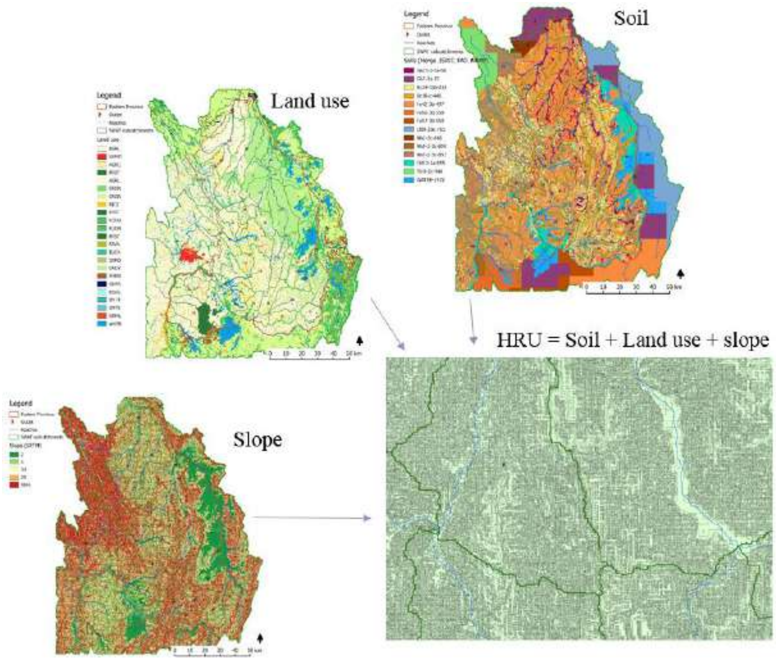


Figure 52: Illustration of static input layers for HRU creation in the SWAT model

SWAT first processes the land phase, followed by the river phase. The output from the land phase is as follows: evapotranspiration, surface runoff, soil water content and groundwater recharge. The output obtained from the river phase is the discharge. The results will be used to estimate the main water balance components in the catchments, especially surface runoff and groundwater recharge, and look for opportunities for recharge enhancement. The model can also quantify the relative impact of land cover changes, soil and water conservation interventions and water infrastructure. This will help in the selection of the most feasible interventions for recharge enhancement. More information on SWAT model, the input data and methodology used is provided on: https://swat.tamu.edu/documentation/ - SWAT2009_Theoretical_Docmumentation.

Detailed land cover and soil maps were obtained, as provided in Chapter 4 which were used as input for the modelling. These maps were translated into existing SWAT land use and soil units. SWAT has the ISRIC WISE Soil Map of the World codes incorporated in the database with all soil properties used by the model provided. The soil units of the existing map were translated into these soil units to be used in the model. SWAT has a large number of land cover units incorporated in its database with all necessary vegetation, physical, and hydrological characteristics. The existing land cover map was linked to these units. Daily rainfall (precipitation) records were obtained from TRMM satellite data for the period 1998-2014.

8.2.2 Improvements to the final model

The model has been adjusted and improved after the presentation of the draft outputs, because more detailed land use shapefiles were provided, and more stream flow gauging data was obtained. The detailed land use data was incorporated in the model and streamflow was compared to gauging data. Based on the stream flow data, it was concluded that the simulated flow was too high. The main reason was found to be an underestimation of the evapotranspiration (ET) by the model. SWAT normally calculates potential evapotranspiration (PET) and ET based on land use and daily climate parameters. However, based on the findings, the PET was adjusted using MODIS PET data. A correction factor has been applied to the SWAT PET data using the daily MODIS PET data for the model area. This resulted in a significantly higher ET in the water balance and a more accurate stream flow (see paragraph 8.5 on page 106 for more information on calibration).

8.3 Models for the Eastern Province

The catchments in the Eastern Province are part of the larger transboundary Akagera Basin, which was not fully incorporated in the model. A general model was created that covers the Eastern Province and some catchment area outside to support the SWAT model setup. This model aims to get an insight in rainfall runoff and off-stream recharge processes in the Eastern Province, and not to simulate lakes and river flow (in-stream) processes. Input data outside the country is of much lower resolution than input data within the catchment. Figure 49 provides the SWAT model setup for the Eastern Province. The catchment is divided into sub-catchments based on stream pattern. Each sub-catchment has one stream (or reach).

Separate models were prepared for three smaller catchments in the Eastern Province. These are:

- Karangazi Catchment,
- Misarara/ Ntemde Catchment
- Cyunuzi Catchment

These catchments were chosen because they entirely located within the Eastern Province, and an evaluation of rainfall-runoff can be made, without incorporation of large dams or lakes. Little is known about the rainfall, surface runoff and recharge processes in the area, while several studies are done on the large river systems and lakes.

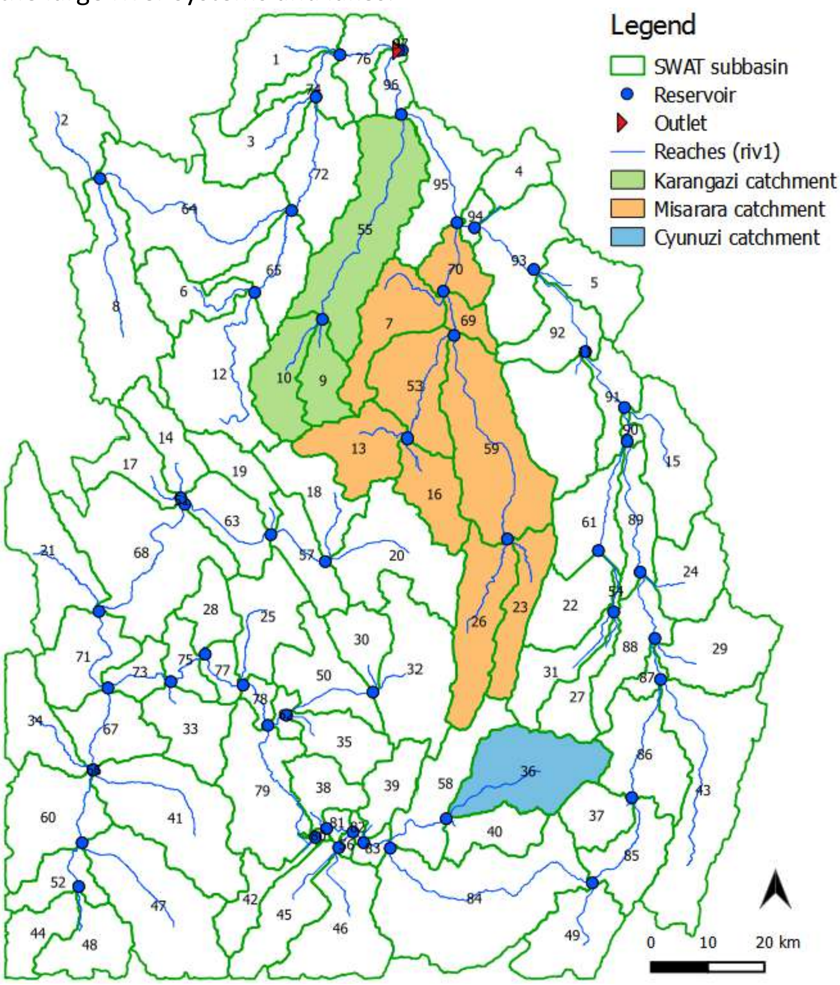


Figure 53: SWAT model setup for the Eastern Province

8.4 Outputs of SWAT Models for Eastern Province

The model was run for 15 years (1999-2013), simulating daily time steps. The results were processed and analysed, the summarized outputs of the main water balance components are presented below.
[7] Figure 54 provides a schematic representation of the SWAT Model water balance of the land phase, with the outputs of Eastern Province catchment. This is an average water balance for all years included in the model.

The water balance equation could be stated as follows:

$$P = \Delta SW + ET + SURQ + LATQ + PERC + GWQ + DA\_RCHG$$

In which:

P = Precipitation

ΔSW = Change in Soil Water (the change in volume stored within the soil profile)

ET = Evapotranspiration (The total of evaporation and transpiration from vegetation, soil, and surface water)

SURQ = Surface Runoff (overland flow directly to streams)

LATQ = Lateral flow (water flowing laterally within the soil profile that enters the main channel)

PERC = Percolation past root zone to shallow aquifer

GWQ = Return flow (shallow aquifer to streams)

DA_RCHG = Recharge to deep aquifer

REVAP = Water in shallow aquifer returning to unsaturated zone (capillary fringe) due to capillary rise or direct abstraction by deep rooting plants (mainly trees) from the shallow aquifer. Within the water balance REVAP is incorporated in the ET.

[7] with the outputs of Eastern Province Catchment. This is an average water balance for all years included in the model.

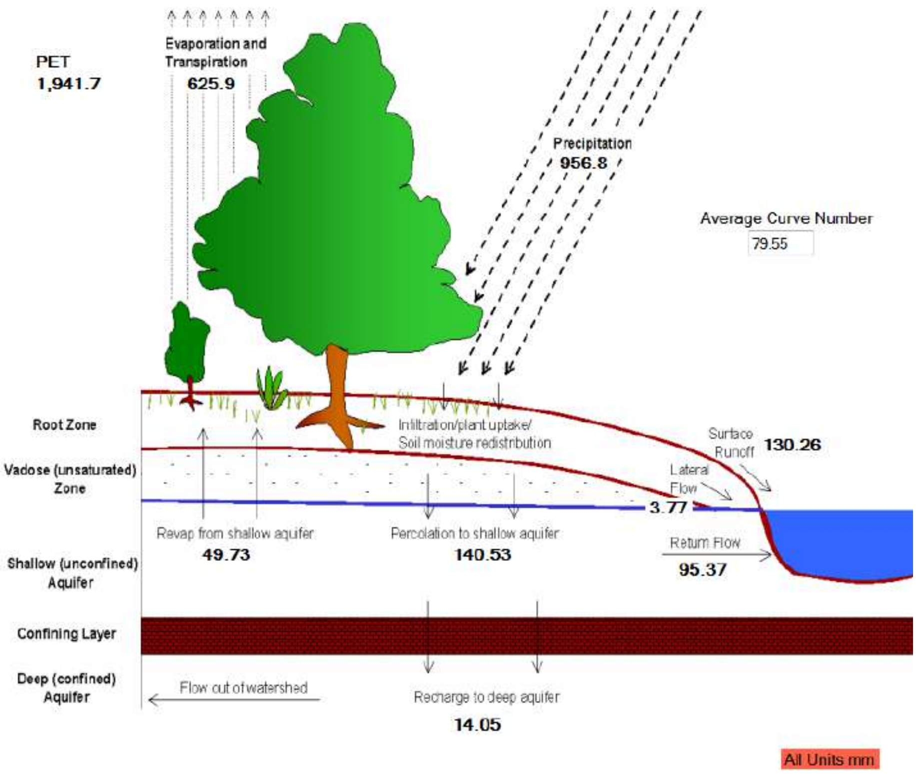


Figure 54: Schematic representation of the SWAT Model water balance of the land phase

The total water balance equation (flow-in=flow-out), might be off-balance for up to a few percent due to the initial 'warm-up' that might occur. In the model one year was used as 'warm-up', but the equilibration period might take longer. In addition to this, slight variation in the water balance might occur due to changes in the storage in the catchment in the soil moisture zone and groundwater.

Table 25 gives an overview of SWAT outputs, providing the average yearly water balance of the catchment. On average 65% of the precipitation leaves the catchment in the form of evapotranspiration while 14% becomes surface runoff and 15% percolates to groundwater (8% when large water bodies and marshlands are excluded). Table 26 provides the average yearly out outputs for the same parameters for all the modelled catchments.

Table 25: Water balance parameters of the Eastern Province (based on SWAT model simulation)

	Eastern Province			Karangazi			Misarara			Cyunuzi		
Parameter	mm	Mm^3	% of P	mm	Mm^3	% of P	mm	Mm^3	% of P	mm	Mm^3	% of P
P	956.8	9,967	100%	923.9	682	100%	907.2	1,618	100%	936.7	286	100%
ET	625.9	6,520	65%	697.6	515	76%	651.8	1,163	56%	632.1	193	67%
SURQ	130.3	1,357	14%	122.8	91	13%	149.3	266	13%	226.5	69	24%
LATQ	3.8	39	0.4%	0.0	0.0	0%	0.0	0.0	0%	0.0	0.0	0%
PERC	140.5	1,464	15%	61.1	45	7%	60.6	108	5%	47.4	14	5%
REVAP	49.7	518	5%	21.0	15	2%	22.6	40	2%	3.3	1	0%
GWQ	95.4	993	10%	34.0	25	4%	31.9	57	3%	39.4	12	4%
DA_RCHG	14.1	146	1%	6.1	5	0.66%	6.1	11	1%	4.7	1	1%

mm = millimeter, Mm^3 = million cubic meter

ET is the main component of the water balance, accounting for 60% of rainfall leaving the system, while SURQ and PERC are the other main components with similar figures, 17 and 16% respectively. LATQ accounts for 0.4% of the water balance, this parameter is 0 in most sub-catchments because of the way that wetlands are modelled, they ‘intercept’ all lateral flow. Some of these parameters are discussed in detail in the next paragraphs.

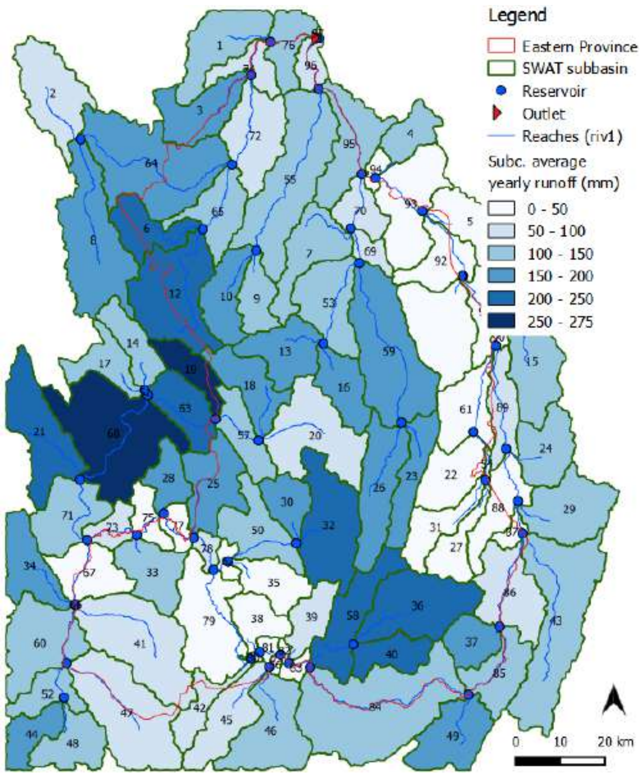
Table 26 provides the yearly summed outputs of the Eastern Province SWAT Model.

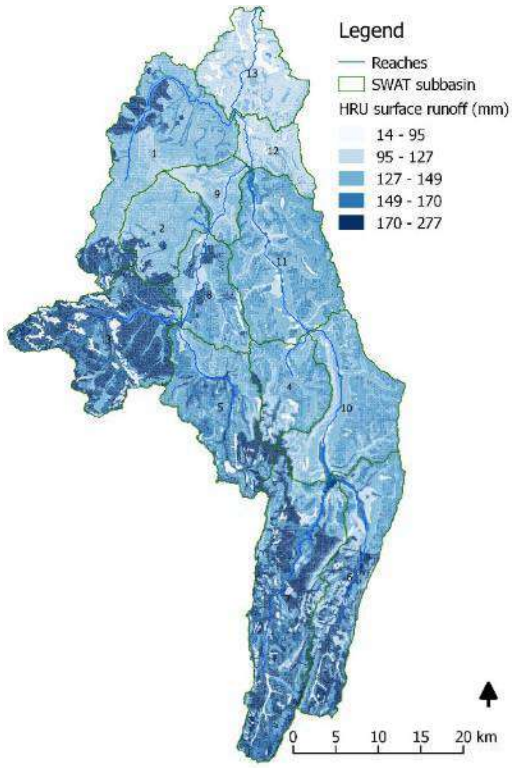
Table 26: Yearly outputs of the SWAT Eastern Province SWAT Model

YEAR	PREC_mm	PET_mm	ET_mm	SURQ_mm	LATQ_mm	PERC_mm	GWQ_mm
1999	782.5	2308.8	585.0	58.1	2.9	77.0	49.3
2000	809.2	2377.5	558.7	82.8	3.3	91.0	46.7
2001	1107.4	2043.6	696.0	163.9	4.3	164.0	93.5
2002	941.0	2099.9	610.4	133.0	3.6	144.9	110.1
2003	821.2	2145.5	651.9	72.8	3.3	77.5	67.7
2004	1129.9	2066.1	645.6	201.1	4.1	167.0	77.1
2005	866.9	2087.0	661.4	107.5	3.3	87.5	105.0
2006	1099.0	1928.2	643.3	174.7	4.5	157.1	72.2
2007	1002.4	1830.4	685.2	123.6	3.9	142.6	124.3
2008	971.7	1781.9	643.9	133.0	4.2	134.0	101.7
2009	925.0	1821.5	606.8	123.8	3.2	131.1	102.0
2010	989.9	1868.1	568.5	171.6	4.4	163.2	101.8
2011	1034.9	1515.4	666.5	128.5	4.1	163.0	115.4
2012	935.3	1626.2	590.6	112.4	3.9	160.2	101.8
2013	936.0	1625.6	574.1	167.1	3.5	150.0	162.2
Average	**956.8**	**1,941.7**	**625.9**	**130.3**	**3.8**	**134.0**	**95.4**

8.4.1 Surface Runoff

Average surface runoff in the Eastern Province catchment is 130 mm/year, or 14% of total annual rainfall. However, surface runoff varies highly throughout the area. Figure 51 presents average yearly surface runoff in mm per sub-catchment in the Eastern Province SWAT model (left) and per HRU in the Misarara Catchment (right), as simulated by the SWAT model. These figures show that there is significant difference in surface runoff between the different HRU’s in the catchment, due to differences in soil type, land use and slope. Especially land use has a high impact on surface runoff, which is the highest in arable crop land.





Average yearly runoff in Eastern Province

Average yearly runoff per HRU in the Misarara Catchment

Figure 55: SWAT output: average yearly runoff in mm

Figure 56 provides the total rainfall surface runoff per year in mm and Mm^3 respectively. The total yearly rainfall is not directly linked to the runoff, as runoff is based on daily rainfall events.

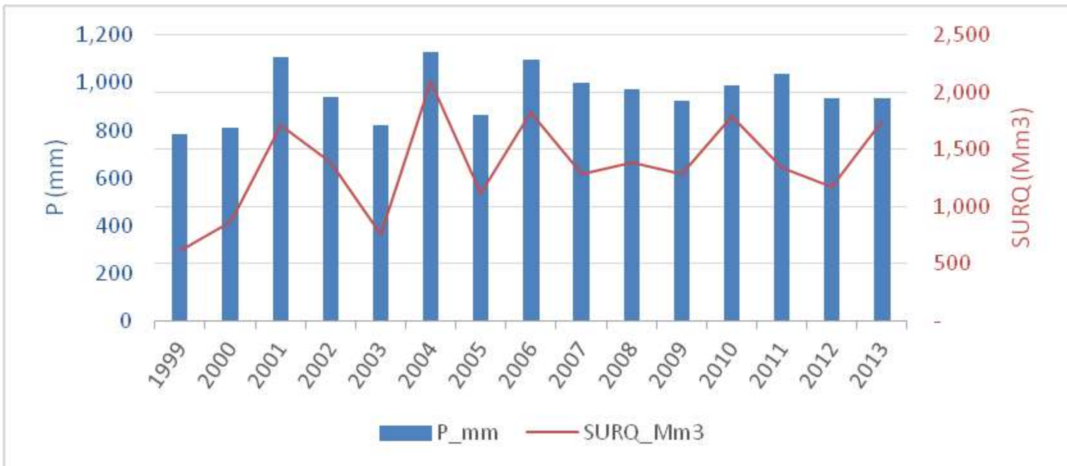
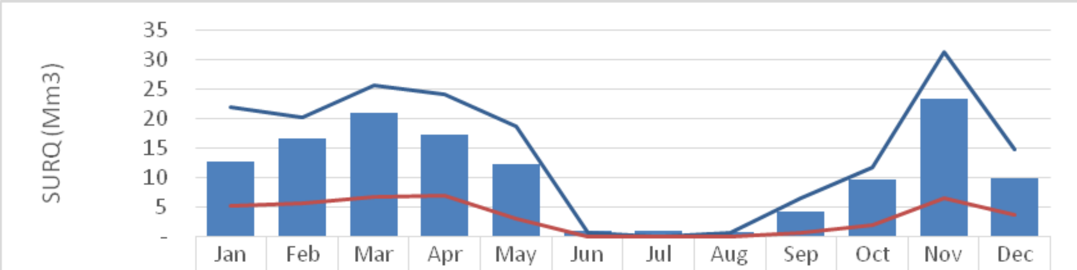


Figure 56: Time series of precipitation and surface runoff in the Eastern Province

Figure 57 provides the average monthly surface runoff in the Eastern Province in million m^3. There is a large variety in monthly runoff in the rainy season between wet and dry years as indicated by the 20^{th} and 80^{th} percentile. The dry season is clearly distinguished, and no surface runoff takes place in both wet and dry years between June and August. Although differences in total annual rainfall are limited, 782 mm in the driest year (1999) and 1130 mm in the wettest year (2004), the relative variations in surface runoff (and other parameters) are much higher. In a very dry year (1999) runoff is only 58 mm, while in a very wet year (2004) runoff is 201 mm.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
average	12.81	16.71	20.95	17.42	12.24	0.97	0.98	0.66	4.29	9.77	23.49	9.98
P=0.8	21.96	20.32	25.79	24.23	18.72	0.57	0.09	0.69	6.46	11.77	31.42	14.91
P=0.2	5.30	5.60	6.76	6.97	3.01	-	-	0.09	0.55	1.92	6.60	3.75

Figure 57: SWAT output: Monthly surface runoff values (million m ^{3})

Generally, surface runoff is still relatively high in the Eastern Province, especially in agriculture and could become much lower through improved land use and SWC and increased tree cover (more information is provided about SWC in Chapter 8).

8.4.2 Groundwater recharge

Due to the basement geology, the main groundwater component is the shallow aquifer, which is considered as all the groundwater in the overburden. The shallow aquifer can be considered as a dynamic underground water storage reservoir that can buffer water in times of high recharge, and slowly releases it later. Recharge of the shallow aquifer mainly comes from infiltration of rainwater into the soil, which percolates from the soil profile through the unsaturated zone, into the saturated zone. Additional recharge can come from streams and rivers, wetlands and from leaking irrigation canals.

Figure 58 provides the yearly rainfall (P), percolation (PERC) and return flow from groundwater to streams (GWQ). Total average annual percolation to shallow groundwater for the Eastern Province, as simulated by the SWAT model is 1,464 Mm^3, which equals 15% of the precipitation. It should be noted that this figure is relatively high due to the recharge of the large lakes and marshlands.

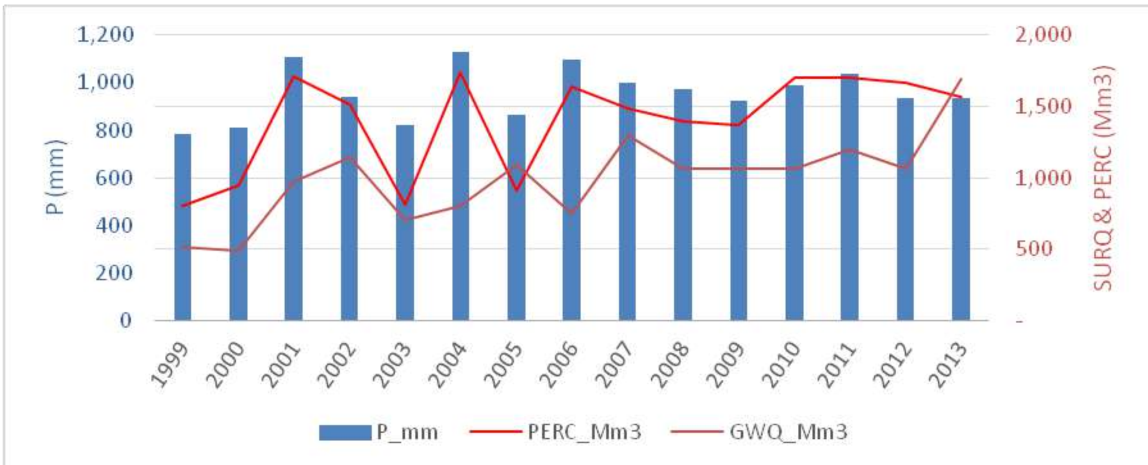
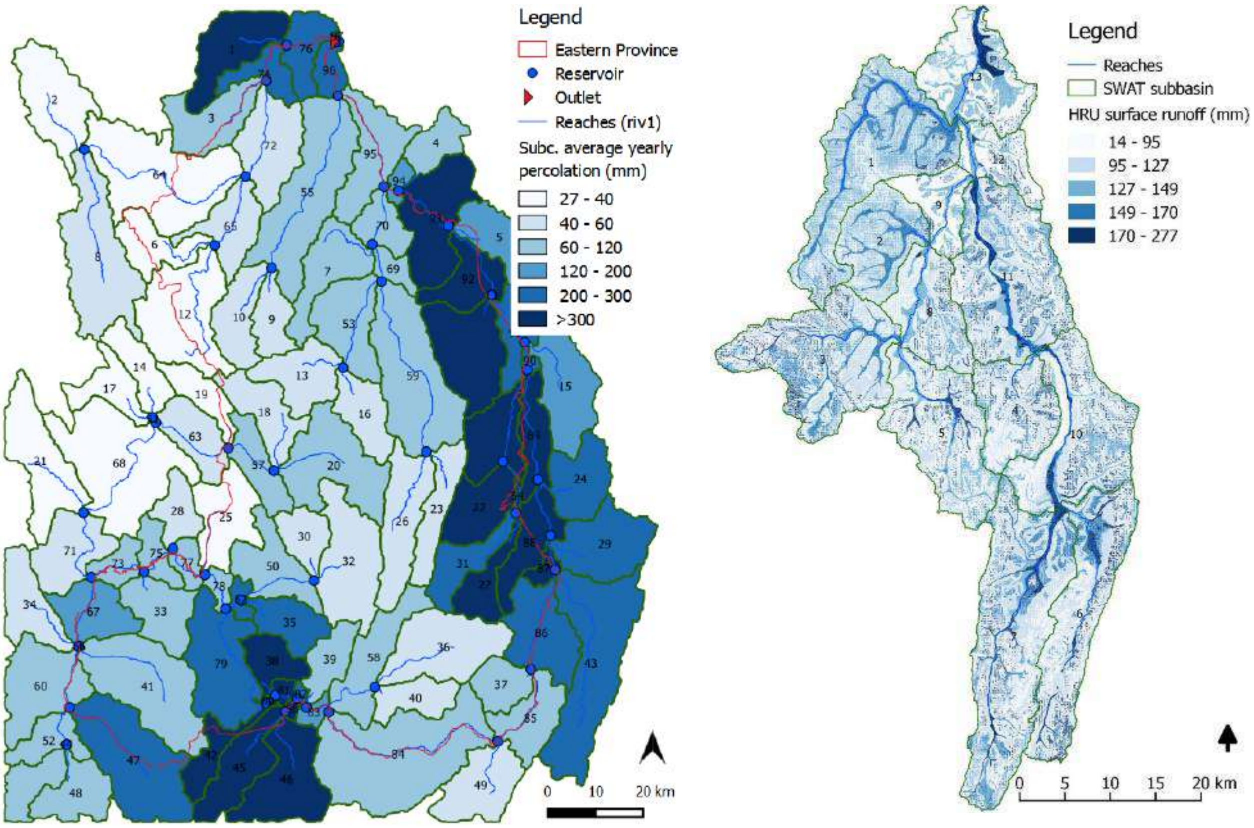


Figure 58: Yearly rainfall (P), percolation to groundwater (PERC) and return flow (GWQ)

As mentioned, sub-catchments with large waterbodies and marshlands have a relative high groundwater recharge, as can be seen in Figure 59. This recharge comes directly from the water bodies and is much higher than average, which means that the percolation directly from land surface is lower than the 15% average for the whole Eastern Province catchment, generally this is between 5-10%, and averagely it is 8% for sub catchments in the Eastern Province.



per subcatchment in the Eastern Province Model *per HRU in the Misarara Catchment*

Figure 59: Percolation to groundwater in mm

The main outflow from the shallow aquifer in the Easter Region is 'return flow'; this is flow from the aquifer towards streams. Much of this occur unseen, where the groundwater directly recharges a perennial stream or river. However, especially in the steep mountainous parts of the Eastern Province groundwater outflow/return flow is visible in the form of springs. These springs are often the start of a stream. Many of these springs are perennial and have a high potential for water supply. Since there is high annual recharge and outflow of the shallow aquifer, sustainable abstraction can be as high as the local aquifer allows. Ground water abstraction from the basement rock - overburden will be mostly limited by the hydrological conductivity of the aquifer formation, rather than recharge or limitations due to sustainability.

The fractured systems in the hard rocks are considered as the deep aquifer. There is minimum information about this aquifer system and especially recharge and groundwater flow is unknown. Deep aquifer recharge in SWAT is only the flow that leaves the basin as ground water flow in the deep system, and is only a closure post in SWAT, as it is not a hydrogeological mode. The deep aquifer recharge can only be given as a percentage of the recharge to shallow groundwater. The deep aquifer recharge, and flow-out from the catchment through the deep system are taken as a fixed percentage of 10% of the percolation to the shallow aquifer.

8.4.3 Sub catchment outflow

Although the SWAT model has been made to simulate land-phase water balance processes, it also includes stream flow characteristics. It should be noted that the stream characteristics are in the default settings or have only roughly been estimated, and the outflow figures are not calibrated. Therefore, the outflow figures are only indicative. Table 27 presents sub catchment outflow for the three sub catchments Karangazi, Misarara and Cyunuzi.

Table 27: SWAT output: outflow data

	Karangazi		Misarara		Cyunuzi	
Year	m^3/s	$Mm^3/year$	m^3/s	$Mm^3/year$	m^3/s	$Mm^3/year$
1999	0.21	6.6	1.94	61.2	0.65	20.5
2000	0.93	29.3	3.36	106.0	0.66	20.8
2001	2.29	72.2	7.86	247.9	2	63.1
2002	2.91	91.8	9.38	295.8	2.45	77.3
2003	0.68	21.4	3.28	103.4	1.36	42.9
2004	2.61	82.3	8.53	269.0	2.99	94.3
2005	2.07	65.3	7.41	233.7	1.84	58.0
2006	3.14	99.0	8.27	260.8	2.01	63.4
2007	3.21	101.2	8.65	272.8	2.38	75.1
2008	4.22	133.1	9.55	301.2	1.53	48.3
2009	2.07	65.3	7.9	249.1	2.4	75.7
2010	3.6	113.5	10.33	325.8	2.86	90.2
2011	2.56	80.7	7.85	247.6	2.26	71.3
2012	3.5	110.4	7.96	251.0	2.02	63.7
2013	6.03	190.2	15.06	474.9	3.32	104.7
Average	**2.67**	**84.2**	**7.82**	**246.7**	**2.05**	**64.6**

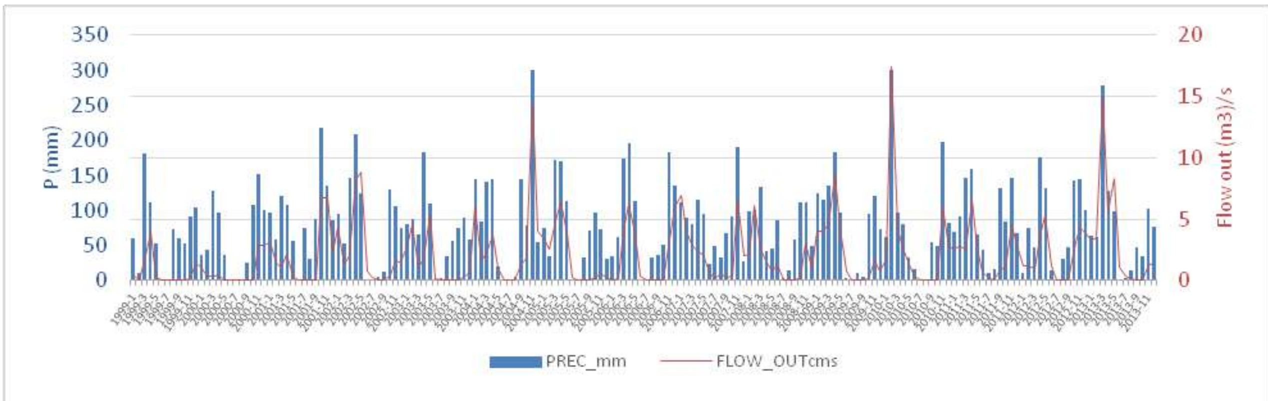


Figure 60: Monthly rainfall and stream outflow for Cyunuzi catchment

8.4.4 Marshlands and irrigation

SWAT provides a wetland module in which wetlands can be modelled per sub-catchment, which was used to model the marshlands. The marshlands and their surface area have been obtained from the land use map. The large paddy rice fields have been modelled per sub-catchment. The paddy fields have been combined and modelled as reservoirs with the general characteristics of the paddy fields.

Within the model area, the total area of marshland is 1,767 km2, when excluding the large lakes and marshlands accompanying it, the total area is 462 km^2. Both in the model simulation and when looking at gauging data, the marshlands and rice fields have an important impact on the water balance.

8.5 Calibration of the outputs

In some studies, surface runoff was estimated relatively high, the annual average runoff is said to be as high as 54-67% of total rainfall in the districts of the Eastern Province (Karamage *et al.,* 2017). This seems not to be in line with the data obtained from satellite imagery, especially ET, which leaves mean net precipitation (Precipitation – ET) for the Eastern Province at around 200 to 300mm only, and field observations. In addition to this, a significant part of streamflow is coming from groundwater, and not directly surface runoff.

8.5.1 Comparison with WRMP hydrological data

Some hydrological information on the scale of Level 1 catchments is provided in the Rwanda Water Resources Resources Master Plan. Although the catchment level differs from the smaller catchments modelled in this study, this study, the general outputs could be compared. Catchments that overlap with the Eastern Province are are Muvumba (NMUV), Lower Akagera (NAKL), Lower Nyabarongo (NNYL), Upper Akagera (NAKU), Akanyaru Akanyaru (NAKN). The most relevant catchments are NAKL, NMUV and NAKU, because they are fully or mostly mostly within the Eastern Province.

Table 28 provides an overview of the hydrological data per Level 1 catchment from the Rwanda Water Resources Master Plan and the results SWAT simulation per modelled catchment. It should be noted that the models use different areas, so the comparison is only indicative to compare the order of magnitude.

Table 28: Comparison Hydrological data

	Hydrological data per Level 1 catchment from the RWRMP					Results SWAT simulation per catchment			
Catchment code	NNYL	NAKN	NAKU	NAKL	NMUV	ER	Kar	Mis	Cyu
Av. annual rainfall [mm/yr]	1 191	1 225	925	835	995	957	924	907.2	936.7
Av. annual evaporation (water balance) [mm/yr]	919	990	760	624	872	626	697.6	651.8	632.1
Av. annual surface water runoff [mm/yr]	272	235	165	211	123	130	122.8	149.3	226.5
Base flow* [m^3/s]	66.8+	16.4°	198.0+	200.0+	3.5	31.5	0.8	1.81	0.38
Av. annual ground water recharge [mm/yr]	165	227	115	125	71	109.4	67.2	66.7	52.2

**: Base flow: when number marked with an ° it is for a partial catchment (upstream for NAKN); when marked with a + the base flow comprises flow from upstream catchments.*

The Eastern Province SWAT model (ER) can be best compared with the area weighted average of NMUV, NAKL, and NAKU catchments. P compares reasonably well (894/950), while ET is lower in the SWAT simulation (714/626). Surface Runoff is lower in the SWAT simulation (180/130). Generally, groundwater recharge compares well, with a weighted average of 112mm, versus 109 mm in the SWAT simulation for the Eastern Province. Base flow for the RWRMP study has the upstream catchments of the Akagera Basin incorporated, while the SWAT models only have the in-catchment base flow contribution figures (GWQ). Nevertheless, the base flow value for the Eastern Province SWAT model seems lower than the RWRMP model. For example, the NMUV catchment is comparable in size to the Misarara Catchment, 1562 and 1783 km^3 respectively, and the base flows are 3.5 and 1.81 m^3/s respectively.

Considering the uncertain reliability of the source data (satellite-based climate data, and regional land cover and soil data) the similarity of the SWAT outputs and the RWRMP data is relative high.

8.5.2 Comparison with gauging station data

The sub-catchments separately modelled in SWAT are part of the level 1 catchments of the RWRMP, Karangazi (Kar) and Misarara (Mis) are part of NAKL, while Cyunuzi (Cyu) is a small part of NAKU. Also, for these catchments, the main water balance figures are in the same order of magnitude.

River flow gauging data is available from the W4GR data portal. This data provides an important source of information for the Eastern Province. As mentioned, the SWAT model focussed on the smaller sub-catchments within the Eastern Province, and not the large rivers and lakes that are part of the Akagera River system. As a matter of fact, no discharge gauging data series are available for the sub-catchments in the Eastern Province with overlap with the model period, only a few point measurements. Nevertheless, the general figures (min, max, mean) can be used to see if the SWAT simulation is within the same order of magnitude as the measure data. Table 29 provides an overview of measured stream flow and the outputs of the SWAT model for the comparing sub-catchment.

Table 29: Overview of relevant gauging data and SWAT simulation outputs for subcatchments

Hydrology Station	Catchment	Start date	end date	Total Samples	Min (m3/s)	Max (m3/s)	Mean (m3/s)	SWAT sub/ reach	Min (m3/s)	Max (m3/s)	Mean (m3/s)	Remarks
Nduruma	Cyunuzi	1992-08-28	2000-02-08	5	0.17	1.41	0.50	36.00	0.03	17.04	2.04	Too few samples, station only measures one of 3 channels
Cyunuzi	Cyunuzi	2016-03-01	2016-12-31	735				36.00				No Q data available on portal
Kagitumba	Muvumba	1970-12-17	2018-05-09	94	3.60	44.10	11.75	76.00	0.33	83.63	14.41	No data in model period
Akagera Outlet	Akagera											No Q data available on portal
Kabuga	Muvumba	2017-09-06	2018-05-08	4	2.73	24.63	9.14	64.00	0.27	39.08	6.57	Only 4 samples
Ngarama	Muvumba	1968-08-02	1980-07-24	22	0.80	5.35	1.84	12.00	0.05	16.70	2.37	
Ngoma	Muvumba	1967-12-12	1976-03-12	18	0.61	2.79	1.09	6.00	0.03	6.60	1.08	
Nyagahanga	Muvumba	1978-08-02	2018-09-11	29	0.05	3.63	1.03					see Ngarama (Sub 65)
Muhazi Outlet	Lake Muhazi	2017-05-09	2018-05-11	5	0.52	9.80	3.17	63.00	0.12	36.40	5.06	Only 5 samples
Gitagata	Lake Cyohoha North	1974-01-01	1981-12-31	2734								No Q data available on portal

Generally, the mean flow compares reasonably well to the measured data, for stations where there are more samples (Kagitumba, Ngarama, Ngoma). The extremes (maximum and minimum) discharge seems to be overestimated by the model. However, it is very difficult to be conclusive about this without consistent long-term gauging data with overlap with the model period.

In conclusion, the SWAT model was developed as a first step to get an understanding of sub-catchment water balance processes in the Eastern Province. The model seems to adequately model the main hydrological detailed calibration of the model is difficult due to the lack of consistent stream gauging data series with overlap with the model simulation period. For future improvement of the model a number of steps can be taken:

- Select separate sub-catchment for detailed model development
- Collect detailed data of rice irrigation, wetlands and reservoirs
- Collect any additional stream flow information that might be available and install automatic gauging stations

Furthermore, improved model components and specific parameters based on detailed sub-catchment data. The detailed models can be used for analysis of impact of interventions in the catchment, such as reservoirs, irrigation, water management interventions and land use change.

9 Potential for enhancing recharge and storage

9.1 Introduction

Enhancing recharge and storage of excess water during wet period can strongly increase water resources and water availability in periods of water scarcity. There is a wide range of possible interventions and strategies to increase recharge and storage. These include valley dams, water reservoirs, valley tanks, sand dams, subsurface dams, recharge facilities and a variety of agricultural soil and water management interventions.

Although many opportunities for storage and recharge are present, often these types of interventions are overlooked when considering water supply interventions, because they are unknown or the potential for such intervention in a specific area is not known. However, within an IWRM approach, storage and recharge are an important aspect of the possible interventions to provide water supply and/or strengthen groundwater resources. Usually groundwater is the preferred option for drinking water supply systems, due to the quantitative and qualitative reliability. However, in areas where groundwater is not available or at high cost, water storage interventions can be considered. In addition to this, water storage facilities are often preferable over groundwater systems for irrigation and livestock water supply. Therefore, as part of this study the potential of storage and recharge will be an integrated part of the assessment and outputs.

Rainwater and runoff water can be recharged and stored using different methods, the main options are, soil moisture recharge by increasing infiltration, groundwater recharge by recharging of an existing or artificial aquifer, storage in closed tanks, or storage in open surface reservoirs. Figure 61 provides some examples of approaches and interventions grouped based on their main purpose, i.e. protection and restoration, soil and water conservation (in agriculture) and water storage for water supply (off-stream and in-stream). Interestingly enough, for some approaches such as protection and restoration of vulnerable and/or degraded areas and SWC, the direct objective is not water storage/recharge; however, they have an enormous positive impact on it.

Figure 61, Figure 62 and Figure 63 provide an illustration of different options for strengthening recharge in the landscape. Ground water recharge interventions are often referred to as Managed Aquifer Recharge (MAR).

Figure 61: Examples of water storage and recharge interventions

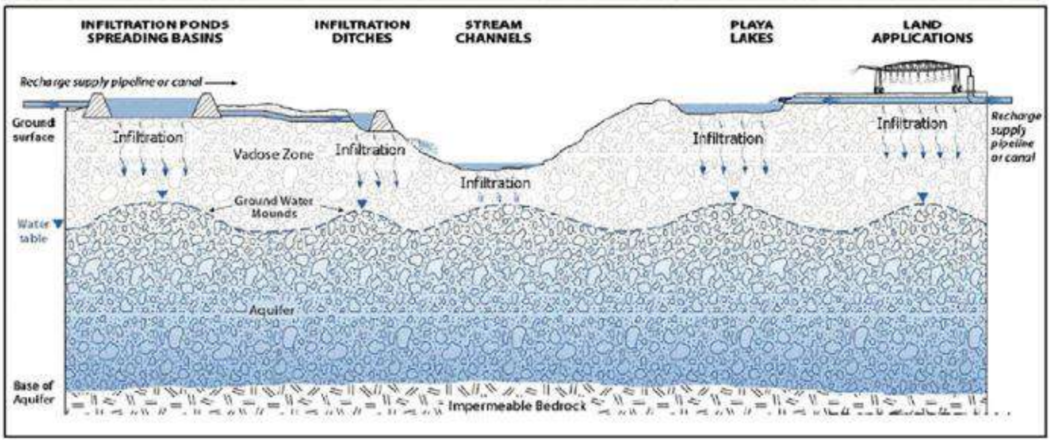


Figure 62: Technologies for diffuse MAR (source: Topper et al. 2004)

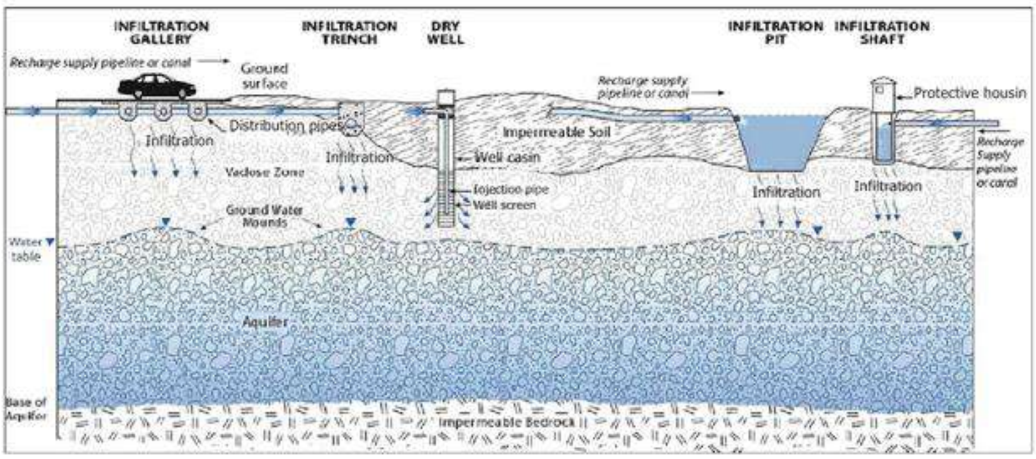


Figure 63: Technologies for point MAR (source: Topper et al. 2004)

9.2 General strategy and benefits

Much of the information that is provided in this chapter was obtained from various policy documents, and the recommendations provided in these documents are incorporated in the suggested recharge strategies. The policy documents include:

- State of the Environment and Outlook report, 2009
- State of the Environment and Outlook report, 2015
- NATIONAL RAINWATER HARVESTING STRATEGY, MINISTRY OF NATURAL RESOURCES, Rwanda Natural Resources Authority, November 2016

Based on these documents, other relevant literature, and the assessment made of the Eastern Province, an approach was developed.

The main focus is on opportunities for enhancing recharge of groundwater through soil and water conservation in agriculture and conservation and strengthening of valuable ecosystems such as forests and wetlands. Additionally, opportunities for local aquifer recharge and opportunities for storage are evaluated and mapped.

This approach would be greatly in line with the practices to implement the Green Growth and Climate Resilience (GGCR) Strategy presented in the State of the Environment and Outlook Report 2015, which include:

- Build, restore and enhance soil fertility through Integrated Soil Fertility Management (ISFM)
- Apply agro-ecological approaches
  a. Promote mixed farming, land husbandry
  b. Promote agroforestry
  c. Crop diversification and higher agrobiodiversity
  d. Reduce and prevent soil erosion
  e. Adopt climate change adaptation and mitigation practices
- Manage irrigation sustainably

This way of Integrated Water Resources Management (IWRM) will greatly benefit water resources without having all the investment and effort coming from the water sector. It is rather a side-benefit from improved land and water utilisation by other sectors, especially agriculture, which improves economy, sustainability, and strengthens the ecosystem.

Increasing recharge through these methods, will increase groundwater availability, mitigate floods, and increase river base flow. Springs are an important and highly underutilized resource in the area. Springs can benefit significantly from increased recharge in their catchment, with an increased yield and an increased flow in dry periods as a result.

The following paragraphs provide information for the different types of recharge and where and how to apply it. The first part provides a map that shows the potential for recharge and storage enhancement in the Eastern Province. The final paragraphs of this chapter provide recommendation for implementation.

9.3 Enhancing groundwater recharge through soil and water conservation (SWC)

Considering the water balance, the most significant gain in ground water recharge can be obtained from reducing surface runoff and storage of streamflow. The most effective way of reducing surface runoff is through appropriate land use planning and SWC. First, by preventing surface runoff through increased infiltration and second by capturing the remaining runoff for recharge or storage. Interventions that are considered are both diffuse small-scale recharge interventions that can be implemented over a large area, such as SWC interventions in agriculture and protection and restoration. Protection and restoration and SWC techniques for increased surface infiltration include, reforestation, agroforestry, rangeland management, mulching and terracing. SWC techniques for interception of surface runoff include, contour bunds and trenches, half-moons, swales, grass and tree strips, etc.

9.3.1 Slope adapted agriculture

Soil and water conservation measures are already practiced in the area and, limited severe erosion such as gully's are present currently. These practices include, terracing, contour bunds, mulching, contour ploughing, grass strips, tree strips, slope protection with trees, and wetland protection. However, still there are many areas where agriculture is applied on steep slopes without appropriate SWC measures applied. This results in a higher surface runoff ratio, and hence loss of water and possibly erosion.

Picture 10 : Exposed soils on steep slopes in grazing lands

Picture 11 : ***exposed soils on steep slopes in settlement area with gully forming***

Picture 12 : Agricultural practices on slopes without appropriate SWC (1)

Picture 13 : Agricultural practices on slopes without appropriate SWC (2)

When agriculture is applied on slopes, specific soil and water conservation measures are required. The Ministry of Environment provide Guidelines for Erosion Control with a matrix of erosion control measures. This matrix has been used to map SWC measures as provided in Figure 67 and
Table 30, page 125.

The pictures below provide some examples of land use planning and SWC measures on steep slopes in western Gatsibo District. Both images show forest cover on the upper slope and bench terracing and agroforestry on the middle and lower slopes.

Picture 14 : Good land-use planning and SWC interventions in Gatsibo

Picture 15 : Good land-use planning (snapshot from Google Earth)

9.3.2 Soil fertility management

Rwanda's GGCR strategy suggests implementing an integrated approach to soil fertility management that employs practices that recover and reuse resources and by also applying fertilizer-enriched compost. This improves soil structure and water retention. Conventional agriculture rapidly depletes soil organic matter (SOM) while repeated cultivation degrades soil structure, lowering crop yields and increasing production costs (UNEP, 2011a). Instead, many sustainable agricultural systems engage in Integrated Soil Fertility Management (ISFM), which combines natural soil amendments, such as organic matter, phosphate and lime, with smaller inputs of inorganic fertilizers (Cantore, 2011).

Other sustainable soil fertility strategies include growing nitrogen-fixing fodder and green manure crops, such as legumes, ferns, clover and/or rice straw and integrating them back into the soil; the no-tillage approach where new seeds are planted into crop residue; and fertilizing with waste biomass or biochar, which is charcoal used as a soil amendment, especially for acidic soils (UNEP, 2011a). Farming systems that make better use of manures, compost, legumes, crop residues or agroforestry to maintain soil nutrient levels will have less need for inorganic fertilizer (FAO, 2012). Additionally, systematic hedging with nitrogen fixing crops that also have an additional harvest (food, feed, wood, etc.) can be a sustainable and productive land management systems and soil conservation measure (State of the Environment and Outlook report, 2015).

Picture 16 : ***ISM practice: mulching***

Picture 17 : ISM practice: ***windbreak with trees for green manure and additional products***

9.4 Protection and restoration of ecosystems

9.4.1 Forest protection and agroforestry

Forests play an important role in the hydrologic cycle, both on continental climate cycles as well as local micro climate. In addition to this, they form an important buffer for rainfall, the canopy intercepts rainfall and trickles it down to the soil where infiltration capacity is increased by the vegetation cover and mulch and humus rich top layer. Forests can also be used for conservation of vulnerable soils and soils on steep slopes.

Naturally eastern Rwanda is covered by savannah with grasses, bushes and trees, gallery forests, and mountain rainforests. Gallery forest around lakes and other water bodies are mainly found in the Akagera complex, where they cover almost 163 hectares (Twarabamenye and Gapusi 2000 in MINITERE 2003a). Today these natural forests in the Eastern Province are mostly restricted to the Akagera National Park and some other protected areas.

Picture 18 : Sharp boundary between the protected and unprotected area

Picture 19 : semi-natural landscape in the protected military zone in Bugesera

Most of the land in the Eastern Province, except for protected areas, is deforested and almost all indigenous tree cover has been removed, and the land is mostly used for agriculture (Figure 64[8]). The high population density has resulted in a sustained conversion of ecosystems and habitat that is threatening biodiversity in Rwanda. For instance, the total surface area of national parks in the country, have been reduced since 1960s in search for land for cultivation and settlements. In some cases, these reductions resulted from illegal encroachments or legal authorization by the government. However, even in cases of the authorized reduction of protected areas, no consideration was given to ecological facts. This is the case for the new boundaries of the Akagera National Park and other protected areas (Rwanda State of the Environment, REMA, 2009).

[8] source: Modeling Rainfall-Runoff Response to Land Use and Land Cover Change in Rwanda (1990–2016), Karamage et al, 2017

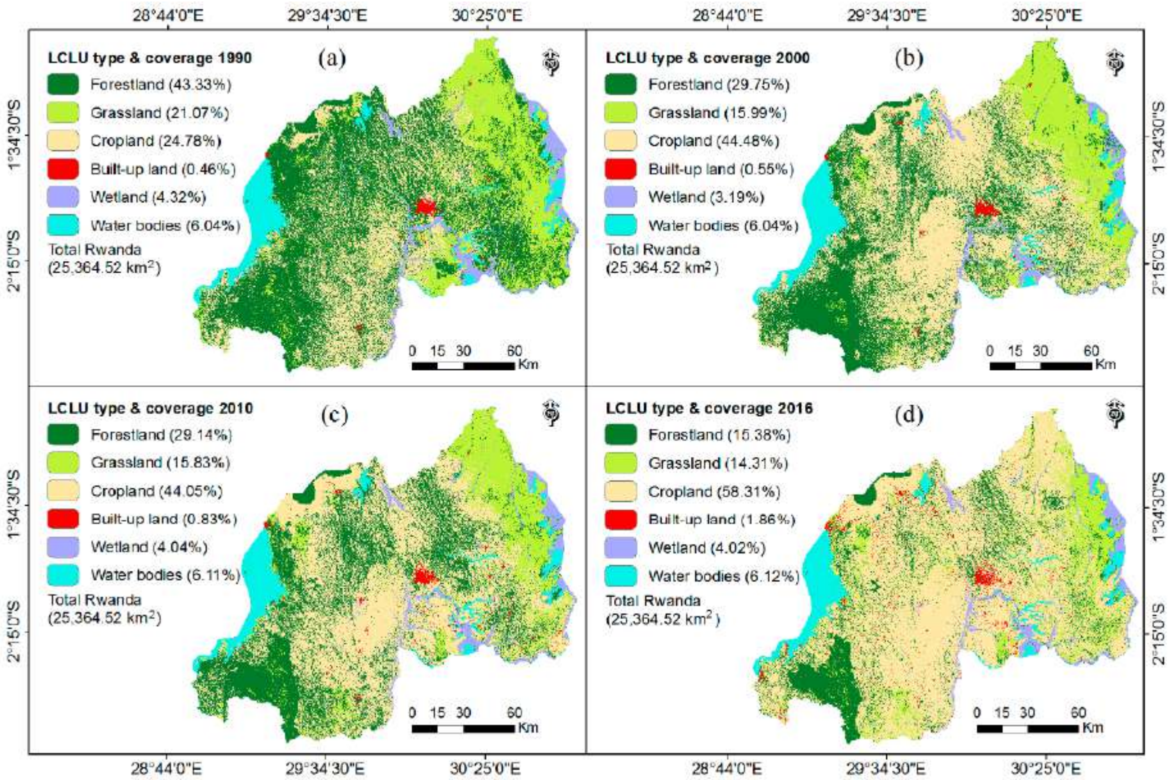


Figure 64: Land cover and land use maps of Rwanda

For conservation of biodiversity and to keep on benefitting of vital ecosystem services, including water resources services, the remnants of all remaining natural forests and other ecosystems should be protected. Furthermore, restoration of the ecosystem could take place through promotion of ecosystem based agroforestry, which can be highly beneficial economically, environmentally and socially. This approach would be greatly in line with the practices to implement the Green Growth and Climate Resilience (GGCR) Strategy presented in the State of the Environment and Outlook Report 2015, which include:

- Build, restore and enhance soil fertility through Integrated Soil Fertility Management (ISFM)
- Apply agro-ecological approaches
    a. Promote mixed farming, land husbandry
        i. Promote agroforestry
    b. Crop diversification and higher agrobiodiversity
    c. Reduce and prevent soil erosion
    d. Adopt climate change adaptation and mitigation practices
- Manage irrigation sustainably

Even though most natural forest cover is severely reduced, some trees are adopted into agriculture through agroforestry practices. Moreover, there are many forest plantations, which contributed to the reduction of the deficit in fuel wood and service wood. However, these are mostly exotic species (mostly eucalyptus). Many of these plantations of are in poor condition due to soil degradation and poor management. To increase water recharge, biodiversity and the ecosystem in general, more (indigenous) tree species matching the local ecosystem could be adopted into the plantations and agroforestry systems. Some species for consideration include Acacia *mearnsi*i, Acacia *melanoxylon* and some species of Eucalyptus like Eucalyptus *saligna*, E. *maideni*, E. *microcorys* and E. *grandis* (Rwanda State of the Environment, REMA, 2009).

Within agroforestry systems, trees could be used as wind-breaks, shade crop and for green manure. Different varieties of fruit and nut producing trees could be promoted. Also, many species are available to produce fuel-wood, charcoal, timber and other products. These trees could be integrated in the current agroforestry systems and in addition, additional tree plantations and polyculture production forests could be planned on vulnerable soils and steep sloping lands. For further promotion of agroforestry, nurseries could be established and training provided to local communities in agroforestry practices. Picture 20 and 21 provide examples of agroforestry applied in the area. In picture 20 valley cropping, can be seen in a silvopasture system with macadamias and a forest plantation in the background as well as a sharp boundary between the protected and unprotected area

Picture 20 : Agroforestry in western Nyagatare District

Picture 21 : Agroforestry practices on slopes in Kirehe District

9.4.2 Rangeland management

Properly managed grazing is highly beneficial for the quality of the rangeland. It increases the carrying capacity and increases infiltration capacity and reduced surface runoff and erosion. Including trees in rangeland can be beneficial for the production of the rangeland. This type of system is called silvopasture, it creates a savanna-like landscape that is close to the natural ecosystem, which is highly productive and resilient. Generally, grass has the highest production in half-shade conditions, and is more resilient to droughts in this situation. Other benefits of including (indigenous) species include:

- Additional food source for livestock, as many tree species provide good fodder
- Diversification in diet of livestock
- Additional products such as wood, fruits and nuts
- Increased biodiversity and resilience to droughts and floods

The picture below is an example of range land with forest cover on the steep slopes on the left hill, and with bare soil and erosion on the right hill

Picture 22 : Rangelands in Gatsibo District

9.4.3 Wetland protection and restoration

Wetlands are known to be the world's most productive ecosystems. They provide important ecosystem services to humans including food and material provision, nutrient cycling, sediment and pollution retention, flood mitigation and groundwater recharge. Wetland ecosystems in the Eastern Province are under great threat due to the constant pressure from human activities; especially the conversion of wetlands into agricultural land has a huge impact. In addition to traditional cropping, large areas of former wetlands have been converted into commercial rice production areas with extensive irrigation systems. These areas produce an effluent with high silt and agricultural pollutants.

Picture 23 : Wetland with natural vegetation and subsistence agriculture

Picture 24 : Wetland completely converted to irrigated rice fields

As described in the Rwanda State of the Environment and Outlook documents, wetland management and restoration will be essential to maintain the above described ecosystem services. Especially for water resources, wetlands are extremely important for flood buffering, filtration, and recharge, therefore wetlands should be a priority in water resources management.

The remaining natural wetlands should be evaluated and protected. The most crucial wetlands in terms of biodiversity, ecosystem services including flooding mitigation, water buffering and filtration should become strictly protected, while other wetland areas could be used for sustainable production, including fishing, controlled grazing and regulated harvesting of reeds and papyrus.

9.4.4 Riparian buffers

Currently very few streams and even large rivers have a riparian buffer zone. Land clearing and cropping takes place far into the river floodplains up until the river edge. This creates several problems, including bank erosion, surface runoff with silt and pollutants directly enter the river and a reduced peak-flow buffering capacity of the river system. Picture 25 and Picture 26 show example of riparian buffers while Picture 27 shows the Akagera river with agriculture up to the riverine marshland at the Rwandan side, while a forested buffer zone is present at the Tanzanian side

Picture 25 : ***Stream without riverine buffer,***

Picture 26 : ***Riparian forest near Nyagatare Town***

Picture 27 : The Akagera River at the Rwandan-Tanzanian border

9.5 Managed aquifer recharge (MAR)

Due to the complex hydrogeology of the most prevalent geology in the project area, i.e. crystalline basement rocks with a relative shallow overburden with low hydraulic conductivity and fractured aquifer systems, point recharge technologies such as infiltration wells might not be efficient for large scale application. These technologies depend on the hydraulic conductivity of the aquifer for their infiltration capacity. Additionally, the complexity of the aquifer makes it difficult to predict the relation between the recharge-point and abstraction, especially in the deep fractured aquifers.

Interesting options for recharge could be lake or dam infiltration. It is possible that some of the dams and ponds recharge an existing aquifer or create a perched aquifer where they are located. Often productive wells can be found directly downstream of an un-lined surface reservoir. In some cases, reservoirs are known to have high infiltration 'losses' and are considered as inefficient or even failed reservoirs. However, these are most likely recharging ground water, and options for production wells should be investigated.

9.5.1 Riverbank infiltration

Riverbank infiltration is abstraction of groundwater from sedimentary formations surrounding the river. It can be abstraction from natural formations or through artificially constructed infiltration galleries. It is preferable over direct surface water abstraction because of the highwater quality, as a result of natural filtration, and it is preferred over deep groundwater because of the easy drilling and the high yields that can be obtained.

Riverbank infiltration is highly feasible in along some rivers in the Eastern Province. Especially the Nyabarongo River, which has favourable conditions due to the coarse grained sediments present in the wide alluvial plains along the river. Here some wells with good yields are already present. Another river with potential for riverbank infiltration could be the Muvumba River, sandy sediments were observed in the riverbed and in the banks up to Nyagatare town. Other large rivers in the Eastern Province could be further investigated. In addition, along perennial rivers that do not have favourable formations in their banks, artificial infiltration galleries can be constructed to provide (pre) filtration for water intakes.

9.5.2 Potential for water storage

There are many water storage interventions present in the Eastern Province. Most common are valley dams, where storage capacity varies from a few hundred cubic meters to millions of cubic meters. Roof rainwater harvesting is also practiced, but not commonly present in the area.

Based on an assessment of the streams and rivers, the potential of sand dams and sub-surface dams is identified as low. Most streams do not have sand streambeds, and most larger streams have a perennial flow due to springs.

The following paragraphs provide some additional information on feasible interventions for water harvesting and storage, including multipurpose dams, valley tanks, road water harvesting, rock catchments and

Multipurpose dams

The pronounced valleys with clay soils and underlying basement rock are feasible for valley dams. These can be large dams for irrigation purposes, but more upstream smaller dams could also be constructed as source for water supply to rural communities. Many large dams are already present and additional sites have been located in for construction of new dams throughout the Eastern Province in various studies, including: A GIS based Framework for Assessing and Mapping Potential Irrigation Areas in Rwanda, Rwanda Agricultural Development Authority. Therefore, the focus of this study is on alternative small scale water storage interventions, which have high potential but are still underutilized in the area. Picture 28 and Picture 29 are examples of types of dams encountered in the area.

Picture 28 : Small earthen valley dam

Picture 29 : Concrete dam with irrigation system

To make water storage dams financially more affordable for community water supply, multipurpose dams could be constructed. These dams could serve as source for irrigation, livestock water supply and domestic water supply.

Generally, the water quality of open reservoirs is not high enough to be used for domestic purposes immediately. To improve water quality, an infiltration gallery could be constructed, or wells could be drilled downstream of the dam. For hygiene concerns it is important to provide separate water supply points for livestock and for domestic use. Some dams with combined use are already present in the province. This dam has a shallow well directly downstream of the dam, which might be recharged by the dam.

Figure 65: Example of a multipurpose dam in Nyagatare District

Valley tanks or ponds

Currently, most reservoirs are dams, while the area has high potential for valley tanks or large ponds (typically ranging in volume from 5000 to 20000 m^3). Rather than storage through a raised embankment, ponds are excavations; soil removed from the ponds can be used to form banks surrounding the reservoir to increase its volume. Ponds are dug into natural depressions or into floodplains to tap water from streams or floodwater from larger rivers. Ponds can also function as a multipurpose water source and provide water for both livestock and domestic purposes (treatment required) and small-scale irrigation. The advantage of ponds is that they can be constructed in flat to gentle sloping areas where a dam would not provide efficient storage. The pond can still have an efficient volume depth ratio, whereas a dam would become a shallow water reservoir with high evaporation and seepage losses.

Figure 66: Example of a ponds or valley tanks in Nyagatare District on Google Earth

Small storage reservoirs from local runoff

While many (large) valley dams are present in the area, few small-scale farm ponds and dams are present. Farm ponds are generally small reservoirs that store up to 5000 m^3. These reservoirs can be constructed manually by the communities and are built of soil by an excavation and or an embankment in a natural depression or hillside where runoff accumulates. The reservoirs collect local runoff or water from hillsides, rocks, roads or small streams.

Picture 30 : Example of a farm pond with a treadle pump for irrigation

Road water management and road water harvesting

Many smaller murrum roads in the area are negatively effected from erosion. While this is a common problem for these types of roads, improved management can both improve the road condition and provide water harvesting options. When the road is being constructed or maintained, at areas with slope and high runoff, water can be diverted towards small storage reservoirs, such as ponds or hillside dams.

Picture 31 : ***Gully erosion at a road***

Picture 32 :Plastic lined pond filled from road water runoff

Rock catchments

Rock catchments capture rainwater runoff from rock outcrops. Water is usually stored in closed or open tanks but can also be stored in a pond or used for aquifer recharge. Water is channelled to the reservoir by small concrete walls or through collection canals at the foot of the rock. When the catchment is properly protected the water quality can be much better than that of earth surface catchments.

Picture 33 : Example of a rock catchment with concrete storage reservoir

9.6 Storage and recharge potential map

The above described interventions for enhancement of recharge and storage are feasible in the Eastern Province, however, not every intervention fits everywhere, and specific applicability depends on local conditions. Potential of the interventions was evaluated based on landscape characteristics, such as soil, slope, land use and land cover. The matrix of erosion control measures from the guidelines of the Ministry of Environment, the Mapping of Erosion in Rwanda and Guidelines for erosion control, June 2018 was used for determining slope and soil classes and intervention suitability. These classes, combined with options for water storage, were used to prepare storage and recharge enhancement potential map, provided in Figure 67. The map provides zones of relative homogenous landscape characteristics, and for each zone the potential for different interventions and strategies for storage and recharge is provided.

Figure 67: Storage and recharge enhancement potential map (legend provided on next page)

Table 30: Legend of storage and recharge enhancement potential map

Zone	Current land use	Details and slope	Recommended land use	Interventions for land and water conservation (Recharge enhancement)	Interventions for storage
A1	Rain fed Agriculture (arable land)	Gentle slopes (0-16%), deep soils	Agroforestry Annual agriculture	Contour ploughing + Alley cropping combined with grass strips. Where slopes are over 6%: Progressive terraces Perennial crops, coffee, tea, banana, fruit trees	Valley tanks, ponds, MAR, floodwater spreading
A2		Steep slopes (16-40%), and/or shallow soils	Agroforestry with perennial crops, coffee, tea, banana, fruit trees + Forestry where soil depth is too limited and unsuitable for crops	Bench terraces (on deep stable soils) reinforced by agroforestry hedges and grass strips, or Progressive terraces (if parent material is not stable) / Contour bunds (4-5 m spacing between terraces) reinforced by agroforestry hedges and grass strips Forestation where soil depth is too limited and unsuitable for crops	Valley dams, hillside dams, rock catchments
A3		Very steep slopes (>40%), deep or shallow soils	Perennial crops Forestry or forest plantations. On shallow/ instable soils only forest or natural vegetation	Narrow cut terraces (or progressive terraces if parent material is not stable) reinforced by agroforestry hedges and grass strips (only on deep soils) Forestation and forest protection In eroded areas: area closures and stone structures above ground	
R1	Rangeland	Gentle slopes (0-16%), deep soils	Agroforestry (silvopasture) Rangeland	Rangeland management (controlled grazing) Protection and management of trees	Valley tanks, ponds, MAR, floodwater spreading
R2		Steep slopes (16-40%), and/or shallow soils	Agroforestry (silvopasture) Rangeland Forestry	Rangeland management (controlled grazing) Protection and management of trees In eroded areas: area closures, stone bunds, tied ridges and trenching Hedges and grass strips	Valley dams, hill-side dams, rock catchments
R3		Very steep slopes (>40%), deep or shallow soils	Forestry On shallow or instable soils only forest or natural vegetation	Protection and management of trees In eroded areas: area closures, stone bunds, tied ridges and trenching	
F1	Forested areas	Natural forest (All slopes)	Natural forest	Forest protection No tree cutting, no grazing	See above (depending on slope)
F2		Forest plantations (all slopes)	Forest plantation Agroforestry Perennial crops	Diversification of tree crops Controlled tree harvesting on slopes	See above (depending on slope)
W1	Open water bodies and wetlands (all slopes)	Floodplains and seasonal wetlands with cropland or grassland	Flood adapted agriculture Controlled grazing	Wetland protection Floodwater spreading and floodwater storage	High potential for valley tanks, ponds, possibly MAR, riverbank infiltration
W2		Irrigated rice fields	Irrigated land	Incorporation of marshland-buffer zones Protection and stabilisation of stream banks	Valley tanks, ponds and dams
W3		Marshlands	Marshlands	Marshland protection Restricted use of products	(Natural water buffer)
W4		Open water bodies, lakes, rivers	No other land use incl. in buffer zone	Protection of floodplains and buffer zone/ riverine buffer with protection of riverine vegetation	Riverbank infiltration, floodwater spreading
U1	Built-up area's	Urban/rural built-up area's	Built-up	Urban water management Infiltration ditches (wadi's) Increased tree cover	Rainwater harvesting, ponds, dams

9.7 Guidelines for implementation

9.7.1 Catchment management strategy

All interventions should be brought under catchment management strategy and specific catchment management plans for each sub-catchment. Within these sub-catchments, micro-catchments can be formed in which local stakeholders are represented. These plans should align with existing policies and practices in Rwanda, including the Rwanda Water Resources Master Plan.

To be able to reach scale in a sustainable manner, there is a great need for further development of the 'soft' component of catchment management. This includes formal and informal regulation, capacity development, training, awareness creation, and facilitation of the management process. All the land users will need to change their behaviour towards land use and all farmers need to adopt SWC strategies and other catchment management activities in their land.
A catchment management strategy should include a combination of 'soft' and 'hard' interventions such as:

- Development of a catchment management plan
- Strategies for stakeholder participation
- Establishment of the institutional structure
- Development of practical guidelines for catchment management
- Land use planning and regulations on land use such as tree cutting, grazing and farming based on land characteristics
- Protection of vulnerable areas by area closures, through social agreements and/or fencing
- Regulations on water use and management
- Water resource monitoring
- Water resource management strategies
- Training of farmers in soil and water conservation, agroforestry, and other sustainable and profitable farming practices
- Establishing tree nurseries
- Implementation of physical soil and water conservation measures
- Water supply infrastructure management
- Etc.

9.7.2 Soil and water conservation in agriculture (Zone A)

Agriculture is the predominant form of land use in the area, with arable croplands being the main type of agriculture. Increasing recharge here will have the most significant impact on recharge in the area. Currently many soils are exposed during or after crop production, no grass, thickets, trees or any other vegetation are present to protect the lands against the erosive effect of water and wind. Consequently, soil erosion takes place, and water is lost to runoff. These challenges are strongly linked to deforestation, which is related to a high demand for wood, and suboptimal agricultural practices, such as cultivation with no or limited input of organic fertilizers.
Widespread implementation and optimization of soil and water conservation practices in the area could allow intensification of agriculture, production of higher value crops, and support conservation and recovery of ecosystem services that are fundamental for long-term sustainability, such as nutrient cycling and soil structure development.

Basic soil and water conservation (zone A1)

To counteract both wind and water erosion, it is important to start with the application of basic soil and water conservation measures. To reduce the detachment and transport capacity of water, run off should be slowed down. Soils should be kept covered as long as possible, either with vegetation or organic mulch, and flow velocities should be lowered with, for example, soil bunds. To limit wind erosion, improve microclimatic conditions on the plots and increase soil stability, it is recommended to plant trees and tree strips (also known as wind breaks), and to promote life fencing for fields and settlements. These interventions could be best implemented through adaptation of agroforestry practices.

Soil and water conservation practices for steep slopes

In agricultural areas on steep slopes (Zone A2 and A3), it is recommended, to replace arable agriculture with permanent crops, such as, for example, fruit trees and where arable agriculture is applied to add SWC practices for slopes.

Deforestation and current agricultural practices on these locations cause soil erosion. Locally, severe gully erosion is present. To address these challenges, it would be best to either ban agriculture from the most vulnerable areas, to implement biological interventions or else to move toward permanent agriculture. As perennial species provide protection throughout the year, they are more effective in counteracting erosion. At the same time these species could provide high-value products that could be processed or marketed generating additional income.

Where farmers keep to arable farming, it is recommended to promote large scale implementation of simple and practical soil and water conservation measures developed specifically for steep slopes. Proposed interventions include contour ploughing, bunds, trenches, tied ridges, grass and tree strips, and hillside terracing. These interventions could be best implemented through adaptation of agroforestry practices.

Restoration of eroded areas

In the areas that are currently severely impacted by sheet and gully erosion and areas threatened by similar challenges , first and foremost crop production and grazing close to and within gullies should be banned. A permanent vegetation cover is essential to stabilize the soils and slow-down erosion. Experience shows that these objectives can best be reached by implementing area closures and riverbank protection. Area closures are areas that are protected against all degrading human activities, including agriculture, grazing and tree-cutting. Gullies naturally have accumulation of water, fertile soils, and seeds (if retained), protection enables vegetation and soil to recover naturally, which can happen rapidly without any further interventions. To be effective it is important to delineate these closure areas and establish rules and regulations in close collaboration with communities. After vegetation is recovered, sustainable harvesting from the area can be allowed, through cut-and-carry systems, fruit harvesting or back-up grazing during emergencies, but restrictions remain in place, until soil and vegetation are fully recovered.

In addition to improved management practices, in eroded areas and gullies, erosion control structures and biological interventions could be implemented. Although dimensions of erosion control structures are variable, most are small scale and can be constructed with manual labour. Gully stabilization should start at its source. The first structures should always be placed in the upper reaches. Implementation further downstream should only be done after stabilization at the top. Biological interventions include reforestation and specifically planting tree and plant species that are effective in soil stabilization.

Water storage for agriculture

Water availability in the area could be improved by making increased use of opportunities for water storage, especially small-scale on farm interventions. Feasible interventions include hillside dams, valley tanks, small dams and ponds. These small-scale interventions can often be implemented by the farmers or communities themselves with locally available inputs. Some technical assistance in siting and design could be provided to increase awareness and effectivity of the interventions.

Implementation

As implementation of these measures on a landscape, large-scale (as it is needed) is rarely feasible and sustainable when implemented by outside organizations. It is recommended to facilitate mobilization and planning, promote and train farmers to do it themselves, but not to pay or compensate communities through cash or food for work. Often when the advantages are highlighted and success stories are shared, farmers are very willing to invest some of their time in protecting and upgrading their fields.

Table 31 provides an overview of activities for increased recharge and storage in agricultural land and how to implement and who to involve.

Table 31: Interventions for SWC in agriculture

Interventions	Activities	How	Who to involve
Basic SWC measures	Provide trainings in good agricultural practices	Farmer field schools, Exchange programmes to successful projects	Farmers and communities, local government, agricultural office, SWC-experts, agricultural experts, NGO's
SWC measures for steep slopes	Provide training on good agricultural practices and implementation of SWC measures specifically for steep slopes	Farmer field schools, exchange visits	
Permanent agriculture and agroforestry	Increase the availability of cheap tree seedlings, improve access to markets. Improve pre-and post-harvest practices and access to market	Set-up tree (commercially viable) nurseries, provide trainings on agroforestry and processing. Select and promote economically and ecologically feasible permanent crops.	Farmers and communities, local government, agricultural office, agroforestry and SWC experts
Closure areas	Promotion of closure areas, training on natural regeneration capacity of fallow lands	Exchange visits to successful projects; facilitation of agreements on delineation, rules and regulations of closure areas; farmer field schools	Communities, community representatives and leaders, local government, agricultural office, SWC-experts, agroforestry experts, NGO's
Open water reservoirs	Promote implementation of improved small-scale reservoirs by communities themselves	Agreements on (expert and material) support to own initiatives; development of promotion material explaining the need to upgrade existing reservoirs	Farmers and communities, local government, water office, water resources expert, water engineers, NGOs
Knowledge dissemination on water source management and WASH	Improve O&M, awareness raising on water point protection and post-treatment of water. Improved response to breakdowns	Technical trainings, sensitization campaigns, establishment of clear regulations and agreements on ownership, management and O&M	Farmers and communities, local government, water office, water engineers, WASH-experts, NGO's

9.7.3 Rangeland management (Zone R)

When rangelands are managed adequately, there is no need for actively implementing SWC interventions. Protection and improved management could be enough for the whole landscape to recover. Adapting and (re)introducing agreements on rangeland management practices could prove a great step forward to combating environmental degradation on rangelands. Agreements on rangelands management practices could include establishment of grazing patterns, assignment of wet season, dry season and emergency-situation grazing areas, sustainable wood harvesting, and wildlife management Locally successful rangeland management practices could be inventoried and studied by external parties, but the agreements itself should be designed and implemented at community level to be sustainable.

Additionally, new proven rangeland management strategies, such as intensive controlled grazing could be introduced. This grazing management method uses a system where cattle of a community are bunched into a large herd, which systematically grazes the area. Animals are kept in a fenced enclosure for one week, after which the enclosure is moved. It is recommended to establish and implement rangeland management activities in coordination and close collaboration with community leaders.

Soil and water conservation

Soil and water conservation measures on the ridges, could be a combination of biological interventions and on critical areas, erosion control measures could be implemented to improve vegetation cover. Biological interventions focus on the active plantation and protection of trees. Interventions could include afforestation and reforestation, preferably with native species that are known to promote soil stability. Erosion control measures include small and larger structures constructed with manual labour, such as gabion dams. Erosion control measures are, however, very often proven to failure if not properly combined with improved management and maintenance. It is, therefore, advisable to only invest in these interventions on locations where there is a direct and very visible advantage to those foreseen to maintain the structure. Construction should at all times, be supervised by an expert.

Increased water storage

Potential for water storage is similar as in agricultural land, however, water demand in rangeland areas will mostly be for livestock. Livestock water facilities could best be robust, low maintenance and easy to access. Small dams, valley tanks, and ponds are most feasible. A simple facility for the livestock to enter the reservoir could be constructed, such as a cattle ramp. The rest of the reservoir should be strictly protected and fenced to protect it from erosion and pollution. Table 32 provides an overview of activities for increased recharge and storage in rangeland, how to implement and who to involve.

Table 32: Rangeland management interventions

Interventions	Activities	How	Who to involve
Rangeland management	Establish no-, wet- and dry-season grazing areas, protect trees	Agreements with communities, establish regulations, introduction cut-and-carry practices, promote landscape stewardship, awareness campaigns	Communities, community representatives and leaders, local government, agricultural office, rangeland experts, NGO's
Biological interventions	Improving the availability of seedlings, protection of trees, sustainable harvesting practices, tree-planting with species for fodder, wood, food	Set-up tree (commercially viable) nurseries, establishment of conservation areas, plantation campaigns,	
Erosion control structures	Recovery of eroded areas with physical interventions. To be built (only) in combination with area closures	Community mobilization	Communities, local government, agricultural office, rangeland experts, NGO's, SWC experts

9.7.4 Forest management and forest plantations (Zone F)

Within the agricultural areas and rangelands there are few areas with natural tree cover. In these areas, forest development, management and protection should be actively promoted. Herein, forest management refers to agreements on sustainable use of forested areas, including controlled harvesting of wood and other natural products. Tree cover could actively be increase by planting (indigenous) trees that provide valuable outputs such as wood, fodder for livestock, nuts and fruits. Table 33 provides an overview of activities for implementation.

Table 33: Interventions on severely eroded areas

Interventions	Activities	How	Who to involve
Forest restoration and Forest plantations	Establish protected forest areas and forest plantations. Improving the availability of seedlings, protection of trees, tree-planting project, delineation of forest areas	Agreements with communities. Set-up tree nurseries, establishment of conservation areas, plantation campaigns	Communities, community representatives and leaders, local government, agricultural office, SWC-experts, agroforestry experts, NGO's
Afforestation	Increase availability of tree seedlings, provide training on reforestation practices	Set-up tree nurseries. Farmer field schools, exchange visits to successful projects	Community representatives, local government, agricultural/forestry office, forestry experts with knowledge of local tree species

9.7.5 Recovering wetlands/floodplains (Zone W)

As described before, wetland management and restoration will be essential to maintain their ecosystem services. Especially for water resources, wetlands are extremely important for flood buffering, filtration, and recharge and wetlands should therefore be a priority in water resources management. The remaining natural wetlands should be evaluated and protected.

Protection and restoration

The most crucial wetlands in terms of biodiversity, ecosystem services including flooding mitigation, water buffering and filtration are the remaining semi-natural marshlands in the area (Zone W3). These areas should become strictly protected, while other wetland areas could be used for sustainable production, including fishing, and regulated harvesting of reeds and papyrus. Strict regulations for protection and sustainable use have to be implemented in cooperation with the communities.

Other (seasonal) flooding areas and floodplains within zone W1 can be used for agriculture and/or grazing, but should be actively managed as wetlands. Herein wetland management refers to agreements on sustainable use of wetlands areas; through flood adapted agriculture and vegetation cover management and protection of central flooding areas and buffer zones. Including controlled harvesting of grass and other natural products.

Currently, very few marshlands, open water bodies, streams and even large rivers (zone W3 and W4) have a riparian buffer zone. Land clearing and cropping takes place far into the river floodplains up until the river edge. This creates several problems, including bank erosion, surface runoff with silt and pollutants directly enter the river and a reduced peak-flow buffering capacity of the river system. Riverbank protection should be implemented to protect these areas. Riverbank protection includes agreements and measures against clearing, construction of buildings, grazing, arable farming and tree-cutting. In addition, tree planting, wildlife management could augment the ecological and economic value of wetland and riverine areas.

Soil and water conservation in wetlands

It is not recommended to use the central parts of wetlands (zone W1), which flood every year, for production of arable crops. Crop production is possible in and close to seasonal floodplains, but only if adapted to flooding conditions and if combined with a series of erosion control interventions. Advanced water management is already implemented in the irrigated rice fields (zone W2), here SWC could be improved by protection of the banks of the streams with trees or erosion controlling grasses and increased marshlands as natural buffer for water, pollutants, and sediments.

In the other wetland areas (zone W1) outside of the main flooding areas, increased SWC and storage can be attained by floodwater spreading and floodwater diversion by means of bunds and ditches, and storage in small reservoirs. To prevent crop failure, either flood resistant crops should be grown, or crops should be grown outside the flooding season. Erosion could be controlled on land used for agriculture, by combining a series of interventions, such as mulching, grass and tree strips soil bunds, and life fencing. In addition, agricultural practices in which different types of vegetation are combined, such as agroforestry, could be promoted.

Table 34: Wetland management interventions

Interventions	Activities	How	Who to involve
Protection of marshlands and other important wetlands	Promotion of closure areas, establishment of regulations, awareness creation, training on sustainable use of wetlands	Exchange visits to successful projects; facilitation of agreements on delineation, rules and regulations of closure areas.	Communities, community representatives and leaders, local government, agricultural office, SWC-experts, agroforestry experts, NGO's
Flood-adapted agriculture	Provide training on flood-adapted agriculture and functioning of wetlands; study the opportunities for floodwater spreading	Farmer field schools, exchange visits, consultancy project	Farmers and communities, local government, agricultural office, SWC-experts, agricultural experts, NGO's
Riverbank protection	Promotion of riverbank protection, training on the functioning and importance of wetlands	Exchange visits to successful projects; facilitation of agreements on delineation, rules and regulations of closure areas; farmer field schools	Farmers and communities, local government, agricultural office, SWC-experts, forestry/agroforestry experts, NGO's

10 Current water supply situation

10.1 Domestic water supplies

Ground water is the most important source for the urban and rural water supplies in Eastern Province. Most of the water supplies are fed by springs, and only a few large towns do have surface water-based water supplies with associated treatment plants (Rwamagana, Nyagatare). The rural water supplies mainly comprise of protected springs and boreholes equipped with handpumps but more recently small solar energy- based systems have been constructed.

The purpose of the study is to assess the groundwater resources situation in Eastern Province with the aim to improve the water supply situation. Ground water can be developed in various ways, and to be able to recommend the most appropriate type of development more information is required about the location of the demand areas and the required volumes.

A detailed analysis of the demand and present water supply infrastructure is beyond the scope of the current project. Nevertheless, we will give some general suggestions on the most appropriate type of groundwater development for the different water supply situations in Eastern Province in general, and for the three target districts specifically that can be used for a groundwater development strategy. It should be noted however that detailed development plans need to be prepared as a combined effort of the different stakeholders based on an analysis of the existing infrastructure, the demand area characteristics and the groundwater development strategy.

The piped water supply systems in the area do usually work, but the biggest challenge is the insufficient amounts of water available to the systems.

Many handpump boreholes have been drilled in the area but the functionality rate is very low. No proper maintenance system is present.

10.2 Other water supplies

Livestock water supply is mainly formed by dams and in some places small solar energy-based systems have been developed for livestock watering. Water supplies for livestock could be developed in the appropriate areas for livestock development and groundwater development.

Groundwater development for agricultural purpose should only be considered in case of high value crop agriculture. Large-scale irrigation requires large volumes of water (up to 1l/s/ha) and these requirements are better met with the development of surface water resources especially in this area where surface water is abundant.

Surface water development for large-scale agriculture in Bugesera.

Picture 34: Large scale surface water development for agricultural use in Bugesera

Picture 35: Small system for domestic use next to dam for livestock use

Picture 36: Water kiosk

11 Recommendations

In addition to recommendations that were stipulated as expected outputs in the ToR, the consultant will make recommendations on other relevant sector topics based on observations made during the execution of the project.

11.1 Strategic recommendations

11.1.1 Ground water development

Ground water can play an important role in the water supply for the Eastern Province. Ground water is the preferable resource for drinking water supply in both rural and urban context, because of its reliable quality and quantity. Ground water can be used for irrigation purposes, especially small-scale drip irrigation of high value crops. However, the transmissivity of the aquifers will limit the production in most areas, and the expenses of ground water development might be too high for it to be economically feasible. Therefore, surface water is the preferred resource for irrigation. The development of ground water should be more coordinated between the various stakeholders. NGOs implement point sources in areas where piped systems are already existing but not working. Regional /district / catchment water development master plans should be prepared based on integrated water management principles to ensure efficient and effective use of financial and (ground)water resources. A close collaboration between RWFA/MINIFRA/WASAC/Districts/NGOs is required.

11.1.2 Water supply system development and management Planning

There is need for a water supply development master plan at a regional / district / catchment scale. This planning process will enable the selection of the most appropriate water resources for each demand, and ensure water supply development activities are coordinated and streamlined.

11.1.3 Construction design

The point water sources (boreholes)in Eastern Province have a very low functionality rate. Many of the boreholes are not working, at the same time, new boreholes are considered in areas where existing piped water supply infrastructure is located. The main reason appeared to be that the piped water supplies were not able to deliver water regularly to the village because of a lack of water or inadequate piped systems. In view of the above, the consult suggest focussing on improving the piped system by repair / rehabilitation / extension of the piped system, rather than making small solar-based systems / handpump boreholes in areas where there is already a piped system. The consultant suggests increasing the delivery capacity of the piped systems by additional supply of groundwater to the existing storage tanks. For this purpose, well-fields need to be identified and developed. The groundwater potential map clearly indicates the target areas where high-yielding boreholes can be drilled.

11.1.4 Operation and maintenance

WASAC is the operator of the piped systems but may be given the responsibility to maintain the handpump boreholes in the operational service areas which cover the whole of Rwanda. Otherwise, alternative solutions of better maintenance schemes should be developed.

11.1.5 Groundwater monitoring

Groundwater monitoring is of utmost important for the management of the groundwater resources. Two types of monitoring boreholes normally exist, one being boreholes that measure the natural situation without being influenced by other boreholes and the other being monitoring boreholes that monitor the impact of groundwater abstraction in other boreholes. When implementing new monitoring, focus should be given to installation of (new) high production boreholes so that aquifer characteristics can be better gauged.

The existing network consists of a number of boreholes in different natural environments with variable hydrogeological characteristics where no nearby pumping is taking place. There is no clear selection procedure for the location of these boreholes. This procedure, as well as a better understanding of how the monitoring information can be best used, should continue to be developed within RWFA.

Additionally, there is need to incorporate abstraction impact monitoring boreholes in areas with large abstraction for town / irrigation water supplies (currently not existing in Eastern Region).

11.1.6 Regulation and enforcement

Borehole siting and drilling

The RWFA should ensure that there is an enabling environment for all stakeholders to follow the required procedures for various water development activities, in order for RWFA to be able to carry out proper management. Recommendation for an enabling environment is given in the strategic recommendations below. The following standard procedures are to be developed:

- Borehole siting
- Borehole drilling and test pumping

For the specific steps to be followed for borehole siting and deliverables to check each step, please refer to Annex 4. Here an extensive checklist for geophysical surveys inclusive of desk study and interpretation is put forward.

Among the steps to be taken during the desk study before any field work, are as follows:

1. Get correct coordinates of location
2. Get correct coordinates of preferred sites
3. Asses topography
    a. Topographical maps
    b. Google earth
    c. Satellite
4. Asses geology
    a. Geology of preferred sites
    b. Geology of surroundings
    c. Faults and fractures
    d. Geology in relation to high yielding boreholes
5. Source/ borehole data
    a. Water source location map
    b. Ground water potential map
    c. Water quality
    d. Success rate
    e. Depth to bedrock
    f. Borehole yield
    g. Static water level
    h. Water strikes
    i. Calibration (geophysical) done on nearby (successful) boreholes
6. Geophysical data nearby
    a. Overview of earlier geophysical surveys nearby (results, correlation with high yielding boreholes or failed sites. Comparison of anomalies and curves to get correlation between shape and success (localized, difficult to correlate beyond local geology and topography)
    b. Arial photos (if available) give higher resolution than satellite.
7. Lineament analysis (different colour for each type of lineament)
    a. DEM (contours)

  b. Topographic maps
  c. Rivers
  d. Google earth
  e. Hill-shade
  f. Fractures and faults geological map
8. Targets for geophysics
  a. In sediments no 1D profiling, VES and ERT only. High resistivities are targets
  b. For hand pump boreholes in flat areas 2 profiles perpendicular. Otherwise target lineament or valley if less than 1000m from preferred site
  c. For production boreholes, target lineaments and valleys only. Cross in different places (orientations)

For an example of a drilling supervision sheet that can be followed as an industry standard in the country please refer to Annex 6. Here a layout and outline along with explanation of characteristics to be recorded and in what form, during drilling. If all characteristics are recorded, gaps in data pertaining to borehole characteristics can be filled as new boreholes are drilled. Among the characteristics to be recorded are:

9. Drilling progress
  a. Date/time
  b. Drilling rod nr.
  c. Depth
  d. Time per rod
  e. Penetration rate (calculated from time per rod)
  f. Formation log and activities (lithology, fractures etc)
  g. Remarks
10. Drilling specifications
  a. Depth from – to (specifications can change with depth)
  b. Bit characteristics (type, diameter)
  c. Drilling method
11. Lining installed
  a. Information pertaining to casings
  b. Diameter, type, material, screen (according to depth)
12. Filling
  a. Gravel pack, backfill, seal, packer or bottom plug.
13. Yield test during drilling
  a. Total yield, per aquifer yield, aquifer type
14. Lithology description
  a. Particle sizes
  b. Overall colour
  c. Mineral colours
  d. Remarks
  e. Interpretation (hydrogeologist needs to be present (supervisor))
15. Development
  a. Method of development
  b. Time spent
  c. Remarks
16. Borehole penetration rate, lithology and design
  a. Visual representation (Log)
17. Signed daily instructions from supervisor to driller
  a. Serves as memorandum of understanding between supervisor and drilling and gives opportunity to assign responsibility if needed.

Groundwater resource management

Ground water resource management has two main components:

- Protected and increased recharge through soil and water conservation and protection and restoration of valuable ecosystems
- Work with land use authorities and other partners to adopt policies and practices and procedures that preserve ground water recharge areas, minimize risk of ground water contamination and that ensure plentiful supplies of high-quality ground water
- Regulations of abstractions based on generic volumes and specific abstraction monitoring (see licensing).

Although generic estimates can be made on aquifer characteristics such as recharge and potential yields of boreholes, due to the fragmented nature of the hydrogeology, sustainability of abstractions will have to be based on local monitoring of abstractions and custom-made licenses for larger abstraction.

11.1.7 Licensing / permits

A licensing system needs to be implemented for:

- Drilling contractors: drillers need licenses to be issued by RWFA. The issuance of the license and renewal are subjected to performance of the contractor. The performance will be linked to the procedures set out in standard procedures. This license is normally given by RDB.
- Ground water consultants: a licensing system for ground water consultants could help the RWFA to regulate the drilling sector. The professionals need to be trained and then used and be involved in ground water development projects, from designing contract documents to certification of final products being the water supplies. The professionals should ensure that borehole siting projects are carried out according to standard procedure and that contractors follow standard procedures during drilling. Licensing the consultants will allow RWFA to know which professionals are operating in the country and their performance.
- Ground water abstraction permits: a system needs to be developed to ensure that water resources are used in a sustainable way. Abstraction permits shall be required for all drilled boreholes. However, abstraction impact monitoring boreholes should be a condition to give permit for above certain threshold abstraction volumes (e.g. larger than 50 m^3/day) and shall be linked to self-regulatory requirements (collection and submission of production and water level data).
- Drilling permit: the licensing permit system could also have a borehole drilling permit component for production boreholes (boreholes that are to be equipped with submersible pumps). The permits need to be requested before drilling starts. Drillers cannot start drilling without such a permit. This will allow RWFA to monitor any production

Borehole numbering: RWFA should implement a source numbering system. Such a system is not only required to facilitate the various licensing / permits system but is also required for the implementation of a groundwater database.

11.1.8 Information management

A lot of ground water related information has been lost in the past 2 decades. Infrastructure has been developed but no investigation, construction and operational data have been collected and/or stored. In addition to the suggestions for enforcement of data collection and submission requirements, RWFA should set up a ground water database to store, validate, analyse and disseminate the generated information. The database should be used to generate technical information, functionality information and water level and abstraction monitoring information. The database could also be extended with a section for the permits suggested above.

11.2 Specific recommendations

11.2.1 Groundwater potential

Since there is high annual recharge and outflow of the shallow aquifer, sustainable abstraction can be as high as the local aquifer allows. Groundwater abstraction from the basement rock - overburden will be mostly limited by the hydrological conductivity of the aquifer formation, rather than recharge or limitations due to sustainability."

The ground water potential map and many other maps are based on the limited amount of information available. All information that becomes available should be used to prepare updated maps which will definitely lead to more reliable outputs and a better understanding of the hydrogeology of the Eastern Province. Special attention should go to the collection of borehole data during drilling, collection of static water levels and water quality information.

11.2.2 Groundwater development

General

As discussed above the development of ground water resources for domestic and other use should be part of an integrated water development plan for an area.

The point water sources (boreholes)in Eastern Province have a very low functionality rate. Many of the boreholes are not working. The current study had to focus on new boreholes and found that even new boreholes were considered in areas where existing piped water supply infrastructure is located. The main reason appeared to be that the piped water supplies were not able to deliver water regularly to the village because of a lack of water or inadequate piped systems.

In view of the above the consult suggest focussing on improving the piped system by repair / rehabilitation / extension of the piped system rather than making small solar-based systems / handpump boreholes in areas where there is already a piped system. The consultant suggests increasing the delivery capacity of the piped systems by additional supply of groundwater to the existing storage tanks. For this purpose well-fields need to be identified and developed. The groundwater potential map clearly indicates the target areas where high yielding boreholes can be drilled.

WASAC is the operator of the piped systems, but could also be given the responsibility to maintain the handpump boreholes in the operational service areas which cover the whole of Rwanda.
The following activities could be part of such a plan if the demand areas have been identified:

1. The first step that is required is the mapping of the demand areas. The demand map should be overlain with the groundwater potential map.
2. Then, the existing infrastructure should be mapped.
3. If there is an existing piped system or where there is an extension, or a new system is planned then:
    a. In the areas indicated by spring potential the first step would be the identification of high capacity springs in an area. The demand and suitability for its use should be evaluated. If the demand cannot be met, the following steps should be considered.
    b. Hydrogeological surveys in Target 1 and Target 2 areas as close as possible where the water is needed (reservoirs).
    c. Water can be pumped from the springs and/or the boreholes to the existing and/or planned storage reservoirs from where it will be gravitated to the kiosks, house connections or other reservoirs.

Picture 37: Storage reservoirs existing piped scheme

Borehole siting

It is highly recommended that hydrogeological surveys including geophysical survey are to be carried out following certain guidelines. Geophysical measurements are only useful when they are carried out as part of a detailed hydrogeological study and focus on target sites identified during the hydrogeological study. The guidelines for a detailed hydrogeological study are given in Annex 4.

It is highly recommended that local consultants and NGOs involved in borehole siting are trained in the use of these guidelines.

The approach for identifying drill sites depends on the purpose and the location of the planned borehole. In all cases, profiles should be aimed at crossing lineaments if they have been identified.

1. Major valleys underlain by faults/fractures:
    a. Handpump borehole: run profile along the lower slope close to the valley but not in the clays. Drill on an anomaly on the profile. One can also run a profile from the bottom of the valley 200 m upward and drill a borehole on an anomaly.
    b. Production wells: run profiles perpendicular over the valley if possible. Drill at the best anomaly. If not possible follow the procedure for handpump boreholes and carry out a profile along the valley.
2. Valley cutting through Quartzite
    a. Handpump borehole: drill in centre of the valley, but better carry out survey with profiling and VES
    b. Production well: run profiles perpendicular to the valley if possible. Drill at best anomaly. If not possible follow the procedure for handpump boreholes.
3. Fissured fractured rocks, lower slopes / minor valleys
    a. Handpump borehole: short profiles and VESes can be carried out. Usually enough water for a handpump.
    b. Production wells: carry out a survey as detailed as possible.
4. Granites / gneisses:
    a. Handpump boreholes: run profile as low as possible on the slope.
    b. Production wells: not applicable, only on lower slopes related to structurally controlled valleys.

Borehole drilling and designs

Borehole drilling is done by a few drilling companies and NGOs in Rwanda. There are no guidelines for the drillers to follow. Drilling project tender documents usually do not have specifications for the drilling techniques, borehole design and pumping test to be carried out and the reports to be produced. Some of the high yielding boreholes have 4" casings which will limit the size of the pump and hence the maximum capacity of the borehole.

It is highly recommended that the national borehole drilling guidelines are developed.

Drilling supervision

The borehole drilling is not supervised which will have an impact on the final quality of the work. The absence of a supervisor also means that hardly any information is recorded during the drilling which is of utmost importance for a better understanding of the hydrogeology in Rwanda.

It is highly recommended that local consultants, NGOs and government staff and drilling company staff are to be trained in drilling supervision. Guidelines for drilling supervision and data collection forms are given in Annex 6.

11.2.3 Recharge enhancement

Water balance and recharge strategy

Based on the SWAT simulation for the Eastern Province model, average annual rainfall in the Eastern Province is 957mm or 9,967Mm^3. On average 65% (626mm, 6,520Mm^3) of the precipitation leaves the catchment in the form of evapotranspiration, while 14% (130mm, 1,357Mm^3) becomes surface runoff which together with return flow from groundwater to streams (10%) leaves the catchment as streamflow. Percolation to groundwater or ground water recharge is 15% (140mm, 1,464Mm^3), of which a large part is recharge from the large wetlands and lake systems, groundwater recharge outside these areas is approximately 8%.

Looking at these figures, the most gain in ground water recharge can be obtained from reducing surface runoff through increasing infiltration, and storage and recharge of streamflow. The most effective way of reducing surface runoff is through appropriate land use planning and SWC. Protection and restoration and SWC techniques for increased surface infiltration include, reforestation, agroforestry, rangeland management, mulching and terracing. SWC techniques for interception of surface runoff include, contour ploughing, contour bunds and trenches, half-moons, swales, grass and tree strips, etc.

Promoting forest protection, agroforestry and wetland management

Most of the land in the Eastern Province, except for protected areas, is deforested and almost all indigenous tree cover has been removed, and the land is mostly used for agriculture currently. For conservation of biodiversity and to keep on benefitting of vital ecosystem services, including water resources services, the remnants of all remaining natural forests and other semi-natural ecosystems should be protected. Moreover, restoration of the ecosystem could take place through promotion of agroforestry. To increase water recharge, biodiversity and the ecosystem in general, more (indigenous) tree species matching the local ecosystem could be adopted into the plantations and agroforestry systems. This approach would be greatly in line with the practices to implement the Green Growth and Climate Resilience (GGCR) Strategy presented in the State of the Environment and Outlook Report, 2015.

Wetlands provide vital ecosystem services, including sediment and pollution retention, flood mitigation and groundwater recharge. Wetland ecosystems in the Eastern Province are under great threat due to the constant pressure from human activities; especially conversion of wetlands into agricultural land has a huge impact. Wetland management and restoration will be essential to maintain the above described ecosystem services. Especially for water resources, wetlands are extremely important for flood buffering, filtration, and recharge and wetlands should therefore be a priority in water resources management. Riparian buffer zones should be implemented to protect streams and rivers from pollution and erosion.

11.2.4 Point recharge interventions

Due to the complex hydrogeology of the most prevalent geology in the project area, i.e. crystalline basement rocks with a relative shallow overburden with low hydraulic conductivity and fractured aquifer systems, point recharge technologies such as infiltration wells might not be efficient for large scale application. These technologies depend on the hydraulic conductivity of the aquifer for their infiltration capacity. In addition to this, the complexity of the aquifer makes it difficult to predict the relation between the recharge-point and abstraction, especially in the deep fractured aquifers.

Riverbank infiltration is a feasible alternative for large water supply systems. It is preferable over direct surface water abstraction because of the high-water quality due to the natural filtration, and it is preferred over deep groundwater because of the easy drilling and the high yields that can be obtained. It is highly feasible in along some rivers in the Eastern Province; especially the Nyabarongo River has favourable conditions in the wide alluvial plains along the river. Other rivers in the Eastern Province should be further investigated for their potential. In addition, along perennial rivers that do not have favourable formations in their banks, artificial infiltration galleries can be constructed to provide (pre-)filtration for water intakes.

11.2.5 Water storage interventions

Usually ground water is the preferred option for drinking water supply systems, due to the quantitative and qualitative reliability. However, in areas where groundwater is not available or at high cost, water storage interventions can be considered. Additionally, water storage facilities are often preferable over groundwater systems for irrigation and livestock water supply.

The pronounced valleys with clay soils and underlying basement rock are feasible for valley dams. These can be large dams for irrigation purposes, but more upstream smaller dams could also be constructed as source for water supply to rural communities. Many large dams are already present and additional sites have been located in for construction of new dams throughout the Eastern Province in various studies. Therefore, more attention could go to alternative small-scale water storage interventions, which have high potential but are still underutilized in the area. In addition to this, dams, valley tanks and ponds could be constructed. The advantage of ponds is that they can be constructed in flat to gentle sloping areas where a dam would not provide efficient storage. To make water storage facilities financially more affordable for community water supply, multipurpose reservoirs could be constructed. These reservoirs could serve as source for irrigation, livestock water supply and domestic water supply.

While many (large) valley dams are present in the area, few small-scale farm ponds and dams are present. These reservoirs can be constructed manually by the communities and are built of soil by an excavation and or an embankment in a natural depression or hillside where runoff accumulates. The reservoirs collect local runoff or water from hillsides, rocks, roads or small streams.

11.2.6 Implementation

A general storage and recharge enhancement map was prepared for the Eastern Province, which provides the recommended interventions per landscape zone. This map can be used for overall planning of activities that focus on recharge and storage. However, most interventions are targeting more than that and require involvement of other sectors, especially agriculture. Therefore, an integrated approach is required, to water management and natural resources management as a whole, such as Integrated Water Resources Management (IWRM) or Integrated Catchment Management (ICM).

All interventions should be brought under a catchment management or IWRM strategy and specific catchment management plans should be developed for each sub-catchment. Within these sub catchments, micro-catchments can be formed in which local stakeholders are represented. These plans should align with existing policies and practices in Rwanda, including the Rwanda Water Resources Master Plan.

To be able to reach scale in a sustainable manner, there is a great need for further development of the ‘soft’ component of catchment management. This includes formal and informal regulation, capacity development, training, awareness creation, and facilitation of the management process. All the land users will need to change their behaviour towards land use and all farmers need to adopt SWC strategies and other catchment management activities in their land.

Specific recommendations for implementation were provided for each landscape zone in Chapter 8.

11.2.7 Integrated development and management approach

In view of the above it is clear that the different stakeholders (RWFA, MININFRA, WASAC, Districts, NGOs, private sector consultants, drilling companies and water supply contractors) need to join hands to ensure a sustainable and efficient development of the groundwater resources in the Eastern Province. There is a need for implementers, regulators and operators in the sector to set guidelines focus on their mandates and respect the mandates of the other stakeholders.

For effective, efficient and sustainable development of water resources in the Eastern Province, there is a need for a joint systematic approach by the stakeholders:

1. an assessment of the current status of each of the piped schemes in Eastern Province
2. an assessment of the location and size of the demand centres in the districts
3. An assessment of the yields of the springs
4. An assessment of the existing borehole status and yields

As soon as this information is available the results of the current project together with the above information can be used for a planning stage.

That information will be compiled in a district/provincial water development plan where all stakeholders will be involved. The districts will be the lead actor in the initiation / planning prioritisation of the of the assessment and development activities by districts, NGOs and WASAC.
The additional supplies can be designed as soon as the additional water is secured through the development of springs, equipment of existing boreholes and the drilling of new boreholes. The major stakeholders must play the following roles:

1. WASAC will be in charge of the design of the schemes and construction supervision of the boreholes and the water supplies. RWFA needs to ensure that the drillers and consultants hired by WASAC are following the procedures and guidelines for drilling activities and borehole siting according to procedures given in the outputs of the current project.
2. WASAC will maintain the existing and new systems (operated by WASAC and private operators) and point sources (operated by communities) that fall under their service areas.
3. The water supply operators will record the water levels and production rates and RWFA will receive, store, process and analyse the information.
4. Proper ground water management needs to be based on reliable ground water data. One of the biggest challenges is the collection of ground water information. There is no habit in the recording of drilling activities and lack of well logs and the habit of not recording and obligation of RWFA has requested stakeholders to fill forms for boreholes already drilled. These forms still need to be collected from the stakeholders and the processed and stored in a database. The collection of borehole data is best done

during the actual drilling of the boreholes. The drilling is normally supervised by an independent person who also collects the information. This information should ideally be collected, processed, stored and analysed by RWFA,

5. RWFA must develop a license for consultants and drillers and these actors will only get a license when they comply with a code of practice set by RWFA.

Ground water resources management requires information on the changes in the status of the water resources which is based on rainfall data, ground water and surface water abstraction data, ground water levels and stream discharges and water quality information.

RWFA has embarked on a ground water monitoring programme with the aim to monitor the static ground water level, which is a good start. The ground water monitoring should be extended to the areas where ground water abstractions will affect the ground water table. Ground water levels and production rates should be monitored. RWFA should also consider using existing non-functional handpump boreholes as monitoring wells rather than drilling new boreholes for ground water monitoring.

11.3 Summary short term way forward

For the drilling projects in pipeline the following activities are suggested:

1. Planning of locations for drilling based on siting results of this project.
2. Confirmation of drilling locations using 1D geophysics and placement of concrete anchored pegs at drill locations. Siting exercise can be used as training in basic surveying.

It is recommended to look for an experienced drilling company to carry out the following activities:

3. Siting for part or all of the remaining drilling projects in pipeline boreholes. It is suggested that an experienced drilling company trains local companies on the job in borehole siting from the desk study phase to the reporting phase. Local companies can apply for the training and will be part of the siting exercise under supervision of that experienced drilling company and RWFA. The local companies will learn how to site boreholes following the siting procedures suggested in the current report (Annex 4).
4. Drilling supervision of the drilling projects in pipeline. It is suggested that the experienced drilling company will train ground water professionals of the RWFA, WASAC, MININFRA and private sector on the job during the drilling of boreholes for the drilling projects in pipeline and/or the WASAC drilling interventions.

For Bugesera it is recommended:

5. To design a detailed exploration project for the assessment of the alluvial aquifer. The project should focus on the mapping of the sediments of the Nyabarongo / Akagera river north of Juru (20 days) and also carry out exploration in other parts of the alluvial plain between this spot and the RN15 bridge (5 days). The project should have an exploration drilling programme during which approximately 15 exploration wells (5” casings) to 25 m should be drilled and test pumped in the first area and 5 wells in other areas identified during the geophysical fieldwork. If the programme is successful large diameter production wells can be drilled.

ANNEXES

Annex 1. Borehole data

Annex 2. Results Geophysical survey

Annex 3. Results Test pumping

Annex 4. Hydrogeological study guidelines and checks

Annex 5. JICA 2014 Geophysical data

Annex 6. Drilling supervision guidelines and forms

Annex 7. A3 format maps

Annex 8. Data attachment

Annex 1. Borehole data

DB_ID	DB_SOURCE	KEY	Type_S_D	X	Y	ALT GPS	DEM	NAME_2	Sector	Village	Cell	Source_nai	Funder	Contractor	Status	Success	Failure	SWLBGL	Comment	Last_visit	Installati
1	DB_GILBERT	BH-EP-GAT-RWI-201		214171	9820120	1437	1474.427	Gatsibo	Rwimbogo			Ndama		Drillcon Ltc	Successful	1	0	1453			28/01/2007
2	DB_GILBERT	BH-EP-GAT-RWI-202		229654	9830627	1317	1300.612	Gatsibo	Rwimbogo			Mucucu IV		Drillcon Ltc	Successful	1	0	1301			02/05/2007
3	DB_GILBERT	BH-EP-GAT-RWI-203		232495	9827510	1357	1353.565	Gatsibo	Rwimbogo			Mucucu I		Drillcon Ltc	Dry	0	1	1354			02/07/2007
4	DB_GILBERT	BH-EP-GAT-RWI-204		232491	9827507		1353.565	Gatsibo	Rwimbogo			Mucucu III		Drillcon Ltc	Dry	0	1	1354			02/09/2007
6	DB_GILBERT	BH-EP-KAY-GAH-201		230995	9807708		1460.748	Kayonza	Gahini			Kahi		Drillcon Ltc	Dry	0	1	1461			23/03/2007
7	DB_GILBERT	BH-EP-KAY-GAH-202		232329	9796800		1439.296	Kayonza	Gahini			Tsima I		Drillcon Ltc	Dry	0	1	1439			24/03/2007
9	DB_GILBERT	BH-EP-NYA-KAR-201		208764	9845728	1359	1343.216	Nyagatare	Karangazi			Mbare II		Drillcon Ltc	Successful	1	0	1343			04/04/2007
10	DB_GILBERT	BH-EP-NYA-KAR-202		210139	9846486	1360	1343.714	Nyagatare	Karangazi			Karangazi II		Drillcon Ltc	Successful	1	0	1332			15/12/2006
11	DB_GILBERT	BH-EP-NYA-KAR-203		209023	9845003	1361	1344.29	Nyagatare	Karangazi			Karangazi I		Drillcon Ltc	Successful	1	0	1332			18/12/2006
12	DB_GILBERT	BH-EP-NYA-KAR-204		208208	9831076		1365.735	Nyagatare	Karangazi			Karama		Drillcon Ltc	Dry	0	1	1366			04/09/2007
13	DB_GILBERT	BH-EP-NYA-KAR-205		210052	9833556	1362	1364.348	Nyagatare	Karangazi			Musenyi II		Drillcon Ltc	Successful	1	0	1347			23/01/2007
14	DB_GILBERT	BH-EP-NYA-KAR-206		209727	9834038		1360.969	Nyagatare	Karangazi			Musenyi I		Drillcon Ltc	Successful	1	0	1361			05/07/2007
15	DB_GILBERT	BH-EP-NYA-NYA-201		206894	9855907		1354.955	Nyagatare	Nyagatare			Burumba I		Drillcon Ltc	Successful	1	0	1326			09/01/2007
16	DB_GILBERT	BH-EP-NYA-NYA-202		201294	9849448	1370	1442.625	Nyagatare	Nyagatare			Bushoga		Drillcon Ltc	Successful	1	0	1436			16/02/2007
17	DB_GILBERT	BH-EP-NYA-NYA-203		203135	9859257	1429	1334.395	Nyagatare	Nyagatare			Barija		Drillcon Ltc	Successful	1	0	1331			
18	DB_GILBERT	BH-EP-NYA-KAT-201		204704	9839764	1472	1371.036	Nyagatare	Katabanyemu			Nyakigando		Drillcon Ltc	Dry	0	1	1341			01/01/2007
19	DB_GILBERT	BH-EP-NYA-KAT-202		200361	9840510	1397	1392.855	Nyagatare	Katabanyemu			Rutoma		Drillcon Ltc	Successful	1	0	1391			09/03/2007
20	DB_GILBERT	BH-EP-NYA-KAT-203		202565	9838250	1387	1383.943	Nyagatare	Katabanyemu			Ntoma		Drillcon Ltc	Successful	1	0	1367			03/03/2007
21	DB_GILBERT	BH-EP-NYA-KAT-205		200076	9836628		1423.88	Nyagatare	Katabanyemu			Kigarama		Drillcon Ltc	Dry	0	1	1424			
22	DB_GILBERT	BH-EP-NYA-MAT-202		216151	9881418	1308	1302.21	Nyagatare	Matimba			Cyembogo II		CGC	Successful	1	0	1302			10/01/2007
23	DB_GILBERT	BH-EP-NYA-MAT-203		216615	9882192	1296	1299.612	Nyagatare	Matimba			Kagitumba I		CGC	Successful	1	0	1300			05/01/2007
24	DB_GILBERT	BH-EP-NYA-MAT-204		214732	9876096	1330	1333.699	Nyagatare	Matimba			Matimba I		CGC	Successful	1	0	1334			
25	DB_GILBERT	BH-EP-NYA-MAT-205		212591	9881500	1323	1319.304	Nyagatare	Matimba			Mitayaya/Rwentanga		CGC	Successful	1	0	1319			16/01/2007
26	DB_GILBERT	BH-EP-NYA-MAT-206		211547	9880048	1322	1322.024	Nyagatare	Matimba			Nyabweshongezi II		CGC	Successful	1	0	1322			20/01/2007
139	DB_GWM/DB_GILI	BH-EP-NYA-KAR-210		206847	9842572		1356.321	Nyagatare	Karangazi		Mbare	Mbare		CGC	Successful	1	0	1336	Abandonec	18/02/2016	29/05/2007
140	DB_GWM/DB_GILI	BH-EP-NYA-MAT-207		214792	9882466	1303	1298.307	Nyagatare	Matimba	Kamahoro		Cyembogo I		CGC	Successful	1	0	1288	Abandonec	18/02/2016	13/01/2007
141	DB_GWM/DB_GILI	BH-EP-NYA-MAT-201		216302	9883080	1297	1298.87	Nyagatare	Matimba	Muvumba	Kagitumba	Musenyi		CGC	Successful	1	0	1276	Abandonec	18/02/2016	03/01/2007
143	DB_GWM/DB_GILI	BH-EP-NYA-TAB-207		197903	9837220	1407	1392.956	Nyagatare	katabagemu			Katabanyemu		Drillcon Ltc	Successful	1	0	1390	confined	18/02/2016	18/03/2007
187	DB_1ST/DB_W4GRR		BH Rehab	219316	9796696	1452	1455.972	Kayonza	Gahini	Gsgahini			LWI		Successful	1	0	1455			13/05/2011
188	DB_1ST			206554	9797825	1458	1446.858	Gatsibo	Kiramuruzi	Nyabisindu			LWI		Successful	1	0	1444			23/09/2011
189	DB_1ST			199084	9782178	1411	1418.612	Rwamagan	Gahengeri	Kiruruma			LWI		Successful	1	0	1416			17/01/2011
190	DB_1ST			179314	9767867	1346	1339.283	Bugesera	Mwogo	Rurenge			LWI		Successful	1	0	1335			17/07/2008
191	DB_1ST			221435	9841657	1339	1327.252	Nyagatare	Nyagatare	Bushoga			LWI		Successful	1	0	1323			20/10/2011
192	DB_1ST			210420	9849873	1348	1346.129	Nyagatare	Nyagatare	Ryabega			LWI		Successful	1	0	1342			11/11/2011
193	DB_1ST/DB_GWM			209735	9824067	1424	1428.495	Gatsibo	Kabarore	Bihinga	Kabarore II		LWI		Successful	1	0	1421	Abandonec	19/02/2016	27/09/2011
194	DB_1ST			193318	9783512	1342	1381.064	Rwamagan	Muyumbu	Akinyambo			LWI		Successful	1	0	1374			14/01/2011
195	DB_1ST			214495	9824284	1395	1418.054	Gatsibo	Kabarore	Nyabikiri			LWI		Successful	1	0	1410			22/09/2011
196	DB_1ST			182620	9743411	1365	1359.666	Bugesera	Kamabuye	Nyakayaga			LWI		Successful	1	0	1350			12/07/2011
197	DB_1ST			202166	9831801	1367	1378.148	Gatsibo	Kabarore	Kibondo I			LWI		Successful	1	0	1368			19/08/2011
198	DB_1ST		BH	208176	9819706	1421	1426.099	Gatsibo	Gitoki	Gakiri			LWI		Successful	1	0	1416			09/09/2011
199	DB_1ST/DB_GILBEI	BH-KAY-KIZ-203		208463	9805194	1483	1496.459	Gatsibo	Kiziguro	Akabingu		Murehe	LWI	SABA	Successful	1	0	1486			31/07/2007
200	DB_1ST			197703	9786906	1130	1421.757	Rwamagan	Gahengeri	Karambo			LWI		Successful	1	0	1410			15/03/2011
201	DB_1ST			205985	9819222	1433	1414.34	Gatsibo	Gitoki	Nyagachamu			LWI		Successful	1	0	1399			09/09/2011
202	DB_1ST			194617	9750875	1338	1332.683	Bugesera	Gashora	Mwendo			LWI		Successful	1	0	1318			10/12/2011
203	DB_1ST			197173	9845936	1370	1361.652	Nyagatare	Rukomo	Rukomo II			LWI		Successful	1	0	1345			17/11/2011
204	DB_1ST			213161	9853809	1347	1354.743	Nyagatare	Nyagatare	Nkerenke			LWI		Successful	1	0	1337			04/11/2011
206	DB_1ST			194484	9750449	1324	1334.978	Bugesera					LWI		Successful	1	0	1315			10/12/2011
207	DB_1ST			231448	9747334	1424	1520.627	Kirehe					LWI		Successful	1	0	1494			14/03/2012
208	DB_1ST			173763	9766388	1405	1409.095	Bugesera							Successful	1	0	1381			25/07/2011
209	DB_1ST			196965	9784277	1393	1397.851	Rwamagana					LWI		Successful	1	0	1368			17/01/2011
210	DB_1ST			219893	9846821	1375	1372.215	Nyagatare					LWI		Successful	1	0	1339			20/10/2011
211	DB_1ST			183965	9770863	1343	1343.672	Bugesera					LWI		Successful	1	0	1310			17/07/2008
212	DB_1ST			179747	9739500	1420	1419.706	Bugesera					LWI		Successful	1	0	1380			12/07/2011
213	DB_1ST			235231	9764940	1513	1491.515	Ngoma					LWI		Successful	1	0	1452			25/04/2012
214	DB_1ST			197306	9783428	1425	1418.944	Rwamagana					LWI		Successful	1	0	1374			28/01/2011
215	DB_1ST			205057	9828855	1445	1371.995	Gatsibo					LWI		Successful	1	0	1325			01/09/2011
216	DB_1ST			222262	9792384	1495	1502.024	Kayonza					LWI		Successful	1	0	1451			03/06/2011
217	DB_1ST			220039	9791283	1535	1536.323	Kayonza					LWI		Successful	1	0	1480			04/08/2011

DB_ID	DB_SOURCE	KEY	Type_S_D	X	Y	ALT GPS	DEM	NAME_2	Sector	Village	Cell	Source_nai	Funder	Contractor	Status	Success	Failure	SWLBGL	Comment	Last_visit	Installati
218	DB_1ST			215606	9783767	1552	1538.027	Rwamagana					LWI		Successful	1	0	1478			26/10/2010
219	DB_1ST			222737	9785476	1575	1568.582	Kayonza					LWI		Successful	1	0	1509			30/03/2011
220	DB_1ST			238381	9791932	1316	1320.393	Kayonza					LWI		Successful	1	0	1260			26/11/2011
221	DB_1ST			229169	9794932	1308	1682.79	Kayonza					LWI		Successful	1	0	1623			26/11/2011
222	DB_1ST			229962	9750781	1479	1469.686	Ngoma					LWI		Successful	1	0	1408			03/05/2012
223	DB_1ST			222065	9786330	1568	1563.127	Kayonza					LWI		Successful	1	0	1498			30/03/2011
224	DB_1ST			222831	9789994	1555	1576.633	Kayonza					LWI		Successful	1	0	1501			24/05/2011
225	DB_1ST			197869	9784156	1475	1478.721	Rwamagana					LWI		Successful	1	0	1399			23/05/2011
226	DB_1ST			222661	9790862	1558	1573.762	Kayonza					LWI		Successful	1	0	1489			05/08/2011
227	DB_1ST			223906	9796139	1592	1598.111	Kayonza					LWI		Successful	1	0	1511			19/05/2011
228	DB_1ST	Mukarange		222376	9789969	1578	1598.271	Kayonza	Mukarange	Abisungany	Bwiza	Bwiza	LWI		Successful	1	0	1506			25/11/2011
229	DB_1ST			225849	9783052	1606	1613.316	Kayonza					LWI		Successful	1	0	1520			03/06/2011
230	DB_1ST			223923	9784312	1600	1612.474	Kayonza					LWI		Successful	1	0	1518			20/05/2011
235	DB_1ST			234480	9783163	1384	1379.791	Kayonza					LWI		Successful	1	0	1370			
236	DB_1ST/DB_GWMA			177846	9758198	1510	1507.386	Bugesera	Ntarama		Kanzenze		LWI		Successful	1	0	1497	Submersibl	20/02/2016	12/03/2014
239	DB_JICA1/DB_1ST			196197	9784413	1385	1372.457	Rwamagan	Gahengeli	Kamurindi	Rweri		LWI		Successful	1	0	1362	they don't	02/09/2015,	17/01/2011
268	DB_JICA1/DB_GWI	Kayonza/Mukarange/K		222741	9789181	1578	1578.833	Kayonza	Mukarange	Angl Churc	Kayonza		LWI		Successful	1	0	1488	They woulc	19/02/2016	07/07/2011
269	DB_JICA1/DB_1ST			222833	9790362	1572	1587.676	Kayonza	Mukarange	Gasogorori	Kayonza		LWI		Successful	1	0	1508	Nothing wa	16/10/2015 @	25/11/2011
272	DB_JICA1			221538	9789685	1605	1596.697	Kayonza	Mukarange	Kabeza	Nyagatovu		LWI		Successful	1	0	1562	The only pr	16/10/2015 @	21/06/2011
273	DB_JICA1/DB_1ST			224207	9795523	1600	1591.708	Kayonza	Gahini	Video	Urugarama		LWI		Successful	1	0	1506	no commit	15/10/2015 @	02/06/2011
282	DB_JICA1/DB_1ST			224705	9788403	1547	1532.014	Kayonza	Mukarange	Gikumba	Rugendabari		LWI		Successful	1	0	1482	They have	22/10/2015 @	25/11/2011
303	DB_JICA1/DB_1ST			220484	9802927	1600	1587.031	Kayonza	Rukara	Mumuri	Rukara		LWI		Successful	1	0	1497	it is very di	23/10/2015 @	07/07/2011
358	DB_JICA1/DB_1ST			236896	9792269	1316	1306.032	Kayonza	Mwili	Ndago	Kageyo		LWI		Successful	1	0	1294	They don't	05/11/2015 @	08/08/2013
364	DB_JICA1/DB_1ST			238867	9796408	1323	1295.081	Kayonza	Mwili	Rwisirabo 1	Kageyo				Successful	1	0	1215	Villagers nc	05/11/2015 @	26/11/2011
400	DB_JICA1/DB_1ST			200541	9760629	1362	1352.934	Ngoma	Rukumberi	Rwimpong	Rwintashya		LWI		Successful	1	0	1343	Need of cle	19/11/2015 @ 11:45	
405	DB_JICA1/DB_1ST			199672	9757541	1360	1356.479	Ngoma	Rukumberi	Gituza	Gituza		LWI		Successful	1	0	1344	people cho	19/11/2015 @ 14:17	
418	DB_JICA1/DB_1ST			228680	9764969	1481	1462.631	Ngoma	Kibungo	Rubimba	Cyasemakamba		LWI		Successful	1	0	1460	its difficult	03/12/2015 @	29/03/2012
419	DB_JICA1/DB_1ST			229101	9765742	1472	1449.376	Ngoma	Kibungo	Gasoro	Gahima		LWI		Successful	1	0	1443	its difficult	03/12/2015 @	28/03/2012
420	DB_JICA1			232390	9766424	1670	1657.182	Ngoma	Kibungo	Karungu	Gatonde		LWI		Successful	1	0	1593	the depht c	04/12/2015 @	29/03/2012
421	DB_JICA1/DB_1ST			233560	9765971	1494	1458.606	Ngoma	Kibungo	Nyagatovu	Gatonde		LWI		Successful	1	0	1439	its difficult	04/12/2015 @	13/03/2012
422	DB_JICA1/DB_1ST			229922	9766323	1554	1527.796	Ngoma	Kibungo	Rwamihurc	Gahima		LWI		Successful	1	0	1453	its difficult	04/12/2015 @	27/04/2012
425	DB_JICA1/DB_1ST			236702	9765069	1605	1584.744	Ngoma	Rukira	Korandebe	Kibatsi		LWI		Successful	1	0	1582	people dor	09/12/2015 @	25/04/2012
427	DB_JICA1/DB_1ST			233017	9763249	1464	1429.429	Ngoma	Rukira	Kagarama	Kibatsi		LWI		Successful	1	0	1386	its difficult	09/12/2015 @	25/04/2012
428	DB_JICA1/DB_1ST			232816	9764772	1467	1460.146	Ngoma	Rukira	Terimbere	Nyaruvumu		LWI		Successful	1	0	1429	its difficult	09/12/2015 @	05/04/2012
429	DB_JICA1/DB_1ST			233850	9763000	1438	1426.4	Ngoma	Rukira	Cyamahehe	Nyaruvumu		LWI		Successful	1	0	1416	its difficult	10/12/2015 @	13/03/2012
434	DB_JICA1/DB_1ST			227958	9755154	1385	1375.931	Ngoma	Murama	Nyakagezi	Mvumba		LWI		Successful	1	0	1372	silty for firs	11/12/2015 @	14/03/2012
435	DB_JICA1/DB_1ST			227328	9753022	1403	1393.4	Ngoma	Murama	Kabahushi	Sakara		LWI		Successful	1	0	1365	training on	11/12/2015 @	23/03/2012
436	DB_JICA1/DB_1ST			227178	9751892	1385	1374.997	Ngoma	Murama	Kavumu	Sakara		LWI		Successful	1	0	1345	no problem	11/12/2015 @	25/04/2012
450	DB_JICA1/DB_1ST			239643	9753529	1399	1366.153	Kirehe	Kirehe	Rurama	Nyabikokora		LWI		Successful	1	0	1356	They never	17/12/2015 @	30/05/2012
458	DB_JICA1/DB_1ST			251037	9743546	1376	1371.577	Kirehe	nyamugari	karembo	kiyanzi		LWI		Successful	1	0	1367	we have nc	17/12/2015 @	29/05/2012
460	DB_JICA1/DB_1ST			258363	9745639	1339	1330.924	Kirehe	mahama	karehe	kiyanzi		LWI		Successful	1	0	1323	No problen	17/12/2015 @17:35	
462	DB_JICA1/DB_1ST			220557	9741514	1528	1510.321	Kirehe	Gahara	Muhero	Muhamba		LWI		Successful	1	0	1416	They comp	24/12/2015 @	20/09/2011
466	DB_JICA1/DB_1ST			247033	9741981	1377	1360.803	Kirehe	Kigarama	Bweranka 1	Kiremera		LWI		Successful	1	0	1343	There is no	31/12/2015 @	29/05/2012
472	DB_JICA1/DB_1ST			245093	9751001	1477	1448.652	Kirehe	kigina	rugando	rugarama		LWI		Successful	1	0	1431	we need ta	22/12/2015 @	29/05/2012
476	SWLDBNYA	N-13B		228932	9774540	1415	1415	Kayonza	Matimba	Bwera	Bwera	Bwera		ADEL	Successful	1	0	1387			27/06/2017
477	SWLDBNYA	N-2 Relocated		214273	9872069	1453	1453	Nyagatare	Katabagem	Byimana	Bayigaburii	Byimana		ADEL	Successful	1	0	1423			08/05/2017
478	SWLDBNYA	N-2		196317	9835714	1428	1428	Nyagatare	Rwempash	Gasinga	Gasinga	Gasinga		ADEL	Successful	1	0	1353			06/07/2017
479	SWLDBNYA	N-10B		206245	9867332	1418	1418	Nyagatare	Tabagwe	Gitengure	Gitengure	Gitengure		ADEL	Successful	1	0	1403			13/03/2017
480	SWLDBNYA	N-9		197221	9856211	1529	1529	Nyagatare	Tabagwe	Kaborogota	Gishuro	Kaborogota		ADEL	Successful	1	0	1454			
481	SWLDBNYA	N-AB		187327	9856658	1287	1287	Nyagatare	Matimba	Kagera	Kagitumba	Kagera		ADEL	Successful	1	0	1252			08/01/2017
482	SWLDBNYA	N-1 (Relocated)		217345	9882250	1370	1370	Nyagatare	Karangazi	Karangazi	Rwisirabo	Karangazi		ADEL	Successful	1	0	1330			07/10/2017
483	SWLDBNYA	N-7		209178	9845235	1485	1485	Nyagatare	Tabagwe	Kayigiro	Gitengure	Kayigiro		ADEL	Successful	1	0	1410			28/02/2017
484	SWLDBNYA	N-BB		196287	9858864	1481	1481	Nyagatare	Karangazi	Kigazi	Kamate	Kigazi		ADEL	Successful	1	0	1416			08/09/2017
485	SWLDBNYA	N-3B Relocated		218207	9847594	1397	1397	Nyagatare	Rwimiyaga	Kirebe	Kirebe	Kirebe		ADEL	Successful	1	0	1332			07/11/2017
486	SWLDBNYA	N-3 Relocated		219896	9859343	1460	1460	Nyagatare	Rwimiyaga	Mahoro	Rwimiyaga	Mahoro		ADEL	Successful	1	0	1385			07/04/2017
487	SWLDBNYA	N-6		212211	9864644	1470	1470	Nyagatare	Musheri	Musheri	Musheri	Musheri		ADEL	Successful	1	0	1432			14/06/2017
488	SWLDBNYA	N-4		209289	9874398	1520	1520	Nyagatare	Musheri	Ntoma	Ntoma	Ntoma		ADEL	Successful	1	0	1475			23/06/2017
489	SWLDBNYA	N-2 Relocated		210866	9870809	1403	1403	Nyagatare	Karangazi	Nyamirama	Nyamirama	Nyamirama Ii		ADEL	Successful	1	0	1358			21/07/2017

DB_ID	DB_SOURCE	KEY	Type_S_D	X	Y	ALT GPS	DEM	NAME_2	Sector	Village	Cell	Source_nai	Funder	Contractor	Status	Success	Failure	SWLBGL	Comment	Last_visit	Installati
490	SWLDBNYA	N-9		217560	9841235	1360	1360	Nyagatare	Musheri	Nyamiyong	Nyamiyong	Nyamiyonga		ADEL	Successful	1	0	1315			13/06/2017
491	SWLDBNYA	N-8		206360	9880504	1486	1486	Nyagatare	Tabagwe	Nyenyeri	Tabagwe	Nyenyeri		ADEL	Successful	1	0	1451			20/02/2017
492	SWLDBNYA	N-1B (Relocated)		190865	9855976	1375	1375	Nyagatare	Rwimiyaga	Rubira	Rutungu	Rubira		ADEL	Successful	1	0	1340			10/11/2017
493	SWLDBNYA	N-2 Relocated		220379	9869908	1444	1444	Nyagatare	Nyagatare	Rutaraka	Rutaraka	Rutaraka		ADEL	Successful	1	0	1414			24/07/2017
494	SWLDBNYA	N-12		204881	9850886	1411	1411	Nyagatare	Matimba	Umudugud	Matimba	Umudugudu Wa I		ADEL	Successful	1	0	1411			26/06/2017
495	SWLDBNYA	N-11		213386	9875630	1340	1340	Nyagatare	Matimba	Umudugud	Matimba	Umudugudu Wa V		ADEL	Successful	1	0	1305			24/06/2017
496	TPMED	PT1		208004	9857719	1362	1362	Nyagatare		Nyarupfubire		Nyarupfubire			Successful	1	0	1333.7			
497	TPMED	PT2		208833	9845758	1346	1346	Nyagatare		MbareII		MbareII			Successful	1	0	1335.8			
498	TPMED	PT3		209658	9846687	1341	1341	Nyagatare		Rugendo I		Rugendo I			Successful	1	0	1341			
499	TPMED	PT4		206847	9842576	1355	1355	Nyagatare		MbareII		MbareII			Successful	1	0	1333			
500	TPMED	PT5		205925	9828978	1370	1370	Gatsibo		Simbwa		Simbwa			Successful	1	0	1353			
501	TPMED	PT6		203462	9827324	1374	1374	Gatsibo		Kibondo II		Kibondo II			Successful	1	0	1374			
502	TPMED	PT7		208271	9829287	1459	1459	Nyagatare		Ruhuda		Ruhuda			Successful	1	0	1409			
503	TPMED	PT8		209608	9828742	1464	1464	Gatsibo							Successful	1	0	1464			
504	TPMED	PT9		209046	9822690	1448	1448	Gatsibo							Successful	1	0	1446.88			
505	TPMED	PT10		221125	9809454	1355	1355	Kayonza		Nyamirama		Nyamirama			Successful	1	0	1351.85			
506	TPMED	PT11		222137	9807875	1361	1361	Kayonza		Ryamanyoni		Ryamanyoni			Successful	1	0	1361.65			
507	TPMED	PT12		221556	9820365	1317	1317	Gatsibo		Ndama II		Ndama II			Successful	1	0	1317			
508	TPMED	PT13		232984	9793062	1380	1380	Kayonza		Kigarama		Kigarama			Successful	1	0	1380.55			
509	TPMED	PT14		210159	9846469	1351	1351	Nyagatare		Karangazi II		Karangazi II			unknown		0	1351			
510	TPMED	PT15		215638	9855364	1332	1332	Nyagatare		Kirebe Diary II		Kirebe Diary II			Successful	1	0	1311.12			
511	TPMED	PT16		213500	9860257	1347	1347	Nyagatare		Kabeza		Kabeza			unknown		0	1331.9			
512	TPMED	PT17		213776	9862704	1343	1343	Nyagatare		Rwimiyaga III		Rwimiyaga III			Successful	1	0	1310.16			
513	TPMED	PT18		206331	9863157	1347	1347	Nyagatare							Successful	1	0	1326.96			
514	TPMED	PT19		212340	9846941	1357	1357	Nyagatare		Buhugoro II		Buhugoro II			Successful	1	0	1351.15			
515	TPMED	PT20		228729	9822763	1314	1314	Gatsibo							Successful	1	0	1279.08			
27	DB_GILBERT			212668	9876962	1356	1366.592	Nyagatare	Musheri			Karucha-Rugarama		CGC	Successful	1	0				38971
28	DB_GILBERT			208391	9876196	1359	1379.623	Nyagatare	Musheri			Kibirizi		CGC	Successful	1	0				39035
29	DB_GILBERT			208554	9873262	1372	1367.907	Nyagatare	Musheri			KiyazA-Musheri		CGC	Successful	1	0				39043
30	DB_GILBERT			209470	9874684	1471	1454.035	Nyagatare	Musheri			Musheri		CGC	Dry	0	1				39045
31	DB_GILBERT			211279	9876340	1346	1354.069	Nyagatare	Musheri			Rugarama I		CGC	Successful	1	0				39047
32	DB_GILBERT			209871	9878394	1370	1364.043	Nyagatare	Musheri			Rugarama II		CGC	Successful	0	1				28/11/2006
33	DB_GILBERT			209006	9880210	1321	1321.059	Nyagatare	Musheri			Nyagatabire II		CGC	Successful	1	0				30/11/2006
34	DB_GILBERT			212462	9873716	1390	1406.195	Nyagatare	Musheri			Karucha-(Humure)		CGC	Dry	0	1				05/12/2006
35	DB_GILBERT			212524	9875476	1352	1353.219	Nyagatare	Musheri			Karucha I		CGC	Successful	1	0				18/12/2006
37	DB_GILBERT			211239	9880858	1314	1315.054	Nyagatare	Musheri			Nyagatabire/Mudugud		CGC	Successful	1	0				22/01/2007
38	DB_GILBERT			205204	9874896	0	1330.588	Nyagatare	Musheri			Cyenombe		CGC	Successful	1	0				
39	DB_GILBERT			206056	9872220	0	1353.463	Nyagatare	Musheri			Kijojo II		CGC	Successful	1	0				
40	DB_GILBERT			221139	9865388	0	1357.638	Nyagatare	Rwimiyaga			Kakagati I		CGC	Successful	1	0				24/02/2007
41	DB_GILBERT			220648	9866260	0	1329.292	Nyagatare	Rwimiyaga			Kakagati II		CGC	Successful	1	0				27/02/2007
42	DB_GILBERT			219805	9867266	0	1309.666	Nyagatare	Rwimiyaga			Kakagati III		CGC	Successful	1	0				23/02/2007
43	DB_GILBERT			217376	9859680	0	1321.304	Nyagatare	Rwimiyaga			Rusa		CGC	Dry	0	1				03/01/2007
44	DB_GILBERT			219070	9858734	0	1344.49	Nyagatare	Rwimiyaga			Kirebe II		CGC	Successful	0	1				03/04/2007
45	DB_GILBERT			211870	9869716	0	1425.113	Nyagatare	Rwimiyaga			Ntoma		CGC	Dry	0	1				03/05/2007
46	DB_GILBERT			216353	9868092	0	1341.547	Nyagatare	Rwimiyaga			Bwera/ Rutungu		CGC	Successful	0	1				03/07/2007
47	DB_GILBERT			214377	9863008	0	1363.514	Nyagatare	Rwimiyaga			Kabeza		CGC	Successful	1	0				03/08/2007
48	DB_GILBERT			214495	9855625	0	1335.692	Nyagatare	Rwimiyaga			Gacundezi		CGC	Successful	1	0				03/10/2007
49	DB_GILBERT			210024	9862092	0	1381.795	Nyagatare	Rwimiyaga			Nyakagando		CGC	Successful	1	0				
50	DB_GILBERT			227173	9853150	0	1295.332	Nyagatare	Rwimiyaga			Gatebe I		CGC	Dry	0	1				05/06/2007
51	DB_GILBERT			193866	9856800	0	1426.45	Nyagatare	Tabagwe			Nyabitekeri T/C		CGC	Successful	1	0				
52	DB_GILBERT			194341	9858348	0	1412.216	Nyagatare	Tabagwe			Nyagasigati		CGC	Successful	1	0				
53	DB_GILBERT			195071	9856816	0	1401.643	Nyagatare	Tabagwe			Nyabitekeri Vet		CGC	Successful	1	0				
54	DB_GILBERT			197450	9859023	0	1407.553	Nyagatare	Tabagwe			Getengure		CGC	Successful	1	0				
55	DB_GILBERT			201251	9857000	0	1337.499	Nyagatare	Tabagwe			Nshure		CGC	Successful	1	0				
56	DB_GILBERT			209681	9866120	0	1348.232	Nyagatare	Rwempasha			Nyendo		CGC	Successful	1	0				
57	DB_GILBERT			210047	9867612	0	1375.511	Nyagatare	Rwempasha			Rwebishorogoto		CGC	Successful	1	0				
58	DB_GILBERT			204843	9868376	0	1345.938	Nyagatare	Rwempasha			Gasinga		CGC	Successful	1	0				13/04/2007
59	DB_GILBERT			206248	9863462	0	1342.206	Nyagatare	Rwempasha			Kabare I		CGC	Successful	1	0				15/04/2007

DB_ID	DB_SOURCE	KEY	Type_S_D	X	Y	ALT GPS	DEM	NAME_2	Sector	Village	Cell	Source_nai	Funder	Contractor	Status	Success	Failure	SWLBGL	Comment	Last_visit	Installati
60	DB_GILBERT			207936	9882386	0	1308.286	Nyagatare	Rwempasha			Kabare II		CGC	Successful	1	0				16/04/2007
61	DB_GILBERT			199241	9859286	0	1369.427	Nyagatare	Rwempasha			Mashaka		CGC	Dry	0	1				26/04/2007
62	DB_GILBERT			206248	9857464	0	1408.584	Nyagatare	Nyagatare			Nyagatare P. School		CGC	Successful	1	0				20/04/2007
63	DB_GILBERT			202617	9851840	0	1374.167	Nyagatare	Nyagatare			Cyonyo		CGC	Successful	1	0				23/04/2007
64	DB_GILBERT			202664	9854156	0	1338.351	Nyagatare	Nyagatare			Rutaraka		CGC	Successful	1	0				29/04/2007
65	DB_GILBERT			200168	9849114	0	1356.526	Nyagatare	Nyagatare			Cyonyo II		CGC	Successful	1	0				05/10/2007
66	DB_GILBERT			218242	9843512	0	1333.382	Nyagatare	Karangazi			Ndama Diary		CGC	Successful	1	0				23/05/2007
67	DB_GILBERT			215347	9838520	0	1350.228	Nyagatare	Karangazi			Nyagashanga		CGC	Dry	0	1				20/05/2007
68	DB_GILBERT			217748	9849982	0	1415.071	Nyagatare	Karangazi			Kamate		CGC	Successful	1	0				26/05/2007
69	DB_GILBERT			196817	9839996	0	1364.209	Nyagatare	Katabagemu			Kajevuba		CGC	Successful	0	1				05/04/2007
70	DB_GILBERT			201124	9837232	0	1393.576	Nyagatare	Katabagemu			Rubira/sangano		CGC	Dry	0	1				19/05/2007
71	DB_GILBERT			201496	9834048	0	1388.043	Nyagatare	Katabagemu			Rubira II		CGC	Successful	1	0				22/05/2007
72	DB_GILBERT			195944	9835526	0	1410.34	Nyagatare	Katabagemu			Ruhuru		CGC	Successful	1	0				24/05/2007
73	DB_GILBERT			194179	9847276	0	1397.475	Nyagatare	Rukomo			Rukomo Hospital		CGC	Dry	0	1				
74	DB_GILBERT			194421	9848026	0	1429.98	Nyagatare	Rukomo			Rukomo H/ Centre		CGC	Dry	0	1				
75	DB_GILBERT			210096	9821898	0	1469.018	Gatsibo	Kabarole			Kabeza		CGC	Dry	0	1				
76	DB_GILBERT			203388	9827620	0	1394.746	Gatsibo	Kabarole			Kibondo II		CGC	Successful	1	0				17/06/2007
77	DB_GILBERT			201796	9822726	0	1412.466	Gatsibo	Kabarole			Kabare		CGC	Successful	1	0				06/12/2007
78	DB_GILBERT			202972	9822806	0	1419.995	Gatsibo	Kabarole			Rutenderi		CGC	Successful	1	0				
79	DB_GILBERT			208823	9826534	0	1415.105	Gatsibo	Kabarole			Ruhuha		CGC	Successful	1	0				15/06/2007
80	DB_GILBERT			205850	9829290	0	1364.965	Nyagatare	Kabarole			Simbwa		CGC	Successful	1	0				
81	DB_GILBERT			208918	9819108	0	1459.654	Gatsibo	Kabarole			Kabingo		CGC	Successful	1	0				21/06/2007
82	DB_GILBERT			216475	9815792	0	1360.764	Gatsibo	Rwimbogo			Ngarama (1) 2		SABA	Successful	1	0				27/03/2007
83	DB_GILBERT			217462	9816108	0	1341.783	Gatsibo	Rwimbogo			Ngarama (1) 3		SABA	Successful	1	0				30/03/2007
84	DB_GILBERT			216917	9817633	0	1375.637	Gatsibo	Rwimbogo			Ngarama II		SABA	Successful	1	0				02/04/2007
85	DB_GILBERT			221210	9821868	0	1323.233	Gatsibo	Rwimbogo			Ndama I		SABA	Successful	1	0				04/07/2007
86	DB_GILBERT			221556	9820367	0	1320.414	Gatsibo	Rwimbogo			Ndama II		SABA	Successful	1	0				04/04/2007
87	DB_GILBERT			206702	9805471	0	1515.314	Gatsibo	Murambi			Mataba I		SABA	Successful	1	0				04/04/2007
88	DB_GILBERT			204670	9803898	0	1546.449	Gatsibo	Murambi			Mataba II		SABA	Successful	1	0				04/11/2007
89	DB_GILBERT			205194	9803853	0	1541.016	Gatsibo	Murambi			Ryampunga I		SABA	Successful	1	0				12/04/2007
90	DB_GILBERT			205490	9803863	0	1536.249	Gatsibo	Murambi			Ryampunga II		SABA	Successful	1	0				09/05/2007
91	DB_GILBERT			206136	9801291	0	1504.393	Gatsibo	Murambi			Kiniga ii		SABA	Successful	1	0				15/08/2007
92	DB_GILBERT			206872	9807081	0	1577.609	Gatsibo	Murambi			Ryanyagapfumu		SABA	Successful	1	0				17/08/2007
93	DB_GILBERT			207184	9800911	0	1493.379	Gatsibo	Murambi			Bushenyi		SABA	Successful	1	0				20/08/2007
94	DB_GILBERT			205503	9801405	0	1516.573	Gatsibo	Murambi			Kiniga I		SABA	Successful	1	0				07/08/2007
95	DB_GILBERT			205747	9799690	0	1486.335	Gatsibo	Murambi			Kagenge		SABA	Successful	1	0				28/08/2007
96	DB_GILBERT			205570	9799404	0	1520.399	Gatsibo	Murambi			Kinunga		SABA	Successful	1	0				
97	DB_GILBERT			206543	9799202	0	1478.474	Gatsibo	Murambi			Nyakabanda		SABA	Successful	1	0				04/08/2007
98	DB_GILBERT			214228	9812985	0	1384.558	Gatsibo	Rugarama			Nyabubare I		SABA	Successful	1	0				11/04/2007
99	DB_GILBERT			214130	9814474	0	1387.451	Gatsibo	Rugarama			Nyabubare II		SABA	Successful	1	0				13/04/2007
100	DB_GILBERT			215605	9813954	0	1359.879	Gatsibo	Rugarama			Matunguru I		SABA	Successful	1	0				18/04/2007
101	DB_GILBERT			216381	9815056	0	1369.196	Gatsibo	Rugarama			Rambura		SABA	Successful	1	0				21/04/2007
102	DB_GILBERT			217447	9814909	0	1365.163	Gatsibo	Rugarama			Tinigiro		SABA	Successful	1	0				24/04/2007
103	DB_GILBERT			217063	9813293	0	1330.188	Gatsibo	Rugarama			Nyenyeri		SABA	Successful	1	0				27/04/2007
104	DB_GILBERT			216015	9811379	0	1337.471	Kayonza	Rugarama			Rukundo I		SABA	Successful	1	0				11/05/2007
105	DB_GILBERT			215504	9810075	0	1380.033	Gatsibo	Rugarama			Rukundo II		SABA	Successful	1	0				09/05/2007
106	DB_GILBERT			211361	9798729	0	1455.998	Gatsibo	Kiramuruzi			Businde		SABA	Dry	0	1				07/09/2007
107	DB_GILBERT			213492	9798138	0	1462.133	Gatsibo	Kiramuruzi			Mataba		SABA	Dry	0	1				09/09/2007
109	DB_GILBERT			217968	9811933	0	1353.557	Kayonza	Murundi			Mukabasaza		SABA	Successful	1	0				16/05/2007
110	DB_GILBERT			226994	9809933	0	1417.31	Kayonza	Murundi			Murugunga		SABA	Successful	1	0				09/06/2007
111	DB_GILBERT			220637	9809055	0	1366.091	Kayonza	Murundi			Nyamirama I		SABA	Successful	1	0				04/06/2007
112	DB_GILBERT			220267	9801136	0	1577.895	Kayonza	Murundi			Nyange		SABA	Successful	1	0				07/06/2007
113	DB_GILBERT			227583	9799130	0	1543.241	Kayonza	Gahini			Juru I		SABA	Successful	1	0				20/06/2007
114	DB_GILBERT			220660	9796825	0	1494.059	Kayonza	Gahini			Umwiga		SABA	Successful	1	0				02/09/2007
115	DB_GILBERT			228044	9795259	0	1486.587	Kayonza	Gahini			Kibombwe		SABA	Successful	1	0				28/06/2007
117	DB_GILBERT			229670	9799686	0	1588.418	Kayonza	Gahini			Julu II		SABA	Dry	0	1				13/06/2007
119	DB_GILBERT			236822	9790743	0	1335.229	Kayonza	Mwili			Ndago II		SABA	Successful	1	0				27/07/2007
120	DB_GILBERT			229298	9793215	0	1584.776	Kayonza	Mwili			Nyakabungo I		SABA	Dry	0	1				30/06/2007

DB_ID	DB_SOURCE	KEY	Type_S_D	X	Y	ALT GPS	DEM	NAME_2	Sector	Village	Cell	Source_nai	Funder	Contractor	Status	Success	Failure	SWLBGL	Comment	Last_visit	Installati
121	DB_GILBERT			228894	9792503	0	1534.023	Kayonza	Mwili			Murwiri I		SABA	Dry	0	1				03/07/2007
122	DB_GILBERT			232871	9793720	0	1383.668	Kayonza	Mwili			Kigarama		SABA	Successful	1	0				08/07/2007
123	DB_GILBERT			239922	9795764	0	1301.853	Kayonza	Mwili			Rwisirabo 2		SABA	Dry	0	1				16/07/2007
126	DB_GILBERT			210148	9807580	0	1440.889	Gatsibo	Kiziguro			Nyagashenyi Ii		SABA	Successful	1	0				06/07/2007
127	DB_GILBERT			209745	9802760	0	1473.982	Gatsibo	Kiziguro			Muringa I		SABA	Successful	1	0				08/09/2007
128	DB_GILBERT			211305	9802729	0	1471.098	Gatsibo	Kiziguro			Muringa Ii		SABA	Successful	1	0				13/07/2007
129	DB_GILBERT			217649	9798397	0	1474.525	Kayonza	Rukara			Butimba II		SABA	Successful	1	0				21/08/2007
130	DB_GILBERT			215900	9798950	0	1501.96	Kayonza	Rukara			Kishaba		SABA	Successful	1	0				24/08/2007
131	DB_GILBERT			216128	9801040	0	1446.928	Gatsibo	Rukara			Ryamuremba		SABA	Successful	1	0				26/08/2007
132	DB_GILBERT			217248	9800694	0	1499.259	Kayonza	Rukara			Ryabagagari		SABA	Dry	0	1				04/09/2007
133	DB_GILBERT			220662	9796825	0	1494.059	Kayonza	Rukara			Kabuga		SABA	Successful	1	0				02/09/2007
173	DB_W4GRR			226938	9810343	0	1439.466	Kayonza							unknown	1	0		PEDCUI		
186	DB_W4GRR			207520	9875804	0	1343.405	Nyagatare							unknown	0	1		saline watre		
232	DB_1ST			188600	9832840	1407	1415.87	Gatsibo					LWI		unknown	1	0				40780
233	DB_1ST			193220	9829857	1427	1474.122	Gatsibo					LWI		unknown	1	0				40782
237	DB_1ST			198684	9757849	1359	1361.464	Ngoma					LWI		unknown	1	0				
294	DB_JICA1/DB_GILBERT			216149	9802286	1473	1468.852	Kayonza	Rukara	Mirambi 2	Rwimishiny	Nyarukarishya i		SABA	Successful	1	0		it is very di	22/10/2015 @	39322
316	DB_JICA1/DB_GILBERT			219559	9810485	1368	1360.411	Kayonza	Murundi	Akamina	Karambi	Nyamirama		SABA	Successful	1	0		they don't	29/10/2015 @	39235
318	DB_JICA1/DB_GILBERT			218495	9811087	1364	1361.176	Kayonza	Murundi	Nyagashan	Karambi	Nyagashanga		SABA	Successful	1	0		its hard to	29/10/2015 @	39224
319	DB_JICA1/DB_GILBERT			219945	9813850	1335	1318.995	Kayonza	Murundi	Ngumeri1	Karambi	Ngumeri		SABA	Successful	1	0		its hard to	29/10/2015 @	39232
322	DB_JICA1/DB_GILBERT			216033	9810991	1364	1366.462	Kayonza	Murundi	Kabana	Karambi	Rwisheke		SABA	Successful	1	0		the water f	30/10/2015 @	39215
323	DB_JICA1			225710	9805772	1401	1390.543	Kayonza	Murundi	Rwakaband	Ryamanyor	Ryakarenzi		SABA	Successful	1	0		even if its r	30/10/2015 @	39241
350	DB_JICA1/DB_GILBERT			228765	9790646	1494	1490.086	Kayonza	Mwili	Nyakagarai	Migera	Rubonobono		SABA	Successful	1	0		They claim	04/11/2015 @	39269
351	DB_JICA1/DB_GILBERT			228853	9791003	1494	1495.054	Kayonza	Mwili	Nyakagarai	Migera	Murwiri 2		SABA	Successful	1	0		They claim	04/11/2015 @	39303
354	DB_JICA1			234061	9791043	1352	1333.204	Kayonza	Mwili	Kabeza	Nyamugali	Kabeza (Rwisirabo)		SABA	Successful	1	0		Water dem	04/11/2015 @	39294
367	DB_JICA1/DB_GILBERT			240593	9796451	1321	1322.226	Kayonza	Mwili	Rwisirabo 2	Kageyo	Sebasengo		SABA	Dry	0	1		They wish t	05/11/2015 @	39288
369	DB_JICA1/DB_GILBERT			221309	9809181	1358	1347.506	Kayonza	Murundi	Kayongo	Murundi	Nyamirama II		SABA	Successful	1	0		it is very di	04/11/2015 @	39236
371	DB_JICA1/DB_GILBERT			221974	9809006	1352	1338.43	Kayonza	Murundi	Kayongo	Murundi	Macuba		SABA	Successful	1	0		the water f	04/11/2015 @	39307
475	DB_GILBERT			206187	9879708	0	1343.239	Nyagatare	Musheri			Nyamiyonga H.C		CGC	Successful	1	0				

DB_ID	DD	Qair_lit_h	Qtest_3hrs	Qtest_24hı	Qtest_72hı	Casings	Screens	ID_Casing	ED_Casing	Functional	Diver_date	Diver_Posi	Baro_Posit	EC	Ph	Soil	Type	TARGET	Lithology	Interpolate	Interpolate
1	81.85	800	700					110						182		Nitisol-Acrisol-Alisol-Lixisol			Bu	910.5701	1452.496
2	81.85	2250	1620													Ferralsol			Ng	2220.97	1301.011
3	90.05	dry														Ferralsol			Ho	4.91431	1297.738
4	53	dry	950													Ferralsol			Ho	4.91431	1297.738
6	86	dry														Nitisol-Acrisol-Alisol-Lixisol			Bl	23.79777	1460.979
7	76.85	dry														Ferralsol			Ho	225.0061	1439.257
9	34.85	2400	1050													Cambisol		WASAC	Ho	2509.96	1340.079
10	56.85	8000						110								Ferralsol		CDP	Ho	7557.438	1340.031
11	51.2	2700	2600					110						898		Clay soil with low infiltration rate			Ho	2782.59	1332.127
12	67	dry														Ferralsol			TM	772.3948	1366.026
13	60.8	2000	870					110						248		Clay soil with low infilt		WASAC	Ho	2000.593	1361.078
14	35	2000	1050													Clay soil with low infilt		WASAC	Ho	1998.979	1360.999
15	70	2450	950					110						316		Cambisol		WASAC	TM	2427.927	1326.121
16	45	2500	2600					110						185		Ferralsol			TM	2399.904	1435.395
17	90.75	1200	770					110						626		Clay soil with low infilt		WASAC	Ho	1200.889	1331.191
18	91	200						110								Cambisol		WASAC	TM	215.5206	1341.113
19	40	3000	1740					110						297		Ferralsol		JOINT	Ho	2671.041	1390.578
20	41	750	710					110						259		Cambisol			TM	779.3671	1366.847
21		dry														Nitisol-Acrisol-Alisol-Lixisol			TM	10.35763	1372.463
22	104	1020						125								Ferralsol		JOINT	Rr	1864.427	1302.024
23	74	3900						125								Clay soil with low infilt		JOINT	Ho	3675.126	1302.812
24	71.5	1500						125								Ferralsol			TM	1511.514	1333.992
25	100	1300						125								Clay soil with low infilt		WASAC	Rr	1338.799	1318.97
26	92	4400						125								Clay soil with low infilt		WASAC	Ng	3028.663	1322.189
139	51	1000														Clay soil with low infilt		WASAC	Ho	1021.462	1334.537
140	52.2	4900						125								Clay soil with low infiltration rate			Ho	4613.24	1288.83
141	92.3	4900						125								Nitisol-Acrisol-Alisol-Lixisol			Ho	4830.158	1277.215
143	43	2300	1800					110						193		Cambisol		WASAC	Ho	2233.218	1389.881
187	70	4980														Mineral soils conditioned by flat tc			Ho	4593.814	1455.014
188	30	1980														Clay soil with low infiltration rate			Ho	1983.461	1444.026
189	19	10800														Nitisol-Acrisol-Alisol-Lixisol			Ng	10100.36	1415.507
190	35	1200														Nitisol-Acrisol-Alisol-Lixisol			Bl	1215.378	1335.108
191	35	3000														Cambisol		WASAC	Ho	2999.422	1323.029
192	60	960														Clay soil with low infiltration rate			Ho	1009.397	1341.924
193	32	3000														Clay soil with low infiltration rate			Ho	2973.998	1421.096
194	40	5100														Nitisol-Acrisol-Alisol-Li:		JOINT	Ho	5214.853	1374.007
195	40	960														Cambisol			TM	1099.742	1409.999
196	24	1980														Nitisol-Acrisol-Alisol-Lixisol			Ho	1982.212	1350.024
197	50	6960														Clay soil with low infilt		CDP	Ho	6066.61	1367.967
198	50	3000														Ferralsol		CDP	TM	3248.199	1415.957
199	54	6000														Ferralsol			TB	5524.812	1485.883
200	40	9900														Nitisol-Acrisol-Alisol-Li:		CDP	Ho	9878.118	1409.702
201	50	4980														Ferralsol			TM	4945.847	1399.171
202	40	4980														Nitisol-Acrisol-Alisol-Lixisol			Mh	4646.491	1317.742
203	50	1800														Cambisol		JOINT	Ho	1770.194	1345.11
204	60	1980														Cambisol			TM	2001.583	1336.9
206	40	3000														Nitisol-Acrisol-Alisol-Lixisol			Ho	3747.117	1315.225
207	60	3000														Nitisol-Acrisol-Alisol-Li:		WASAC	Rr	3024.948	1493.548
208	100	3000														Ferralsol			Nm	2997.865	1381.028
209	70	4020														Nitisol-Acrisol-Alisol-Li:		CDP	Ng	4201.396	1368.679
210	80	960														Cambisol			TM	964.6805	1338.899
211	95	2700														Nitisol-Acrisol-Alisol-Lixisol			Ho	2699.353	1310.051
212	75	3000														Ferralsol			TB		1379.946
213	60	1980														Mineral soils conditioned by flat tc			Rr	2198.229	1452.699
214	110	5100														Cambisol		CDP	Ng	5142.568	1374.306
215	90	1500														Ferralsol			Ho	2535.209	1359.413
216	80	4980														Ferralsol			Nm	4920.731	1452.283
217	100	1980														Nitisol-Acrisol-Alisol-Lixisol			Bl	2260.511	1480.224

DB_ID	DD	Qair_lit_h	Qtest_3hrs	Qtest_24h	Qtest_72h	Casings	Screens	ID_Casing	ED_Casing	Functional	Diver_date	Diver_Posi	Baro_Posit	EC	Ph	Soil	Type	TARGET	Lithology	Interpolate	Interpolate
218	122	3000														Ferralsol			TB	3000.557	1478.033
219	134	4200														Ferralsol			Bl	3907.756	1502.669
220	100	4020														Clay soil with low infilt		WASAC	Ho	3932.572	1323.383
221	100	3000														Cambisol		CDP	Gi	2695.976	1516.765
222	105	3000														Mineral soils conditioned by flat t			Rr	3027.434	1407.928
223	140	2100														Nitisol-Acrisol-Alisol-Lixisol			Bl	2269.355	1498.106
224	125	6960														Ferralsol			Bl	3372.652	1502.906
225	110	3600														Nitisol-Acrisol-Alisol-Li		CDP	Ng	3638.625	1397.622
226	120	1980														Nitisol-Acrisol-Alisol-Lixisol			Bl	2278.158	1489.489
227	130	6960														Ferralsol			Bl	6537.999	1510.696
228	132	1980									########	100	-			Ferralsol			Bl	3084.658	1504.354
229	145	4020														Ferralsol		JOINT	Gi	3935.993	1519.992
230	140	1980														Ferralsol			Bl	2099.007	1517.952
235	55	1200														Ferralsol			Rr	1234.354	1370.182
236	30	600														Ferralsol			Bl	600.6723	1496.496
239	50	7200								Yes						Nitisol-Acrisol-Alisol-Lixisol			Ho	6834.813	1363.661
268	120	3600								Yes						Ferralsol		CDP	Bl	3681.613	1490.654
269	120	3000								No						Nitisol-Acrisol-Alisol-Lixisol			Bl	3372.652	1501.934
272	75	4800								Yes						Clay soil with low infiltration rate			Nm	4502.148	1500.003
273	115	1020								No						Ferralsol			Bl	1323.424	1506.183
282	75	3000								No						Nitisol-Acrisol-Alisol-Lixisol			Bl	3019.104	1482.707
303	135	3000								No						Nitisol-Acrisol-Alisol-Lixisol			Bl	3069.87	1496.491
358	30	1500								No						Mineral soils condition		WASAC	Ho	2064.856	1295.128
364	105	3000								Yes						Ferralsol		WASAC	Ho	1813.572	1378.369
400	50	900								No						Mineral soils conditioned by flat t			TB	904.185	1342.945
405	42	1020								Yes						Ferralsol			TB	1026.571	1343.963
418	45	4980								Yes						Histosol			Ho	4693.523	1459.525
419	55	4020								No						Histosol		CDP	Nm	4054.665	1443.955
420	95	1980								No						Mineral soils condition		CDP	Nm	2129.576	1582.389
421	70	3000								No						Ferralsol			Rr	2909.32	1441.398
422	90	1980								No						Cambisol		CDP	Nm	2255.609	1453.067
425	25	1980								Yes						Cambisol			Gi	2101.419	1580.87
427	70	4020								No						Ferralsol			Rr	4099.519	1390.121
428	80	1020								Yes						Ferralsol			Rr	1967.086	1429.726
429	50	4980								Yes						Ferralsol			Ho	4691.098	1414.947
434	40	4980								Yes						Cambisol			Rr	4866.52	1372.172
435	65	3000								Yes						Cambisol			Kb	3599.814	1365.219
436	60	4020								Yes						Cambisol			Rr	3871.393	1378.646
450	40	1980								No						Cambisol			Ho	1988.018	1356.233
458	40	4020								No						Cambisol			TM	4005.578	1342.409
460	45	1188								Yes						Clay soil with low infilt		CDP	TM	1188.242	1323.111
462	150	1980								No						Ferralsol			Kg	2002.534	1416.088
466	40	4020								Yes						Ferralsol			Ak	4017.752	1343.018
472	60	4980								Yes						Ferralsol			Ho	4953.78	1430.947
476	90	2000	4000					140											Nm	2762.646	1387.113
477	90	1500	1500					140										WASAC	TM	779.8972	1422.376
478	121	1200	2000					140											Ho	611.785	1353.195
479	100	12000	12000					140										WASAC	TM	1283.48	1402.995
480	90	9000	10000					140										WASAC	TM	1007.011	1453.047
481	90	2500	2500					140											Ng	1296.051	1342.076
482	120	2000	2500					140											Ho	3860.942	1327.195
483	122	1500	1500					140											Ho	2932.935	1337.1
484	130	1000	1000					140										WASAC	TM	1057.162	1415.862
485	90	1300	1300					140											Gi	1387.375	1332.111
486	140	1500	2000					140										CDP	TM	372.3803	1384.738
487	100	3000	5000					140											TM	1949.5	1431.553
488	110	1500	2000					140										CDP	TM	633.1641	1474.749
489	105	3000	3000					140										CDP	Gi	746.7958	1358.513

DB_ID	DD	Qair_lit_h	Qtest_3hrs	Qtest_24hı	Qtest_72hı	Casings	Screens	ID_Casing	ED_Casing	Functional	Diver_date	Diver_Posi	Baro_Posit	EC	Ph	Soil	Type	TARGET	Lithology	Interpolate	Interpolate
490	108	1200	2500					140											TM	2198.655	1315.068
491	114	8000	8000					140										WASAC	Ng	2924.385	1442.172
492	100	3000	3000					140											TM	1557.221	1340.037
493	90	6000	6000					140										WASAC	Rr	1103.746	1413.847
494	86	2500	6000					140											TM	1569.598	1362.326
495	100	1200	3000					140											TM	1903.675	1305.726
496	70	3000	3000															WASAC	TM	2300.517	1333.698
497	35	2000	2000															WASAC	Ho	2509.96	1337.94
498	80	unknown																	Ho	6481.75	1340.906
499	51	2000	2000															WASAC	Ho	1021.462	1334.537
500	59	unknown																	Ho	7015.827	1353.098
501		unknown																	Ho	3816.282	1373.998
502	100	unknown																	TM	2958.445	1369.416
503		unknown																	TM	2759.953	1383.87
504	30	3500	3500															JOINT	TM	1583.02	1446.735
505	45	3000	3000															WASAC	TM	2975.566	1352
506		12000	12000																Ho	6764.089	1362.007
507		unknown																	Ho	8782.403	1317.026
508	55	12000	12000																Nm	7521.707	1382.618
509		unknown																CDP	Ho	7557.438	1340.031
510	57.92	5500	5500																Ho	3288.592	1311.323
511	56.75	unknown																	Ho	2412.383	1332.058
512	74.5	3000	3000															JOINT	Ho	3731.417	1310.662
513	59.1	8000	8000															WASAC	TM	3899.35	1327.331
514	44.72	25000	25000																Ho	4056.074	1339.643
515	69	3000	3000																Ng	2906.066	1279.282
27	65.7	720						125						0		Ferralsol		WASAC	TM	728.4083	1336.56
28	69.3	3000						125						0		Ferralsol		WASAC	TM	1890.399	1459.396
29	65.7	2900						0						0		Cambisol			TM	2360.889	1445.308
30	100.02	dry						0						0		Ferralsol		CDP	TM	523.971	1467.932
31	63.47	800						125						0		Cambisol			Ho	1031.599	1372.491
32	104	300						0						0		Ferralsol		JOINT	Ng	387.6645	1385.016
33	57.93	1000						125						0		Ferralsol		WASAC	Ho	1061.651	1378.193
34	98	dry						0						0		Ferralsol			TM	113.5726	1418.058
35	64	2900						125						0		Clay soil with low infiltration rate			TM	2805.791	1336.018
37	71.5	1020						125						0		Clay soil with low infiltration rate			Ho	1561.234	1323.545
38	60	1600						0						0		Clay soil with low infiltration rate			Ho	1562.42	1436.788
39	57.4	1400						0						0		Cambisol			TM	1402.676	1416.542
40	86.1	1970						0						0		Clay soil with low infilt		JOINT	Ho	1969.992	1394.045
41	85.5	1530						0						0		Clay soil with low infilt		JOINT	Ho	1526.472	1397.913
42	92.3	870						0						0		Ferralsol		JOINT	Rr	893.9561	1404.462
43	97.3	dry						0						0		Clay soil with low infilt		CDP	Ho	277.9082	1352.709
44	92.2	180						0						0		Clay soil with low infilt		CDP	Ho	184.7793	1377.656
45	92.4	dry						0						0		Ferralsol			TM	11.76116	1391.069
46	87	310						0						0		Ferralsol		WASAC	Ho	345.9724	1409.636
47	81	4080						0						0		Ferralsol		JOINT	TM	3627.523	1327.225
48	96	4200						0						0		Ferralsol			Ho	3990.252	1321.641
49	70.7	2780						0						0		Cambisol		WASAC	TM	2751.622	1368.235
50	76.8	dry						0						0		Clay soil with low infiltration rate			Ho	0.66897	1346.966
51	47	2660						0						0		Ferralsol			Ho	2518.793	1379.629
52	52.2	1300						0						0		Cambisol		WASAC	Ho	1301.914	1399.988
53	52.1	900						0						0		Ferralsol		WASAC	Ho	914.6333	1410.485
54	73.2	340						0						0		Ferralsol		WASAC	TM	362.3418	1409.8
55	52.1	1100						0						0		Clay soil with low infiltration rate			Ho	1101.593	1368.052
56	86.17	720						0						0		Ferralsol			Ho	790.6489	1416.197
57	74.58	960						0						0		Ferralsol			Ho	960.2528	1410.16
58	52.02	700						0						0		Ferralsol		WASAC	Ho	893.6763	1393.564
59	59.73	4000						0						0		Clay soil with low infilt		WASAC	Ho	3990.774	1328.777

DB_ID	DD	Qair_lit_h	Qtest_3hrs	Qtest_24h	Qtest_72h	Casings	Screens	ID_Casing	ED_Casing	Functional	Diver_date	Diver_Posi	Baro_Posit	EC	Ph	Soil	Type	TARGET	Lithology	Interpolate	Interpolate
60	57.94	960						0						0							1405.394
61	63.3	dry						0						0		Cambisol			TM	113.5435	1394.303
62	57.8	2400						0						0		Ferralsol		WASAC	TM	2391.604	1335.042
63	61.1	550						0						0		Ferralsol			TM	588.126	1390.979
64	54	1080						0						0		Cambisol			Ho	1084.173	1369.892
65	42	2430						0						0		Cambisol			TM	2403.344	1421.317
66	80.54	3000						0						0		Cambisol		WASAC	TM	2938.348	1326.472
67	75	dry						0						0		Clay soil with low infiltration rate			Ho	7.6157	1329.753
68	60	790						0						0		Ferralsol		CDP	TM	798.8451	1334.147
69	54.6	68						0						0		Ferralsol			Ho	124.2706	1370.131
70	72.9	380						0						0		Clay soil with low infilt		JOINT	Ho	384.5073	1367.355
71	63.7	1800						0						0		Clay soil with low infiltration rate			TM	1821.355	1366.474
72	52.2	514						0						0		Cambisol			TM	624.0944	1353.663
73	0	dry						0						0		Ferralsol			Ho	29.94559	1345.064
74	0	dry						0						0		Cambisol			Ho	41.84884	1347.922
75	0	dry						0						0		Ferralsol		JOINT	TM	180.4918	1430.406
76	0	3800						0						0		Ferralsol			TM	3801.94	1373.768
77	0	6000						0						0		Clay soil with low infiltration rate			TM	5777.532	1387.473
78	0	3600						0						0		Cambisol			TM	3675.677	1393.145
79	0	2800						0						0		Ferralsol			TM	2805.262	1400.689
80	0	9000						0						0		Clay soil with low infiltration rate			Ho	8522.624	1354.318
81	0	9000						0						0		Ferralsol		CDP	Ho	8932.452	1415.966
82	60	3800						0						0		Clay soil with low infiltration rate			Ho	4130.648	1405.172
83	54	6000						0						0		Clay soil with low infiltration rate			Ho	5422.457	1389.785
84	54	3600						0						0		Ferralsol			Ho	3662.257	1399.932
85	60	2800						0						0		Clay soil with low infiltration rate			Ho	3098.006	1333.277
86	66	9000						0						0		Ferralsol			Ho	8782.403	1317.026
87	51	5400						0						0		Ferralsol			TB	5386.949	1478.607
88	60	7200						0						0		Ferralsol			TB	7174.896	1470.671
89	60	7200						0						0		Ferralsol			TB	7207.024	1471.016
90	54	8200						0						0		Ferralsol			TB	7207.024	1471.466
91	55	2880						0						0		Ferralsol			Ho	3044.727	1456.523
92	55	3600						0						0		Ferralsol			TB	3715.36	1476.781
93	30	1190						0						0		Ferralsol			Ho	1659.381	1454.642
94	42	6000						0						0		Ferralsol			TB	4639.849	1458.425
95	48	4000						0						0		Ferralsol		CDP	TB	3558.023	1448.346
96	42	1080						0						0		Ferralsol		CDP	TB	2387.706	1448.71
97	22	720						0						0		Ferralsol			Ho	987.4884	1446.504
98	60	5400						0						0		Ferralsol			TM	5400.848	1422.141
99	57	7200						0						0		Ferralsol		WASAC	TM	7105.646	1418.666
100	56	5000						0						0		Ferralsol		JOINT	TM	5212.519	1412.424
101	60	7000						0						0		Ferralsol			Ho	5945.686	1404.049
102	54	5800						0						0		Ferralsol			Ho	5742.78	1396.405
103	45	4300						0						0		Ferralsol			Ho	4507.726	1402.323
104	56	3200						0						0		Clay soil with low infiltration rate			TM	3407.823	1412.21
105	69.5	3600						0						0		Ferralsol			TM	3672.768	1419.861
106	54	dry						0						0		Clay soil with low infiltration rate			Ho	229.1539	1449.58
107	51	dry						0						0		Mineral soils conditioned by flat tc			TB	47.09692	1445.684
109	63	6380						0						0		Ferralsol			Ho	5787.893	1395.194
110	51	3600						0						0		Ferralsol		WASAC	Ng	3594.119	1417.995
111	57	3600						0						0		Ferralsol			TM	3639.972	1356.805
112	69	2160						0						0		Ferralsol			Bl	2190.583	1478.344
113	75	1600						0						0		Cambisol		WASAC	Gi	1588.159	1501.373
114	40	972						0						0		Cambisol			Ho	2325.677	1468.644
115	45	2160						0						0		Cambisol			Bl	2158.689	1524.618
117	63	dry						0						0		Ferralsol			Bl	279.6599	1490.44
119	57	7200						0						0		Nitisol-Acrisol-Alisol-Li		WASAC	Rr	6748.056	1332.72
120	60	dry						0						0		Nitisol-Acrisol-Alisol-Lixisol			Gi	311.575	1528.124

DB_ID	DD	Qair_lit_h	Qtest_3hrs	Qtest_24h	Qtest_72h	Casings	Screens	ID_Casing	ED_Casing	Functional	Diver_date	Diver_Posi	Baro_Posit	EC	Ph	Soil	Type	TARGET	Lithology	Interpolate	Interpolate
121	0	dry						0						0		Nitisol-Acrisol-Alisol-Lixisol			Gi	270.7607	1525.002
122	57	10800						0						0		Ferralsol			Nm	9718.534	1396.258
123	55	dry						0						0		Clay soil with low infiltration rate			Ho	177.1511	1356.206
126	39	1800						0						0		Ferralsol			Ho	1853.924	1470.683
127	42	1500						0						0		Ferralsol			Ho	1561.122	1470.185
128	57	1080						0						0		Cambisol		WASAC	Ng	1248.42	1464.548
129	60	2880						0						0		Ferralsol			Ho	2936.939	1455.393
130	51	1000						0						0		Ferralsol			TB	1166.784	1454.672
131	48	12960						0						0		Mineral soils condition		CDP	Ho	11529.79	1470.796
132	45	dry						0						0		Nitisol-Acrisol-Alisol-Li		WASAC	Bl	1263.354	1465.5
133	40	3600						0						0		Cambisol			Ho	2325.677	1468.644
173	0	3600						0						0		Ferralsol		WASAC	Ng	3599.184	1414.319
186	0	200						0						0		Cambisol		WASAC	Ho	394.9115	1457.964
232	55	3000						0						0		Cambisol			Ho	2999.066	1362.876
233	75	1980						0						0		Ferralsol			Gi	1993.459	1366.257
237	70	1020						0						0		Ferralsol			TB	1025.797	1341.696
294	42	10000						0		No				0		Ferralsol			Ho	9876.743	1485.223
316	42	1080						0		Yes				0		Clay soil with low infiltration rate			Ho	1469.235	1372.52
318	57	2900						0		No				0		Ferralsol			Ho	3108.421	1388.907
319	57	3400						0		No				0		Clay soil with low infiltration rate			Ho	3498.091	1380.027
322	63	4320						0		No				0		Ferralsol			TM	3510.974	1412.839
323	51	1080						0		No				0		Nitisol-Acrisol-Alisol-Lixisol			Ng	1114.234	1437.702
350	57	720						0		No				0		Nitisol-Acrisol-Alisol-Lixisol			Bl	1014.246	1527.847
351	78	1180						0		No				0		Nitisol-Acrisol-Alisol-Lixisol			Bl	1067.262	1523.444
354	36	1440						0		No				0		Ferralsol		JOINT	Rr	1552.332	1417.292
367	57	dry						0		No				0		Clay soil with low infilt		CDP	Ho	62.76681	1343.967
369	57	2700						0		No				0		Clay soil with low infiltration rate			TM	4189.377	1352
371	47	7200						0		No				0		Clay soil with low infiltration rate			Ho	6814.449	1360.989
475	86.07	3500						0						0		Clay soil with low infilt		WASAC	Ng	3478.022	1440.43

Name	District	Latitude	Longitude	Alti	Date	Comments	Discharge (l/m)	discharge (m3/hr)
SP1	Bugesera	-02 08' 03.35965"	30 06' 47.13408"	1362.54	10/03/2009	.07 Nyamata cell		
SP2	Bugesera	-02 10' 23.88997"	30 03' 03.28529"	1372.88	10/03/2009	10-mar-09 .15		
SP3	Bugesera	-02 10' 24.38846"	30 03' 03.33144"	1376.48	16/03/2009	05.Mwiherero		
SP4	Bugesera	-02 09' 57.64449"	29 59' 46.23475"	1364.95	16/03/2009	16-mar-09 .14		
SP5	Bugesera	-02 09' 22.54601"	30 00' 04.99054"	1359.18	16/03/2009	16-mar-09 .13		
SP6	Bugesera	-02 12' 19.22791"	30 00' 12.24396"	1389.7	17/03/2009	15.Kavumu		
SP7	Bugesera	-02 08' 26.97117"	30 03' 41.66618"	1360.86	10/03/2009	10-mar-09 .23		
SP8	Bugesera	-02 09' 23.81546"	30 04' 56.02152"	1374.56	10/03/2009	10-mar-09 .17		
SP9	Bugesera	-02 10' 32.92311"	30 02' 01.60336"	1375.28	16/03/2009	02.Kanyinya		
SP10	Bugesera	-02 11' 21.47143"	30 02' 11.47445"	1436.57	16/03/2009	06.Rwingeso		
SP11	Bugesera	-02 09' 51.86178"	30 03' 36.14418"	1373.6	10/03/2009	10-mar-09 .14		
SP12	Gatsibo	-01 40' 49.00189"	30 26' 31.17563"	1341.88	07/12/2009	ACTIVE LOG		
SP13	Gatsibo	-01 41' 00.69223"	30 26' 29.20823"	1347.64	07/12/2009	RUGARAMA MATUNGURU NYABAGENDWA 410		
SP14	Gatsibo	-01 41' 03.60109"	30 26' 19.65790"	1348.12	18/02/2009	RUGARAMA KANYANGESE AGAKIRE407		
SP15	Gatsibo	-01 41' 11.16864"	30 21' 05.37113"	1443.05	07/12/2009	Rugarama Remera Akajevuba 693		
SP16	Gatsibo	-01 41' 15.40971"	30 23' 55.67921"	0	07/12/2009	RUGARAMA GIHUTA GASHENYI 240 It is working		
SP17	Gatsibo	-01 41' 16.29897"	30 21' 30.15734"	1462.76	07/12/2009	Rugarama Remera Akajevuba 692		
SP18	Gatsibo	-01 41' 17.72714"	30 22' 25.14468"	0	07/12/2009	RUGARAMA MATARE GAKENYERO 231 Not good		
SP19	Gatsibo	-01 41' 19.59919"	30 22' 14.91510"	1481.03	07/12/2009	Rugarama Remera Kanyiranzage 691		
SP20	Gatsibo	-01 41' 27.05479"	30 23' 06.64627"	0	07/12/2009	RUGARAMA MATARE GITSIMBA B 230 Public in use		
SP21	Gatsibo	-01 41' 27.65920"	30 19' 18.53346"	1543.27	07/12/2009	REMERA KIGABIRO NYAGAKOMBE 423		
SP22	Gatsibo	-01 41' 40.69141"	30 26' 06.31669"	1360.14	07/12/2009	RUGARAAMA MATUNGURU NYABAGENDWA 411		
SP23	Gatsibo	-01 41' 46.11866"	30 16' 58.10934"	1588.69	07/12/2009	KAGEYO GITUZA GISIZA 451		
SP24	Gatsibo	-01 41' 47.55951"	30 25' 44.04281"	1364.23	18/02/2009	RUGARAMA KANYANGESE CYAMIRITA 402		
SP25	Gatsibo	-01 41' 50.30572"	30 24' 48.96104"	1390.42	07/12/2009	REMERA KANYANGESE 421		
SP26	Gatsibo	-01 41' 56.66628"	30 26' 00.12692"	1362.78	07/12/2009	RUGARAMA MATUNGURU KABASAZA412		
SP27	Gatsibo	-01 42' 01.27428"	30 22' 23.03879"	1467.09	07/12/2009	Rugarama Remera Kanyiranzage 687		
SP28	Gatsibo	-01 42' 07.72566"	30 23' 10.58590"	0	07/12/2009	RUGARAMA MATARE KABANA 229 Not in good conditions		
SP29	Gatsibo	-01 42' 10.37471"	30 24' 53.72867"	1392.34	18/02/2009	RUGARAMA KANYANGESE KANYANGESE 401		
SP30	Gatsibo	-01 42' 17.78204"	30 18' 10.94602"	1655.26	07/12/2009	Remera Butiruka Kerekezo 701		
SP31	Gatsibo	-01 42' 39.01095"	30 23' 47.97377"	0	07/12/2009	RUGARAMA GIHUTA NYAGAHANGA 250 working		
SP32	Gatsibo	-01 42' 45.05558"	30 21' 59.88503"	0	07/12/2009	RUGARAMA BUGARAMA AKABARE 228 Not in good conditions		
SP33	Gatsibo	-01 42' 50.56037"	30 25' 03.02765"	1389.94	18/02/2009	RUGARAMA KANYANGESE KANYANGE 400		
SP34	Gatsibo	-01 42' 53.23719"	30 18' 26.67856"	1551.68	07/12/2009	Remera Butiruka Kerekezo 702		
SP35	Gatsibo	-01 42' 59.19913"	30 25' 33.70580"	1445.7	18/02/2009	RUGARAMA NYANGESE KANYANGESE 399		
SP36	Gatsibo	-01 43' 15.26573"	30 25' 17.42196"	1403.88	18/02/2009	RUGARAMA KANYANGESE 398		
SP37	Gatsibo	-01 43' 34.40805"	30 25' 13.06592"	1406.52	18/02/2009	RUGARAMA KANYANGESE RUGARAMA 397		
SP38	Gatsibo	-01 43' 52.01961"	30 25' 39.02293"	1431.04	18/02/2009	RUGARAMA KANYANGESE AKAZINGA 395		
SP39	Gatsibo	-01 43' 54.50270"	30 25' 48.11250"	1439.21	18/02/2009	RUGARAMA KANYANGESE AKAZINGA 396		
SP40	Gatsibo	-01 43' 56.81650"	30 25' 09.28952"	1405.56	17/02/2009			
SP41	Gatsibo	-01 43' 56.83310"	30 25' 09.11845"	1408.45	31/12/1989	Kiziguro Ndatemwa Akarambo 640		
SP42	Gatsibo	-01 43' 56.89586"	30 25' 09.29618"	0	07/12/2009	KIZIGURO NDATEMWA KARAMBO 185 Public in		
SP43	Gatsibo	-01 43' 56.91759"	30 25' 09.25212"	1408.45	17/02/2009	KIZIGURO NDATEMWA KARAMBO 345		
SP44	Gatsibo	-01 44' 00.77756"	30 25' 05.87798"	0	07/12/2009	KIZIGURO NDATEMWA KARAMBO 184 Public in		
SP45	Gatsibo	-01 44' 00.78208"	30 25' 05.86891"	1405.32	17/02/2009	KIZIGURO NDATEMWA KARAMBO 344		
SP46	Gatsibo	-01 44' 00.80351"	30 25' 05.85260"	1407.24	07/12/2009	Kiziguro Ndatemwa Akarambo 639		
SP47	Gatsibo	-01 44' 00.83579"	30 25' 05.84962"	1404.12	17/02/2009	20.6 l/min 65.9 ms/m 22.3	20	1.0
SP48	Gatsibo	-01 44' 17.92472"	30 24' 55.88737"	1411.81	17/02/2009			
SP49	Gatsibo	-01 44' 17.98446"	30 24' 55.95167"	0	07/12/2009	KIZIGURO NDATEMWA MATABA 183. Ground		
SP50	Gatsibo	-01 44' 18.02761"	30 24' 55.86988"	1407.97	07/12/2009	Kiziguro Ndatemwa Mataba 638		
SP51	Gatsibo	-01 44' 20.43708"	30 26' 44.46524"	0	07/12/2009	KIZIGURO MBOGO AKABUYE 212 Public in use ground water		
SP52	Gatsibo	-01 44' 30.66213"	30 23' 21.20413"	1433.92	07/12/2009	Kiziguro Ndatemwa Akabagendo 649		
SP53	Gatsibo	-01 44' 30.66213"	30 23' 21.20413"	1433.92	07/12/2009	Kiziguro Ndatemwa Akabagendo 649		
SP54	Gatsibo	-01 44' 33.20768"	30 23' 22.71678"	1430.8	07/12/2009	Kiziguro Ndatemwa Akabagendo 649		
SP55	Gatsibo	-01 44' 33.23332"	30 23' 22.75933"	1429.6	17/02/2009	KIZIGURO NDATEMWA AKABAGENDO 355		
SP56	Gatsibo	-01 44' 33.29880"	30 23' 22.82964"	0	07/12/2009	KIZIGURO NDATEMWA AKABAGENDO 195 Public in use		
SP57	Gatsibo	-01 44' 45.27218"	30 21' 02.10380"	0	07/12/2009	REMERA RWARENGA NYARUBUYE 291 Working		
SP58	Gatsibo	-01 44' 45.69041"	30 18' 44.55986"	1584.13	03/02/2009	03-feb-09 .24		
SP59	Gatsibo	-01 44' 49.14181"	30 18' 55.54562"	1576.92	03/02/2009	21.Nyakagezi		
SP60	Gatsibo	-01 44' 50.24953"	30 25' 06.07775"	1423.83	17/02/2009	37.5 l/min 62 ms/m 22.6	37	2.0
SP61	Gatsibo	-01 44' 50.27970"	30 25' 05.96669"	1428.15	17/02/2009	KIZIGURO NDATEMWA MISHUNZI 340		
SP62	Gatsibo	-01 44' 50.29328"	30 25' 05.93591"	0	07/12/2009	KIZIGURO NDATEMWA MISHUNZI 181 In use		
SP63	Gatsibo	-01 44' 50.31108"	30 25' 05.96971"	1436.81	07/12/2009	Kiziguro Ndatemwa Mishunzi 635		
SP64	Gatsibo	-01 44' 50.33432"	30 25' 05.95283"	1435.84	07/12/2009	Kiziguro Ndatemwa Mishunzi 635		
SP65	Gatsibo	-01 44' 56.38769"	30 24' 25.67423"	1421.42	17/02/2009	2.83 ms/m 22.6		
SP66	Gatsibo	-01 44' 56.41757"	30 24' 25.59334"	1425.99	07/12/2009	Kiziguro Ndatemwa Rukungu 633	2	0.1
SP67	Gatsibo	-01 44' 56.45106"	30 24' 25.61324"	1414.45	17/02/2009	KIZIGURO NDATEMWA RUKUNGU 338		
SP68	Gatsibo	-01 44' 56.56965"	30 24' 25.74785"	0	07/12/2009	KIZIGURO NDATEMWA RUKUNGU 179 Not in use		
SP69	Gatsibo	-01 45' 01.67101"	30 25' 09.06686"	1445.46	17/02/2009	KIZIGURO AGAKOMEYE BISHENYI 367		
SP70	Gatsibo	-01 45' 09.03367"	30 19' 12.25013"	1579.32	03/02/2009	20.Gakoni		
SP71	Gatsibo	-01 45' 09.89486"	30 25' 25.51033"	1468.05	17/02/2009	KIZIGURO NDATEMWA MISHUNZI 341		
SP72	Gatsibo	-01 45' 09.93711"	30 25' 25.53780"	1469.73	17/02/2009	44.8 ms/m 20.2	44	2.0
SP73	Gatsibo	-01 45' 11.01495"	30 19' 57.37030"	0	07/12/2009	REMERA RWARENGA NYARUBUYE 286 cleaned		
SP74	Gatsibo	-01 45' 16.36345"	30 23' 49.66775"	1446.42	07/12/2009	Kiziguro Ndatemwa Gorora 652		
SP75	Gatsibo	-01 45' 16.51643"	30 23' 49.53289"	1448.1	17/02/2009	KIZGURO NDATEMWA RYARUGEMA 358		
SP76	Gatsibo	-01 45' 18.28317"	30 24' 52.01687"	1461.08	17/02/2009	KIZIGURO AGAKOMEYE BISHENYI 368		
SP77	Gatsibo	-01 45' 18.98504"	30 24' 39.65936"	1440.17	07/12/2009	Kiziguro Ndatemwa Bishenyi 634		
SP78	Gatsibo	-01 45' 19.01974"	30 24' 39.75109"	1437.77	17/02/2009	KIZIGURO NDATEMWA RUKUNGU 339		
SP79	Gatsibo	-01 45' 19.04871"	30 24' 39.76826"	0	07/12/2009	KIZIGURO NDATEMWA RUKUNGU 180 Public in use To be treated		
SP80	Gatsibo	-01 45' 19.05293"	30 24' 39.75109"	1435.6	17/02/2009	15.4 ms/m 22.6	15	0.9
SP81	Gatsibo	-01 45' 19.10664"	30 19' 17.85814"	0	07/12/2009	REMERA RWARENGA NYARUBUYE 288 working		
SP82	Gatsibo	-01 45' 20.14949"	30 25' 58.07806"	0	07/12/2009	KIZIGURO. MBOGO RYAMUHUZI 216 In use Public		
SP83	Gatsibo	-01 45' 40.27702"	30 24' 28.45937"	1443.05	17/02/2009	KIZIGURO AGAKOMEYE AKINGONDO 369		
SP84	Gatsibo	-01 45' 49.34969"	30 24' 12.04787"	1429.84	17/02/2009	KIZIGURO AGAKOMEYE AKINGONDO 372		
SP85	Gatsibo	-01 45' 50.72174"	30 24' 13.36738"	1433.44	17/02/2009	KIZIGURO AGAKOMEYE AKINGONDO 371		
SP86	Gatsibo	-01 45' 52.90761"	30 24' 12.89545"	1436.57	17/02/2009	KIZIGURO AGAKOMEYE AKINGONDO 370		
SP87	Gatsibo	-01 46' 42.24741"	30 24' 38.40224"	1475.98	07/12/2009	Kiziguro Rubona Rubira 667		
SP88	Gatsibo	-01 46' 57.23164"	30 24' 22.97808"	1469.73	07/12/2009	Kiziguro Rubona Rubira 669		
SP89	Gatsibo	-01 50' 02.85495"	30 19' 54.85462"	1461.08	26/01/2009	30.Nyakariba		

SP90	Gatsibo	-01 47' 11.48835''	30 26' 39.36480''	1458.91	07/12/2009	Kiziguro Rubona Rubindi 684
SP91	Gatsibo	-01 47' 12.63862''	30 26' 43.67616''	1461.8	07/12/2009	Kiziguro Rubona Rubindi 685
SP92	Gatsibo	-01 47' 27.54741''	30 20' 29.02553''	1516.35	26/01/2009	11.Ngaruye
SP93	Gatsibo	-01 47' 29.19314''	30 20' 03.69496''	1550.72	26/01/2009	10.Rwimondo-Kadogo
SP94	Gatsibo	-01 47' 32.66868''	30 24' 43.64003''	1490.64	22/01/2009	01.Kidobogo
SP95	Gatsibo	-01 40' 17.82161''	30 15' 28.95412''	0	07/12/2009	KAGEYO KINTU RUTOMA 306 In use
SP96	Gatsibo	-01 40' 18.43959''	30 21' 51.31055''	0	07/12/2009	RUGARAMA MATARE NYAGATARE 235 In use but in bad condition
SP97	Gatsibo	-01 39' 16.40976''	30 25' 38.14817''	0	07/12/2009	RWIMBOGO NYAMATETE RUTEMBO Working
SP98	Gatsibo	-01 40' 21.20120''	30 18' 45.31756''	0	07/12/2009	REMERA NYAGAKOMBE RUNYINYA 256 not
SP99	Gatsibo	-01 39' 17.46135''	30 18' 38.03335''	1464.92	07/12/2009	REMERA KIGABIROKANYINYA 425
SP100	Gatsibo	-01 40' 26.18367''	30 15' 34.09110''	0	07/12/2009	KAGEYO KINTU RUTOMA 307 In use
SP101	Gatsibo	-01 40' 28.38673''	30 19' 40.35468''	1535.1	07/12/2009	Gitoki Cyabusheshe Binunga 776
SP102	Gatsibo	-01 37' 37.48754''	30 22' 03.49241''	1412.53	07/12/2009	Gitoki Nyamirama Kinteko 780
SP103	Gatsibo	-01 40' 28.46519''	30 19' 40.28560''	1555.53	07/12/2009	REMERA RWAKARUGU AKABUGA 424
SP104	Gatsibo	-01 40' 29.74822''	30 26' 00.70357''	1362.54	18/02/2009	RUGARAMA KANYANGESE RUGAZI 406
SP105	Gatsibo	-01 37' 45.19963''	30 13' 21.57280''	0	07/12/2009	GATSIBO NYAGAHANGA RUGARAMA 353 In use
SP106	Gatsibo	-01 37' 48.23401''	30 14' 36.69612''	1655.5	07/12/2009	GATSIBO MANISHYA RUGARAMA 538
SP107	Gatsibo	-01 40' 31.96608''	30 26' 50.83274''	1346.92	07/12/2009	RUGARAMA MATUNGURU RAMBURA 420
SP108	Gatsibo	-01 37' 52.42138''	30 17' 53.83838''	1432.96	07/12/2009	Gitoki Mpondwa Bwiza 753
SP109	Gatsibo	-01 40' 34.14017''	30 15' 51.22076''	0	07/12/2009	KAGEYO NYAGISOZI KINYANA In use
SP110	Gatsibo	-01 40' 36.51976''	30 17' 46.20808''	1568.02	07/12/2009	REMERA KIGABIRO BYIMANA 428
SP111	Gatsibo	-01 39' 23.62366''	30 18' 09.18860''	1461.56	07/12/2009	REMERA KIGABIRO BYIMANA 426
SP112	Gatsibo	-01 39' 30.19091''	30 16' 52.06984''	1520.92	07/12/2009	KAGEYO BISETSA CYABUHIMBIRU 472
SP113	Gatsibo	-01 40' 39.02609''	30 22' 55.52260''	0	07/12/2009	RUGARAMA MATARE MATARE 233 Ground Water
SP114	Gatsibo	-01 39' 32.16827''	30 14' 52.80223''	0	07/12/2009	KAGEYO KINTU GAKERI 295 In use
SP115	Gatsibo	-01 37' 52.44159''	30 13' 33.48826''	0	07/12/2009	GATSIBO NYAGAHANGA RUGARAMA 354 In use
SP116	Gatsibo	-01 39' 41.68904''	30 26' 04.08404''	0	07/12/2009	RWIMBOGO NYAMATETE RWIMBOGO 495 Working
SP117	Gatsibo	-01 40' 42.13530''	30 22' 41.27045''	0	07/12/2009	RUGARAMA MATARE MATARE 234 Working
SP118	Gatsibo	-01 37' 56.28466''	30 26' 21.65788''	0	07/12/2009	RWIMBOGO NYAMATETE NYAMATETE 491 Public in use
SP119	Gatsibo	-01 37' 56.45817''	30 21' 32.00285''	1409.17	07/12/2009	Gitoki Nyamirama Minago 750
SP120	Gatsibo	-01 39' 44.61027''	30 16' 36.97579''	1581.96	07/12/2009	KAGEYO BUSETSA CYABUHIMBIRI 471
SP121	Gatsibo	-01 40' 44.12443''	30 16' 22.73779''	0	07/12/2009	KAGEYO NYGISOZI KINYINYA 310 Not cleaned
SP122	Gatsibo	-01 38' 01.24812''	30 14' 02.75212''	1547.6	07/12/2009	GATSIBO MANISHYA MANISHYA 539
SP123	Gatsibo	-01 39' 59.30150''	30 15' 27.15811''	0	07/12/2009	KAGEYO NYAGISOZI KINYINYA 312 In use
SP124	Gatsibo	-01 40' 45.70800''	30 16' 04.17904''	0	07/12/2009	KAGEYO NYAGISOZI KASHANGO 309 In use
SP125	Gatsibo	-01 38' 10.70553''	30 20' 06.87898''	1432.96	07/12/2009	GITOKI KARUBUNGO GISHARARA 491
SP126	Gatsibo	-01 40' 00.26709''	30 22' 10.13963''	0	07/12/2009	RUGARAMA MATARE NYARUSAMBU 236 Working
SP127	Gatsibo	-01 38' 10.83498''	30 20' 07.02474''	1437.05	07/12/2009	Gitoki Karubungo Gisharara 746
SP128	Gatsibo	-01 37' 42.60127''	30 22' 12.45374''	1404.6	07/12/2009	Gitoki Nyamirama Kinteko 781
SP129	Gatsibo	-01 38' 19.55551''	30 13' 49.24675''	0	07/12/2009	GATSIBO NYAGAHANGA NYAKIBANDE 356 In use
SP130	Gatsibo	-01 40' 46.53842''	30 23' 24.47117''	0	07/12/2009	RUGARAMA MATARE RWANKUBA 232 Working
SP131	Gatsibo	-01 38' 31.88646''	30 20' 02.73386''	1442.81	07/12/2009	Gitoki Nyamirama Nyamuraza 745
SP132	Gatsibo	-01 40' 05.75167''	30 14' 38.78182''	0	07/12/2009	KAGEYO KINTU RUTOMA 301 In use
SP133	Gatsibo	-01 38' 34.03853''	30 15' 24.11287''	1611.52	07/12/2009	KAGEYO BUSETSA NYARUSANGE 478
SP134	Gatsibo	-01 40' 06.21516''	30 14' 37.44928''	0	07/12/2009	KAGEYO KINTU RUTOMA 303 in use
SP135	Gatsibo	-01 38' 34.12664''	30 15' 22.73782''	1622.34	07/12/2009	KAGEYO BUSETSA NYARUSANGE 477
SP136	Gatsibo	-01 38' 34.65832''	30 16' 18.06791''	1485.83	07/12/2009	KAGEYO BISETSA KANINGA 475
SP137	Gatsibo	-01 38' 36.00925''	30 26' 10.86252''	0	07/12/2009	RWIMBOGO NYAMATETE KIYOVU 492 Public in
SP138	Gatsibo	-01 38' 36.27630''	30 16' 34.99298''	1471.41	07/12/2009	KAGEYO BUSETSA RUGARAMA 468
SP139	Gatsibo	-01 38' 41.68031''	30 20' 00.93786''	1445.94	07/12/2009	Gitoki Nyamirama Akagarama 747
SP140	Gatsibo	-01 38' 42.43408''	30 14' 39.02622''	1549.04	07/12/2009	GATSIBO MANISHYA NYARUHANGA 537
SP141	Gatsibo	-01 40' 07.50393''	30 17' 33.72263''	1500.97	07/12/2009	GITOKI MPONDWA GAHAMA 427
SP142	Gatsibo	-01 40' 10.31683''	30 24' 53.99935''	1369.99	18/02/2009	RUGARAMA KANYANGESE MUNINI 404
SP143	Gatsibo	-01 40' 16.26580''	30 27' 00.71834''	1348.12	07/12/2009	RUGARAMA MATUNGURU RAMBURA 419
SP144	Gatsibo	-01 37' 24.13034''	30 13' 21.49525''	0	07/12/2009	GATSIBO NYAGAHANGA NYAGAHANGA 352 In use
SP145	Gatsibo	-01 38' 47.51915''	30 13' 38.49002''	0	07/12/2009	GATSIBO NYAGAHANGA NYAKIBANDE 357 In use
SP146	Gatsibo	-01 38' 51.86312''	30 18' 24.64085''	1441.61	07/12/2009	Gitoki Mpondwa Nyaruhanga
SP147	Gatsibo	-01 37' 27.58204''	30 17' 48.40267''	1436.33	07/12/2009	Kageyo Busetsa Nyarbuye 741
SP148	Gatsibo	-01 40' 48.75929''	30 16' 16.44211''	0	07/12/2009	KAGEYO NYAGISOZI KAGEYO 311 Not working
SP149	Gatsibo	-01 37' 27.60286''	30 17' 48.47147''	1426.47	07/12/2009	KAGEYO BUSETSA NYARUBUYE 464
SP150	Gatsibo	-01 37' 32.83609''	30 21' 00.05461''	1390.9	07/12/2009	Gitoki Nyamirama Rukiri 782
SP151	Gatsibo	-01 30' 42.88327''	30 12' 21.24936''	1420.7	07/12/2009	NYAGIHANGANYAGITABIREKAMURARA552
SP152	Gatsibo	-01 39' 12.41219''	30 25' 45.25496''	0	31/12/1989	RWIMBOGO NYAMATETE UMUREGO 493 Working
SP153	Gatsibo	-01 31' 17.72165''	30 10' 48.78545''	1463.96	07/12/2009	Nyagihanga Murambi Kabeza 793
SP154	Gatsibo	-01 31' 30.36400''	30 12' 42.28214''	1451.46	07/12/2009	NYAGIHANGANYAGITABIREBYIMANA555
SP155	Gatsibo	-01 31' 39.68321''	30 16' 27.58508''	0	07/12/2009	NGARAMA KIGASHA CYABAHIMA 466 Working public in use
SP156	Gatsibo	-01 31' 52.49575''	30 13' 24.63856''	1464.2	07/12/2009	NYAGIHANGAMAYANGEMATABA563
SP157	Gatsibo	-01 32' 16.26146''	30 10' 42.59449''	1494.48	07/12/2009	Nyagihanga Murambi Kabeza 800
SP158	Gatsibo	-01 32' 25.42406''	30 13' 52.12031''	1439.69	07/12/2009	NYAGIHANGAGITINDAKABUYE581
SP159	Gatsibo	-01 32' 29.16332''	30 10' 53.41912''	1513.23	07/12/2009	Nyagihanga Murambi Umugamba 797
SP160	Gatsibo	-01 32' 31.35462''	30 10' 34.49798''	1492.32	07/12/2009	Nyagihanga Murambi Birembo 802
SP161	Gatsibo	-01 32' 42.61286''	30 10' 38.24054''	1507.7	07/12/2009	Nyagihanga Murambi Kagarama 801
SP162	Gatsibo	-01 32' 44.51840''	30 10' 32.69078''	1502.41	07/12/2009	Nyagihanga Murambi Kagarama 803
SP163	Gatsibo	-01 32' 44.61767''	30 13' 42.30926''	1479.82	07/12/2009	NYAGIHANGAGITINDAKABUYE582
SP164	Gatsibo	-01 32' 51.07932''	30 14' 03.61482''	0	07/12/2009	NGARAMA NGARAMA RUGARAMA 387 In use
SP165	Gatsibo	-01 32' 53.63000''	30 13' 10.08282''	1486.79	07/12/2009	NYAGIHANGAMAYANGERWEZA580
SP166	Gatsibo	-01 33' 30.84766''	30 12' 50.18461''	1528.37	07/12/2009	NYAGIHANGAGITINDAMAYANGERWEZA579
SP167	Gatsibo	-01 33' 35.92156''	30 15' 28.52924''	0	07/12/2009	NGARAMA NYARUBUNGO RWIRI 397 In use
SP168	Gatsibo	-01 33' 39.12734''	30 15' 22.63914''	0	07/12/2009	NGARAMA NGARAMA KABEHO 398 In use
SP169	Gatsibo	-01 33' 40.73022''	30 15' 34.07177''	0	07/12/2009	NGARAMA NYARUBUNGO RWIRI 396 In use
SP170	Gatsibo	-01 33' 45.53738''	30 13' 58.46578''	1519.72	31/12/1989	NYAGIHANGAGITINDAISANGANO591
SP171	Gatsibo	-01 33' 46.60104''	30 15' 46.21896''	0	07/12/2009	NGARAMA NYARUBUNGO RWIRI 395 In use
SP172	Gatsibo	-01 33' 48.85179''	30 10' 05.39371''	1560.09	07/12/2009	Nyagihanga Murambi Rukoma 804
SP173	Gatsibo	-01 34' 16.72490''	30 12' 10.55538''	1500.25	07/12/2009	Nyagihanga Nyamirama Rugarama 830
SP174	Gatsibo	-01 34' 16.89539''	30 12' 10.46729''	1499.05	07/12/2009	Nyagihanga Nyamirama Burembo 829
SP175	Gatsibo	-01 34' 25.26348''	30 15' 12.30725''	0	07/12/2009	GATSIBO NYABICWAMBA RUTOVU 375 In use
SP176	Gatsibo	-01 34' 29.33859''	30 13' 36.26375''	1599.03	07/12/2009	NYAGIHANGAGITINDAKINTARAMA588
SP177	Gatsibo	-01 34' 33.51026''	30 10' 56.24015''	1849.93	07/12/2009	Nyagihanga Murambi Kanyinya 805
SP178	Gatsibo	-01 34' 49.31917''	30 13' 36.23477''	1606.96	07/12/2009	NYAGIHANGAGITINDANYABUKINGI587
SP179	Gatsibo	-01 35' 04.50527''	30 15' 45.46580''	0	07/12/2009	GATSIBO NYABICWAMBA GATOMA 376 In use
SP180	Gatsibo	-01 35' 17.77828''	30 11' 06.42930''	1847.53	07/12/2009	Nyagihanga Murambi Kanyinya 817

SP181	Gatsibo	-01 35' 27.13882"	30 16' 58.09789"	0	07/12/2009	GATSIBO NYABICWAMBA RUCUMBO 382 In use		
SP182	Gatsibo	-01 35' 33.37657"	30 13' 43.89737"	0	07/12/2009	GATSIBO GATSIBO HANIKA 334 In use		
SP183	Gatsibo	-01 35' 48.53641"	30 11' 36.31538"	1768.94	07/12/2009	Nyagihanga Nyamirama Butumba 823		
SP184	Gatsibo	-01 35' 49.28958"	30 12' 53.86021"	0	07/12/2009	GATSIBO NYAGAHANGA MANGARAMA 345 In use		
SP185	Gatsibo	-01 35' 51.62632"	30 12' 27.01667"	0	07/12/2009	GATSIBO NYAGAHANGA KARAMA 346 In use		
SP186	Gatsibo	-01 35' 54.42654"	30 16' 44.32850"	0	07/12/2009	GATSIBO KADUHA RYABAKAME 384 In use		
SP187	Gatsibo	-01 35' 58.39514"	30 12' 32.97197"	1575.95	07/12/2009	Nyagihanga Nyamirama Burembo 827		
SP188	Gatsibo	-01 35' 59.48626"	30 13' 14.44670"	0	07/12/2009	GATSIBO GATSIBO NYARUKONI 341 In use		
SP189	Gatsibo	-01 35' 59.85138"	30 17' 39.75760"	1416.62	07/12/2009	Gitoki Rubira Kavumu 763		
SP190	Gatsibo	-01 36' 04.62262"	30 11' 06.15440"	1727.36	07/12/2009	Nyagihanga Nyamirama Kabuga 821		
SP191	Gatsibo	-01 36' 04.66185"	30 14' 59.15587"	0	07/12/2009	GATSIBO NYAGAHANGA NYAKAGARAMA 362 In use		
SP192	Gatsibo	-01 36' 04.70470"	30 14' 59.21682"	1523.8	07/12/2009	GATSIBO MUGERA KAVUMU 523		
SP193	Gatsibo	-01 36' 07.46540"	30 17' 09.23662"	1410.13	07/12/2009	GATSIBO MUGERA KAMASAPFU 528		
SP194	Gatsibo	-01 36' 12.73423"	30 13' 21.86249"	0	07/12/2009	GATSIBO GATSIBO YARUKONI 340. In use		
SP195	Gatsibo	-01 36' 12.74539"	30 17' 42.23735"	1416.86	07/12/2009	Gitoki Rubira Gikuyu 762		
SP196	Gatsibo	-01 36' 18.87541"	30 13' 40.69160"	0	07/12/2009	GATSIBO GATSIBO NYARUKONI 399 In use		
SP197	Gatsibo	-01 36' 21.69495"	30 14' 09.83324"	0	07/12/2009	GATSIBO GATSIBO NYARUKONI 337 In use		
SP198	Gatsibo	-01 36' 22.46954"	30 14' 13.29641"	1566.82	07/12/2009	GATSIBO MUGERANYARUKONI 534		
SP199	Gatsibo	-01 36' 23.16266"	30 14' 01.39394"	0	07/12/2009	GATSIBO GATSIBO NYARUKONI 338 In use		
SP200	Gatsibo	-01 36' 37.92389"	30 13' 23.95934"	1541.35	07/12/2009	GATSIBO MANISHYA NYARUKONI 540		
SP201	Gatsibo	-01 36' 38.65895"	30 11' 24.62957"	1736.01	07/12/2009	Nyagihanga Nyamirama Rugogwe 820		
SP202	Gatsibo	-01 36' 47.02825"	30 13' 17.11870"	1545.19	06/07/2009	150 l/min	150	9.0
SP203	Gatsibo	-01 36' 47.03217"	30 13' 16.84139"	0	07/12/2009	GATSIBO NYAGAHANGA NYAGAHANGA 349 In		
SP204	Gatsibo	-01 36' 49.36016"	30 14' 08.03875"	1569.95	07/12/2009	GATSIBO MUGERA KABUGA 536		
SP205	Gatsibo	-01 36' 55.11813"	30 17' 42.51887"	1418.78	07/12/2009	Gitoki Rubira Nyakarama 754		
SP206	Gatsibo	-01 36' 55.33629"	30 12' 41.15297"	0	07/12/2009	GATSIBO NYAGAHANGA KIZINGA 360 In use		
SP207	Gatsibo	-01 36' 56.95849"	30 12' 39.78184"	0	07/12/2009	GATSIBO NYAGAHANGA KIZINGA 359 In use		
SP208	Gatsibo	-01 36' 59.03814"	30 20' 29.55689"	1389.46	07/12/2009	GITOKI KARUBUNGO RWAMUHINGA 500		
SP209	Gatsibo	-01 38' 57.82265"	30 20' 08.03710"	1458.67	07/12/2009	Gitoki Nyamirama Akagarama 748		
SP210	Gatsibo	-01 37' 03.62532"	30 24' 01.55848"	1486.55	24/02/2009	KABARORE KARENGE NYARUBUYE 620 Good		
SP211	Gatsibo	-01 37' 04.11084"	30 24' 02.44681"	1487.27	24/02/2009	KABARORE KARENGE NYARUBUYE 621 Good		
SP212	Gatsibo	-01 37' 18.80538"	30 15' 34.87565"	1481.75	07/12/2009	KAGEYO BUSETSA KAYENZI482		
SP213	Gicumbi	-01 37' 15.33316"	30 11' 31.33442"	1817.96	07/12/2009	Nyagihanga Nyamirama Rugogwe 818		
SP214	Gicumbi	-01 37' 00.43976"	30 11' 25.66244"	1770.38	07/12/2009	Nyagihanga Nyamirama rugogwe 819		
SP215	Kayonza	-01 58' 37.73055"	30 31' 29.03974"	1506.74	07/01/2009	14 Gatare		
SP216	Kayonza	-02 03' 36.64625"	30 33' 40.62593"	1534.38	29/12/2008	Kabeza 12l/min 16	12	0.7
SP217	Kayonza	-01 45' 00.59377"	30 30' 05.06765"	1388.98	19/01/2009	26.Nyamga		
SP218	Kayonza	-01 59' 21.43400"	30 29' 03.10150"	1432.96	08/01/2009	07 Nyakariba		
SP219	Kayonza	-01 59' 28.04199"	30 29' 43.43348"	1444.26	07/01/2009	17 Karaso		
SP220	Kayonza	-01 59' 28.30904"	30 31' 18.79810"	1477.9	07/01/2009	12 Gitoki		
SP221	Kayonza	-01 48' 08.71254"	30 30' 50.16337"	1481.51	15/01/2009	.04 Ryakiramba		
SP222	Kayonza	-01 56' 49.05432"	30 32' 44.11417"	1493.04	31/12/2008	30-dec-08 .05		
SP223	Kayonza	-01 59' 49.52679"	30 38' 56.91239"	1416.38	23/12/2008	16.Kiburara		
SP224	Kayonza	-02 04' 10.03231"	30 35' 22.42622"	1425.99	23/12/2008	03.Kaguruka		
SP225	Kayonza	-01 59' 52.39249"	30 29' 18.19374"	1395.23	08/01/2009	08 Rwanyakagora		
SP226	Kayonza	-01 56' 17.36439"	30 33' 14.42513"	1487.76	31/12/2008	30-dec-08 .17		
SP227	Kayonza	-01 55' 10.61188"	30 30' 55.83233"	1474.78	31/12/2008	19.Gashuhe		
SP228	Kayonza	-02 04' 15.75075"	30 35' 32.36402"	1431.52	23/12/2008	02.Kidimba		
SP229	Kayonza	-02 00' 08.48383"	30 30' 29.92540"	1441.37	07/01/2009	18 Rwabujeni		
SP230	Kayonza	-02 00' 14.13076"	30 28' 48.04212"	1366.63	08/01/2009	08-jan-09 .10		
SP231	Kayonza	-01 43' 09.62515"	30 28' 02.95396"	1373.84	19/01/2009	36.Gisagora		
SP232	Kayonza	-02 00' 23.12497"	30 29' 38.48694"	1398.83	08/01/2009	06 Rutaka		
SP233	Kayonza	-01 44' 18.38941"	30 29' 33.36688"	1382.97	19/01/2009	27.Kayongo		
SP234	Kayonza	-01 50' 43.82455"	30 35' 31.98412"	1413.97	07/01/2009	02-jan-09 .16		
SP235	Kayonza	-01 56' 33.57130"	30 31' 40.37192"	1501.93	31/12/2008	30-dec-08.03		
SP236	Kayonza	-01 49' 37.65443"	30 34' 09.38860"	1482.47	13/01/2009	13-jan-09 .11		
SP237	Kayonza	-02 00' 32.11436"	30 29' 09.35041"	1362.78	08/01/2009	05 Rwanyakajyugo		
SP238	Kayonza	-01 54' 19.00323"	30 33' 29.95308"	1467.57	07/01/2009	30.Rugege 2		
SP239	Kayonza	-02 02' 27.01869"	30 40' 20.50849"	1443.53	29/12/2008	29-dec-08 .36		
SP240	Kayonza	-02 01' 50.66071"	30 39' 12.90024"	1465.88	23/12/2008	23-dec-08 .09		
SP241	Kayonza	-01 47' 24.12678"	30 29' 33.04309"	1498.33	15/01/2009	21. Kajara		
SP242	Kayonza	-01 54' 25.93922"	30 33' 35.75632"	1469.25	07/01/2009	29.Rugege 1		
SP243	Kayonza	-01 47' 31.58390"	30 29' 30.81318"	1502.65	15/01/2009	20. Nyakariba		
SP244	Kayonza	-01 57' 29.83563"	30 28' 40.08623"	1405.32	31/12/2008	32.Rudondogoro		
SP245	Kayonza	-02 00' 50.69453"	30 30' 41.92052"	1376.72	07/01/2009	16 Akabuye		
SP246	Kayonza	-02 00' 58.76359"	30 40' 37.09502"	1448.58	29/12/2008	29-dec-08 .34		
SP247	Kayonza	-01 57' 04.22623"	30 29' 24.69642"	1494.96	31/12/2008	33.Rwamurama		
SP248	Kayonza	-01 42' 19.54787"	30 26' 48.61910"	1353.89	07/12/2009	RUGARAMA MATIUNGURU NYAMATA415		
SP249	Kayonza	-02 01' 00.19840"	30 32' 45.84833"	1434.4	22/12/2008	Tank+pump 02		
SP250	Kayonza	-01 55' 06.47612"	30 34' 34.64044"	1403.88	22/12/2008	22-dec-08 .09		
SP251	Kayonza	-01 56' 17.64411"	30 33' 11.85815"	1489.92	31/12/2008	30-dec-08 .16		
SP252	Kayonza	-02 02' 16.02177"	30 36' 43.16627"	1481.75	23/12/2008	01.Nyaruriba		
SP253	Kayonza	-02 01' 12.94124"	30 30' 36.00655"	1371.44	07/01/2009	07-jan-09 .15		
SP254	Kirehe	-02 10' 34.81055"	30 42' 41.91059"	1589.17	17/12/2008	15-dec-08 .04		
SP255	Kirehe	-02 10' 06.01831"	30 47' 20.90544"	1664.15	26/01/2009	Cyereta 22 l/min 6.01 ms/m 21.6	22	1.0
SP256	Kirehe	-02 06' 07.75678"	30 45' 36.64166"	1300.54	17/12/2008	94.6l/min	94	5.0
SP257	Kirehe	-02 11' 51.39312"	30 48' 01.94594"	1614.89	27/01/2009	Kasinzi SP/Nyamugari/Nyabitare/38sec(12L)		
SP258	Kirehe	-02 11' 51.43053"	30 48' 02.06514"	1613.69	26/01/2009	Kansinzi 24.1 l/min 7.24 ms/m 21.5	24	1.0
SP259	Kirehe	-02 09' 36.17086"	30 43' 36.77992"	1627.14	27/01/2009	Nkakwa SP/Nkakwa/Nyarutunga/21sec(12L)		
SP260	Kirehe	-02 11' 57.48240"	30 37' 17.51099"	1430.56	17/12/2008	16-dec-08 .09 Gatagata		
SP261	Kirehe	-02 08' 36.71855"	30 39' 34.84278"	1719.67	17/12/2008	15-dec-08 .06		
SP262	Kirehe	-02 10' 08.96368"	30 44' 40.27805"	1552.64	27/01/2009	Nkawa SP/Nkawa/Nyarutunga/2min4sec(12L)		
SP263	Kirehe	-02 12' 19.83020"	30 35' 52.27278"	1393.31	21/01/2009	Gahama 13.5 l/min 9.53 ms/m 24	13	0.8
SP264	Kirehe	-02 12' 23.92553"	30 47' 41.38177"	1586.77	27/01/2009	Rutsoka SP/Nyamugari/Nabitare/35sec		
SP265	Kirehe	-02 12' 34.66536"	30 48' 20.20021"	1456.03	27/01/2009	Nyakagera		
SP266	Kirehe	-02 11' 26.80695"	30 48' 11.51017"	1669.2	26/01/2009	Nyakagera 5 l/min 3.2 ms/m 22.3	5	0.3
SP267	Kirehe	-02 10' 53.86114"	30 48' 21.88912"	1666.56	26/01/2009	Kamarobe 4.26 ms/m 21		
SP268	Kirehe	-02 09' 00.13333"	30 40' 28.10021"	1724	17/12/2008	15-dec-08 .05		
SP269	Kirehe	-02 13' 05.30461"	30 47' 56.48399"	1475.26	27/01/2009	Kamombo		
SP270	Kirehe	-02 13' 11.71012"	30 36' 05.48240"	1375.76	17/12/2008	16-dec-08 .10		
SP271	Kirehe	-02 21' 46.49098"	30 40' 54.54905"	1377.2	15/12/2008	37.2l/min 09	37	2.0

SP272	Kirehe	-02 09' 02.00478"	30 43' 35.30316"	1644.45	17/12/2008	17-dec-08 .20		
SP273	Kirehe	-02 09' 47.81956"	30 44' 11.75708"	1575.95	27/01/2009	Gashongi SP2/Birembo/Nyarutunga		
SP274	Kirehe	-02 10' 23.26294"	30 44' 46.61599"	1558.65	27/01/2009	Nkawa SP2/Nkawa/Nyarytunga/constructed by GermanNGO1970'/pipe broken		
SP275	Kirehe	-02 10' 09.05963"	30 43' 37.87648"	1640.36	17/12/2008	15-dec-08 02		
SP276	Kirehe	-02 13' 49.18699"	30 41' 33.60404"	1506.98	16/12/2008	Gahama 10l/min 25	10	0.6
SP277	Kirehe	-02 05' 58.52237"	30 47' 56.54735"	1396.91	17/12/2008	Kayanga 10		
SP278	Kirehe	-02 09' 46.84280"	30 40' 09.72250"	1649.49	17/12/2008	15-dec-08.07		
SP279	Kirehe	-02 13' 51.28595"	30 39' 00.61787"	1387.78	12/12/2008	3.Kamasaro		
SP280	Kirehe	-02 11' 31.30723"	30 38' 07.52280"	1484.15	17/12/2008	16-dec-08 .08		
SP281	Kirehe	-02 11' 32.93063"	30 49' 13.40000"	1451.71	28/01/2009	Nyagahanga 50.6 l/min 33 ms/m 23.3	50	3.0
SP282	Kirehe	-02 09' 57.24105"	30 43' 47.28709"	1593.02	17/12/2008	15-dec-08 03		
SP283	Kirehe	-02 07' 50.27010"	30 47' 37.15670"	1543.51	17/12/2008	Keretav 07		
SP284	Kirehe	-02 14' 19.66751"	30 41' 10.62830"	1486.55	16/12/2008	Rwakiriba 108.5l/min 26	108	6.0
SP285	Kirehe	-02 14' 24.00062"	30 47' 01.41097"	1428.15	30/09/2009	Kaborogota		
SP286	Kirehe	-02 14' 28.10440"	30 37' 18.72826"	1384.17	12/12/2008	6.Rwesero		
SP287	Kirehe	-02 14' 37.91726"	30 45' 57.68953"	1528.61	27/01/2009	Gitanbogo SP/Rwamagawa/Nyabitare/3min14sec		
SP288	Kirehe	-02 14' 37.91726"	30 45' 57.68953"	1528.61	29/01/2009	Bitanbogo SP/Nyarubuye sec		
SP289	Kirehe	-02 14' 37.98395"	30 45' 14.51747"	1614.65	27/01/2009	Gahama SP/Mponguhe/Nyabitare/57sec	57	3.0
SP290	Kirehe	-02 14' 49.96909"	30 35' 39.85282"	1363.51	17/12/2008	16-dec-08 .17		
SP291	Kirehe	-02 14' 51.02280"	30 46' 00.05164"	1437.53	30/09/2009	30/09/2009 08:46		
SP292	Kirehe	-02 21' 10.60312"	30 39' 35.45201"	1612.24	15/12/2008	SP Nyakagera 37		
SP293	Kirehe	-02 14' 51.15617"	30 37' 29.84315"	1390.18	12/12/2008	12-dec-08 .7		
SP294	Kirehe	-02 09' 47.82076"	30 44' 10.96260"	1576.44	27/01/2009	Gashongi SP1/Birembo/Nyarutunga		
SP295	Kirehe	-02 09' 32.45482"	30 48' 53.06123"	1588.69	18/12/2008	Gakirarwgo 007		
SP296	Kirehe	-02 15' 02.95937"	30 38' 58.78532"	1479.1	12/12/2008	4.Rwaba		
SP297	Kirehe	-02 15' 28.29266"	30 34' 43.79790"	1348.85	21/01/2009	Kabirizi 15.8 l/min 14.86 ms/m 22.5	15	0.9
SP298	Kirehe	-02 15' 33.25251"	30 37' 48.67316"	1472.13	12/12/2008	5.Rusasa		
SP299	Kirehe	-02 15' 38.55000"	30 44' 43.26508"	1501.69	29/01/2009	Mayizi SP/Mayizi/Nyamugari/much water overfloweded/developed in 1966/pipe leaking		
SP300	Kirehe	-02 15' 46.10578"	30 35' 14.36140"	1413.25	09/12/2008	new source		
SP301	Kirehe	-02 15' 48.46968"	30 44' 47.23818"	1454.83	29/09/2009	Alt source for Mahama]		
SP302	Kirehe	-02 15' 57.35557"	30 40' 53.12179"	1510.59	16/12/2008	Koheve 60l/min27	60	3.0
SP303	Kirehe	-02 16' 01.36189"	30 38' 08.08285"	1505.54	12/12/2008	2.Gahama		
SP304	Kirehe	-02 16' 08.79275"	30 44' 07.03021"	1478.62	16/12/2008	30-60l/min 08	60	3.0
SP305	Kirehe	-02 16' 10.71760"	30 44' 07.90134"	1480.55	16/12/2008	1994construction 07		
SP306	Kirehe	-02 08' 25.60938"	30 43' 41.20324"	1588.93	17/12/2008	17-dec-08 .19		
SP307	Kirehe	-02 22' 21.91444"	30 32' 17.06816"	1343.08	08/12/2008	Butezi		
SP308	Kirehe	-02 22' 49.48762"	30 33' 15.18613"	1471.89	10/12/2008	>87l/min	87	5.0
SP309	Kirehe	-02 10' 29.26743"	30 49' 39.97168"	1419.98	28/01/2009	Rwkibira		
SP310	Kirehe	-02 17' 10.09537"	30 42' 05.80093"	1555.53	16/12/2008	Muguruka 12		
SP311	Kirehe	-02 17' 13.07604"	30 43' 29.75038"	1467.57	16/12/2008	+pump Kabugwe funded China 09		
SP312	Kirehe	-02 17' 17.54343"	30 42' 53.31154"	1521.4	16/12/2008	Gasebura to Kabugwe funded China 10		
SP313	Kirehe	-02 17' 39.02672"	30 32' 35.17548"	1342.6	08/12/2008	Kabagera		
SP314	Kirehe	-02 17' 39.51887"	30 35' 15.32548"	1388.98	09/12/2008	Station pump		
SP315	Kirehe	-02 17' 58.09119"	30 42' 14.05616"	1676.89	16/12/2008	Tank+pump 44l/min 02	44	2.0
SP316	Kirehe	-02 18' 59.40256"	30 31' 59.27462"	1356.54	08/12/2008	Gashongora		
SP317	Kirehe	-02 19' 46.03659"	30 35' 42.81025"	1465.4	11/12/2008	11/12/2008 11:01		
SP318	Kirehe	-02 19' 49.26983"	30 33' 25.62541"	1354.13	10/12/2008	Contaminated		
SP319	Kirehe	-02 20' 09.66169"	30 40' 13.06164"	1608.64	11/12/2008	Nyagashagara pump 02		
SP320	Kirehe	-02 20' 13.77482"	30 41' 04.57526"	1570.43	11/12/2008	Gashanga-1 gravity 04		
SP321	Kirehe	-02 20' 14.37108"	30 41' 04.44066"	1566.1	11/12/2008	3		
SP322	Kirehe	-02 20' 40.60811"	30 36' 59.25672"	1529.09	11/12/2008	cyizanye		
SP323	Kirehe	-02 20' 47.41586"	30 34' 04.81138"	1409.89	10/12/2008	>20l/min	20	1.0
SP324	Kirehe	-02 20' 47.42159"	30 34' 06.81589"	1418.3	10/12/2008	>33l/min	33	1.0
SP325	Ngoma	-02 11' 33.10625"	30 30' 46.58706"	1539.67	22/01/2009	PomPstation/Rebero/Gahurire/own generator(2h/day)/constructed by UNDP/secture has a committee		
SP326	Ngoma	-02 16' 32.81736"	30 30' 45.93316"	1390.18	30/01/2009	Rwankombe SP/Muyange/Muzingira		
SP327	Ngoma	-02 05' 07.51450"	30 27' 16.45963"	1336.83	30/12/2008	Gisaya 15.7l/min 06	15	0.9
SP328	Ngoma	-02 14' 04.94731"	30 33' 04.42274"	1348.12	21/01/2009	Kagomogomo 7.2 l/min 26.7 ms/m 22.8	7	0.4
SP329	Ngoma	-02 14' 06.38997"	30 35' 03.43961"	1412.29	21/01/2009	Ruvuzi 54.5 l/min 12.66 ms/m 23.1	54	3.0
SP330	Ngoma	-02 16' 45.25634"	30 29' 55.76356"	1352.69	30/01/2009	Kiyanzi SP/Gatonde/Muzingira/24sec(12L)	30	1.0
SP331	Ngoma	-02 14' 06.72431"	30 35' 03.56302"	1424.31	17/12/2008	16-dec-08 .16		
SP332	Ngoma	-02 13' 15.90563"	30 33' 04.15480"	1375.76	21/01/2009	Nyakagezi 12.5 l/min 19.31 ms/m 22.5	12	0.7
SP333	Ngoma	-02 17' 02.53476"	30 23' 12.61486"	1335.39	23/01/2009	Kagatwa SP/Urukomo/Kibimba/1min 18sec(1	9	0.5
SP334	Ngoma	-02 14' 08.38423"	30 35' 03.76490"	1405.32	21/01/2009	Ruvuzi 30 l/min	30	1.0
SP335	Ngoma	-02 12' 20.61897"	30 33' 47.94214"	1351.49	28/01/2009			
SP336	Ngoma	-02 06' 54.58362"	30 24' 56.34212"	1346.2	12/01/2009	Kakimana little 10		
SP337	Ngoma	-02 12' 11.19446"	30 27' 50.77238"	1353.41	31/12/2008	Rwezamenyo 8.1l/min 20	8	0.5
SP338	Ngoma	-02 06' 06.17049"	30 35' 52.07845"	1542.79	02/01/2009	Nyvutoma 31l/min 05	31	1.0
SP339	Ngoma	-02 12' 53.53853"	30 26' 15.86191"	1370.71	31/12/2008	Nyamokuron 42.6l/min 22	42	2.0
SP340	Ngoma	-02 06' 55.36394"	30 31' 03.71824"	1372.4	30/12/2008	8.3l/min 20	8	0.5
SP341	Ngoma	-02 12' 13.03935"	30 28' 30.46044"	1348.12	22/01/2009	Gahondo sprind/Gahondo/Birenga/35sec(12	20	1.0
SP342	Ngoma	-02 05' 27.73919"	30 33' 12.00841"	1546.15	29/12/2008	old pump facirity nouse 18		
SP343	Ngoma	-02 11' 59.10370"	30 28' 23.67955"	1344.04	31/12/2008	Nangogosigane 8.2l/min 19	8	0.5
SP344	Ngoma	-02 14' 18.42974"	30 31' 27.34633"	1362.06	21/01/2009	Kagenzanda 15.8 l/min 18.01 ms/m 22.9	15	0.9
SP345	Ngoma	-02 09' 49.44085"	30 35' 02.70575"	1390.9	15/01/2009	Rukoko 31.4 l/min 41	31	1.0
SP346	Ngoma	-02 05' 30.78836"	30 35' 12.80648"	1453.15	23/12/2008	04.Gicaca		
SP347	Ngoma	-02 06' 20.51561"	30 23' 23.92289"	1359.9	16/01/2009	Nagatunga 11.2 l/min 18	11	0.7
SP348	Ngoma	-02 05' 31.54062"	30 33' 10.89554"	1548.08	29/12/2008	Ngezi 34.9l/min 17	34	2.0
SP349	Ngoma	-02 05' 06.80630"	30 26' 06.49594"	1360.86	05/01/2009	Kizanye 5l/min 20	5	0.3
SP350	Ngoma	-02 05' 32.04243"	30 27' 47.01438"	1344.04	30/12/2008	Rwarumba 6.9l/min 04	6	0.4
SP351	Ngoma	-02 15' 02.37790"	30 30' 41.05087"	1377.44	30/01/2009	Samuko SP2/Shyagashya/Muzingira		
SP352	Ngoma	-02 12' 54.23345"	30 23' 40.21883"	1339.95	20/01/2009	Kiriko SP/Nyarurembo/Rukoma/no facility		
SP353	Ngoma	-02 14' 22.42851"	30 23' 59.45287"	1343.56	20/01/2009	Kizanye SP/Kizanye/Gafunzo		
SP354	Ngoma	-02 12' 19.07734"	30 28' 27.16082"	1342.6	22/01/2009	Gatashya SP/Gahondo/Birenga/118sec(12L)	118	7.0
SP355	Ngoma	-02 10' 04.92508"	30 33' 40.37306"	1488.23	02/01/2009	Nyamuganda 162l/min 01	162	9.0
SP356	Ngoma	-02 10' 25.20077"	30 34' 47.79818"	1386.82	15/01/2009	Rubirizi 52.9 l/min 39	52	3.0
SP357	Ngoma	-02 09' 23.83749"	30 27' 22.87210"	1424.31	05/01/2009	Nyakabingo 10.3l/min 13	10	0.6
SP358	Ngoma	-02 05' 38.01946"	30 24' 18.27684"	1340.43	16/01/2009	Kavumu 21		
SP359	Ngoma	-02 14' 23.52476"	30 32' 52.68383"	1350.29	21/01/2009	Kavumu 24.3 l/min 21.7 ms/m 22.3	24	1.0
SP360	Ngoma	-02 15' 26.95924"	30 29' 02.09998"	1329.38	30/01/2009	Musenyi SP/Musenyi/Mutenderi/30sec(12L)	24	1.0
SP361	Ngoma	-02 06' 27.67128"	30 24' 21.01730"	1339.95	16/01/2009	Kabakebura 20		
SP362	Ngoma	-02 13' 25.41916"	30 28' 48.02945"	1343.8	22/01/2009	Karisizo SP2(Dry)/Karisizo/Birenga/pipe under ground was broken		

SP363	Ngoma	-02 13' 29.12373"	30 28' 57.05868"	1347.16	22/01/2009	Kareisizo SP1/karisizo/Birenga/35sec(12L)	20	1.0
SP364	Ngoma	-02 05' 50.21795"	30 31' 28.30771"	1382.97	30/12/2008	Gitobe 62.3l/min 22	62	3.0
SP365	Ngoma	-02 06' 04.87870"	30 25' 34.97074"	1338.51	12/01/2009	Kabitende 14.8l/min 15	14	0.8
SP366	Ngoma	-02 05' 50.47172"	30 25' 24.32114"	1337.07	12/01/2009	Kabebwa 14.8l/min 14	14	0.8
SP367	Ngoma	-02 10' 29.67208"	30 34' 38.64767"	1381.53	15/01/2009	Nyagataba 27 l/min 40	27	1.0
SP368	Ngoma	-02 07' 01.00362"	30 24' 09.41569"	1362.54	16/01/2009	Kawusega 5.4 l/min 22	5	0.3
SP369	Ngoma	-02 11' 54.06872"	30 34' 49.83467"	1475.02	15/01/2009	Rwanyakagezi 60 l/min 36	60	3.0
SP370	Ngoma	-02 05' 56.19679"	30 25' 33.73147"	1347.4	05/01/2009	not usable 19		
SP371	Ngoma	-02 06' 08.56516"	30 27' 15.65035"	1341.15	05/01/2009	13.5l/min 23	13	0.8
SP372	Ngoma	-02 10' 35.08062"	30 26' 20.19743"	1351.73	05/01/2009	Kamuhabura 23.1l/min 10	23	1.0
SP373	Ngoma	-02 10' 03.42086"	30 29' 21.62101"	1392.59	31/12/2008	Kabukware 20.9l/min 08	20	1.0
SP374	Ngoma	-02 13' 01.62750"	30 24' 30.45118"	1413.25	20/01/2009	Nyakagezi SP/Nyakagerzi/gafunzo/(broken Tank1970)		
SP375	Ngoma	-02 07' 03.49275"	30 34' 49.53533"	1485.83	02/01/2009	Gasebeya 44.7l/min 03	44	2.0
SP376	Ngoma	-02 03' 54.99347"	30 32' 11.42938"	1406.52	29/12/2008	Gacaca 72l/min 13	72	4.0
SP377	Ngoma	-02 12' 44.14751"	30 33' 29.95582"	1359.42	21/01/2009	Nyakagezi2 16.5 l/min 32.8 ms/m 22.4	16	1.0
SP378	Ngoma	-02 07' 09.40400"	30 31' 31.60099"	1383.69	30/12/2008	7.5l/min 21	7	0.4
SP379	Ngoma	-02 12' 25.47682"	30 27' 26.92789"	1333.94	31/12/2008	notusable 21		
SP380	Ngoma	-02 07' 11.63754"	30 29' 27.73806"	1377.2	30/12/2008	Gafubo 19.7l/min 02	19	1.0
SP381	Ngoma	-02 07' 12.87049"	30 22' 32.09275"	1338.27	16/01/2009	Nyakagezi 40.5 l/min 08	40	2.0
SP382	Ngoma	-02 10' 45.24079"	30 28' 13.74600"	1408.93	31/12/2008	Karuhora 34.1l/min 17	34	2.0
SP383	Ngoma	-02 15' 32.40278"	30 25' 37.02688"	1353.65	23/01/2009	Akaniga SP/Kigoma/Kigoma/11sec(12L)		
SP384	Ngoma	-02 10' 46.34036"	30 26' 28.65120"	1351.25	31/12/2008	Gasetsa 128.5l/min 23	128	7.0
SP385	Ngoma	-02 07' 19.01107"	30 28' 27.50300"	1365.43	30/12/2008	Kabashumba 9.1l/min 03	9	0.5
SP386	Ngoma	-02 07' 20.70267"	30 25' 14.38608"	1378.89	12/01/2009	Kabaromba 39.6l/min 07	39	2.0
SP387	Ngoma	-02 10' 47.21272"	30 30' 42.57590"	1544.47	21/01/2009	Nyakagezi SP/Kabimba/Karama/3min 9sec(12L)		
SP388	Ngoma	-02 07' 22.86017"	30 23' 35.25504"	1356.06	16/01/2009	Gishandaro 31.3 l/min 23	31	1.0
SP389	Ngoma	-02 07' 24.30223"	30 25' 54.93382"	1370.71	12/01/2009	Gahama 5.9l/min 04	5	0.3
SP390	Ngoma	-02 07' 30.22525"	30 30' 44.50619"	1401.96	30/12/2008	Mashoza 14.7l/min 01	14	0.8
SP391	Ngoma	-02 07' 31.52730"	30 25' 56.35747"	1386.1	12/01/2009	Kanzeyi 21.9l/min 03	21	1.0
SP392	Ngoma	-02 05' 57.45358"	30 24' 26.56980"	1338.27	12/01/2009	Akabeza little 13		
SP393	Ngoma	-02 07' 38.91440"	30 28' 44.37678"	1349.81	31/12/2008	Ryabudakiranyo 32.7l/min 14		
SP394	Ngoma	-02 14' 54.40600"	30 30' 40.77716"	1384.89	30/01/2009	Samuko SP/Shyagashya/Muzingira/33sec(1:	21	1.0
SP395	Ngoma	-02 07' 47.57247"	30 37' 28.48800"	1487.51	29/09/2009	New source		
SP396	Ngoma	-02 10' 55.22052"	30 27' 01.78592"	1357.98	05/01/2009	Budihidihi 60.7l/min 11	60	3.0
SP397	Ngoma	-02 07' 54.83526"	30 26' 21.34950"	1383.69	12/01/2009	Kizanyi 22l/min 02	22	1.0
SP398	Ngoma	-02 15' 03.13861"	30 32' 52.32174"	1341.63	21/01/2009			
SP399	Ngoma	-02 06' 32.73220"	30 34' 36.34741"	1463.48	02/01/2009	Nyakagezi 51.6l/min 04	51	3.0
SP400	Ngoma	-02 06' 48.07672"	30 24' 46.72962"	1355.57	12/01/2009	Gakindo 2.7l/min 09	2	0.1
SP401	Ngoma	-02 14' 58.20140"	30 30' 39.75880"	1380.09	30/01/2009	Samuko SP3/not used		
SP402	Ngoma	-02 11' 02.28717"	30 27' 04.80823"	1358.22	31/12/2008	Cyerwa 68.8l/min 24	68	4.0
SP403	Ngoma	-02 12' 44.97913"	30 34' 20.58438"	1429.6	21/01/2009	Mbonyi 19 l/min 14.03 ms/m 23.2	19	1.0
SP404	Ngoma	-02 08' 13.14143"	30 35' 48.88295"	1412.53	15/01/2009	Gasagare noprotect 44		
SP405	Ngoma	-02 11' 08.30071"	30 28' 40.99721"	1361.34	31/12/2008	Kantuyenabo 25.3l/min 18	25	1.0
SP406	Ngoma	-02 08' 19.87073"	30 24' 48.35938"	1372.64	16/01/2009	Cyizanye_Kimarama 34		
SP407	Ngoma	-02 08' 29.67363"	30 29' 50.04359"	1367.11	31/12/2008	Karuhura 107.7l/min 05	107	6.0
SP408	Ngoma	-02 10' 08.51890"	30 26' 04.30825"	1378.65	13/01/2009	Nyakagazi 3.3 l/min 18	3	0.2
SP409	Ngoma	-02 08' 30.14044"	30 39' 00.22770"	1672.57	15/01/2009	Kanyabishambi 35.8 l/min 18	35	2.0
SP410	Ngoma	-02 08' 32.26505"	30 30' 21.05489"	1393.79	31/12/2008	Kwamuhire 43.5l/min 03	43	2.0
SP411	Ngoma	-02 08' 49.91613"	30 35' 30.88784"	1406.52	15/01/2009	Kanshobone 17.9 l/min 43	17	1.0
SP412	Ngoma	-02 10' 08.54968"	30 26' 18.25868"	1362.54	13/01/2009	Idunda 13.5 l/min 17	13	0.8
SP413	Ngoma	-02 09' 01.02319"	30 28' 52.64922"	1365.67	31/12/2008	Nyakabingo 40.5l/min 10	40	2.0
SP414	Ngoma	-02 09' 05.87108"	30 24' 53.57599"	1346.92	13/01/2009	Rwibumba 08		
SP415	Ngoma	-02 11' 31.92611"	30 33' 56.50214"	1376.96	15/01/2009	kinganzo 46.2 l/min 38	46	2.0
SP416	Ngoma	-02 09' 07.20783"	30 28' 51.66854"	1370.71	31/12/2008	Rutabago 12l/min 09	12	0.7
SP417	Ngoma	-02 09' 07.24494"	30 25' 13.96362"	1354.13	13/01/2009	Gashyununu2 6.7l/min 12	6	0.4
SP418	Ngoma	-02 09' 07.38526"	30 25' 14.55866"	1355.57	13/01/2009	Gashyununu 24.5l/min 11	24	1.0
SP419	Ngoma	-02 09' 10.61849"	30 31' 53.04536"	1445.7	30/12/2008	Source of Kibungo + pump 26		
SP420	Ngoma	-02 09' 11.93321"	30 25' 31.95660"	1380.81	13/01/2009	Kabakobe 21l/min 10	21	1.0
SP421	Ngoma	-02 15' 54.02940"	30 21' 24.66220"	1330.82	23/01/2009	Kaberanya SP/Umuka/Ihanika		
SP422	Ngoma	-02 11' 36.97799"	30 24' 09.70841"	1351.97	13/01/2009	Kinugwe 11.6 l/min 41	11	0.7
SP423	Ngoma	-02 11' 39.48944"	30 29' 15.56822"	1375.04	22/01/2009	Kafurebe SP/Murusenyi/Birenga/14sec(12L)	70	4.0
SP424	Ngoma	-02 09' 15.21804"	30 35' 18.84750"	1398.59	15/01/2009	Kumugano 4.9 l/min 42	4	0.2
SP425	Ngoma	-02 11' 47.01203"	30 32' 24.15440"	1408.69	21/01/2009	Kabashima 65 l/min 13.05 ms/m 21.9	65	3.0
SP426	Ngoma	-02 12' 47.50627"	30 34' 25.37465"	1431.52	21/01/2009	Mbonyi 40 l/min	40	2.0
SP427	Ngoma	-02 11' 51.33277"	30 29' 29.36447"	1381.29	22/01/2009	Kamugurusj SP/Murusenyi/Birenga/21sec(1:	34	2.0
SP428	Ngoma	-02 09' 22.47208"	30 31' 56.27374"	1439.45	30/12/2008	Gahaya 26.1l/min 27	26	1.0
SP429	Nyagatare	-01 23' 01.58463"	30 22' 53.57874"	1374.08	07/12/2009	Karangazi Mbare Mbare 870		
SP430	Nyagatare	-01 16' 32.89271"	30 10' 17.80072"	0	07/12/2009	TABAGWE GISHURO NYAGATARE 567 Public in use Working		
SP431	Nyagatare	-01 17' 14.10432"	30 12' 28.04018"	0	07/12/2009	TABAGWE TABAGWE TABAGWE 566 Working public in use		
SP432	Nyagatare	-01 18' 41.20101"	30 12' 02.04638"	0	07/12/2009	TABAGWE NYAGATOMA MUTUNGISA 573 Working public in use		
SP433	Nyagatare	-01 18' 42.12798"	30 10' 29.29130"	0	07/12/2009	TABAGWE SHONGA NYAKANONI 570 Public in		
SP434	Nyagatare	-01 19' 00.45498"	30 10' 48.68044"	0	07/12/2009	TABAGWE SHONGA NYAKIGANDO 568 Public in use		
SP435	Nyagatare	-01 19' 18.85922"	30 10' 12.72169"	0	07/12/2009	TABAGWE SHONGA NYAKANONI 569 Public in use		
SP436	Nyagatare	-01 19' 45.45171"	30 10' 25.64134"	0	07/12/2009	TABAGWE SHONGA MOSHONGA 572 Working Public in use		
SP437	Nyagatare	-01 22' 08.24303"	30 09' 09.07146"	1500.01	07/12/2009	KARAMA NDEGO KABABANDA 799		
SP438	Nyagatare	-01 22' 10.05262"	30 08' 15.09378"	1694.44	07/12/2009	KARAMA NDEGO RUBANDA 800		
SP439	Nyagatare	-01 23' 06.45002"	30 06' 42.66608"	0	01/03/2009	KIYOMBE KARAMBO RWAKASHANDE 631 Public In use not constructed		
SP440	Nyagatare	-01 23' 31.30112"	30 07' 42.84952"	1651.9	07/12/2009	KIYOMBE TOVU GASHURO 737		
SP441	Nyagatare	-01 24' 04.84922"	30 07' 20.82641"	0	01/03/2009	KIYOMBE KARAMBO RUGARAMA 630 Captage		
SP442	Nyagatare	-01 25' 43.48327"	30 10' 09.56510"	1542.55	07/12/2009	GATUNDA NYANGARA RAMIRO 897		
SP443	Nyagatare	-01 25' 46.98083"	30 06' 23.12698"	1706.21	01/03/2009	KIYOMBE KABUNGO BITARE		
SP444	Nyagatare	-01 26' 11.27461"	30 09' 53.92033"	1581.48	07/12/2009	GATUNDA NYANGARA RYANYABUKWENDE 901		
SP445	Nyagatare	-01 26' 33.38191"	30 09' 55.38956"	1569.71	07/12/2009	GATUNDA NYANGARA RYANYABUKWENDE 903		
SP446	Nyagatare	-01 26' 51.24059"	30 11' 01.19458"	0	01/03/2009	MUKAMA KAGINA CYABAHURURA 605 Public in use Working		
SP447	Nyagatare	-01 26' 55.89476"	30 10' 57.69912"	0	01/03/2009	MUKAMA KAGINA KABEZA 614 Public in use		
SP448	Nyagatare	-01 27' 06.41915"	30 12' 30.98646"	1392.83	07/12/2009	Mimuli Mahoro Cyambwana 988		
SP449	Nyagatare	-01 27' 08.26856"	30 08' 29.54965"	1720.15	07/12/2009	KIYOMBE KAJUMBA NYANGE 825		
SP450	Nyagatare	-01 28' 02.61981"	30 08' 25.02704"	1831.66	07/12/2009	KIYOMBE KAJUMBA GISHORO 827		
SP451	Nyagatare	-01 28' 14.03103"	30 17' 08.87906"	1389.46	07/12/2009	Katabagemu Katabagemu Kagogo 903		
SP452	Nyagatare	-01 28' 15.16229"	30 14' 08.71768"	1383.21	07/12/2009	Mimuli Bibare Nyaruziba 968		
SP453	Nyagatare	-01 28' 32.37855"	30 11' 03.25068"	1421.18	07/12/2009	Mimuli Gakoma Rusororo 997		

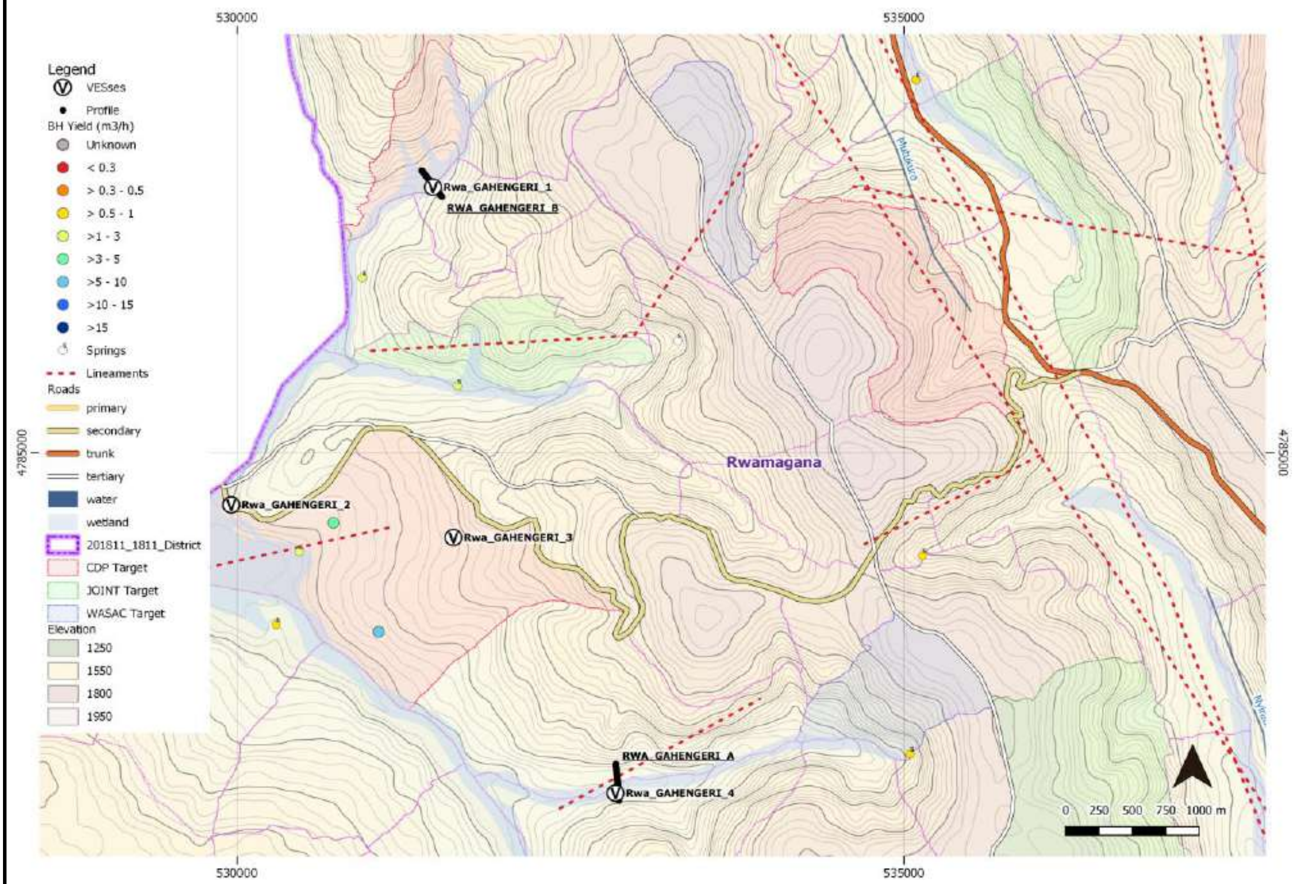
SP454	Nyagatare	-01 28' 51.78550"	30 07' 59.62404"	0	02/03/2009	KIYOMBE KABUNGO KABINDI. 640 Not Working To Rheabilitate		
SP455	Nyagatare	-01 29' 18.30075"	30 08' 23.33904"	0	02/03/2009	KIYOMBE KABUNGO MATABA 642 Captage		
SP456	Nyagatare	-01 29' 19.57533"	30 08' 22.95280"	0	02/03/2009	KIYOMBE KABUNGO MATABA 641 Not Working Damaged by errosion actions		
SP457	Nyagatare	-01 23' 31.59261"	30 07' 42.75088"	1647.81	02/06/2009	SP		
SP458	Rwamagar	-02 02' 49.98477"	30 22' 52.12283"	1339.47	14/01/2009	Rwafigi 11		
SP459	Rwamagar	-01 50' 40.40273"	30 15' 49.48963"	1521.88	12/02/2009	Buyongwe 32.4 l/min 31.9 ms/m 23.9	32	1.0
SP460	Rwamagar	-01 54' 48.71067"	30 22' 18.02132"	1459.16	09/01/2009	Gakatsi 56.7l/min 12	56	3.0
SP461	Rwamagar	-01 53' 35.49381"	30 16' 52.40752"	1434.16	12/02/2009	Gahondohondo 76.7 l/min 31.8 ms/m 23.4	76	4.0
SP462	Rwamagar	-01 55' 05.88439"	30 18' 55.48378"	1464.44	09/02/2009	Kwamusa 22.4 l/min 52.9 ms/m 22.4	22	1.0
SP463	Rwamagar	-01 55' 42.67990"	30 21' 38.39630"	1452.91	09/01/2009	Ngaruye 44.8l/min 03	44	2.0
SP464	Rwamagar	-01 55' 56.06275"	30 16' 41.19996"	1388.98	09/02/2009	Gikono 41.3 l/min 35.6 ms/m 23.6	41	2.0
SP465	Rwamagar	-01 56' 12.03641"	30 17' 57.69654"	1497.85	09/02/2009	Rwinka 12.3 l/min 47 ms/m 23.3	12	0.7
SP466	Rwamagar	-01 56' 23.51553"	30 17' 04.30123"	1412.77	09/02/2009	Nyakariba 43.1 l/min 53.4 ms/m 22.1	43	2.0
SP467	Rwamagar	-01 56' 28.98171"	30 26' 23.20976"	1456.27	10/01/2009	Kabura 67.9l/min 02	67	4.0
SP468	Rwamagar	-01 56' 40.58273"	30 21' 16.25458"	1485.59	09/01/2009	Nyakagezi 86.5l/min 02	86	5.0
SP469	Rwamagar	-01 57' 05.52194"	30 16' 25.93211"	1375.04	09/02/2009	Rwagacuzi 33.5 l/min 16.95 ms/m 23.2	33	2.0
SP470	Rwamagar	-01 57' 06.48422"	30 18' 57.06133"	1617.53	06/02/2009	Agatare 26.1 l/min 75.7 ms/m 21.6	26	1.0
SP471	Rwamagar	-01 57' 24.00072"	30 16' 20.32500"	1376.24	05/02/2009	Kampigika 28.9 l/min 57 ms/m 23.1	28	1.0
SP472	Rwamagar	-01 57' 56.76970"	30 18' 54.05922"	1530.53	06/02/2009	Mugomero 17.8 l/min 48.6 ms/m 22.1	17	1.0
SP473	Rwamagar	-02 02' 08.91649"	30 25' 17.96873"	1344.76	14/01/2009	Cyaruhogo 7.9 l/min 10	7	0.4
SP474	Rwamagar	-01 59' 11.03303"	30 16' 38.13028"	1439.21	05/02/2009	Kayevuba 10.6 l/min 12.96 ms/m 22.2	10	0.6
SP475	Rwamagar	-01 59' 12.00406"	30 15' 56.40358"	1381.29	05/02/2009			
SP476	Rwamagar	-01 59' 37.26644"	30 15' 20.42431"	1362.06	05/02/2009	Kwazakariya 25 l/min 37.2 ms/m 22.4	25	1.0
SP477	Rwamagar	-01 59' 41.13999"	30 23' 06.72803"	1405.56	14/01/2009	Gikono 05		
SP478	Rwamagar	-01 59' 49.82884"	30 20' 12.96013"	1483.19	29/01/2009	Samatare 36.8 l/min old WS 19		
SP479	Rwamagar	-01 59' 53.15139"	30 17' 32.14082"	1473.82	05/02/2009	Kajororo 11.9 l/min 14.92 ms/m 23.9	11	0.7
SP480	Rwamagar	-02 00' 02.79225"	30 15' 14.02240"	1354.85	05/02/2009	Kwarivera 32.4 l/min 27.6 ms/m 23.5	11	0.7
SP481	Rwamagar	-01 53' 38.24515"	30 17' 21.70608"	1442.33	09/02/2009		32	1.0
SP482	Rwamagar	-02 00' 37.98911"	30 21' 58.04978"	1444.04	20/01/2009	Byimana 32.4 l/min		
SP483	Rwamagar	-01 53' 43.29522"	30 17' 42.51044"	1440.17	09/02/2009	Nyirabuhene 60.3 l/min 46.5 ms/m 24.4	32	1.0
SP484	Rwamagar	-02 01' 22.89985"	30 23' 58.60374"	1368.55	14/01/2009	Rwamutanazi 24.2 l/min 03	60	3.0
SP485	Rwamagar	-02 01' 26.01027"	30 23' 38.81476"	1384.17	14/01/2009	Cyahafi 23.3 l/min 02	23	1.0
SP486	Rwamagar	-02 01' 29.35274"	30 25' 01.63358"	1361.1	14/01/2009	Gatare 88 l/min 09	88	5.0

Annex 2. Results Geophysical survey

Site	District	VES	X (easting)	Y (northing)	Expected formation	Target
Site_1	Rwamagana	EX_2	531438	4787124	Quartzites, Schists and sediments	Production
Site_4	Bugesera border	Profile C (entire profile)	527423	4770717	Coarse Sediments	Production
Site_5	Bugesera	VES_1	506423	4754673	Quartzites, Schists and sediments	Hand pump
Site_8	Bugesera	VES_4	514013	4763034	Schists & Quartzite (Granite observed)	Production
Site_9	Bugesera	VES_2	507490	4766734	Schists and sandstones	Hand pump
Site_13	Ngoma	EX_2	559108	4761764	Quartzites, Schists	Midrange production
Site_13	Ngoma	VES_2	557662	4765959	Quartzites, Schists	Hand pump
Site_17	Kirehe	EX_7	587477	4769033	Sediments & Sandstone / Quartzite ridges	Hand pump
Site_18	Kirehe	EX_3	573536	4753995	Coarse sediments	Production
Site_18	Kirehe	VES_2	573283	4757194	Sediments & Sandstone / Quartzite ridges	Hand pump
Site_20	Kayonza	EX_2	557897	4808217	Quartzite Schists and Sediments	Midrange production
Site_21	Kayonza	EX_1	560848	4797203	Quartzite Schists and Sediments	Hand pump
Site_22	Kayonza	EX_2	558709	4800480	Quartzite Schists and Sediments	Hand pump
Site_25	Kayonza	EX_1	575940	4799809	Quartzite Schists and Sediments	Hand pump
Site_26	Gatsibo	EX_1	545446	4815482	Quartzite Schists and Sediments	Hand pump
Site_29	Gatsibo	VES_1	543600	4802782	Schists & Sediments	Hand pump
Site_31	Nyagatare	VES_6	522440	4849204	Quartzite Schists and sediments	Hand pump
Site_32	Nyagatare	EX_3	532909	4833436	Granites and schists	Midrange production
Site_34	Nyagatare/Gatsibo	VES_8	544607	4827935	Granites	Production
Site_35	Nyagatare	VES_4	533989	4846741	Granites & Sediments	Hand pump

Location:	GAT_GAHENGERI				1
Recommended Site:	EX_2	coordinate (E)	531438	coordinate (N)	4787124
Expected DTB (m):	20	Altitude (amsl)		1445	
Recommended Depth (m):	40	Accessibility Site:		Accessible	
Alternative Site:	-	coordinate (E)		coordinate (N)	
Expected DTB (m):		Altitude (amsl)			
Recommended Depth (m):		Accessibility Site:			
Expected Formation:	Quartzite Schists and Sediments	Accessibility Village:		Good	
Int yield (l/h) : 9 936	SWL (m asl): 1 432	Target:		CDP	
Remarks:	The main purpose in this area is to verifiy the results in expected high yielding side valleys. Profile B crosses a CDP target, both profiles are in a formation which alternates between Schists and Quartzites according to the geological map, overlain by sediments in the valleys. During test pumping cuttings of granite were found which led to the conclusion that this formation is underlain by granites. This can also be seen in the ERT profiles showing a weathered formation (characterized by the gradual increase in resistivity). This weathered interface is expected to be the main reason for the high yielding boreholes in the area. Both profiles show a lot of promise on where this layer is thickest. Both have non- functional boreholes present with reported high yields (in the range of 10m3/h). Before drilling rehabilitation is a likely way forward. Most of Rwamagana is characterized by this formation and similar results could yield similar high yielding boreholes. The borehole on RWA_GAHENGERI_B (VES_1) was test pumped, but the borehole was poorly constructed, though high yielding until collapse. It is recommended to drill a new borehole in close proximity. Similar results are expected around the 150m mark, as is seen with the anomaly on the 1D Extraction. Profile A is largely masked but shows similar results. EX_3 shows masked results since the area is waterlogged (clay) but overall the results of the interpretation are similar to profile B, showing a high yielding weathered interface with the underlaying granite bedrock. The not functional borehole on profile A (VES_4) is completely waterlogged. It is advisable to locate an area close by that is not prone to flooding to drill a new borehole. The weathered zone is expected to be wide and extend in that particular valley. For production boreholes we recommend to verify the exact location with a small profile and VES when the descision to drill is made, in order to make the right spot is maintained. GPS coordinates allow for an error margin of 5m which can be enough to miss out on the potential.				

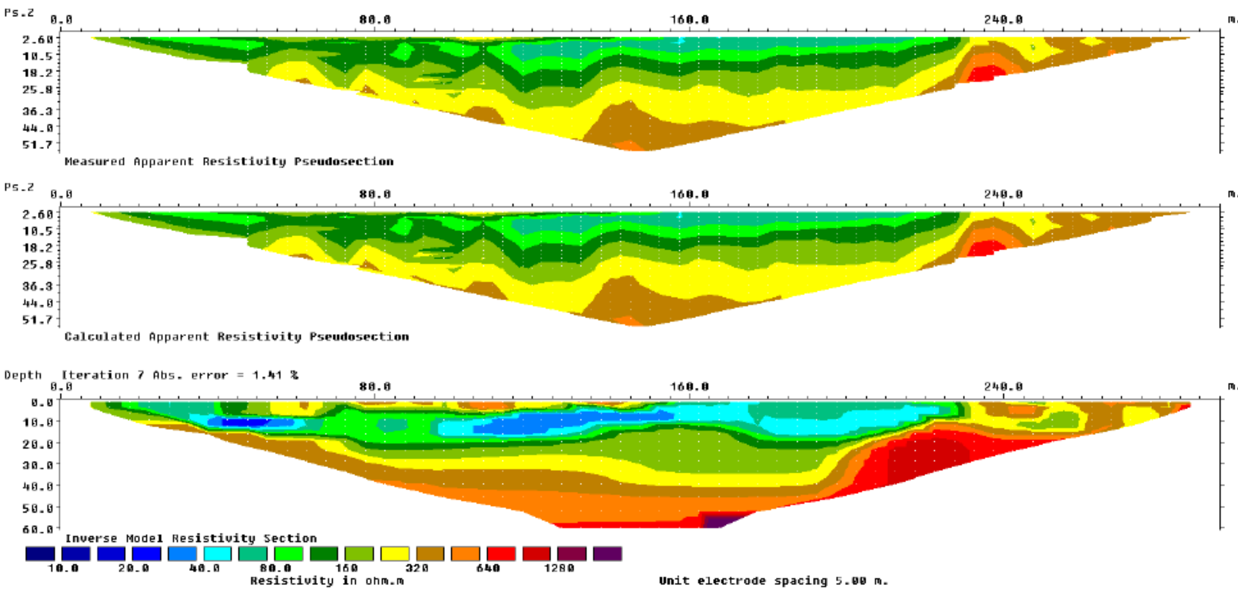
Location map geophysical measurements



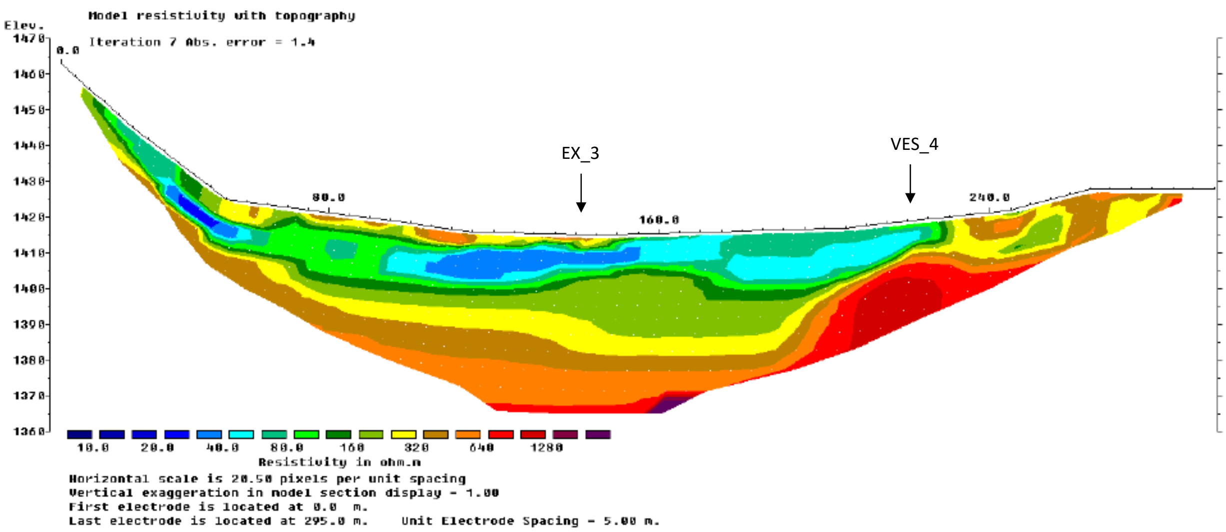
Site	GAT_GAHENGERI		Village	Kiruruma|Kamugasa			
Cell	Rweri|Mutamwa		Sector	Gahengeri			
			District	Rwamagana			
Rating per site (max. 100 points):							
	EX_2	2	3	4	5	6	7
Local topography (0-20 points)	20						
Lineament (0-20 points)	20						
Anomaly (0-30 points)	20						
VES (0 -15 points)	10						
Earlier results (0 - 15)	15						
Total	84						
Remarks	Most VESses were done on existing boreholes. As indicate rehabilitation of the existing boreholes is a good strategy. In case a replacement needs to be drilled as is needed with RWA_GAHENGERI_1, EX_2 has almost identical results in every aspect.						
Geophysical measurements							

RWA_GAHENGERI_A SCHLUMBERGER PSEUDO

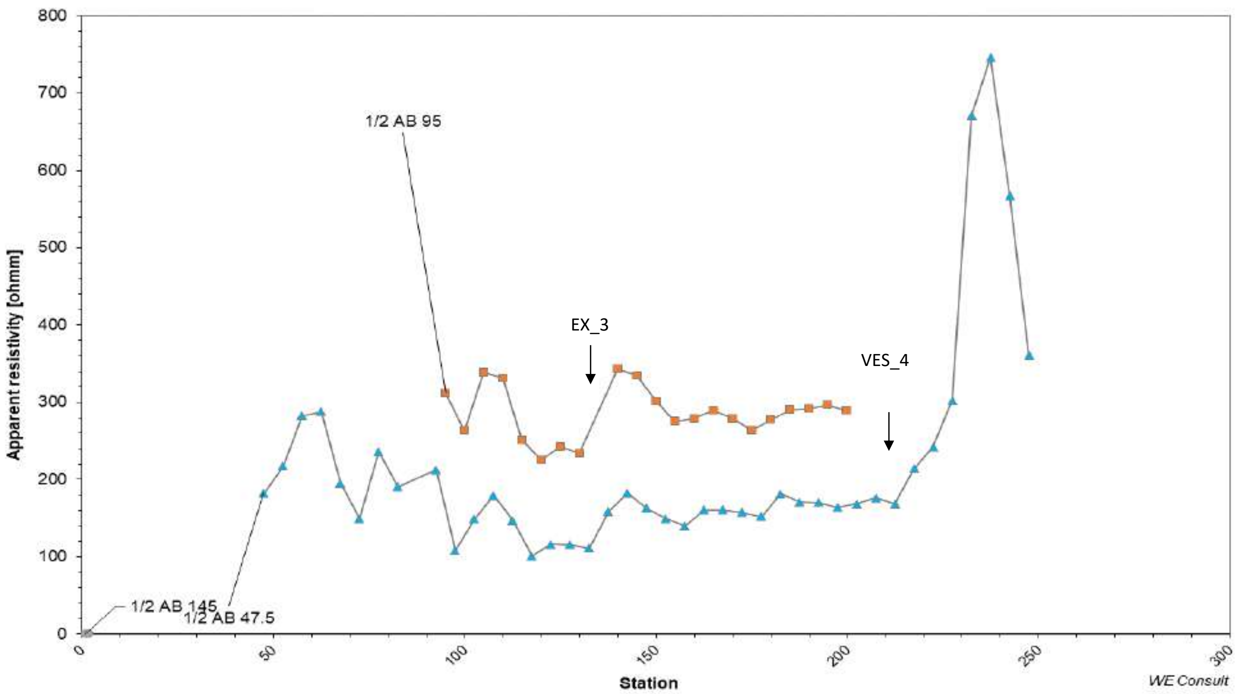
Verification of side valley results | Results for high yielding production well expected



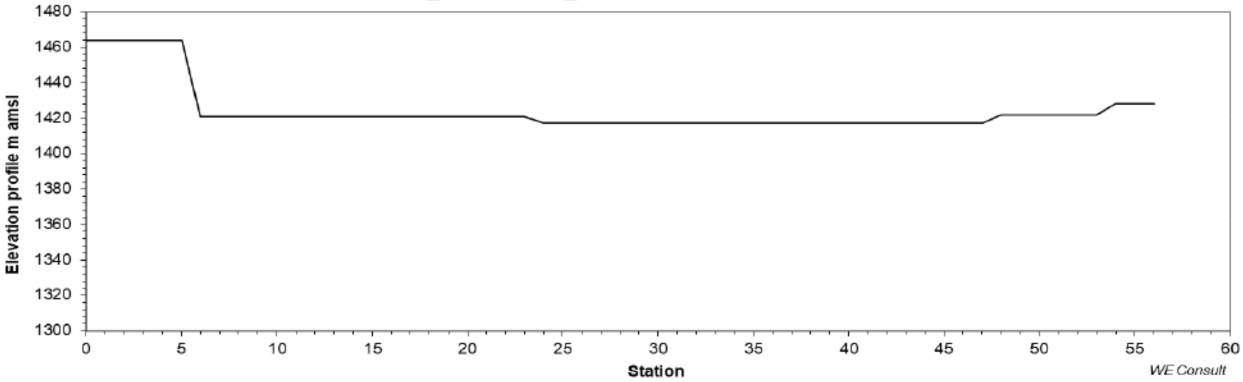
RWA_GAHENGERI_A SCHLUMBERGER TOPO



RWA_GAHENGERI_A SCHLUMBERGER 1D EXTRACTION

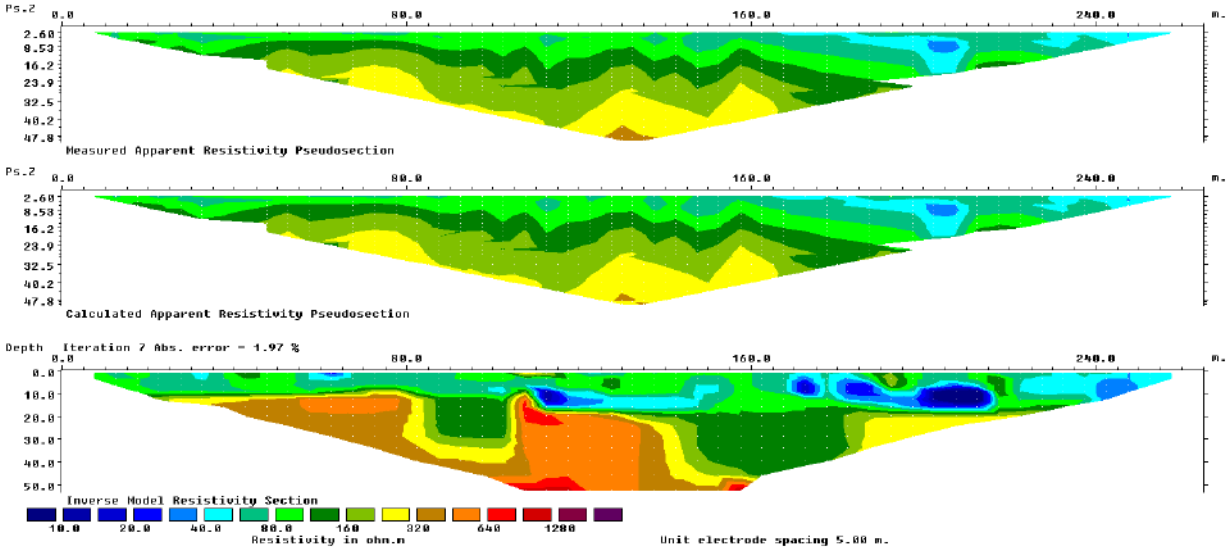


RWA_GAHENGERI_A SCHLUMBERGER ELEVATION

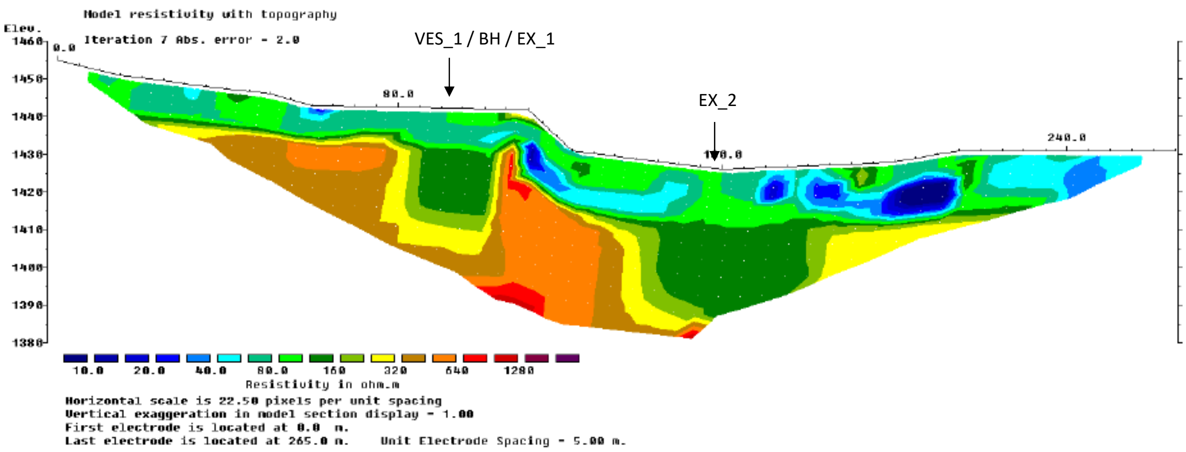


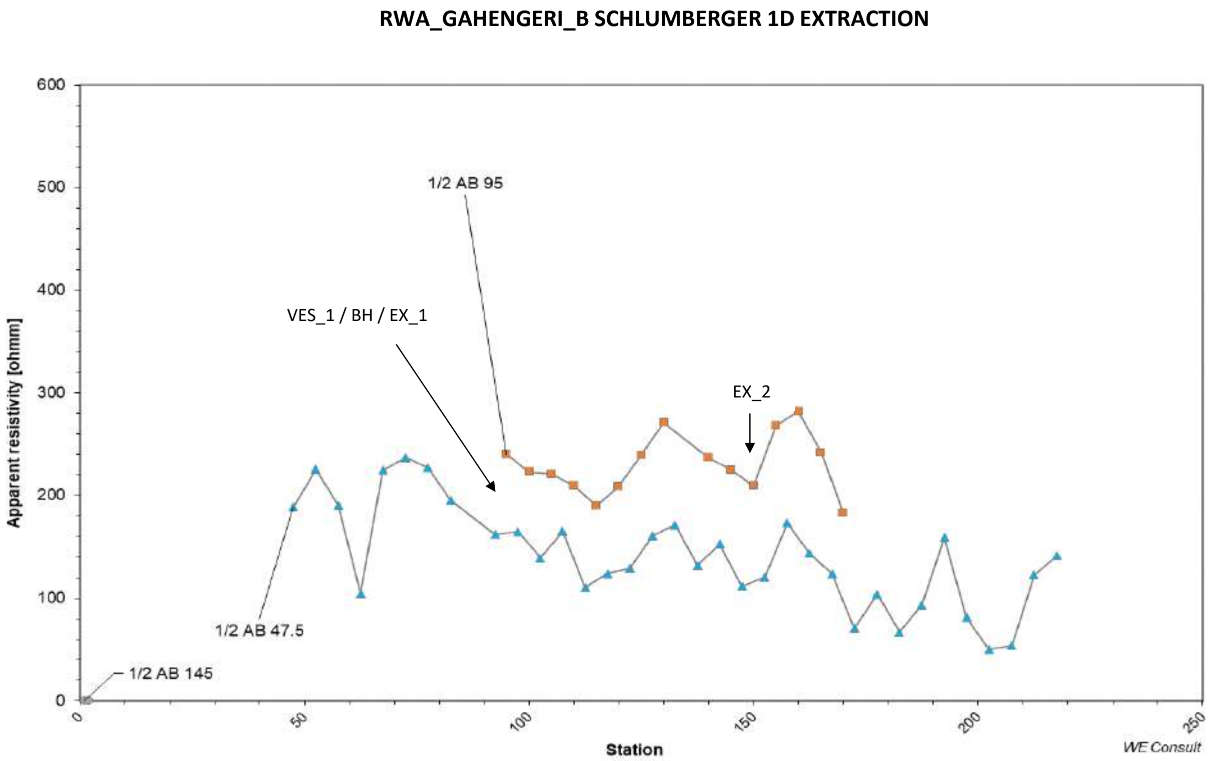
RWA_GAHENGERI_B SCHLUMBERGER PSEUDO

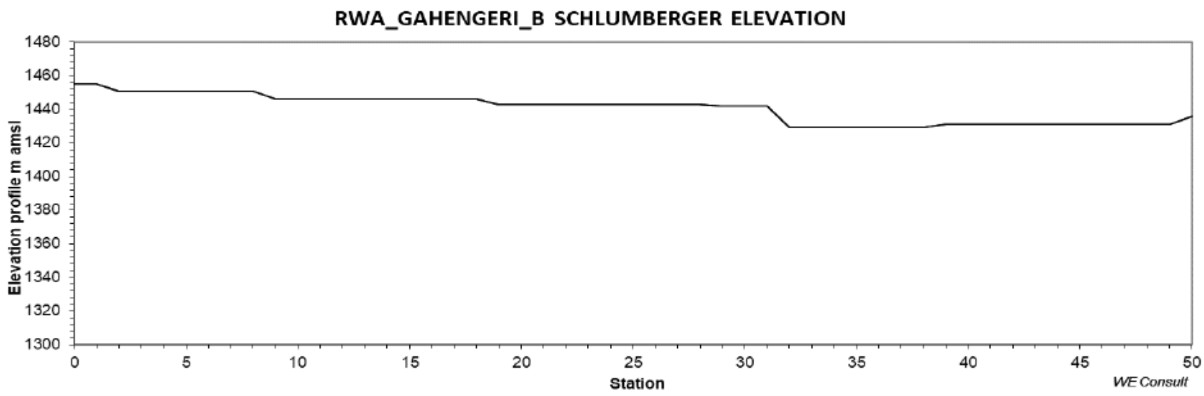
Verification of side valley results | Results for high yielding production well expected



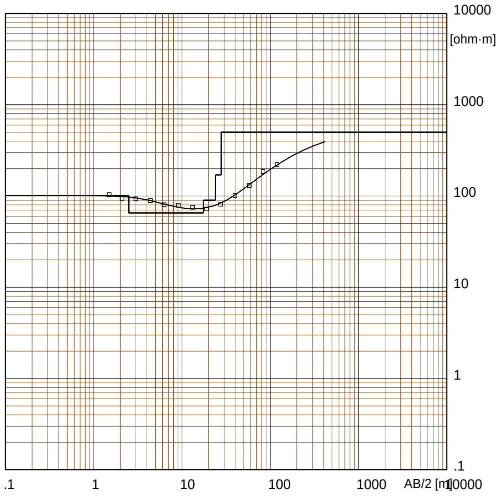
RWA_GAHENGERI_B SCHLUMBERGER TOPO




RWA_GAHENGERI_B SCHLUMBERGER 1D EXTRACTION
Apparent resistivity [ohmm]
Station
1/2 AB 95
VES_1 / BH / EX_1
EX_2
1/2 AB 47.5
1/2 AB 145
WE Consult


RWA_GAHENGERI_B SCHLUMBERGER ELEVATION
Elevation profile m amsl
Station
WE Consult

ELECTICAL SOUNDING_SCHLUM
RWA_GAHENGERI_1
EXISTING BH 9,9 m3/h | SWL 12 mbgl
NOT FUNCTIONAL
TESTPUMPED UNDER THIS PROJECT



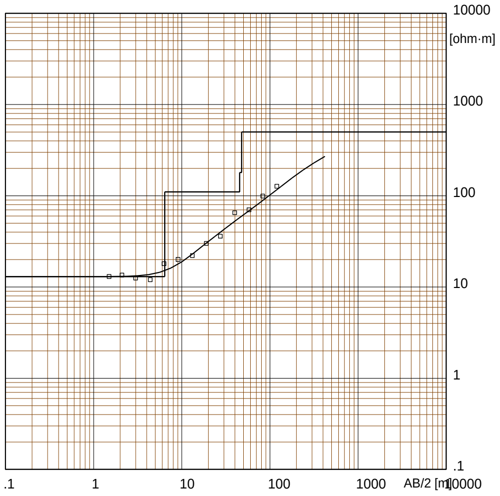
Location X = 197707 Y = 9786893 Z = 1418 Azim = 60/240

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
101	2.5		1418
65	15	2.5	1415.5
90	6.5	18	1400
170	3.8	24	1394
500		28	1390

This was a calibraion VES done in the bottom of a swamp in Rwamagana District.The interpreted layers are: top soil, coarse gravel, weathered rock and hard

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
RWA_GAHENGERI_2
EXISTING BH 7.2 m3/h | SWL 10 mbgl
FUNCTIONAL
TESTPUMPED UNDER THIS PROJECT



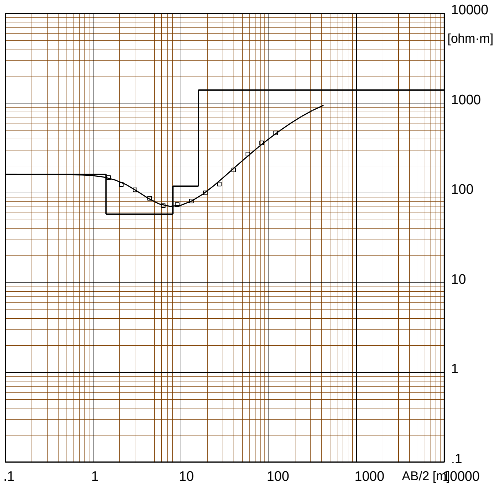
Location X = 196198 Y = 9784415 Z = 1387 Azim = 30/210

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
13	6.4		1387
110	39	6.4	1380.6
180	2.5	45	1342
500		48	1339

This was a calibraion VES done close to the road.The interpreted layers are: top soil,sandy clays , weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
RWA_GAHENGERI_3
EXISTING BH 3.6 m3/h | SWL 80 mbgl
NOT FUNCTIONAL (TOO DEEP/HIGH ELEVATION)



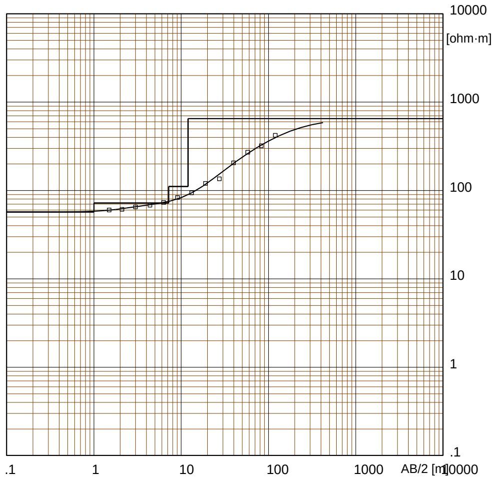
Location X = 197865 Y = 9784163 Z = 1465 Azim = 180/360

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
161	1.4		1465
58	6.7	1.4	1463.6
119	7.7	8.1	1456.9
1400		16	1449

This was a calibration VES on a non functional borehole Rwamagana located on an elevated area. The interpreted layers are: top soil, clay, weathered rock and hard

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
RWA_GAHENGERI_4
EXISTING BH 10.8 m3/h | SWL 3 mbgl
NOT FUNCTIONAL (WATERLOGGED)



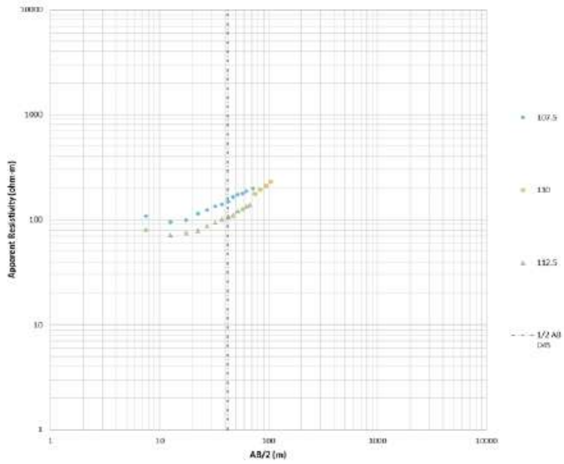
Location X = 199084 Y = 9782174 Z = 1405 Azim = 90/270

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
57	1		1405
72	6.2	1	1404
111	4.8	7.2	1397.8
650		12	1393

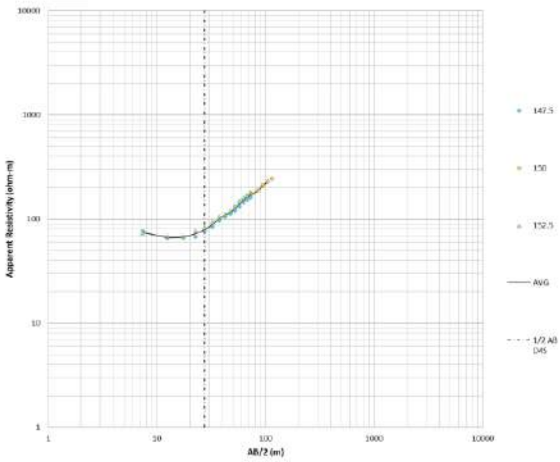
The calibration VES was done on one of the non_functional boreholes in Rwamagana which was drilled in a swamp. The interpreted layers are: top soil, clay,

W-GeoSoft / WinSev 6.3

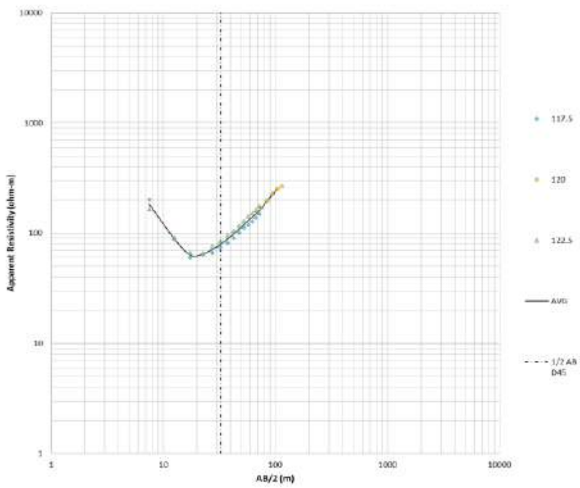
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
RWA_GAHENGERI_B_EX_1 (110 m)
SAME LOCATION AS RWA_GAHENGERI_1



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
RWA_GAHENGERI_B_EX_2 (150 m)
SIMILAR RESULTS RWA_GAHENGERI_1

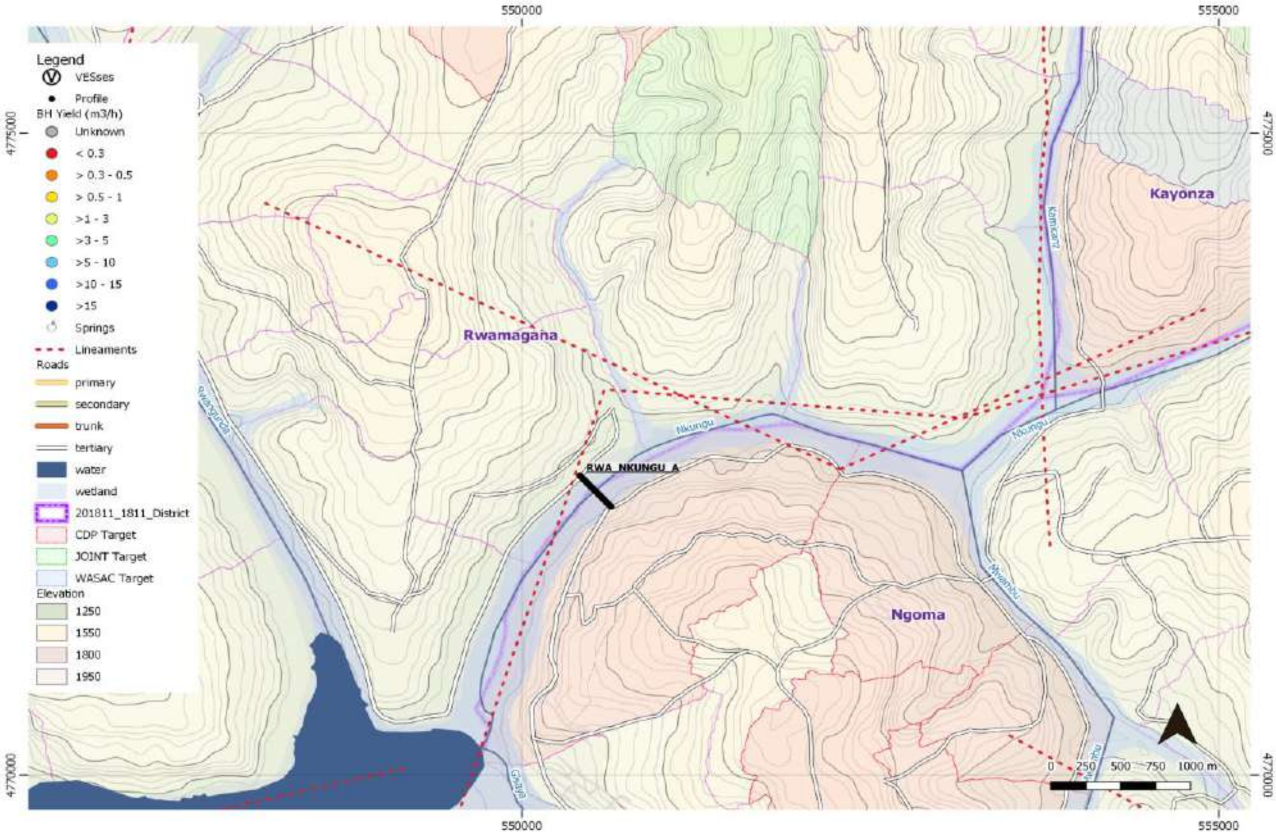


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
RWA_GAHENGERI_B_EX_3 (120 m)
EXPECTED SIMILAR RESULTS TO RWA
GAHENGERI_1 (MASKED)



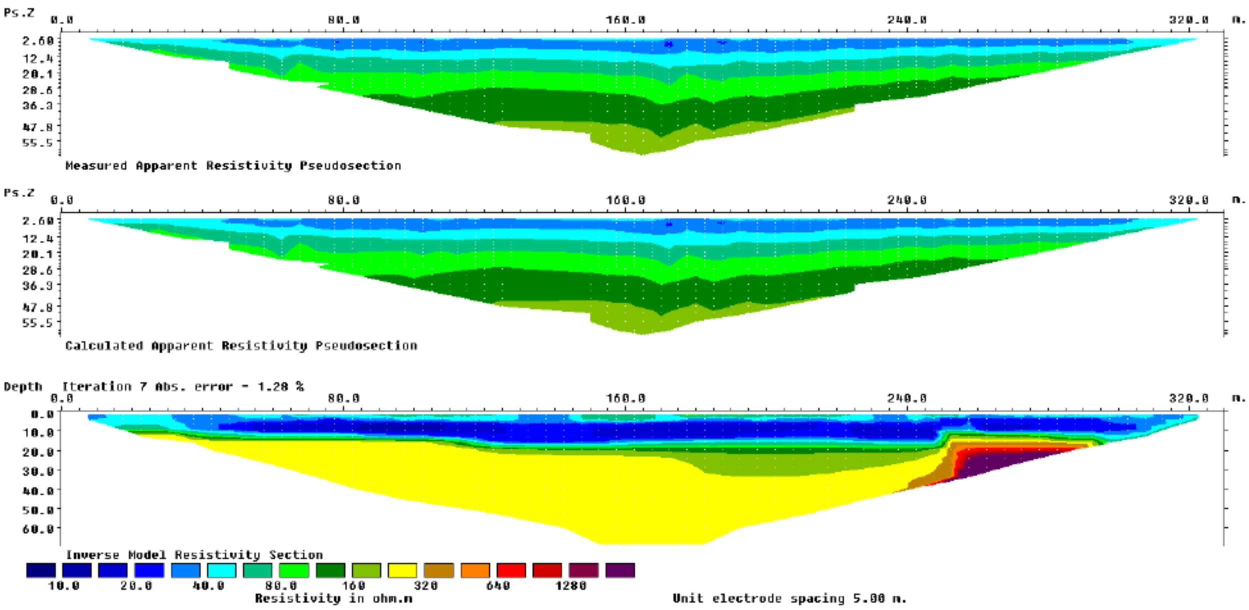
Location:	GAT_NKUNGU					2
Recommended Site:		None		coordinate (E)		coordinate (N)
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:		Accessible
Alternative Site:				coordinate (E)		coordinate (N)
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:		
Expected Formation:		Schists and Sediments		Accessibility Village:		Good
Int yield (l/h) :	3 073	SWL (m asl):	1 339	Target:		CDP
Remarks:	The purpose of this profile to verify assumptions about the geology underlaying the sediments. The geological map shows a great likelyhood of granites, but in fact as can be derived from the results most of the sediments are underlain by schists. There is an apparent Lineament towards the beginning of the profile. Not visible on the 2D interpretation and 1D extraction. According to the geological map there are granites in the area but the results are typical for schists overlain with sediments. The VES extractions show bending off 45 deg after greater depth which indicates that after the masking effect wears off the rock is not hard enough for a 45 degrees angle, typical for schists. Based on the results there is likely minor potential for shallow water ground water in the valley enough for a hand pump, but the lack of anomalies and masked results for the vertical soundings doesn't allow pinpointing of these exact locations. The interpolated yield is from far which means that the actual yield is likely going to be lower than the 3 m3/h indicated. The static water level is very close to the surface in the sediments.					

Location map geophysical measurements

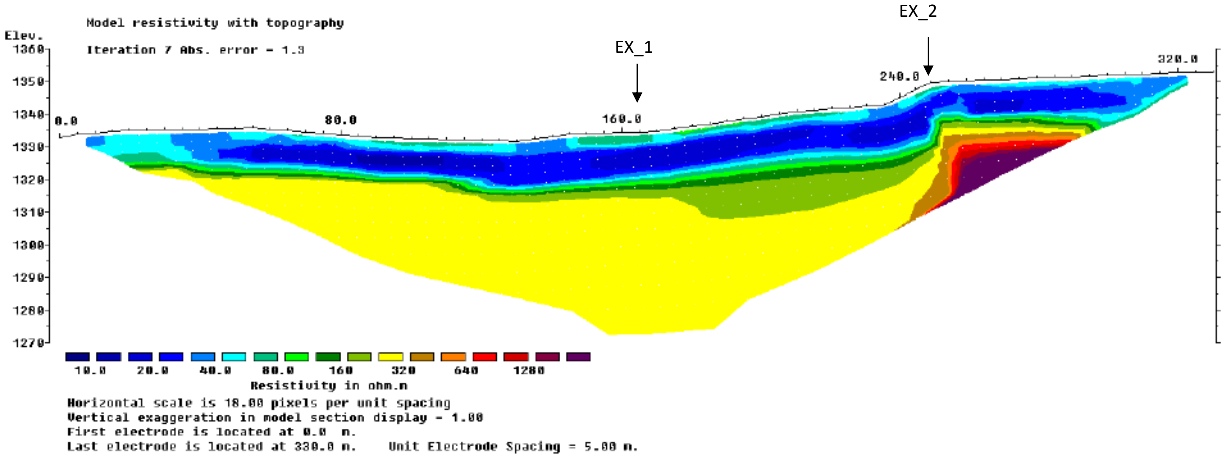


Site	GAT_NKUNGU		Village	Rushangara			
Cell	Nkungu		Sector	Munyaga			
			District	Rwamagana			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks	No actual soundings were perfomed but extraction made from the 2D profile. Results typical for schists overlain by (clayey) sediments, showing low potential but in most cases enough for a handpump borehole. However the homogeneous nature of the results does not allow for pinpointing an exact location.						
Geophysical measurements							

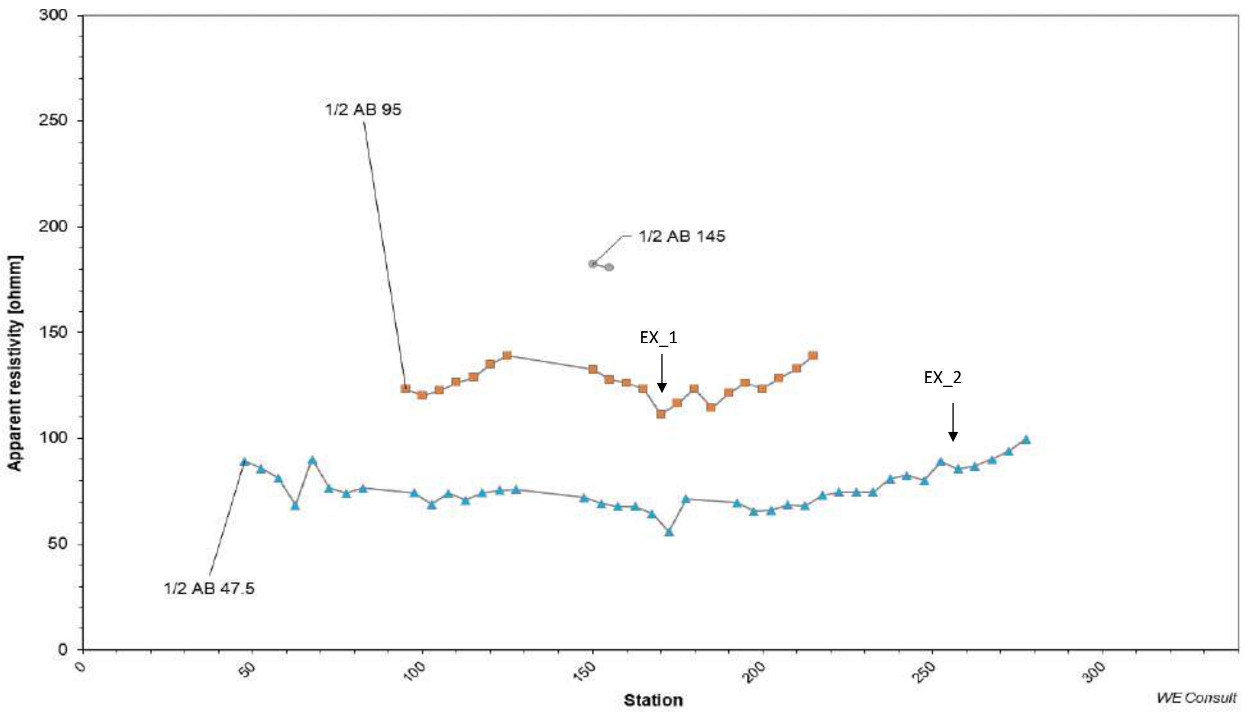
RWA_NKUNGU_A SCHLUMBERGER PSEUDO



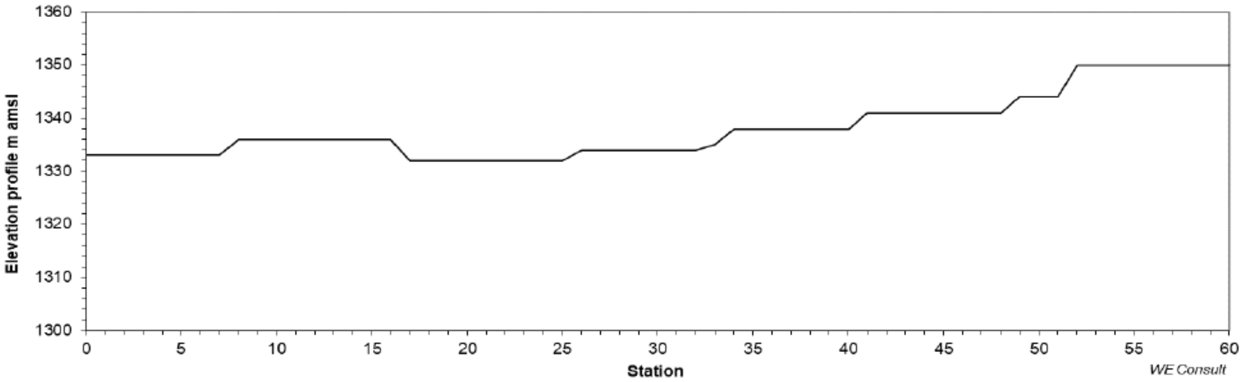
RWA_NKUNGU_A SCHLUMBERGER TOPO



RWA_NKUNGU_A SCHLUMBERGER 1D EXTRACTION

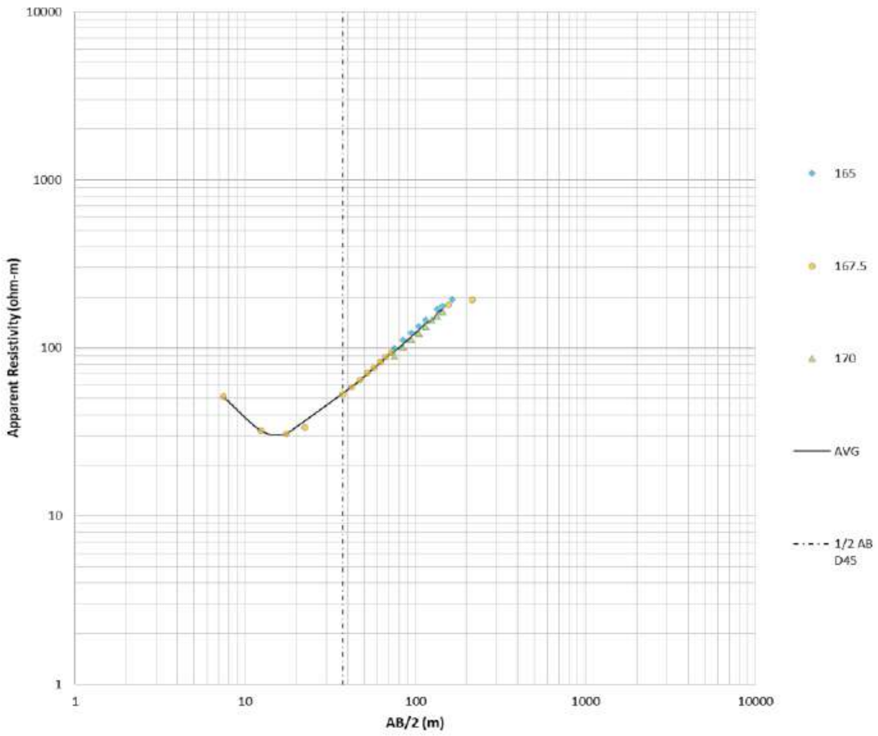


RWA_NKUNGU_A SCHLUMBERGER ELEVATION

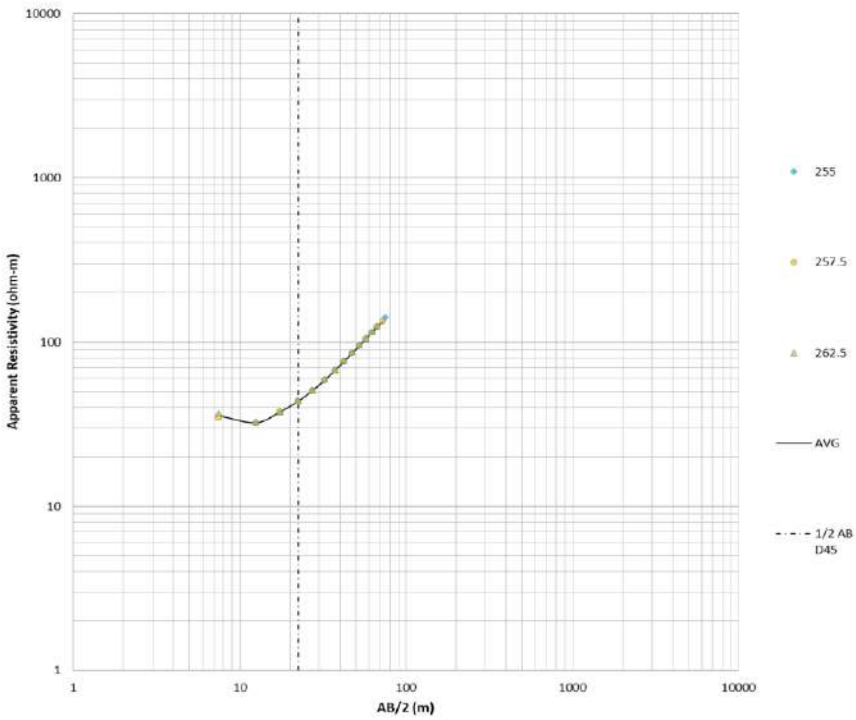


Best VES: **NO VES**

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
RWA_NKUNGU_A_EX_1 (170 m)
MASKED RESULTS

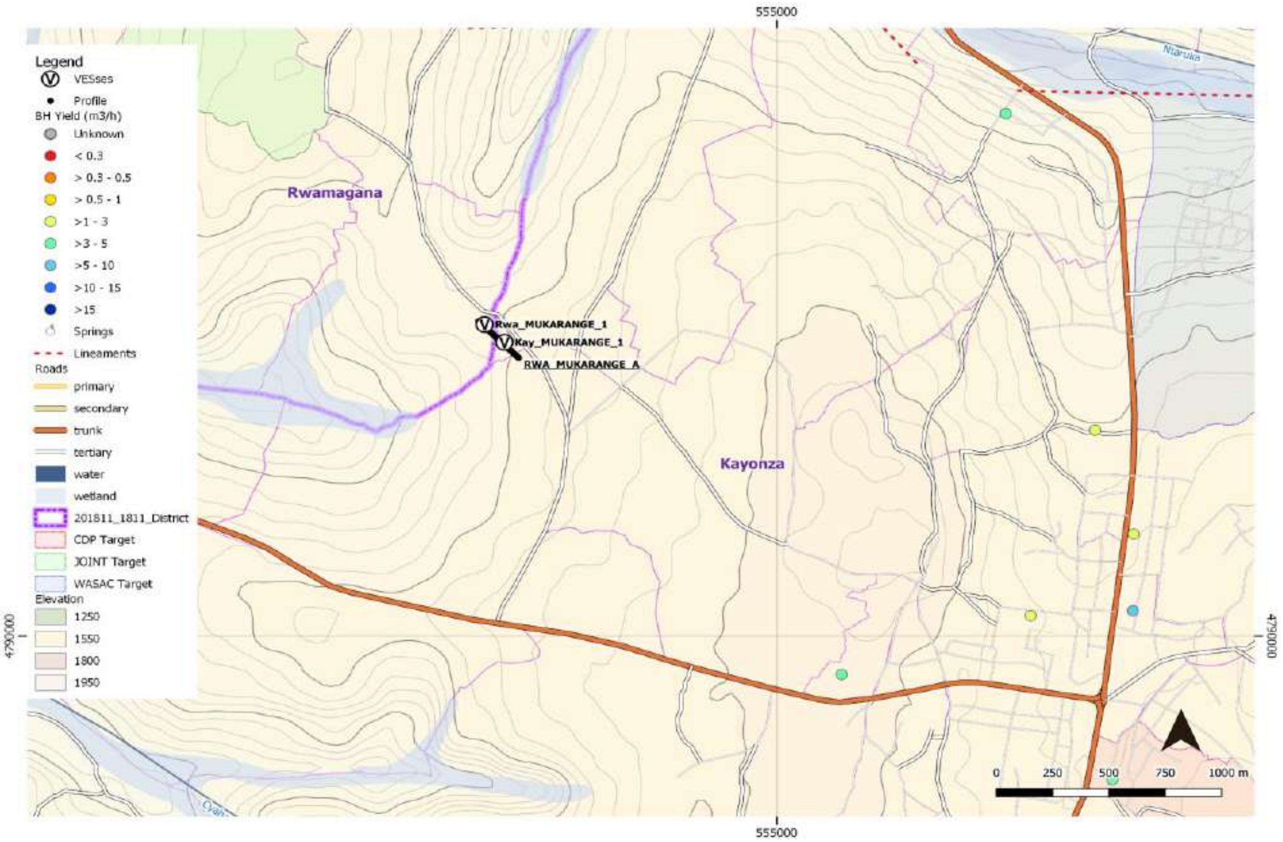


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
RWA_NKUNGU_A_EX_2 (260 m)
MASKED RESULTS OF INTERFASE BETWEEN
SEDIMENTS AND HARD ROCK



Location:	RWA_MUKARANGE				
Recommended Site:			coordinate (E)		coordinate (N)
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:		Accessible
Alternative Site:			coordinate (E)		coordinate (N)
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:		
Expected Formation:		Granites to Schists	Accessibility Village:		Good
Int yield (l/h) :	2 261	SWL (m asl):	1 548	Target:	None
Remarks:	This site was originally intended purely for the calibration of a borehole (VES_1). However the values on the short profile kept dropping which led to another interesting sounding which is typical of homogeneous schists. The Borehole seems to be where the granites and schists are interfacing more while 130 meters further, parallel to the slope the results show no trace of granites. While VES_2 does show you characteristics for Schists, it shows you nothing besides. Vertical electrical soundings are very innefective for finding water in soft formations, since there is no contrast to use to make recommendations. The profile however does show a very good anomaly on that location, though not as good as the one the borehole is supposed to be on. As can be seen the borehole misses the anomaly just. If drilled 20 - 30 meters south east allong the profile, a better yield could be gotten than the current 2m3/h. The borehole is dillapated and clearly long abandoned, but if demand rises in the area just this could be considered. Expect the water to be deep since the borehole is high on the slope.				

Location map geophysical measurements



Site	3	Village	Karwiru			
Cell	Kitazigurwa	Sector	Mukarange			
		District	Rwamagana			

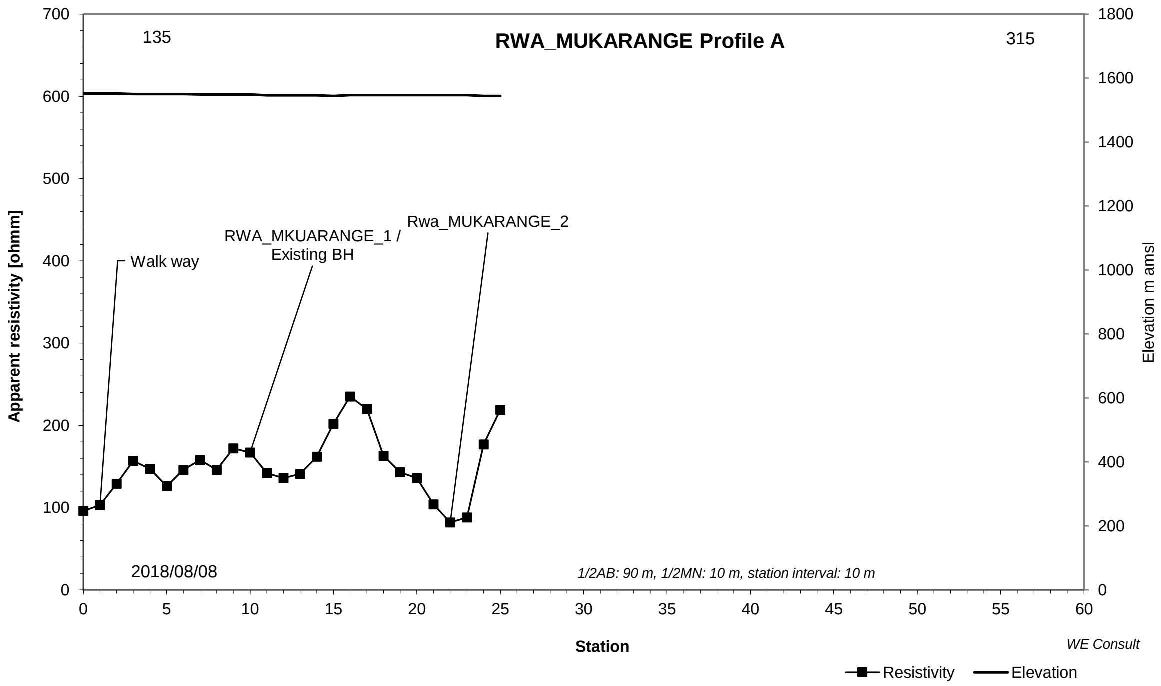
WE Consult

Rating per site (max. 100 points):

	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							

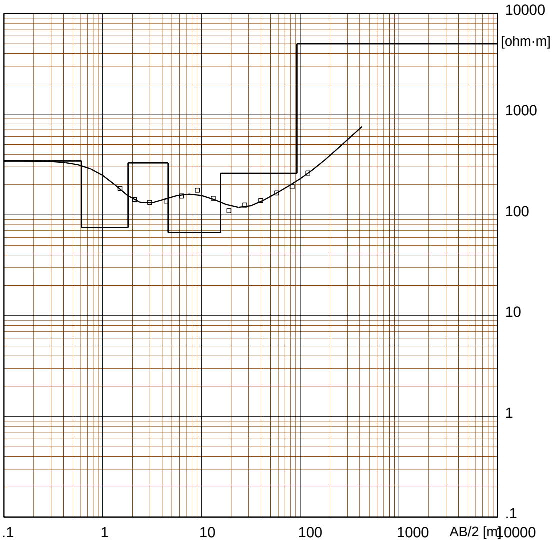
Geophysical measurements

RWA_GAHENGERI_A SCHLUMBERGER PSEUDO



ELECTICAL SOUNDING_SCHLUM
RWA_MUKARANGE_1
EXISTING BH 1,9 m3/h | SWL 56 mbgl
NOT FUNCTIONAL, ABANDONED
HIGH ON SLOPE

242-Calib



Location X = 220037 Y = 9791280 Z = 1531 Azim = 140/320

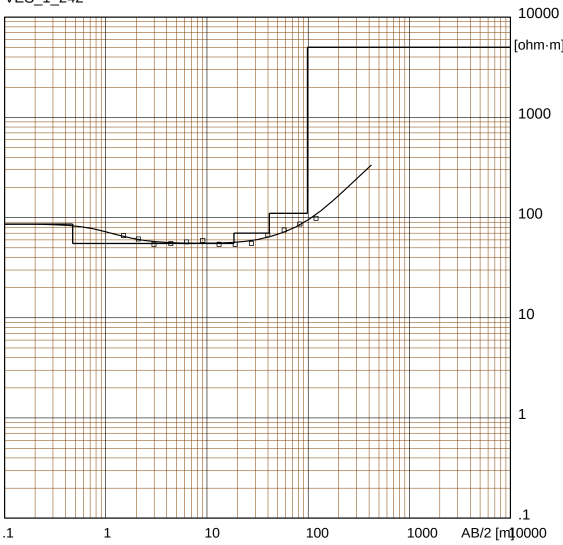
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
344	.61		1531
75	1.2	.61	1530.4
329	2.8	1.8	1529.2
67	11	4.6	1526.4
259	77	16	1515

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
RWA_MUKARANGE_2
TYPICAL FOR SCHISTS
HIGH ON SLOPE

Electrical sounding Schlumberger - 242-1.WS3

VES_1_242



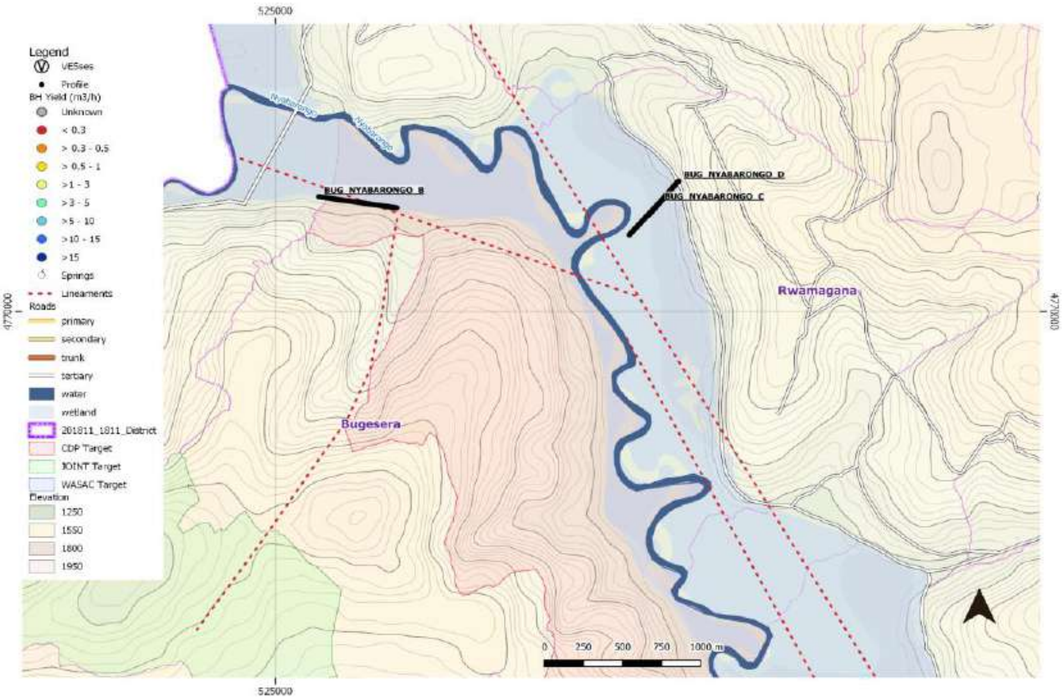
Location X = 219949 Y = 9791366 Z = 1538 Azim = 140/320

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
86	.47		1538
55	18	.47	1537.5
70	23	18	1520
110	57	41	1497
5000		98	1440

W-GeoSoft / WinSev 6.3

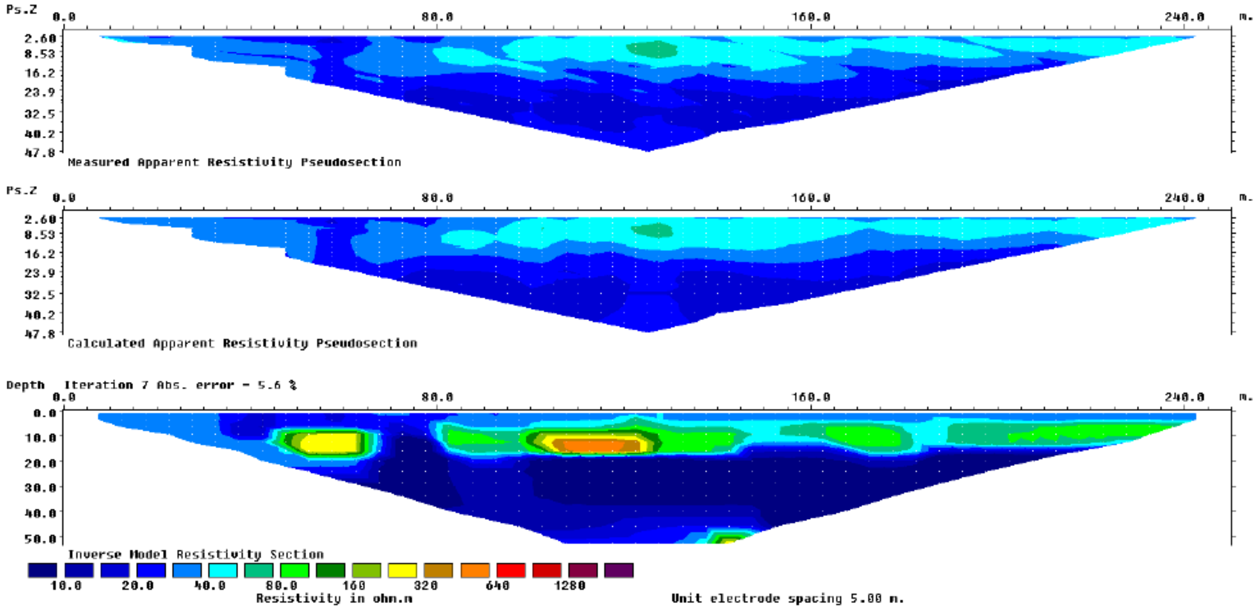
Location:	BUG_NYABARONGO				4
Recommended Site:	Profile C	coordinate (E)	527423	coordinate (N)	4770717
Expected DTB (m):		Altitude (amsl)	1335	1025	
Recommended Depth (m):		Accessibility Site:		Challenging	
Alternative Site:		coordinate (E)		coordinate (N)	
Expected DTB (m):		Altitude (amsl)		1018	
Recommended Depth (m):		Accessibility Site:			
Expected Formation:	Quartzite Schists and Sediment	Accessibility Village:		Good	
Int yield (l/h) : 4 003	SWL (m asl): 1 330	Target:		PRODUCTION	
Remarks:	The main purpose was to explore whether coarse high yielding sediment aquifers are present. Profile A near the bridge crossing out of Bugesera District shows the presence of pockets of coarse materials but the area was difficult to survey. Further along the Nyabarongo a large deposit area was identified before which the Nyabarongo becomes more narrow (picks up flow rate), after which it wildy meanders (depositing the sediments picked up with the increased flow rate). This in theory is an ideal area for production wells in coarse sedimentary layers, similar to a wellfield now supplying Kigali. Profile B is done close and parallel to the slopes. While there are nice anomalies that are most visible on the extracted 1D profile that surely provide nice opportunities for drilling, it would be a shame to ignore the easy to extract potential of the deposit area. VES extractions from profile B are fruitless since all results will show up masked by the clay. Profile C and D are done in the deposit area. They clearly show an unitermitted layer of higher resistivity sediments (sand/ coarse sand) which reaches all the way to the river starting 80 meters from the slopes. These sediments can typically be identified by the Extracted VESses shown. However if the sediments are overlain by a large packet of clay, the results will be masked making it difficult to determine what is going on. For locating these kind of sediment packets with 1D equipment only it is adviced to run a profile with 1/2 AB of 90, and another profile on top with 1/2 AB of where you expect the pocket to be (some are deeper then others). If you see the lower 1/2 AB values overtaking (being higher then) the 1/2 AB 90 values you know that you are in a higher resitivity pocket (sands and better) underlain by clay. ERT will be most cost efficient. While drilling on profile C could already be suggested, instead the Consultant suggests further exploration of the rest of the deposit area to identify additional pockets (or find out that it is in fact throughout the area). This will allow for the possible Design of a well field which would be able to supply large parts of Bugesera, including the airport. Due to the soil conditions if drilling is considered, small towable rigs should be considered for drilling.				

Location map geophysical measurements

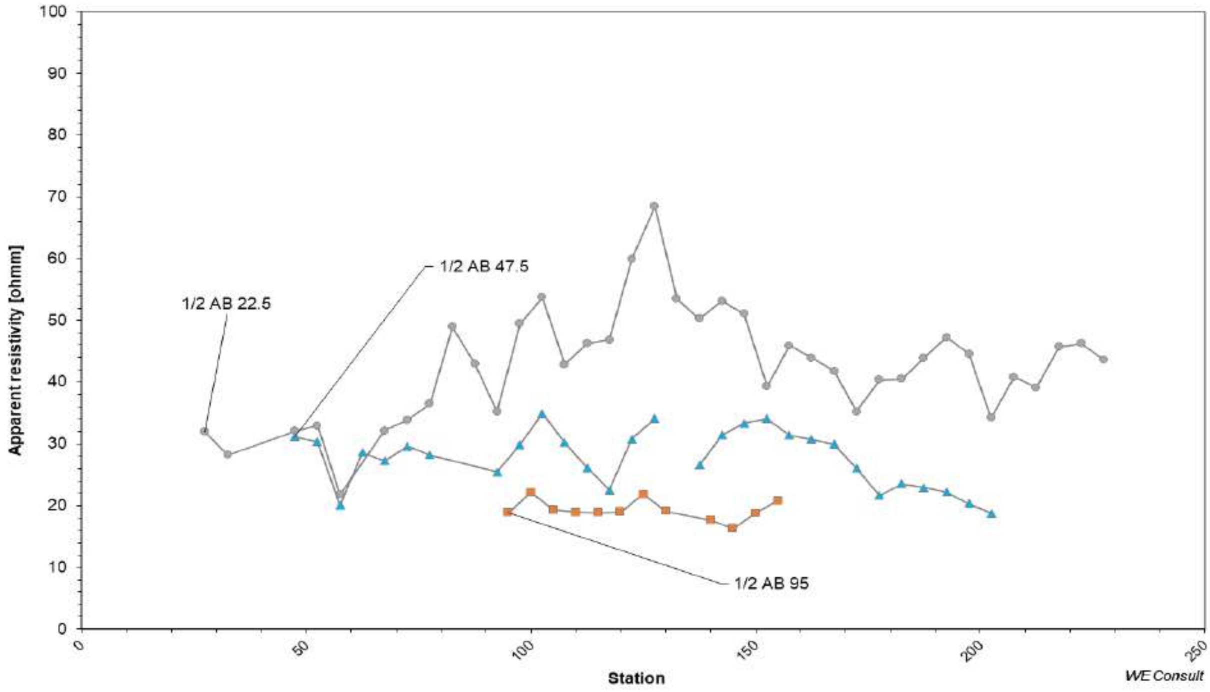


Site	4		Village	Kamashaza			
Cell	Rwimbogo		Sector	Nyakaliro			
			District	Rwamagana			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

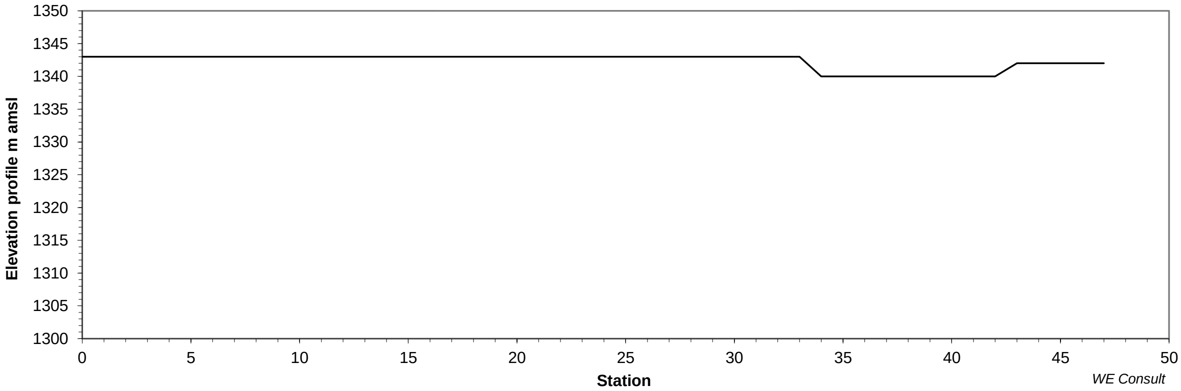
BUG_NYABARONGO_A SCHLUMBERGER PSEUDO



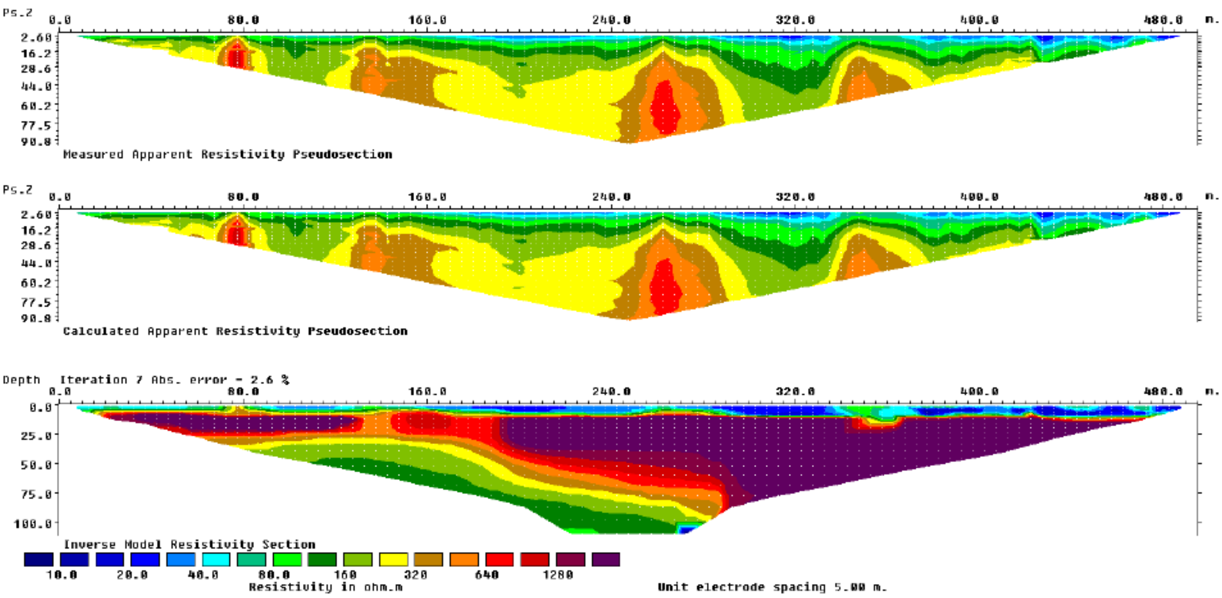
BUG_NYABARONGO_A SCHLUMBERGER 1D EXTRACTION



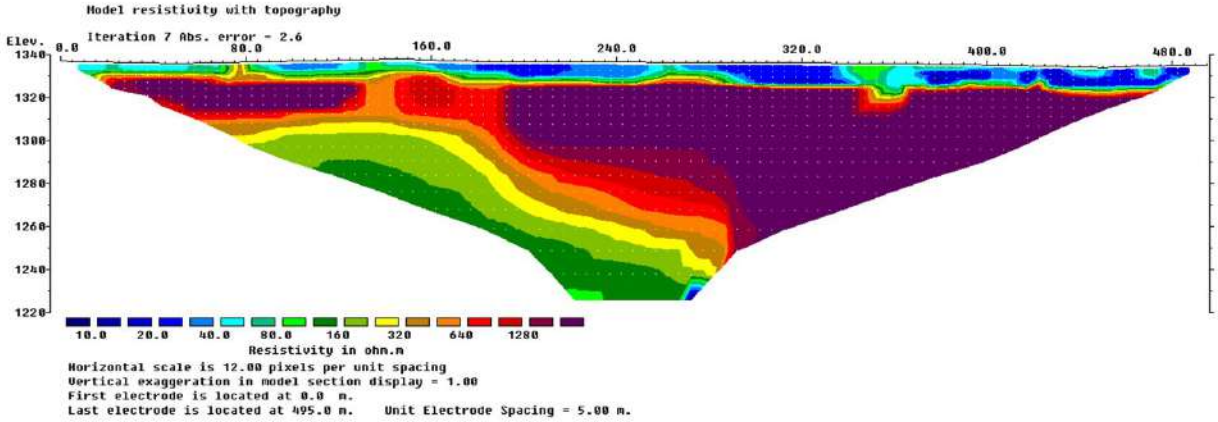
BUG_NYABARONGO_A SCHLUMBERGER ELEVATION



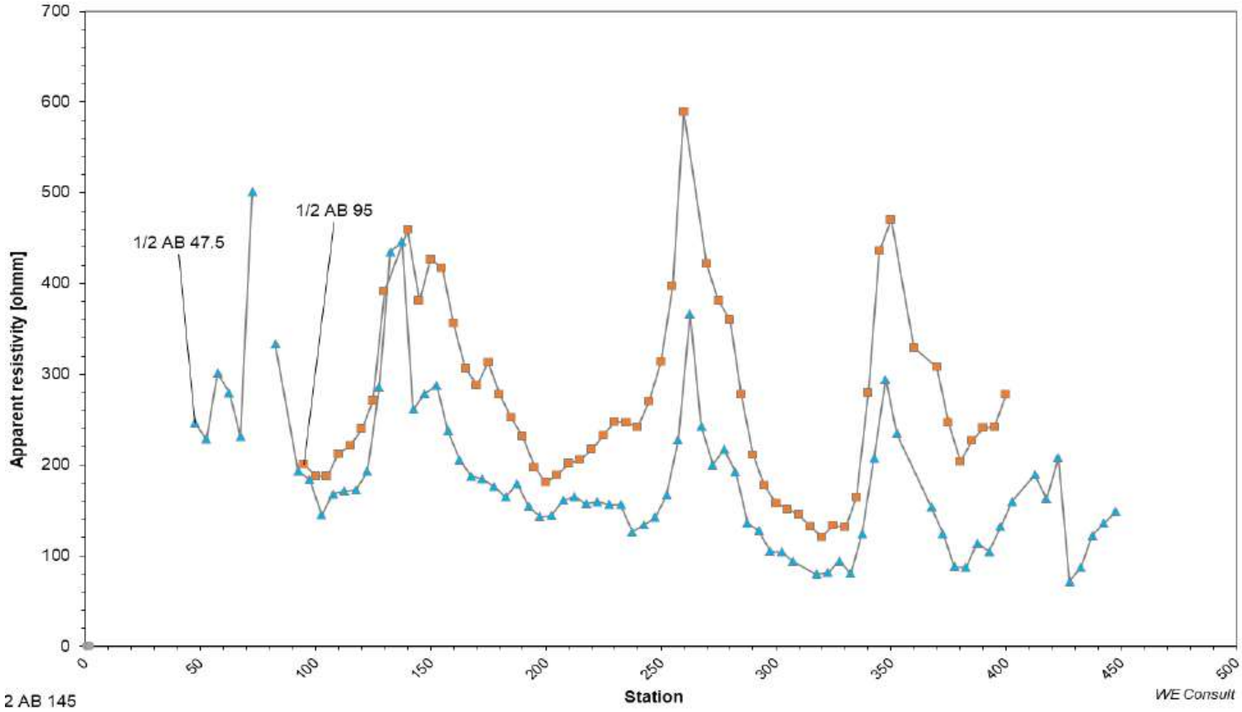
BUG_NYABARONGO_B SCHLUMBERGER PSEUDO



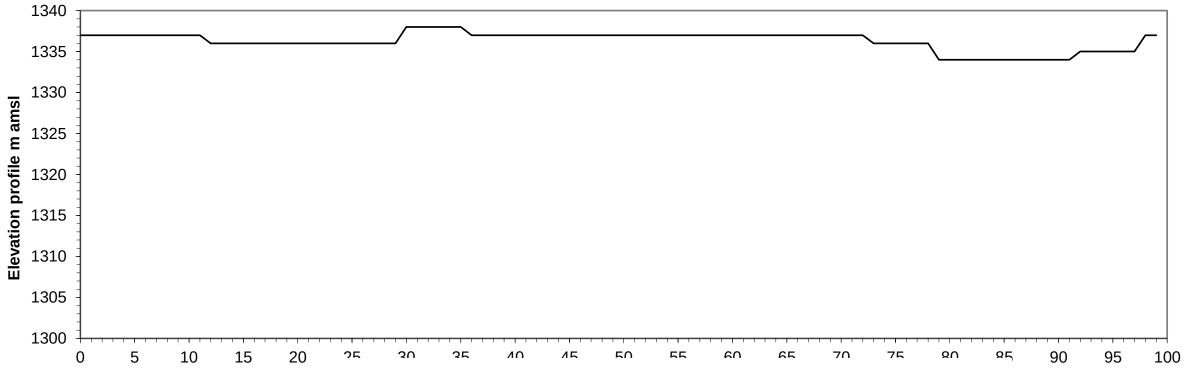
BUG_NYABARONGO_B SCHLUMBERGER TOPO



BUG_NYABARONGO_B SCHLUMBERGER 1D EXTRACTION

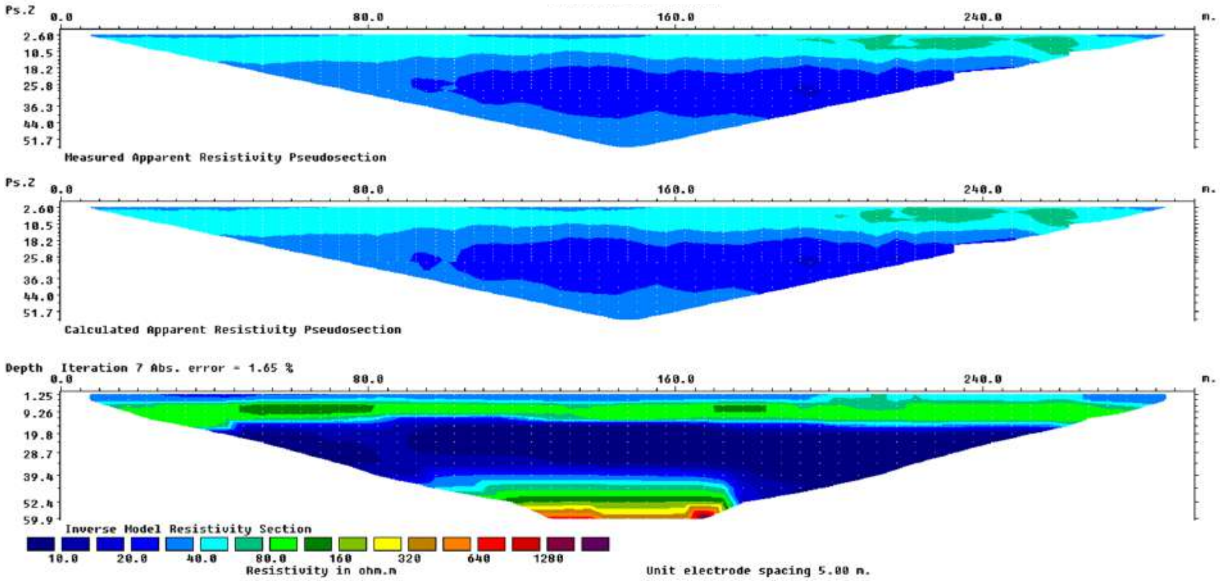


BUG_NYABARONGO_B SCHLUMBERGER ELEVATION

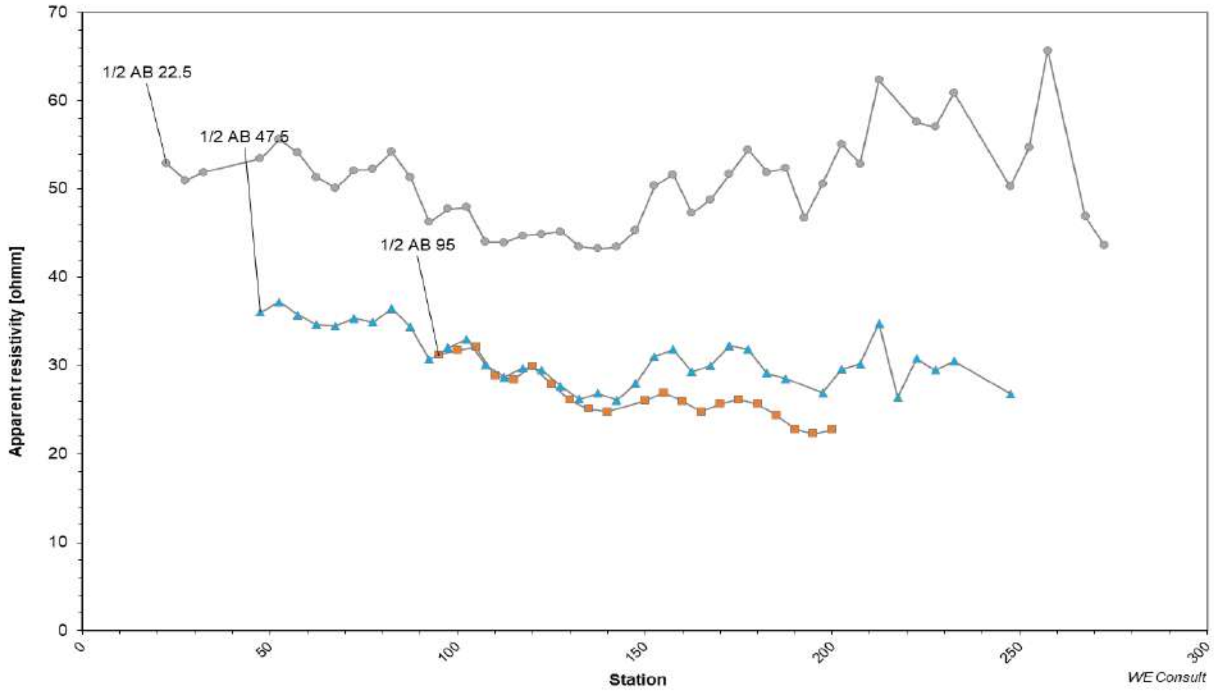


BUG_NYABARONGO_C SCHLUMBERGER PSEUDO

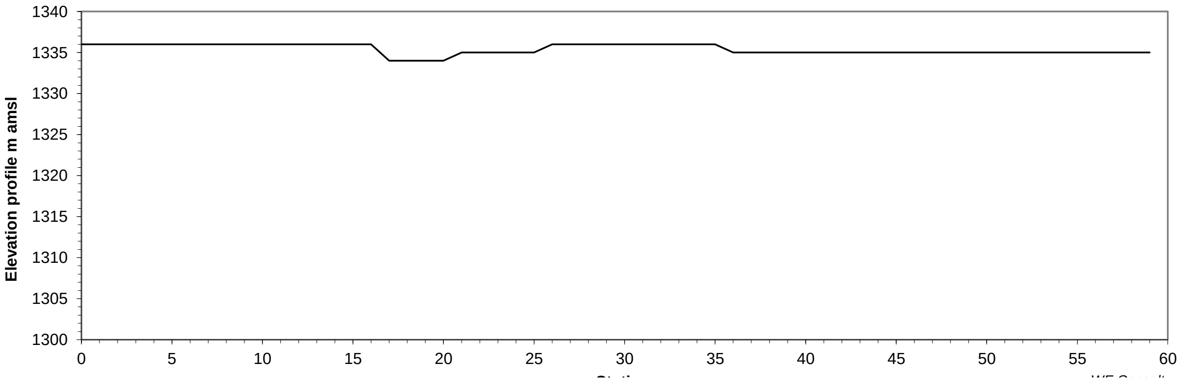
WE Consult



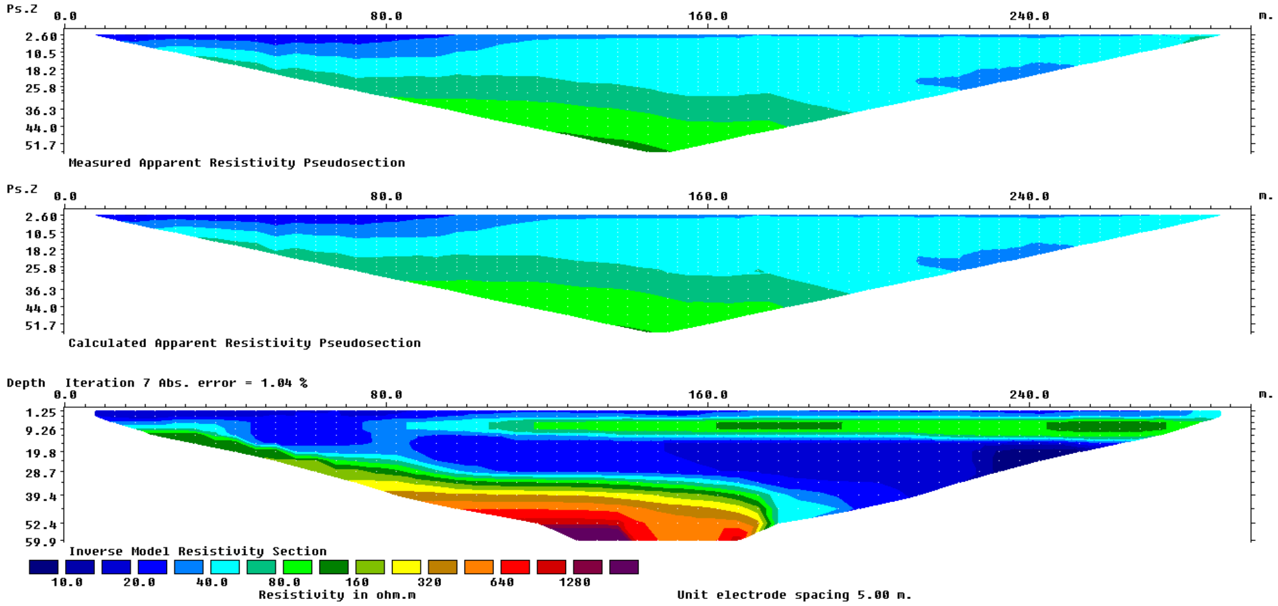
BUG_NYABARONGO_C SCHLUMBERGER 1D EXTRACTION



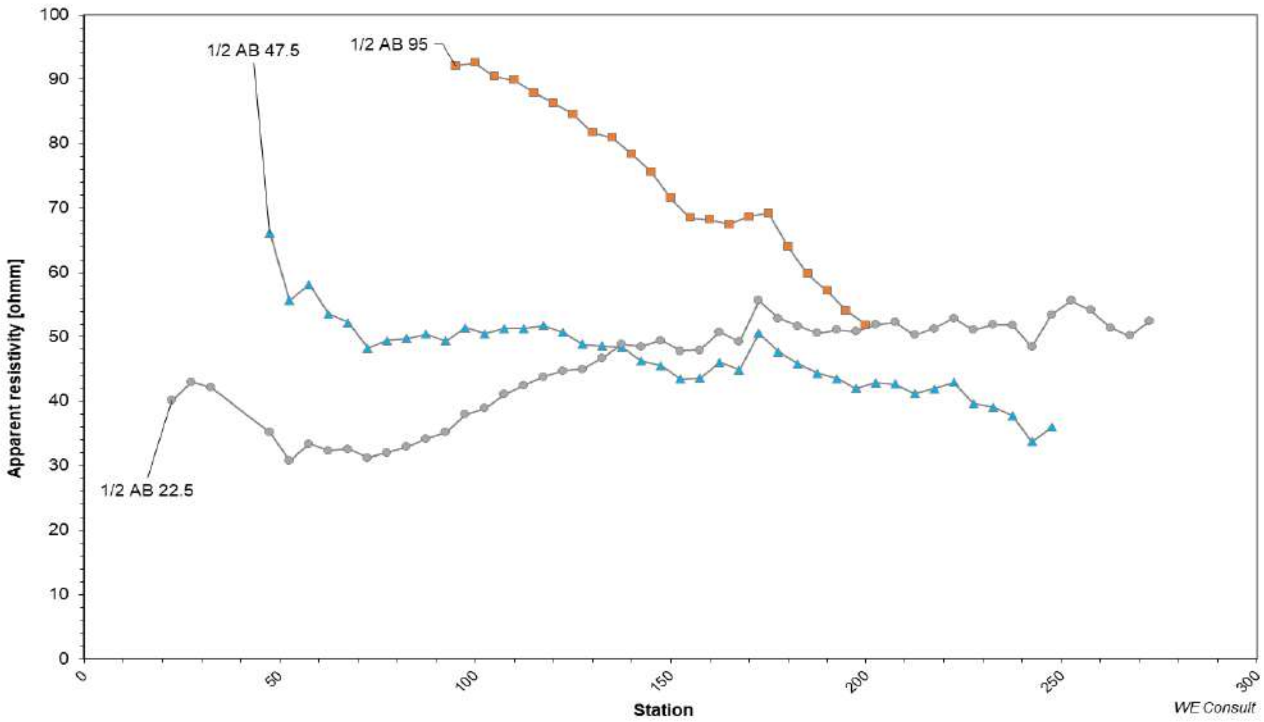
BUG_NYABARONGO_C SCHLUMBERGER ELEVATION

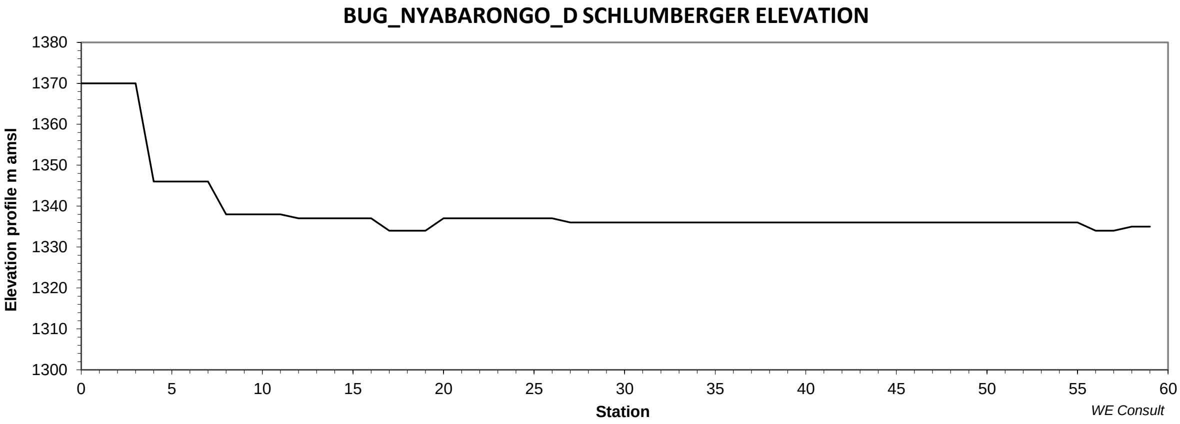


BUG_NYABARONGO_D SCHLUMBERGER PSEUDO



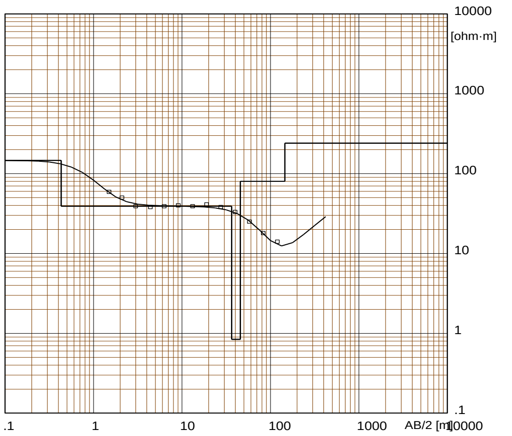
BUG_NYABARONGO_C SCHLUMBERGER 1D EXTRACTION




BUG_NYABARONGO_D SCHLUMBERGER ELEVATION
Elevation profile m amsl
1380
1370
1360
1350
1340
1330
1320
1310
1300
0
5
10
15
20
25
30
35
40
45
50
55
60
Station
WE Consult

Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_SCHLUM
BUG_NYABARONGO_1
CALIBRATION ON EXISTING BOREHOLE
SANDY FORMATIONS CONFIRMED



Location X = 175972 Y = 9771686 Z = 1340 Azim = 100/290

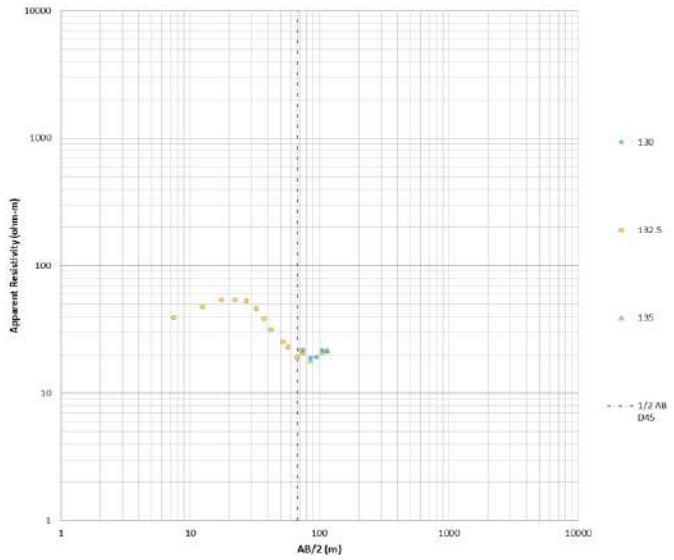
Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
146	.43		1340
39	36	.43	1339.6
.84	9.3	36	1304
80	100	45	1295
240		145	1195

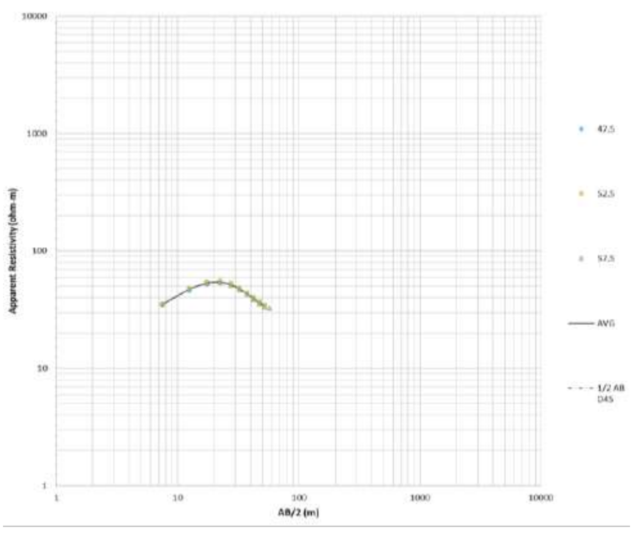
The calibraion VES was done on a borehole along a river. The interpreted layers are:to soil, clay and sandy clays.

W-GeoSoft / WinSev 6.3

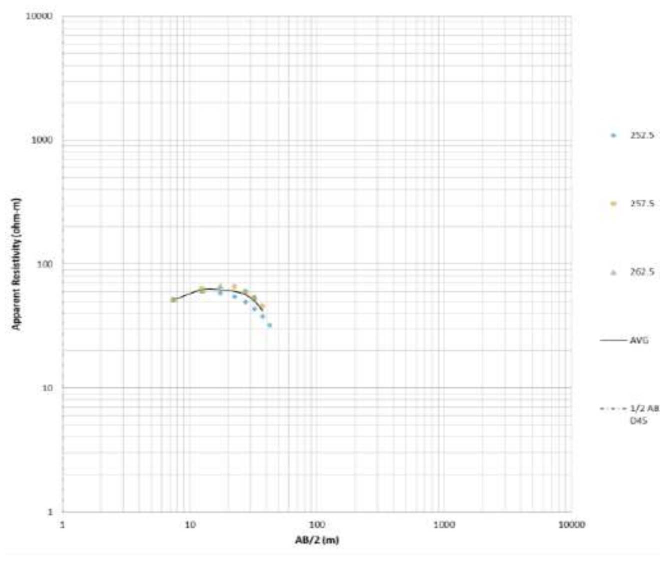
ELECTICAL SOUNDING_SCHLUM
BUG_NYABARONGO_A_EX_1 (130m)
ON POSITIVE ANOMALY/HIGH RESISTANCE POCKET
CURVE SHOWS INCREASE IN RESISTANCE 10-20 1/2AB.
SANDY LAYER SURROUNDED BY CLAY



ELECTICAL SOUNDING_SCHLUM
BUG_NYABARONGO_C_EX_3 (52 m)
ON POSITIVE ANOMALY/HIGH RESISTANCE
SHALLOW LAYER THROUGHOUT
CURVE SHOWS INCREASE IN RESISTANCE 10-20
1/2AB. SANDY LAYER SURROUNDED BY CLAY

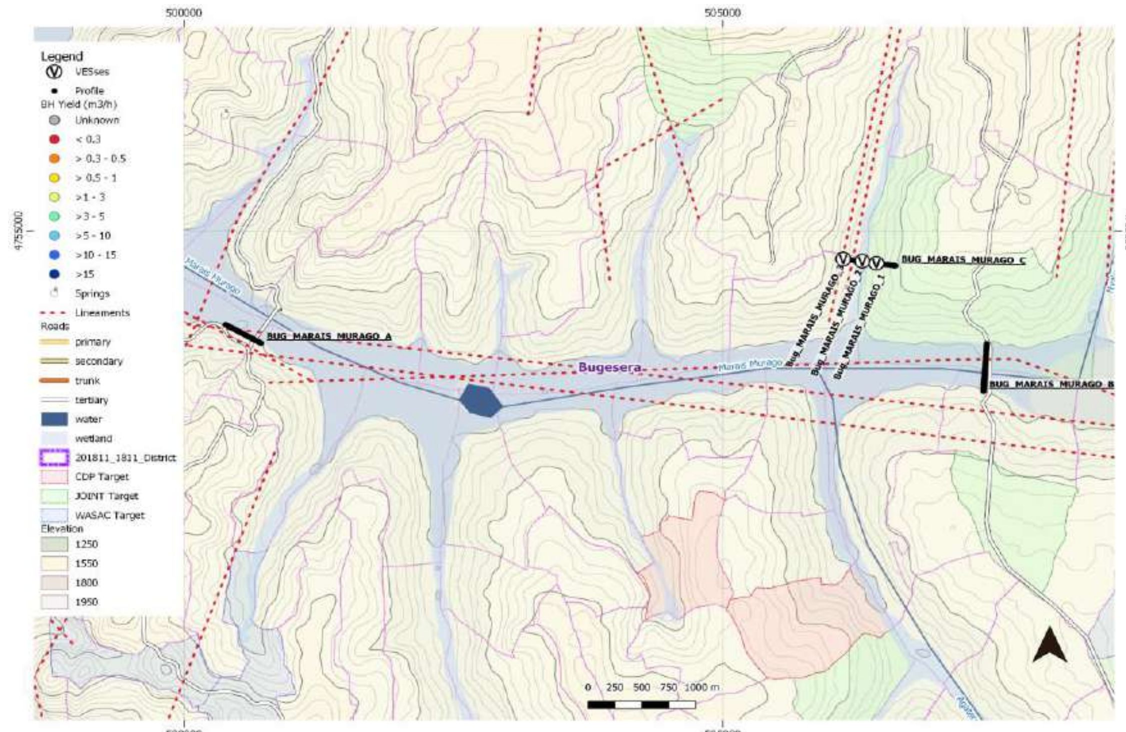


ELECTICAL SOUNDING_SCHLUM
BUG_NYABARONGO_D_EX_4 (257 m)
ON POSITIVE ANOMALY/HIGH RESISTANCE
SHALLOW LAYER THROUGHOUT
CURVE SHOWS INCREASE IN RESISTANCE 10-20
1/2AB. SANDY LAYER SURROUNDED BY CLAY,
THROUGHOUT THE PROFILE. COARSE SAND



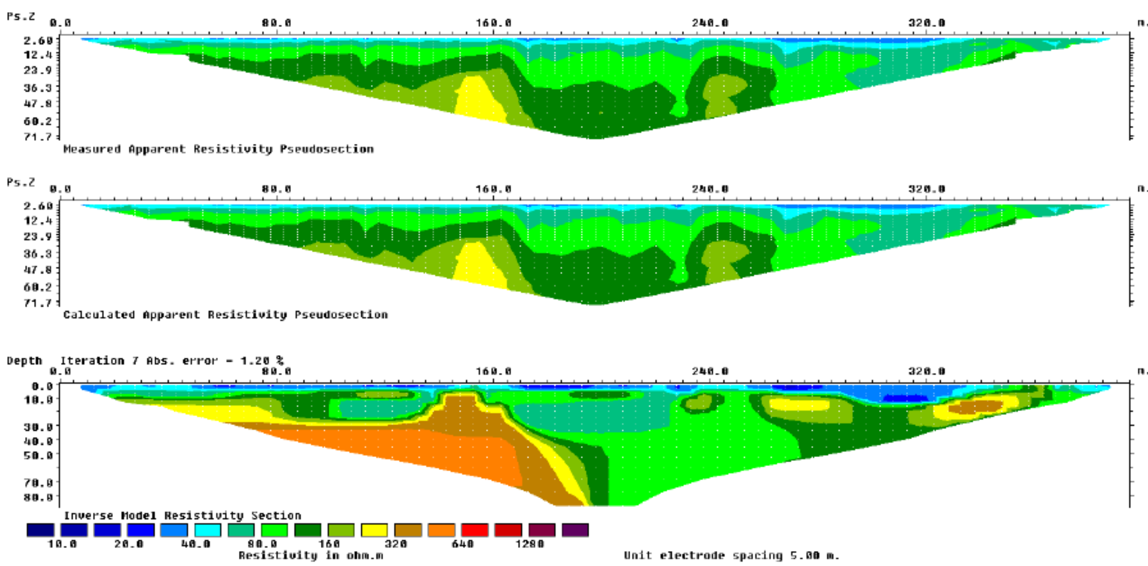
Location:	BUG_MARAIS MURAGO				5
Recommended Site:	VES_1	coordinate (E)	506423	coordinate (N)	4754673
Expected DTB (m):		Altitude (amsl)		1370	
Recommended Depth (m):		Accessibility Site:		Accessible	
Alternative Site:		coordinate (E)		coordinate (N)	
Expected DTB (m):		Altitude (amsl)		1018	
Recommended Depth (m):		Accessibility Site:			
Expected Formation:		Quartzite Schists and Sediments		Accessibility Village:	Good
Int yield (l/h) :	1,622	SWL (m asl):	1,357	Target:	JOINT PROXIMITY
Remarks:	The main purpose of this survey was to explore one of the major valleys in Bugesera to see what the potential is and what could be its characteristics. Originally, Profile A and B were supposed to be close together, however the supposed road, crossing the valley, was never finished. A break in the quartzite vein is very visible in the valley near profile A. While the profile crosses perpendicular to the vein, making it difficult to see the break, it does confirm the presence of the quartzite intermitted by schists. If this location is in the future made accessible more investigations should be done perpendicular to profile A for high potential production sites. Profile B crosses the main valley supposedly underlain by granites. The results are typical for these major valleys. The quick alternation of layers in the inverse model is typical for weathering. The results are similar throughout the profile with little variation. If handpumps are needed they can be drilled in the main valley, while finding locations where the weathering is the deepest, which should become visible on a profile. VESses will be completely masked. Profile C (1D) was done in one of the side valleys where masking seems to be less of an issue. The profile shows little variation in terms of anomalies. Best option for drilling for a handpump is on VES_1, showing a wide VES, which in sediments and granite could singify a deeper weathering.				

Location map geophysical measurements

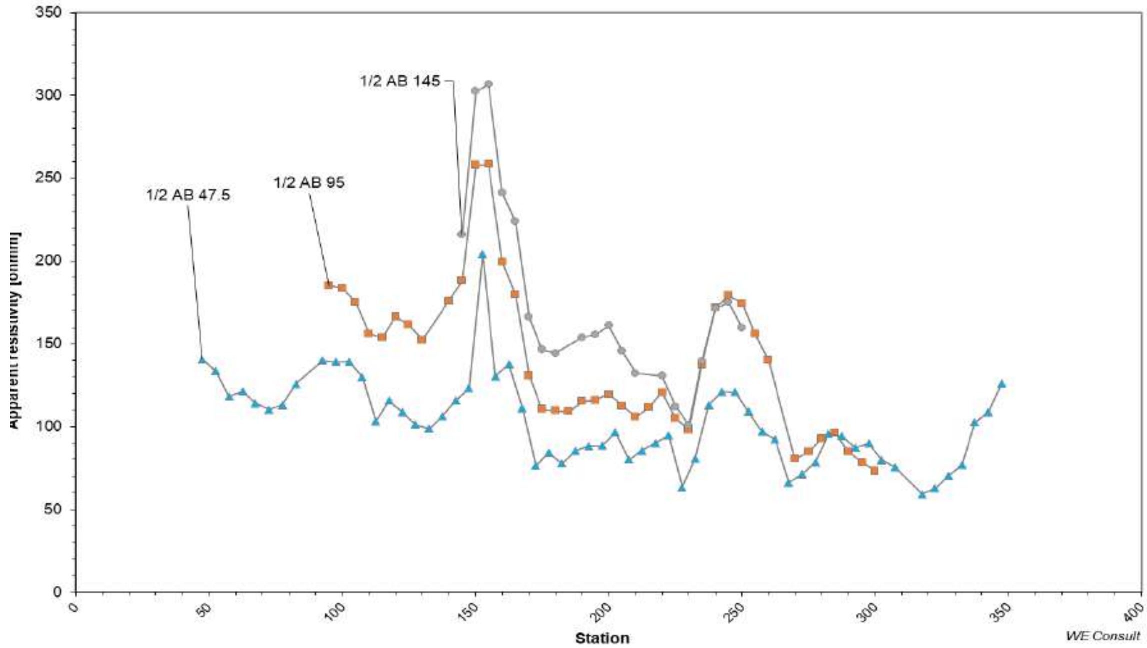


Site	5		Village	Rubwirwa			
Cell	Kamabuye		Sector	Shyara			
			District	Bugesera			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	14	18	14				
Lineament (0-20 points)	5	5	5				
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)	5	5	5				
Total	39	28	31				
Remarks							
Geophysical measurements							

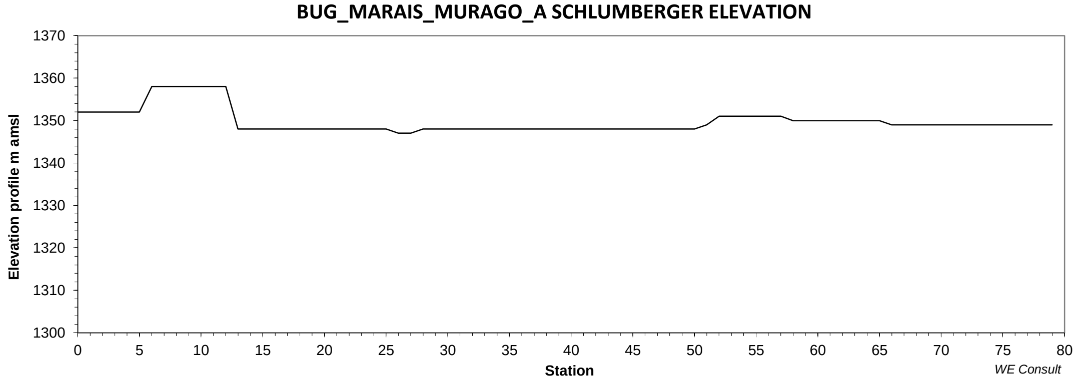
BUG_MARAIS_MURAGO_A SCHLUMBERGER PSEUDO



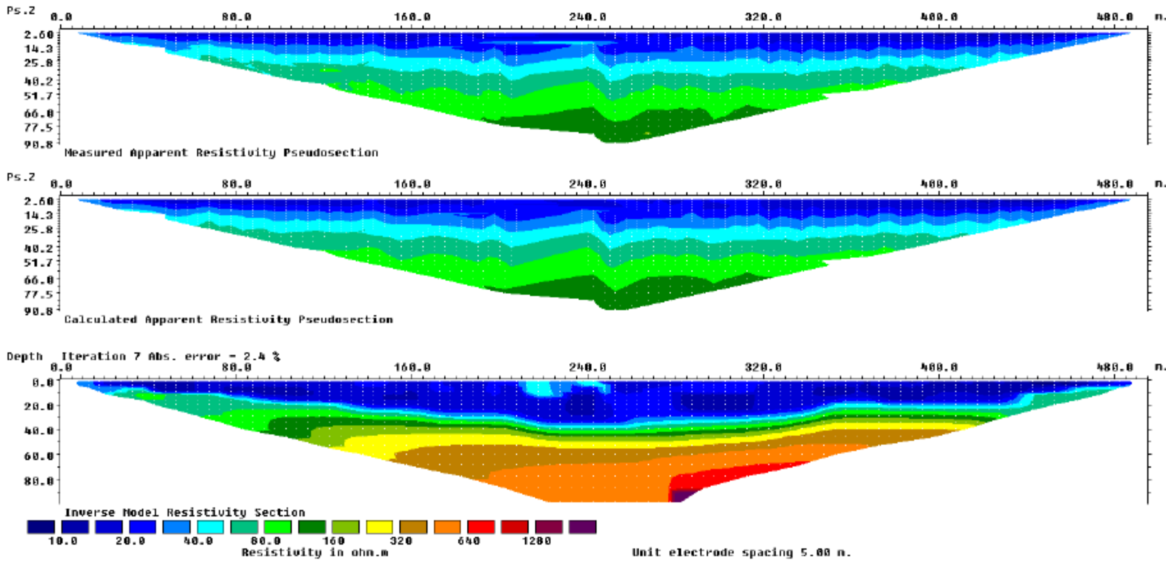
BUG_MARAIS_MURAGO_A SCHLUMBERGER 1D EXTRACTION



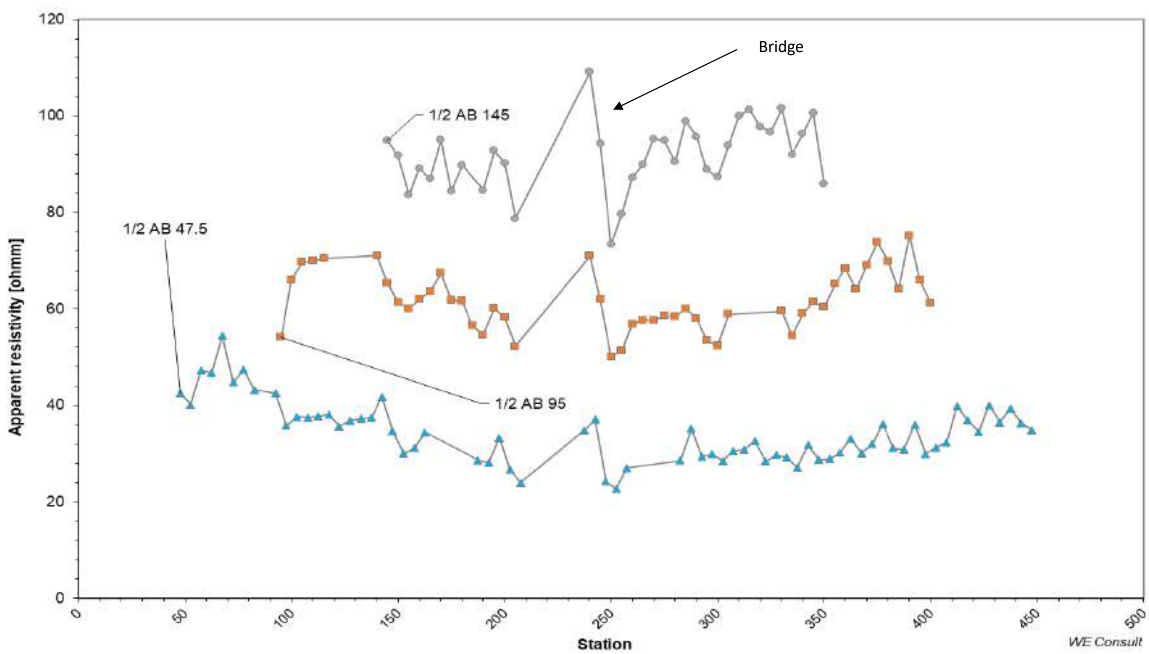
BUG_MARAIS_MURAGO_A SCHLUMBERGER ELEVATION

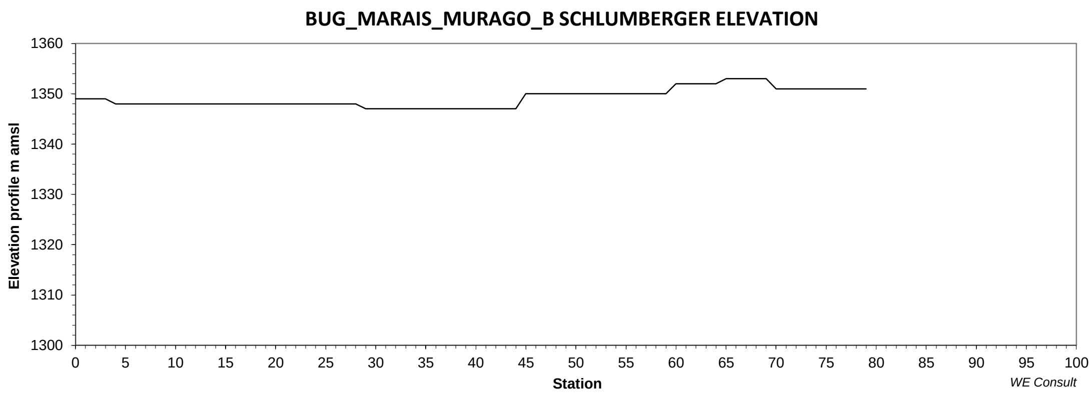


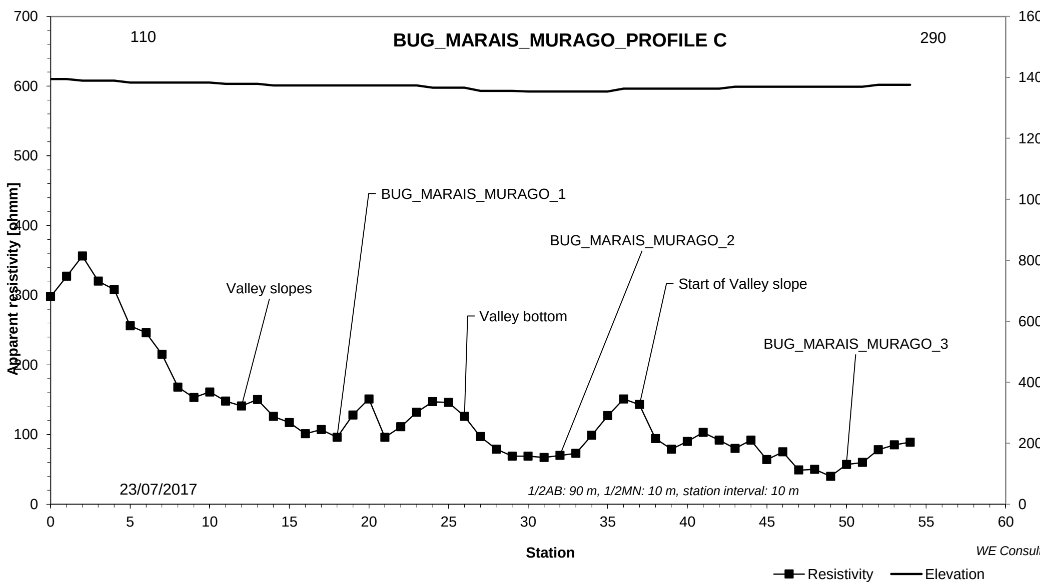
BUG_MARAIS_MURAGO_B SCHLUMBERGER PSEUDO



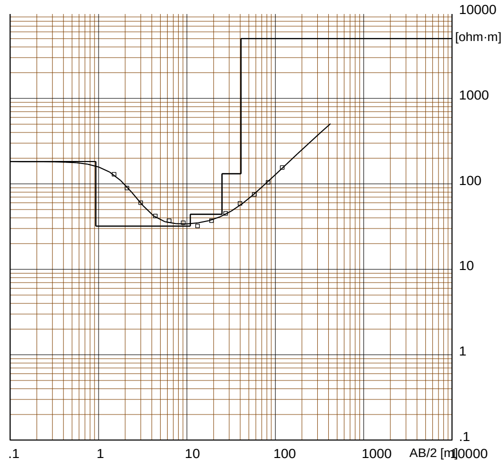
RWA_GAHENGERI_B SCHLUMBERGER 1D EXTRACTION




BUG_MARAIS_MURAGO_B SCHLUMBERGER ELEVATION
Elevation profile m amsl
1360
1350
1340
1330
1320
1310
1300
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Station
WE Consult


BUG_MARAIS_MURAGO_PROFILE C
110
290
Apparent resistivity [ohmm]
Elevation m amsl
700
600
500
400
300
200
100
0
1600
1400
1200
1000
800
600
400
200
0
BUG_MARAIS_MURAGO_1
BUG_MARAIS_MURAGO_2
Valley slopes
Start of Valley slope
Valley bottom
BUG_MARAIS_MURAGO_3
23/07/2017
1/2AB: 90 m, 1/2MN: 10 m, station interval: 10 m
0 5 10 15 20 25 30 35 40 45 50 55 60
Station
WE Consult
Resistivity
Elevation

ELECTICAL SOUNDING_SCHLUM
BUG_MARAIS_MURAGO_1



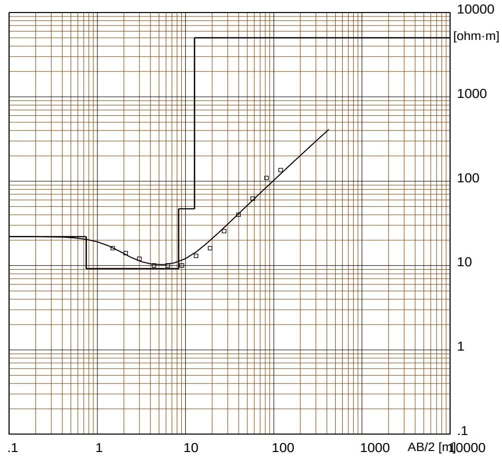
Location X = 172700 Y = 9754421 Z = 1362 Azim = 170/340

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
182	.93		1362
32	10	.93	1361.1
44	14	11	1351
131	16	25	1337
5000		41	1321

The VES was carried out on station 18 of profile A. The interpreted layers are:top soil, clay, saturated sandy clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_MARAIS_MURAGO_2



Location X = 172569 Y = 975442 Z = 1356 Azim = 170/340

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
22	.75		1392
9.2	7.6	.75	1391.2
47	4.3	8.4	1383.6
5000		13	1379

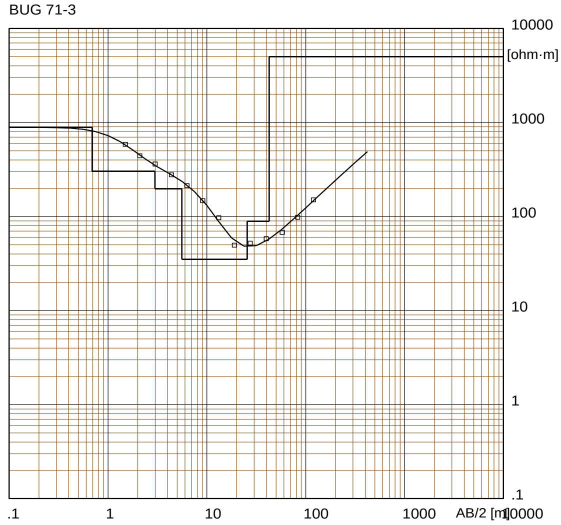
The VES was carried out on station 31 of profile A. The interpreted layers are: top soil, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_MARAIS_MURAGO_3
PASSING ON POSSIBLE LINEAMENT

Electrical sounding Schlumberger - BUG 71-VES 3.WS3

BUG 71-3



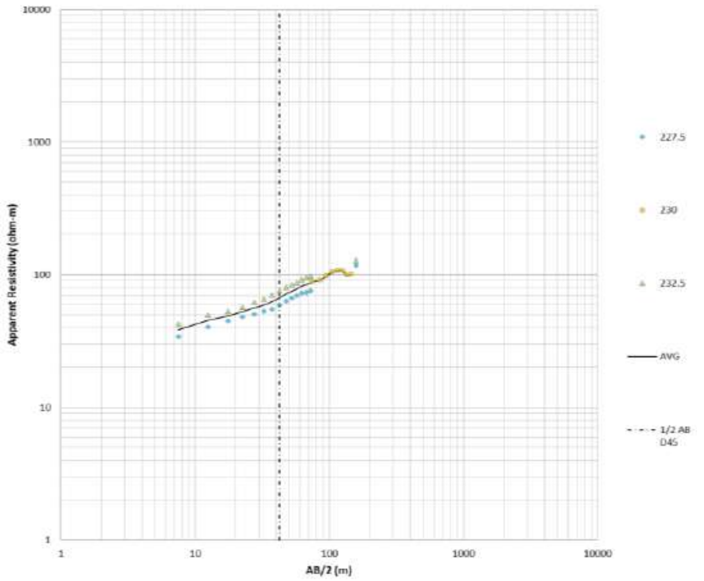
Location X = 172392 Y = 9754464 Z = 1373 Azim = 170/340

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
888	.69		1373
303	2.3	.69	1372.3
197	2.6	3	1370
35	20	5.6	1367.4
89	17	26	1347
5000		43	1330

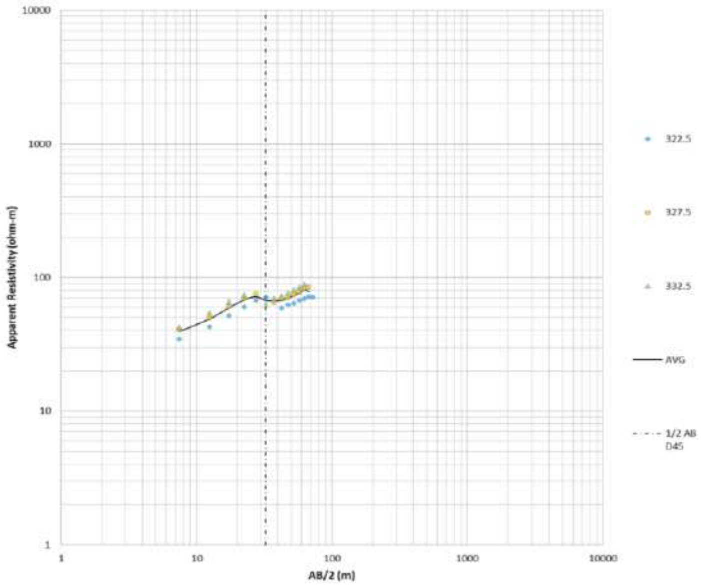
The VES was done on station 49 of profile A. The interpreted layers are: Top soil, sand, sandy clay, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

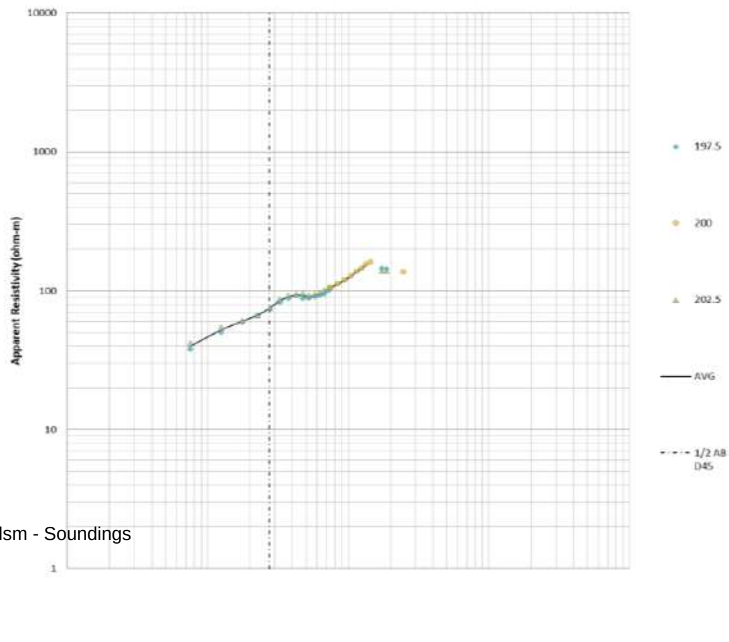
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
BUG_MARAIS_MURAGO_A_EX_1 (230 m)
ON ANOMALY IN WIDE AREA IN ERT



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
BUG_MARAIS_MURAGO_A_EX_2 (327 m)
ON MINOR ANOMALY

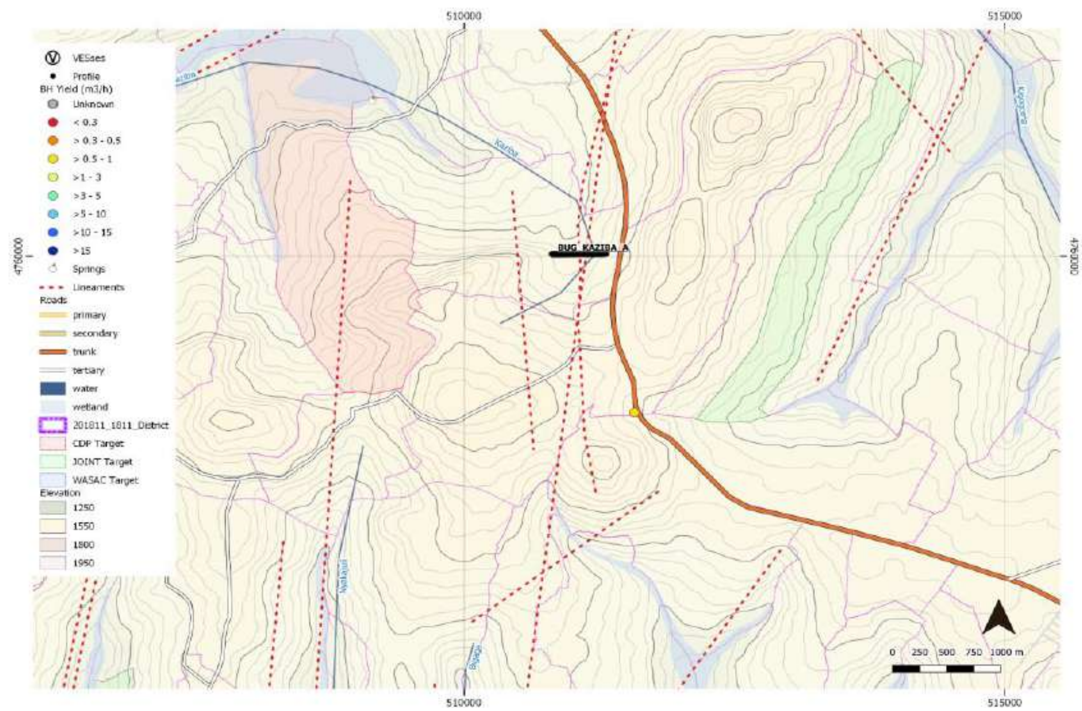


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
BUG_MARAIS_MURAGO_A_EX_3 (200 m)
ON EDGE OF WIDE LOW RES AREA IN ERT



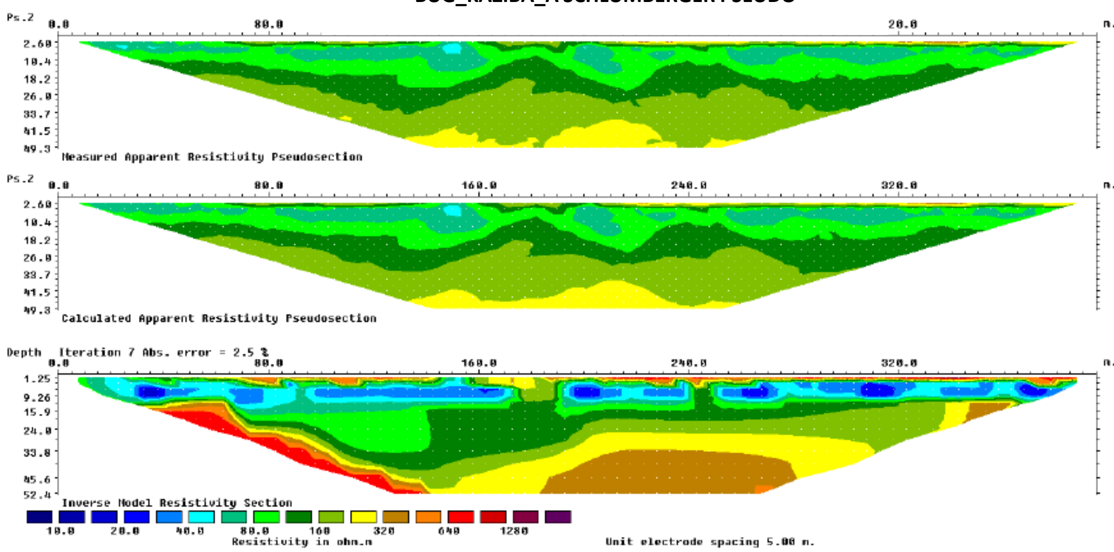
Location:	BUG_KAZIBA				6
Recommended Site:			coordinate (E)		coordinate (N)
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:		Accessible
Alternative Site:			coordinate (E)		coordinate (N)
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:		
Expected Formation:		sandstones with black schists, some volcanic sediments	Accessibility Village:		Good
Int yield (l/h) :	5,318	SWL (m asl):	1,453	Target:	None
Remarks:	This profile was done to verify the characteristics of sandstones in valleys. As can be seen, it is less homogeneous then when looking at results from more schist like formations. No other conclusions to be drawn from this profile. At 150 m on the profile, a good anomaly is sighted which is more visible on the 1D extraction. The VES is difficult to interpret due to masking from overlaying clays. An attempt was also made to see whether the valley could classify as a quatzite vein break, it does not.				

Location map geophysical measurements

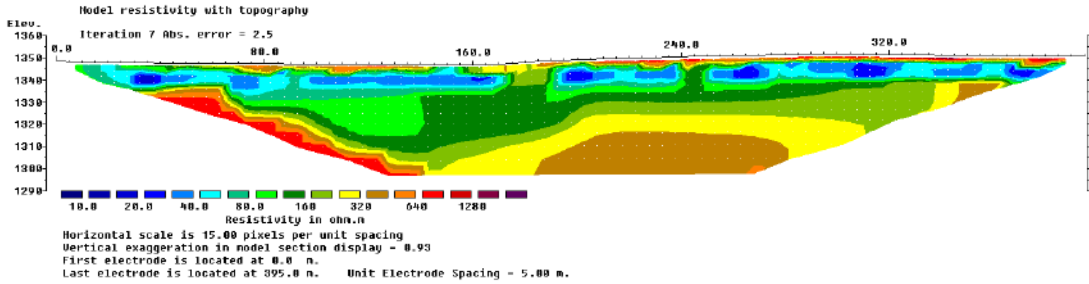


Site	BUG_KAZIBA		Village				
Parish	Cell		Sector				
			District	#N/A			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

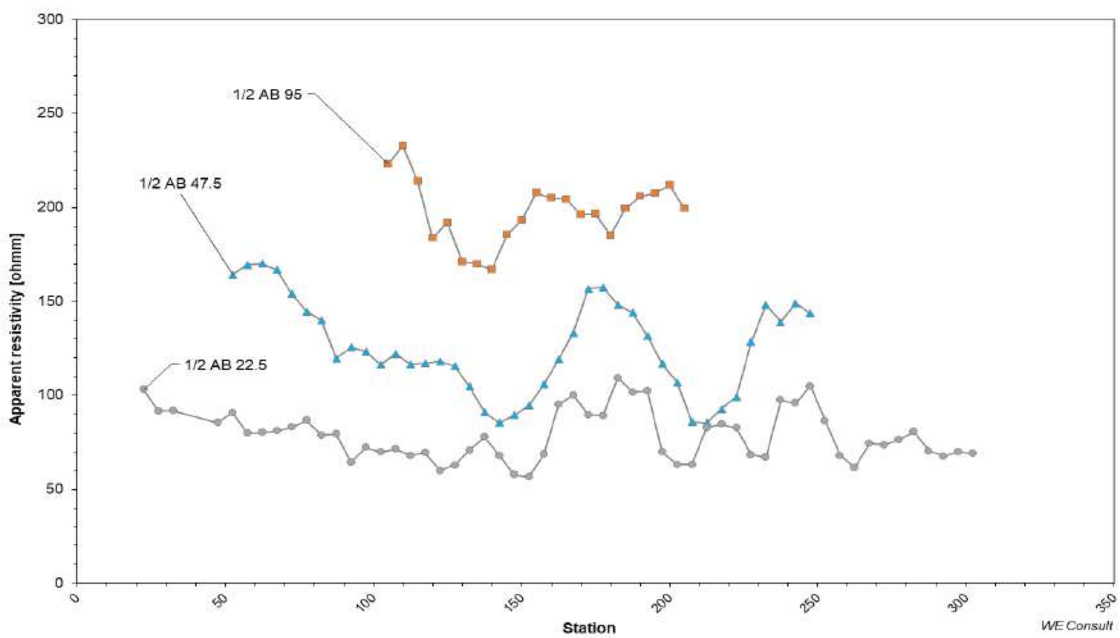
BUG_KAZIBA_A SCHLUMBERGER PSEUDO



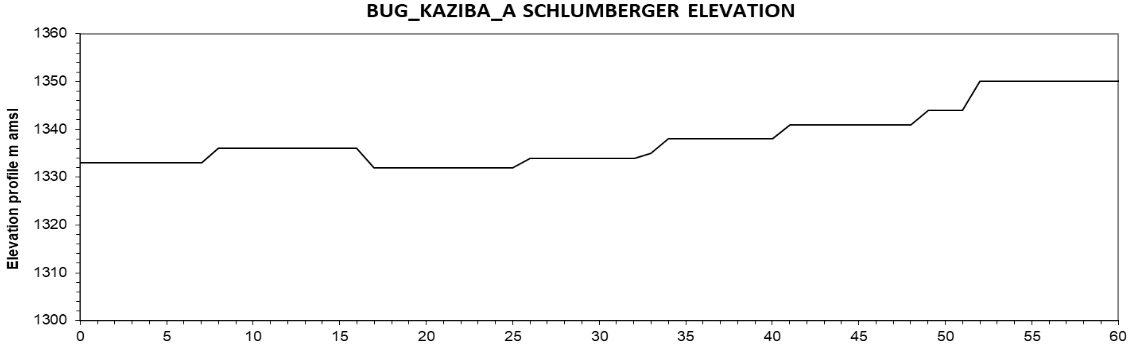
BUG_KAZIBA_A SCHLUMBERGER TOPO



BUG_KAZIBA_A SCHLUMBERGER 1D EXTRACTION

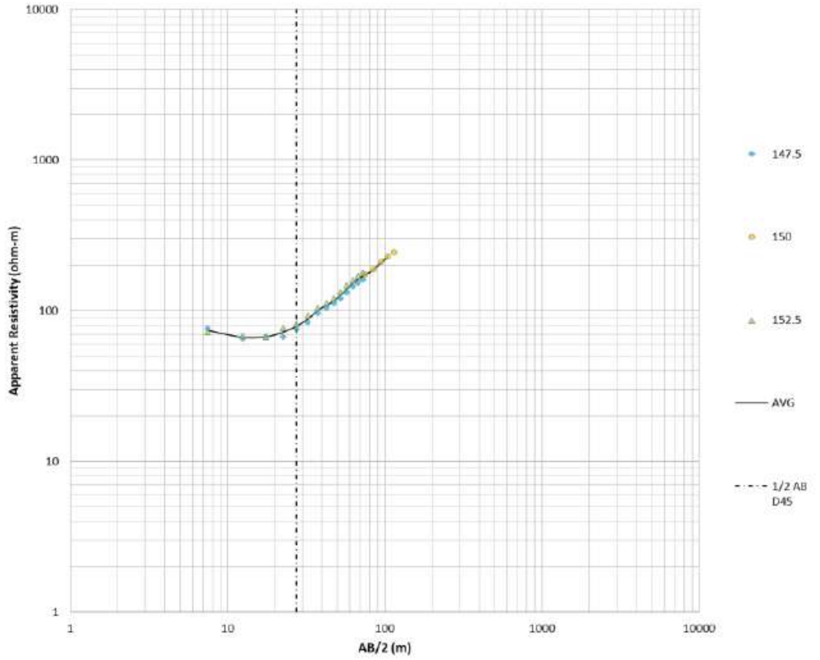


BUG_KAZIBA_A SCHLUMBERGER ELEVATION



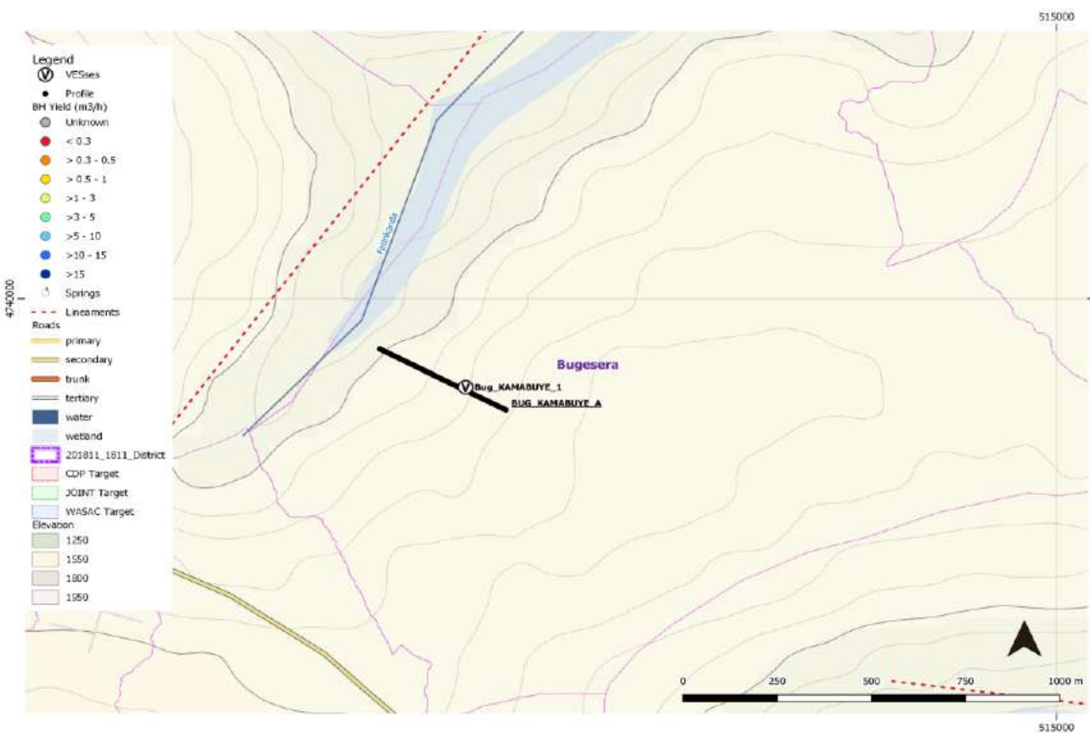
Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
BUG_KAZIBA_A_EX_1 (150 m)
ON ANOMALY



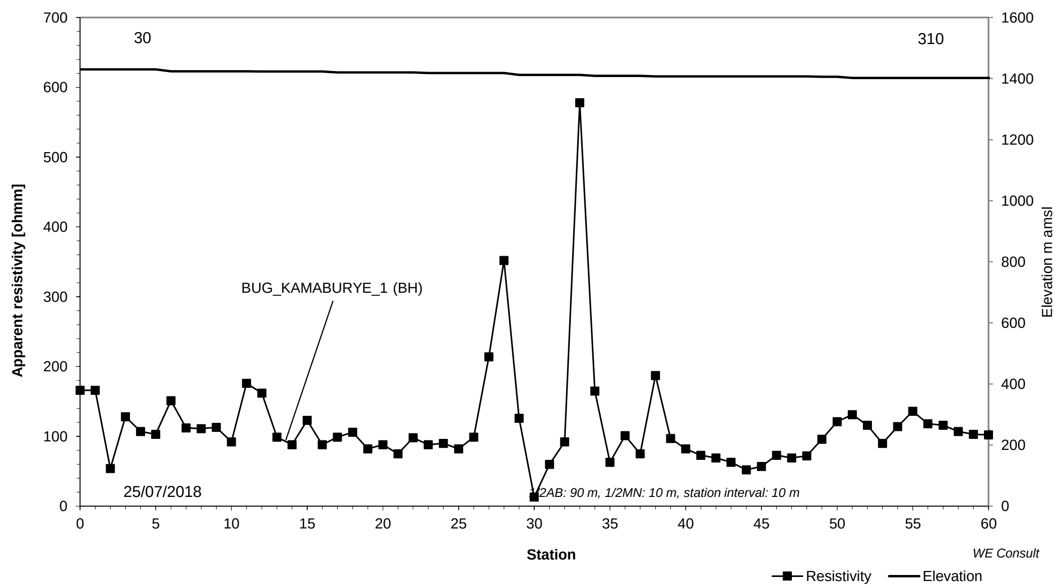
Location:	BUG_KAMABUYE				7
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Expected Formation:		Granites (Schists)		Accessibility Village:	Good
Int yield (l/h) :	2,500	SWL (m asl):	1,427	Target:	None
Remarks:	Calibration on a borehole on a granite slope in Bugesera. The borehole is not in clear anomaly on the profile. The VES shows that bedrock is apparently reached at 30 1/2 AB, after which the curve goes down again. This is not typical for granites and likely more typical for softer formations like schists or sandstones. The high resistivity at the start however, could signify an alternation between quatzites and schists, rather then granites. Drilling information from boreholes in the area would certainly help determine the geological situation towards the south of Bugesera				

Location map geophysical measurements



Site	7		Village	Nyakayaga			
Cell	Nyakayaga		Sector	Kamabuye			
			District	Bugesera			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks	Calibration only						
Geophysical measurements							

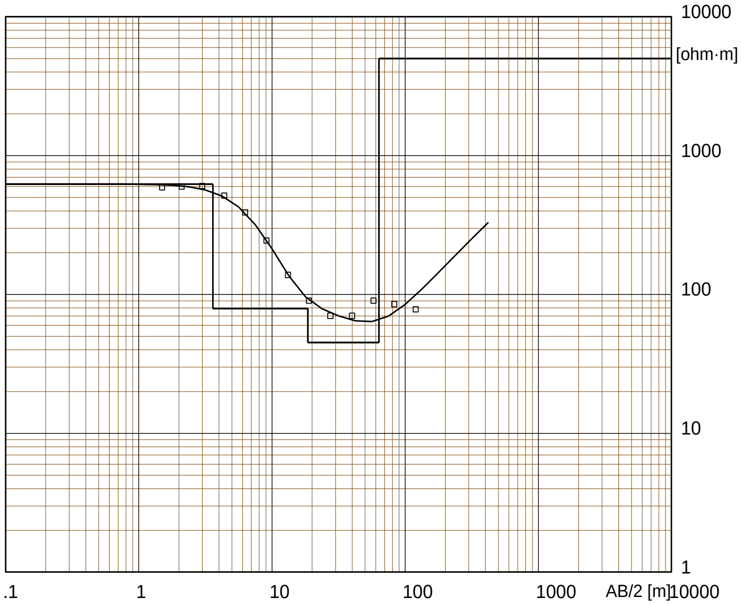
BUG_KAMABUYE_A PROFILE



Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_SCHLUM
BUG_KAMABUYE_1
EXISTING BH 3 m3/h | SWL 40 mbgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - 303.WS3



Location X = 179746 Y = 9739494 Z = 1414 Azim = 120-300

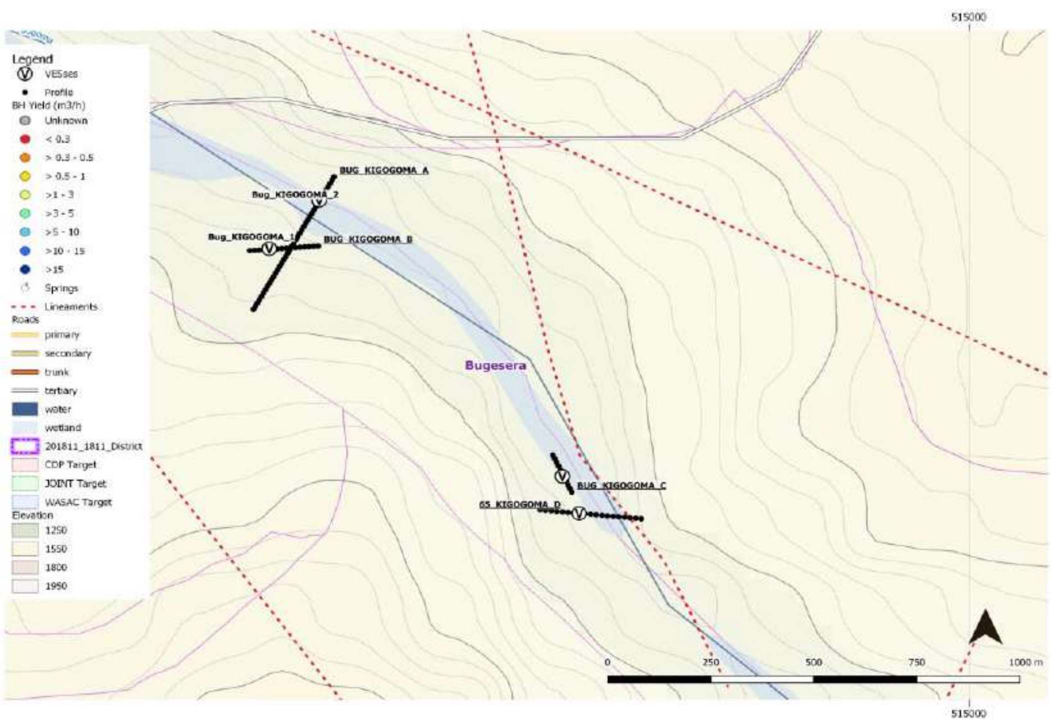
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
623	3.6		1414
79	15	3.6	1410.4
45	45	19	1395
5000		64	1350

The VES was carried out on a non functional BH. The interpreted layers are: top soil,sandy clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

Location:	BUG_KIGOMA						8
Recommended Site:		VES_4		coordinate (E)	514013	coordinate (N)	4763034
Expected DTB (m):				Altitude (amsl)		1377	
Recommended Depth (m):				Accessibility Site:		Accessible	
Alternative Site:				coordinate (E)		coordinate (N)	
Expected DTB (m):				Altitude (amsl)			
Recommended Depth (m):				Accessibility Site:			
Expected Formation:		Schists & Quartzite (Granite observed)		Accessibility Village:		Good	
Int yield (l/h) :	10,000	SWL (m asl):	1,376	Target:		PRODUCTION	
Remarks:	According to the geological map, the area is characterized by sandstones, schists and quatzites. However, when reaching on-site, granite outcrops could easily be identified. Likely part of the formation that can be seen to the east of the site. There is an existing borehole there which was not in the database at the time of the visit. However, this being a very characteristic broken valley with fractured and weathered granite outcrops on the surface, this borehole was selected for testpumping since the conditions signify production value. The borehole shows a very nice anomaly on Profile C where it is located. This round anomaly, but wider, is also found on profile D. Both VESes are extremely similar and if tranformation of the testpumped 10m3/h borehole to a production site should fail, VES_4 provides a good alternative for drilling. This location, with its characteristics could also be a prime target for a production well field to supply more of the surrounding areas. It is surrounded by areas currently targeted by WASAC and the CDP alike. If drilling should commence (especially for production) it is good to do a short confirmation survey since pegging in a busy community like this one is not possible. All VESes done show potential for a production borehole.						

Location map geophysical measurements

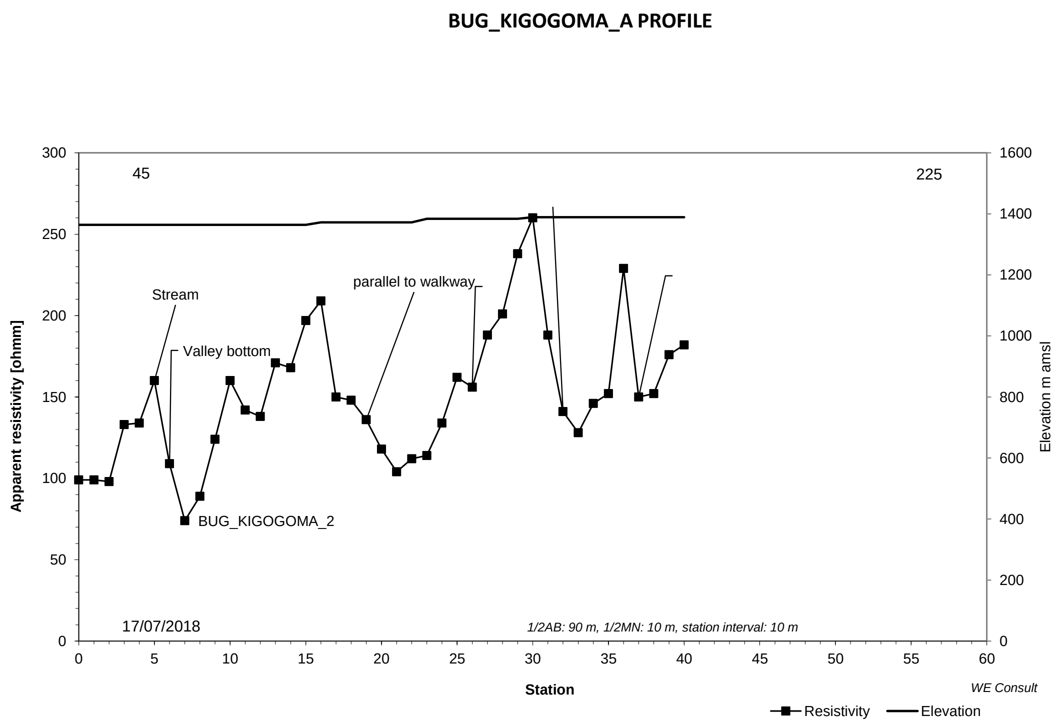


Site	8		Village	Kiyogoma		
Cell	Murama		Sector	Nyamata		
			District	Bugesera		

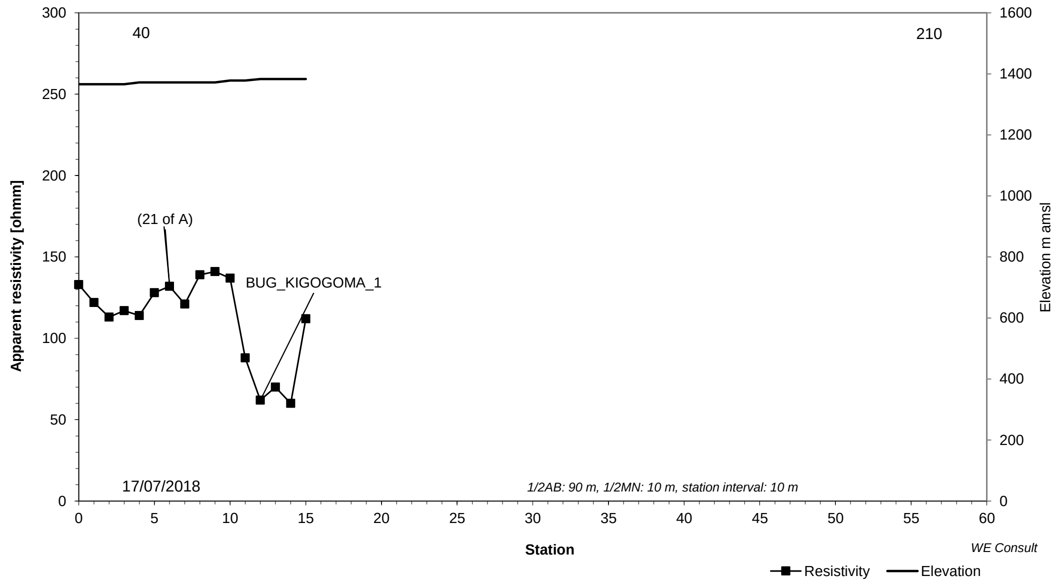
Rating per site (max. 100 points):

	1	2	3	4	5	6	7
Local topography (0-20 points)	20	20	20	20			
Lineament (0-20 points)	20	20	20	20			
Anomaly (0-30 points)	25	7	7	7			
VES (0 -15 points)	5	5	10	10			
Earlier results (0 - 15)	5	5	10	10			
Total	79	79	91	91			

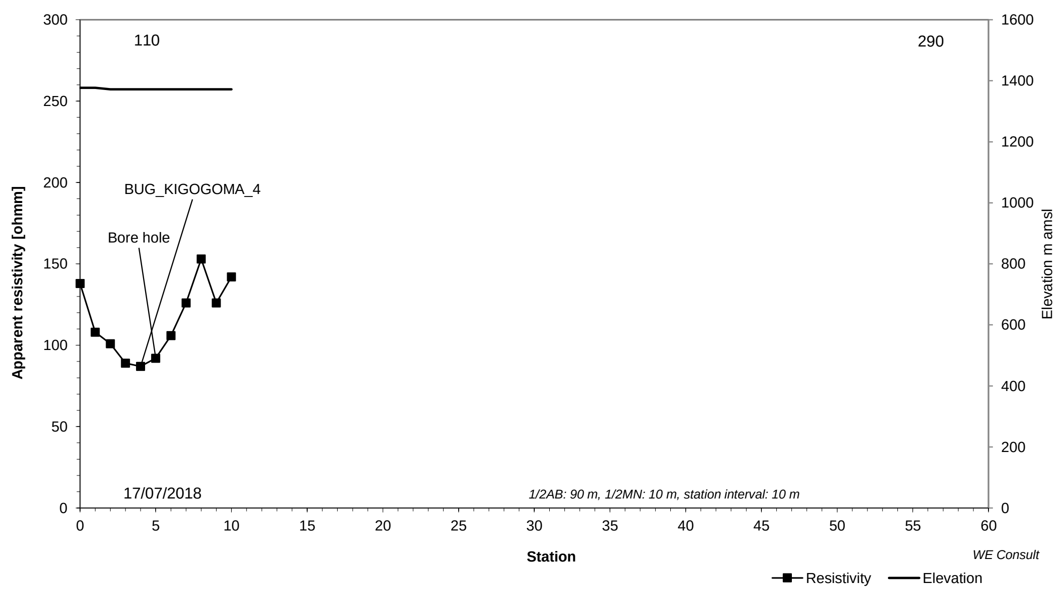
Remarks	All VESses show potential for production. VES_3 was done as a calibration, VES_4 is almost identical and upstream (ground water catchment). VES_1 and 2 are downstream, but closer again to spring potential.
Geophysical measurements	



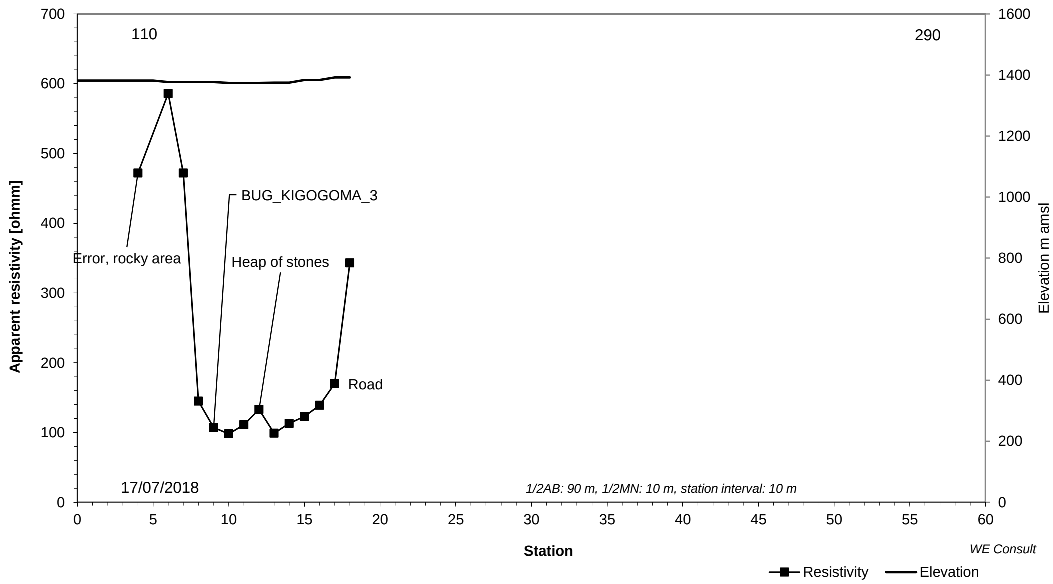
BUG_KIGOGOMA_B PROFILE



BUG_KIGOGOMA_C PROFILE



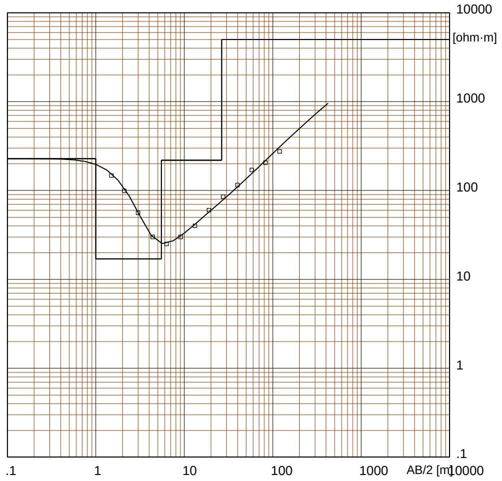
BUG_KIGOGOMA_D PROFILE



Best VES: **VES_4**

WE Consult

ELECTICAL SOUNDING_SCHLUM
BUG_KIGOGOMA_1

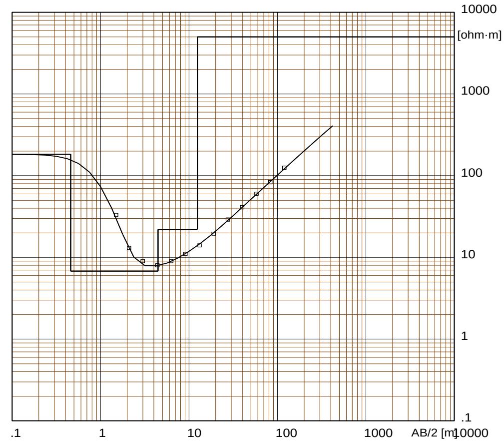


Location X = 1796569 Y = 9763404 Z = 1377 Azim = 150/330

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
228	1		1377
17	4.5	1	1376
219	21	5.5	1371.5
5000		26	1351

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_KIGOGOMA_2

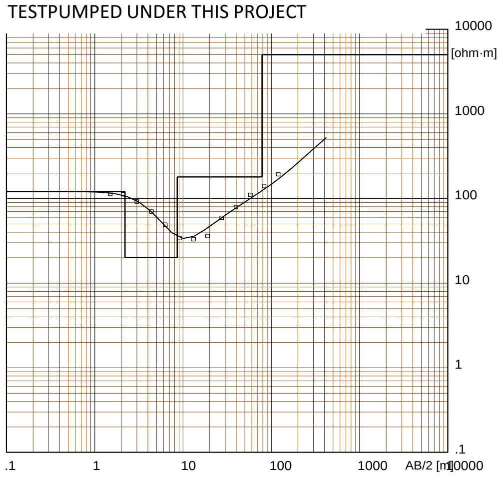


Location X = 179690 Y = 9763531 Z = 1360 Azim = 120/300

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
183	.46		1360
6.8	4	.46	1359.5
22	8	4.5	1355.5
5000		12	1348

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_KIGOGOMA_3
EXISTING BH 10 m3/h
FUNCTIONAL
TESTPUMPED UNDER THIS PROJECT



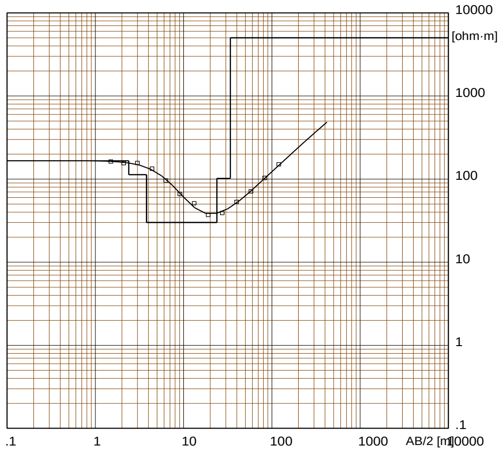
Location X = 180322 Y = 9762709 Z = 1377 Azim = 310/130

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
121	2.2		1377
20	6.4	2.2	1374.8
180	70	8.6	1368.4
5000		79	1298

The VES was done on station 10 of profile A. The interpreted layers are: top soil, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_KIGOGOMA_4



Location X = 180281 Y = 9762806 Z = 1368 Azim = 310/130

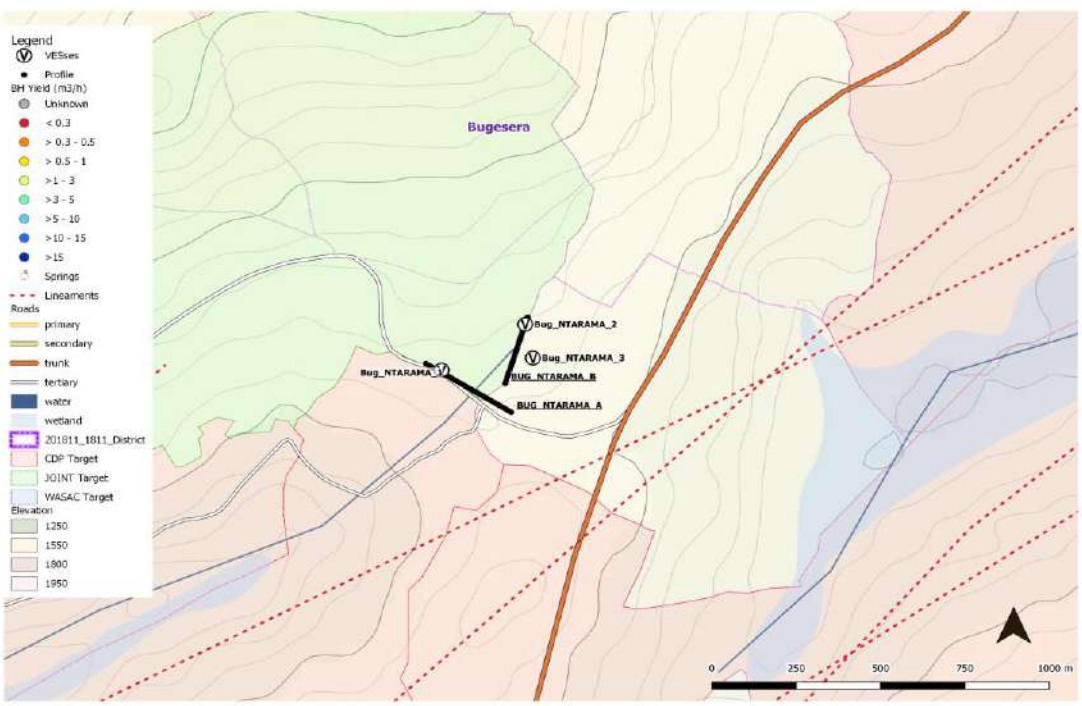
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
166	2.4		1368
113	1.4	2.4	1365.6
30	20	3.8	1364.2
102	10	24	1344
5000		34	1334

The calibration VES was done in Bugesera District. The interpreted layers are: top soil, sandy clay, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

Location:	BUG_NTARAMA					9
Recommended Site:		VES_2		coordinate (E) 507490	coordinate (N)	4766734
Expected DTB (m):				Altitude (amsl)	1381	
Recommended Depth (m):				Accessibility Site:	Accessible	
Alternative Site:				coordinate (E)	coordinate (N)	
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:		
Expected Formation:		Schists and sandstones		Accessibility Village:	Good	
Int yield (l/h) :	2,998	SWL (m asl):	1,414	Target:	JOINT	
Remarks:	This location was selected for confirmation by drilling in difficult formations, and calibration of an existing borehole. VES_1 and VES_2 done in close proximity of the existing borehole show the same sounding results which are to be expected in a schist like formation with varying densities. It however, gives very little information in terms of ground water potential. The profile is taken to be more conclusive, with VES_2 having a good pronounced anomaly and showing greater contrast at the investigated depth. Before attempting to drill, while confirmation of assumptions by drilling is appreciated, attempt should be made to rehabilitate the existing borehole. The static water level seems to be within reasonable reach.					

Location map geophysical measurements



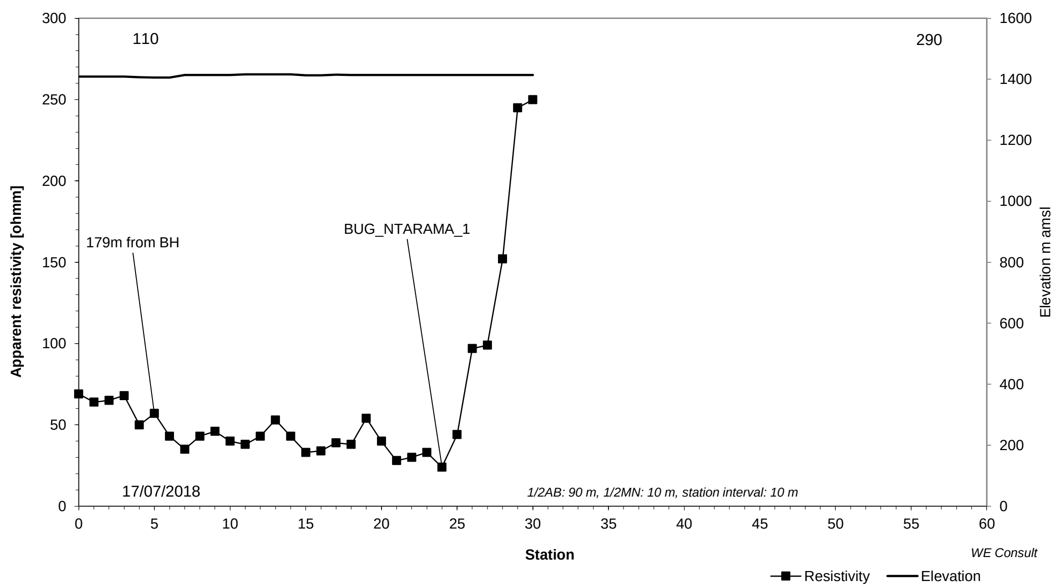
Site	9		Village	Rwangara		
Cell	Kanzenze		Sector	Ntarama		
			District	Bugesera		

Rating per site (max. 100 points):

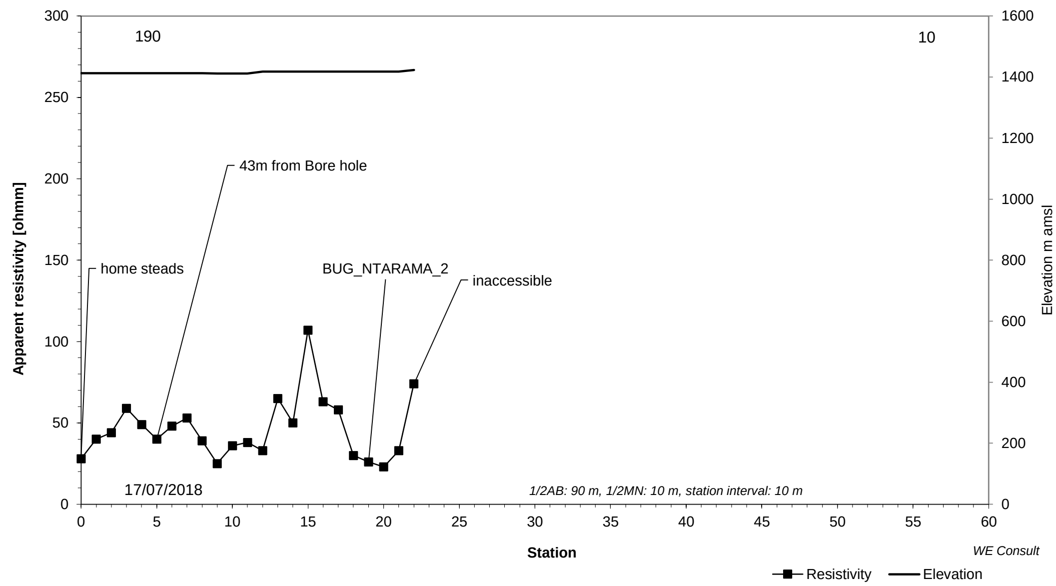
	1	2	3	4	5	6	7
Local topography (0-20 points)	6	6	6				
Lineament (0-20 points)	3	3	3				
Anomaly (0-30 points)	17	5					
VES (0 -15 points)							
Earlier results (0 - 15)	5	5	5				
Total	31	42	22				
Remarks							

Geophysical measurements

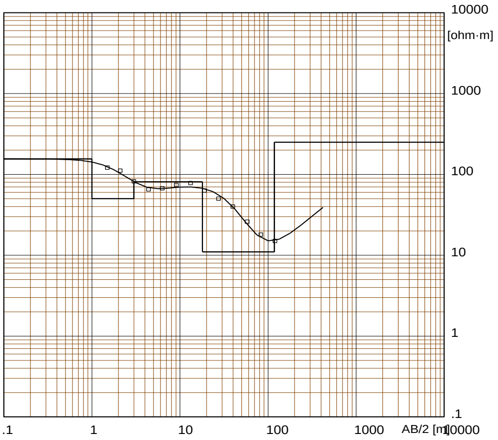
BUG_NTARAMA_A PROFILE



BUG_NTARAMA_B PROFILE



ELECTICAL SOUNDING_SCHLUM
BUG_NTARAMA_1



Location X = 173497 Y = 9766350 Z = 1414 Azim = 110/290

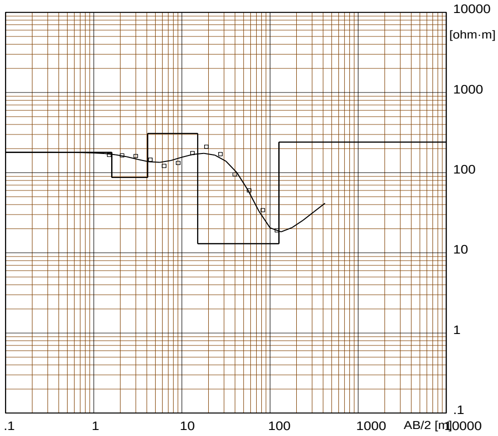
Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
155	1		1414
50	2	1	1413
81	15	3	1411
11	100	18	1396
250		118	1296

The VES was carried out on station 24 of profile A. The interpreted layers are: top soil, clay and sandy clays.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_NTARAMA_2



Location X = 173497 Y = 9766350 Z = 1414 Azim = 110/290

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
179	1.6		1414
87	2.5	1.6	1412.4
308	11	4.1	1409.9
13	111	15	1399
240		126	1288

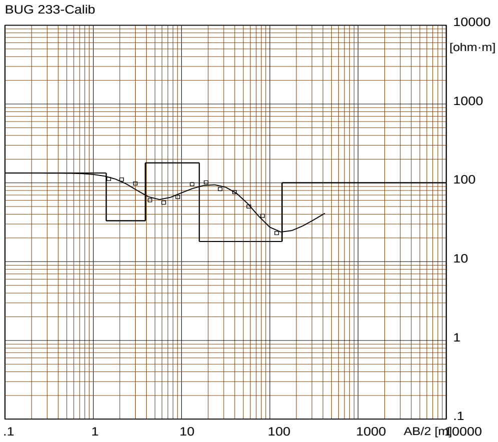
The VES was carried out on staion 20 of profile B. The interpreted layers are: Top soil, clay, and sandy clay.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
BUG_NTARAMA_3
EXISTING BH 3 m3/h | SWL 28 m bgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - BUG 233-Calib.WS3

BUG 233-Calib



Location X = 173768 Y = 9766389 Z = 1412 Azim = 120/300

Model

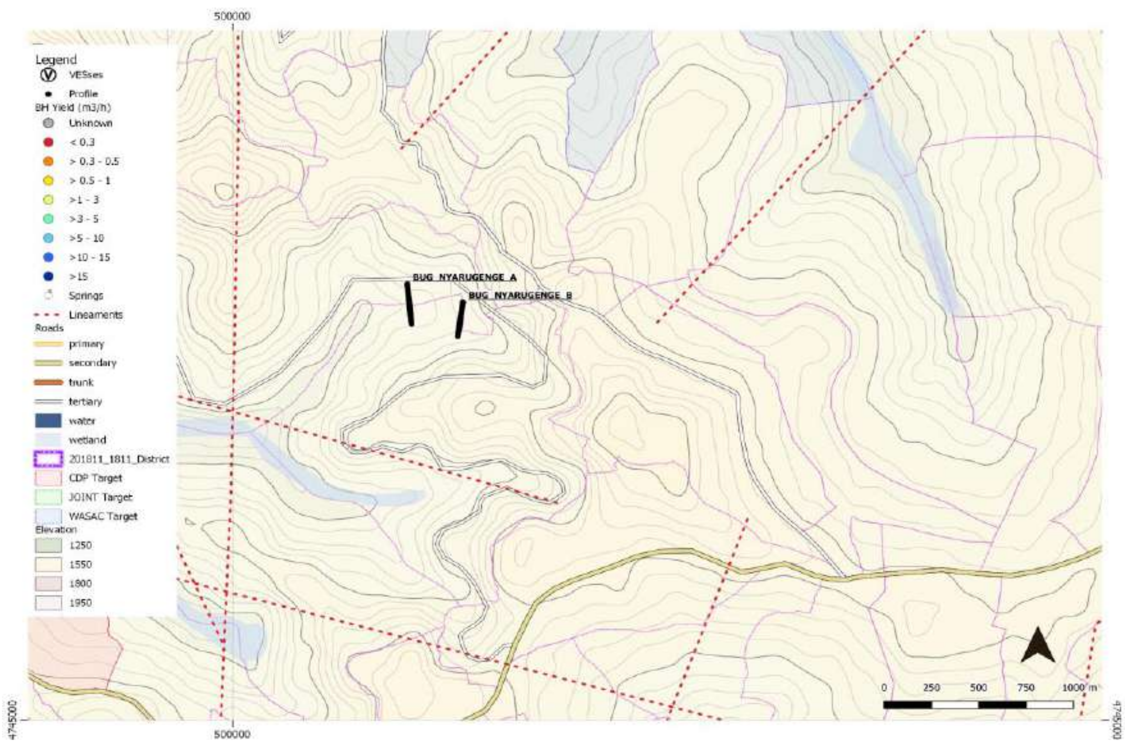
Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
133	1.4		1412
33	2.5	1.4	1410.6
179	12	3.9	1408.1
18	122	16	1396
100		138	1274

This was a calibration VES. The interpreted layers are: top soil, clay and sandy clay.

W-GeoSoft / WinSev 6.3

Location:	**BUG_NYARUGENGE**						10
Recommended Site:				coordinate (E)		coordinate (N)	
Expected DTB (m):				Altitude (amsl)			
Recommended Depth (m):				Accessibility Site:			
Alternative Site:				coordinate (E)		coordinate (N)	
Expected DTB (m):				Altitude (amsl)			
Recommended Depth (m):				Accessibility Site:			
Expected Formation:		Schists underlain by sandstone/granites		Accessibility Village:		None	
Int yield (l/h) :	#DIV/0!	SWL (m asl):	1,423	Target:		NONE	
Remarks:	Profiles done for charactisation of formation in a suposedly homogeneous schists for which the profiles show high variance. There is a high likelyhood that the the Mh (schists) formation is only shallow and underlain by sandstones (coming in from the west) or granites (coming in from the east). The site is sadly unaccesible and no VESes perpendicular to the profiles could be done.						

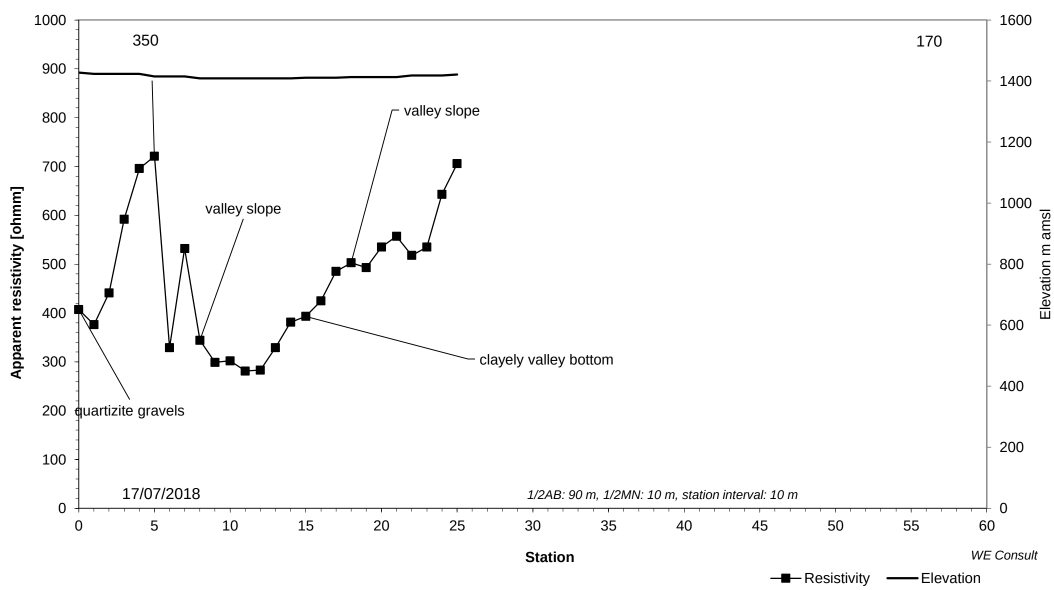
Location map geophysical measurements



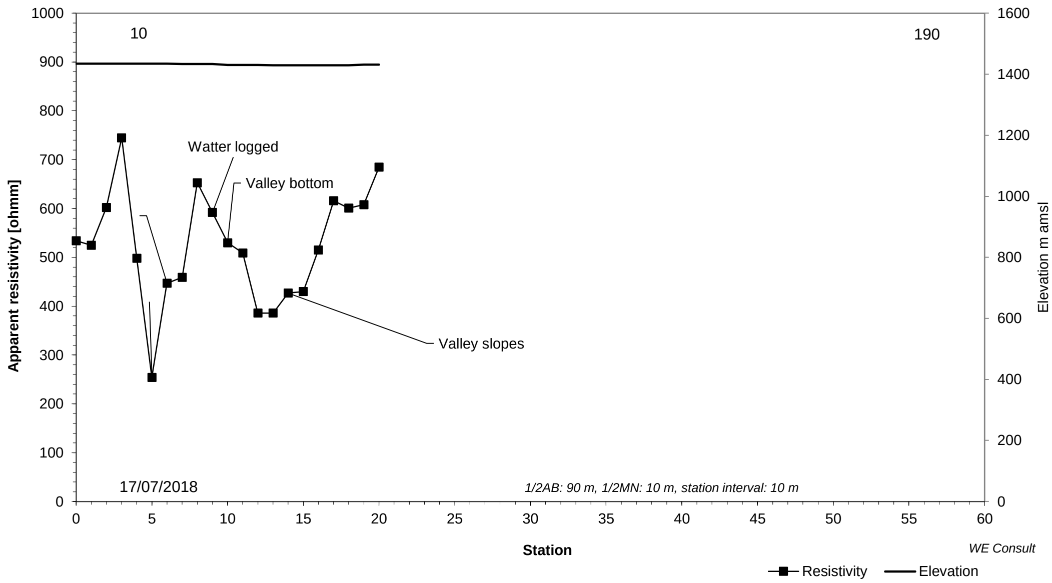
Site	10		Village	Kamweru		
Cell	Rutare		Sector	Shyara		
			District	Bugesera		
Rating per site (max. 100 points):							

	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks	No VESses done						
Geophysical measurements							

BUG_NYARUGENGE_A PROFILE

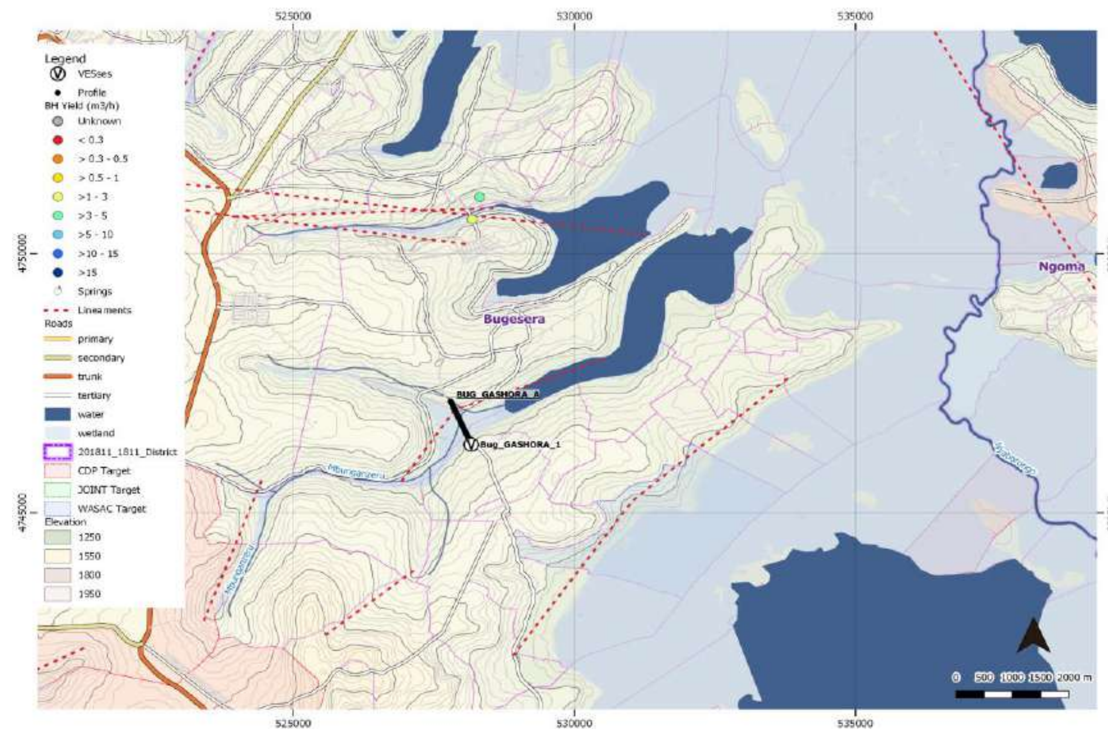


BUG_NYARUGENGE_B PROFILE



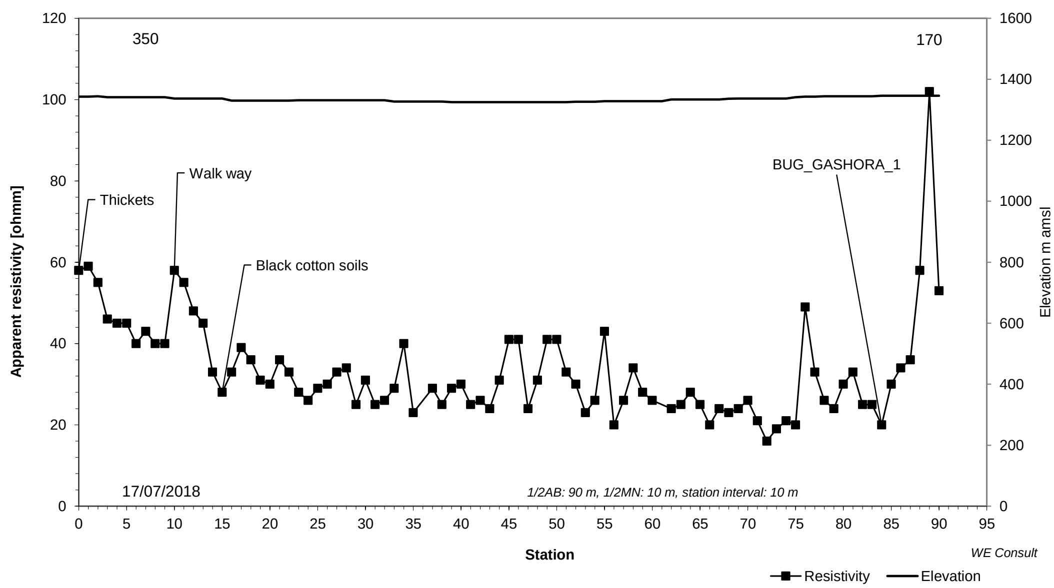
Location:	BUG_GASHORA				11
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Expected Formation:		Schists		Accessibility Village:	Good
Int yield (l/h) :	3,266	SWL (m asl):	1,334	Target:	NONE
Remarks:	The purpose of this profile was to cross one of the valleys coming from the lake complex and wetlands to the east which are situated in a highly faulted zone (though inaccesible). To the north, a similar valley show boreholes with good yields. The profile shows typical results for a valley, low resistivities likely caused by clays (confirmed by visual confirmation of cotton soils). The VES was done on the slope of the valley to bypass some of the masking effects of the clays, while also targeting a (minor) anomaly. The VES still shows the masking effect however, signifying how strong the effect can be, even on the outskirts of the valley. No conclusions can be made as to the ground water potential, though proximity to the wetlands and lakes and location in a valley would suggest availability. A kink in the VES curve usually signifies something significant happening. However, in this case the curve rises beyond 45 degrees (which is physically impossible) and is thus considered an error.				

Location map geophysical measurements



Site	11	Village	Gaharwa			
Cell	Mwendo	Sector	Gashora			
		District	Bugesera			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	5						
Lineament (0-20 points)							
Anomaly (0-30 points)	5						
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	17						
Remarks							
Geophysical measurements							

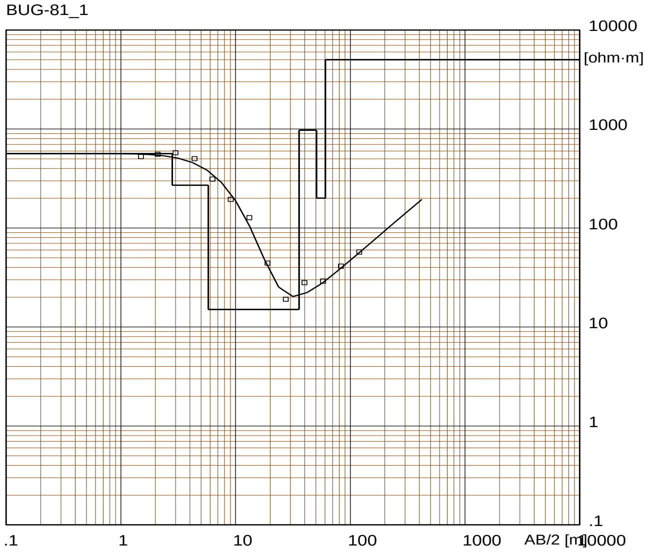
BUG_GASHORA_A PROFILE



Best VES: **VES_1**

ELECTICAL SOUNDING_SCHLUM
BUG_GASHORA_1

Electrical sounding Schlumberger - BUG_81_1.WS3



Location X = 194477 Y = 9746095 Z = 1341 Azim = 350/160

Model

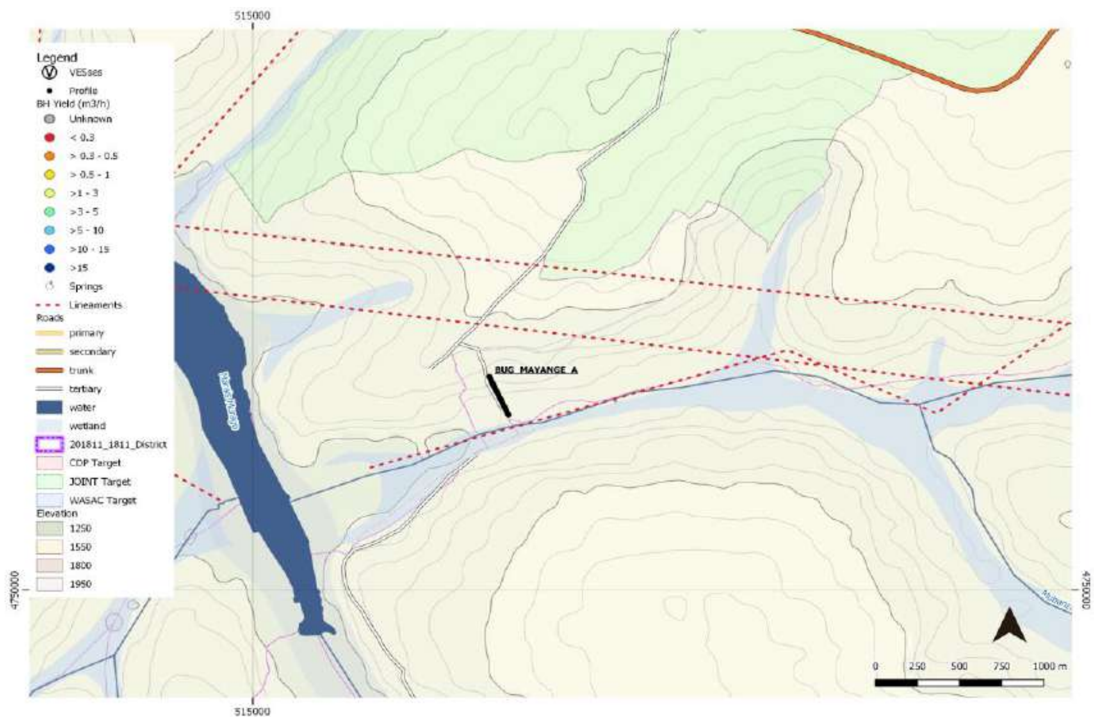
Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
564	2.8		1341
270	3	2.8	1338.2
15	30	5.8	1335.2
973	15	36	1305
200	10	51	1290
5000		61	1280

The VES was carried out on station 88 of profile A. The interpreted layers are: top soil, sandy clays, clay, laterites, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

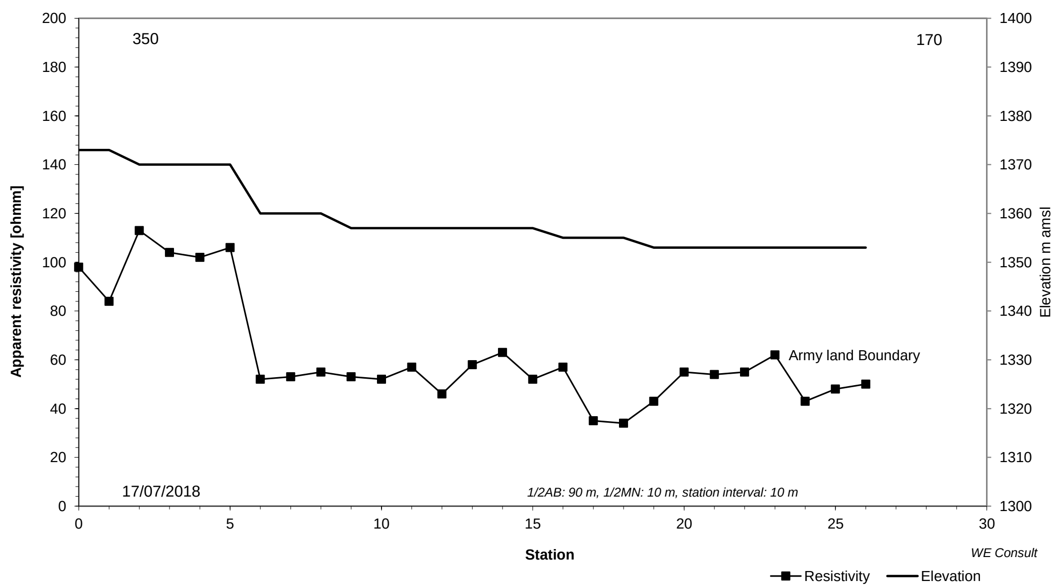
Location:	**BUG_MAYANGE**				12
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	1025
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	1018
Recommended Depth (m):				Accessibility Site:	Accessible
Expected Formation:		Schists		Accessibility Village:	Good
Int yield (l/h) :	2,142	SWL (m asl):	1,359	Target:	NONE
Remarks:	Not considered, halfway through the survey were confronted military personel and were not allowed to continue. The valley is estimated to have potential for shallow hand pump operated boreholes. SWL is still around only 20m deep on the highest point of the profile on the slope. Included still in the sites to indicate accesiblity issues if water sources are needed in that area.				

Location map geophysical measurements



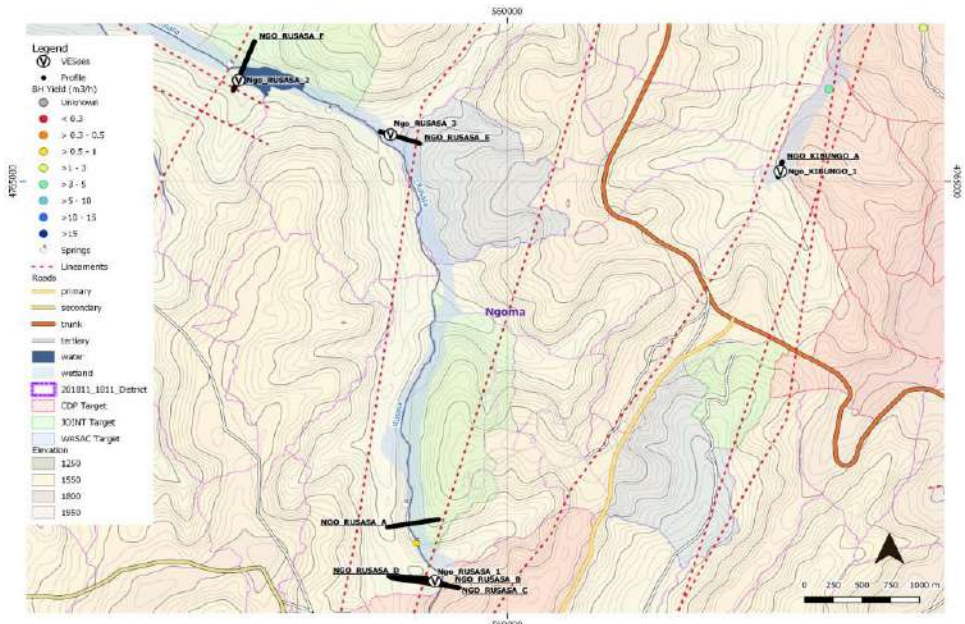
Site	12		Village	Rwimikoni I			
Cell	Mbyo		Sector	Mayange			
			District	Bugesera			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

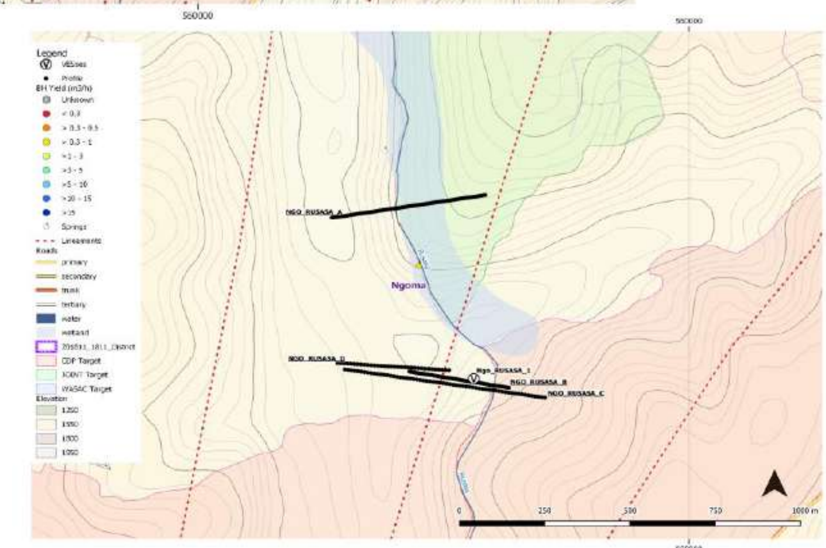
BUG_MAYANGE_A PROFILE



Location:	NGO_RUSASA					13
Recommended Site:		EX_2		coordinate (E) 559108	coordinate (N)	4761764
Expected DTB (m):		45		Altitude (amsl)	1487	
Recommended Depth (m):		80		Accessibility Site:	Accessible	
Alternative Site:		VES_2		coordinate (E) 557662	coordinate (N)	4765959
Expected DTB (m):		58		Altitude (amsl)	1369	
Recommended Depth (m):		80		Accessibility Site:	Accessible	
Expected Formation:		Quartzites, Schists		Accessibility Village:	Good	
Int yield (l/h) :	3,592	SWL (m asl):	1,458	Target:	CDP & WASAC	
Remarks:	The Rusasa is cutting through multiple quartzite bands and those locations form the main targets for this site. Profile A is done close to the treatment and distribution plant of WASAC in order to find more water to supply the surrounding communities. The profile is done in the valley as it is cutting through the quartzite band. The profile shows a clear distinction between the soft schist formation and the quartzite formation, however the values are oposite of what it is expected to be, signifying a shift in the geological formations on the used geological map is in order. Profile B is a 2D profile done parallel to Profile C (1D). The profiles match up but the VESes seem slightly different. Both are typical however for the schist like formations they are situated in, with slightly high resistivities to boot. Profile D is parallel to Profile C. This confirms that down from profile A you are in the soft formations. The best potential is before the bend, close to profile A. Here there are also multiple springs which seem to line up on the imaginary line that can be drawn of the interface between the soft and hard formations. Profile E is supposedly perpendicular on a quartzite band, however the resistivities are too low for quartzite, and similar to profile F, which is in the soft formations. Having missed the opportunity to confirm a different formation of quartzite, the results are still positive. The anomaly for VES_2 is very out of order with the rest of the shapes on the profiles meaning something significant is happening. Then, if we look at the VES_2, the masking effect is there a bit, but less than with VES_3 which becomes indistinguisable. VES_2 starts with a higher resistivity meaning that the effects of the clays are less. What we can make out is that the rise to 45 degrees is not stable and varies. If you look at the profile it is close to a high resitivity block which could be quartzites. With the shape of the anomaly, location on the profile and the satisfactory results of the profile (as much as can be expected with a masking effect) VES_2 seems a good location to drill for hand pumps or small scale systems if the yield is sufficient.					

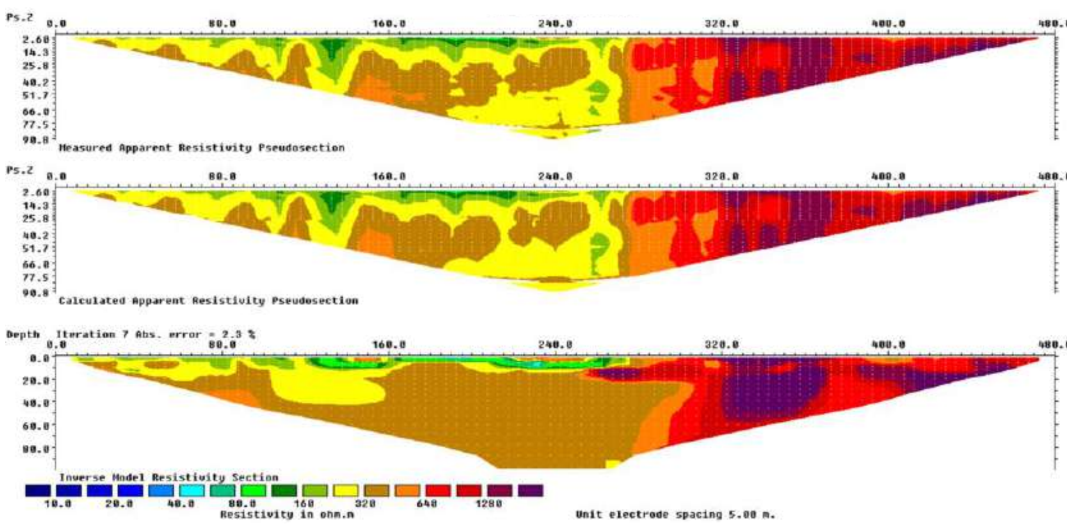
Location map geophysical measurements



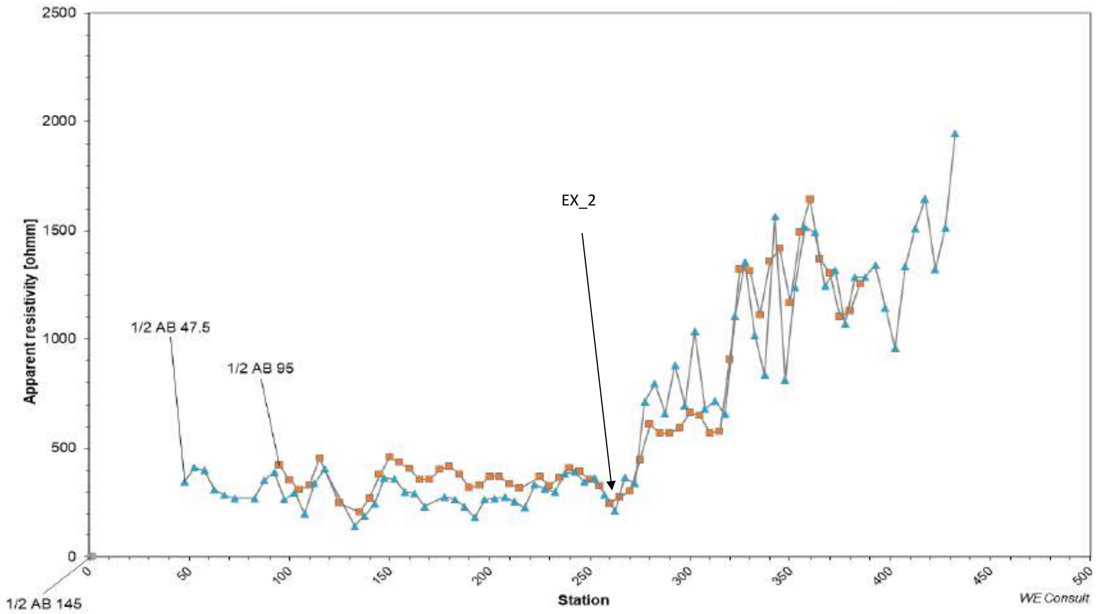


Site	NGO_RUSASA		Village	Rwasaburo			
Cell	Musya		Sector	Rurenge			
			District	Ngoma			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	9	13	13				
Lineament (0-20 points)	5	10	10				
Anomaly (0-30 points)	4	7	2				
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	18	42	33				
Remarks							
Geophysical measurements							

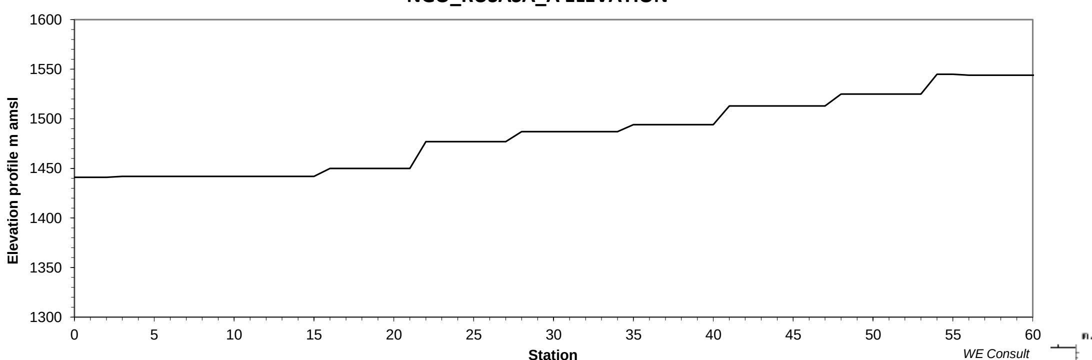
NGO_RUSASA_A SCHLUMBERGER PSEUDO

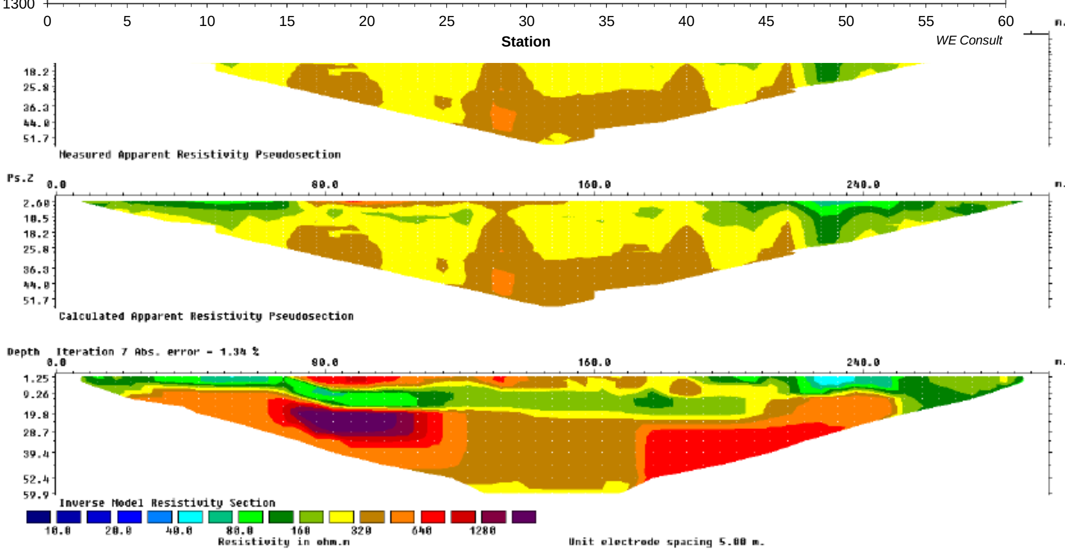


NGO_RUSASA_A SCHLUMBERGER 1D EXTRACTION

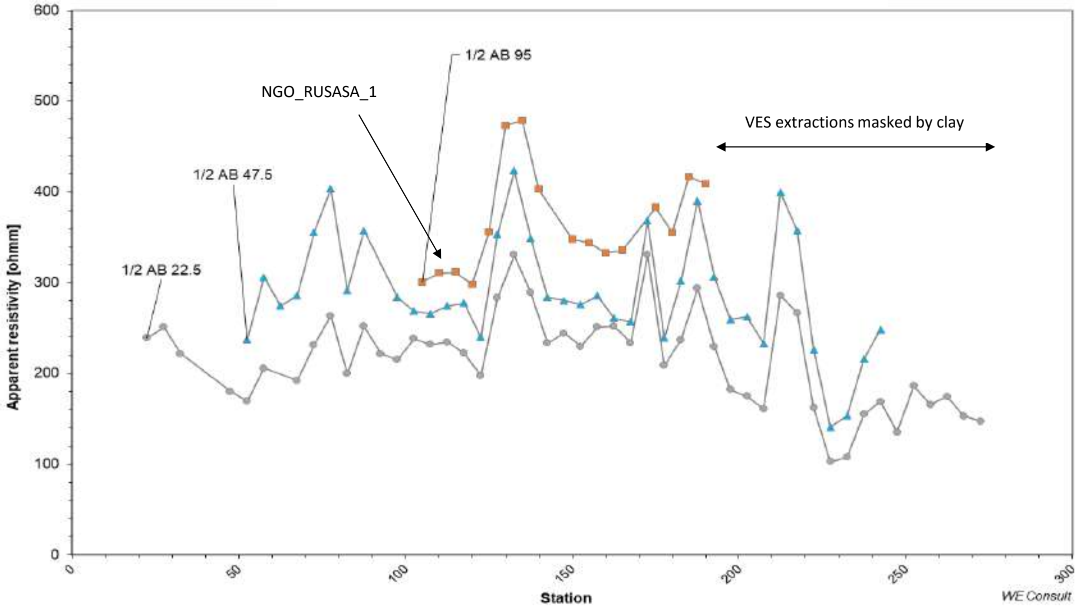


NGO_RUSASA_A ELEVATION

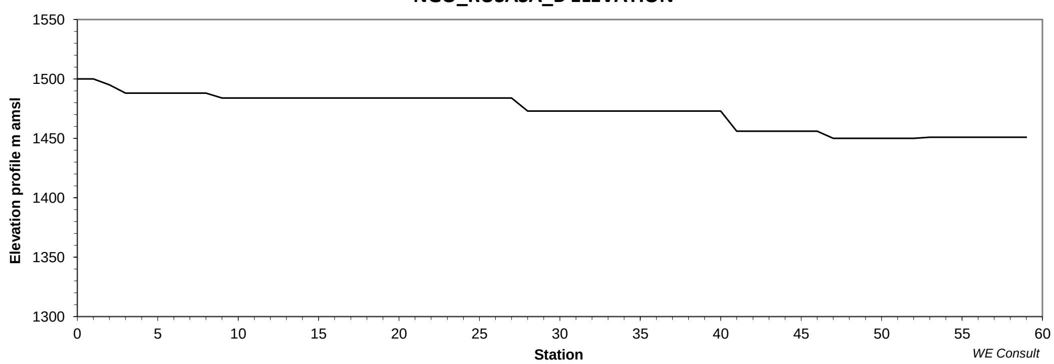




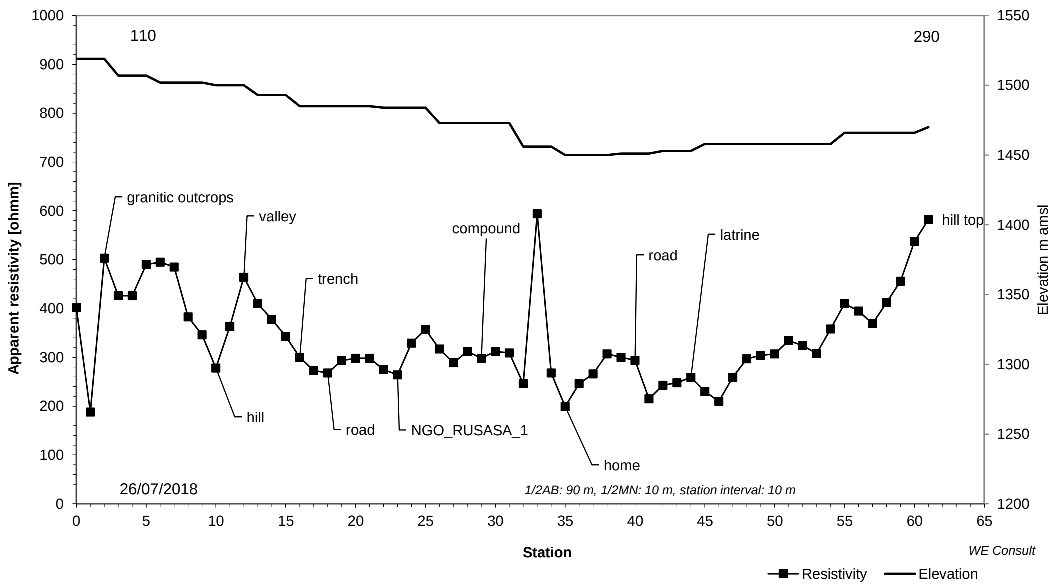
NGO_RUSASA_B SCHLUMBERGER 1D EXTRACTION

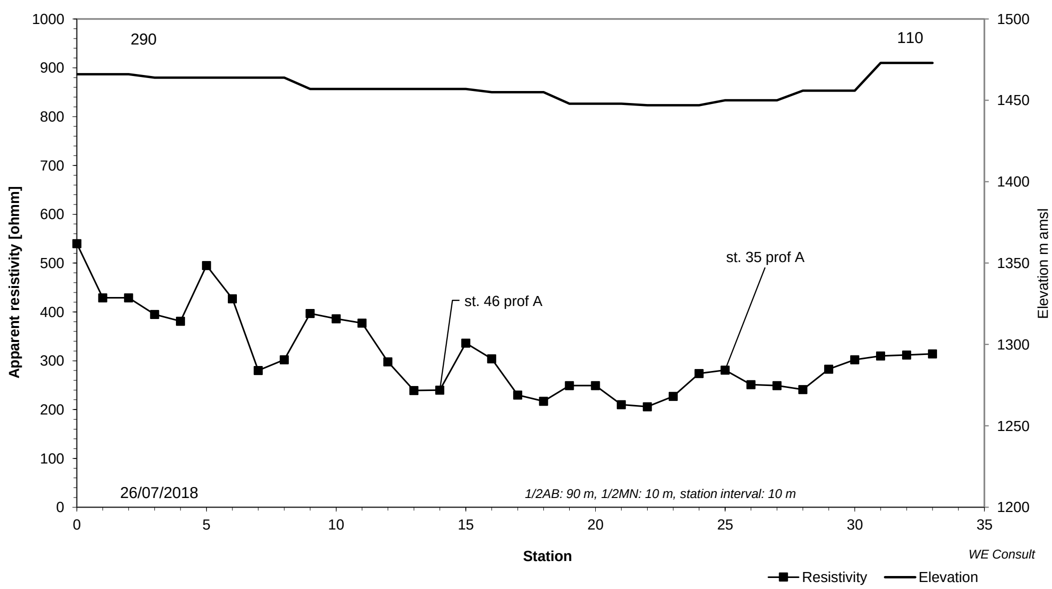


NGO_RUSASA_B ELEVATION

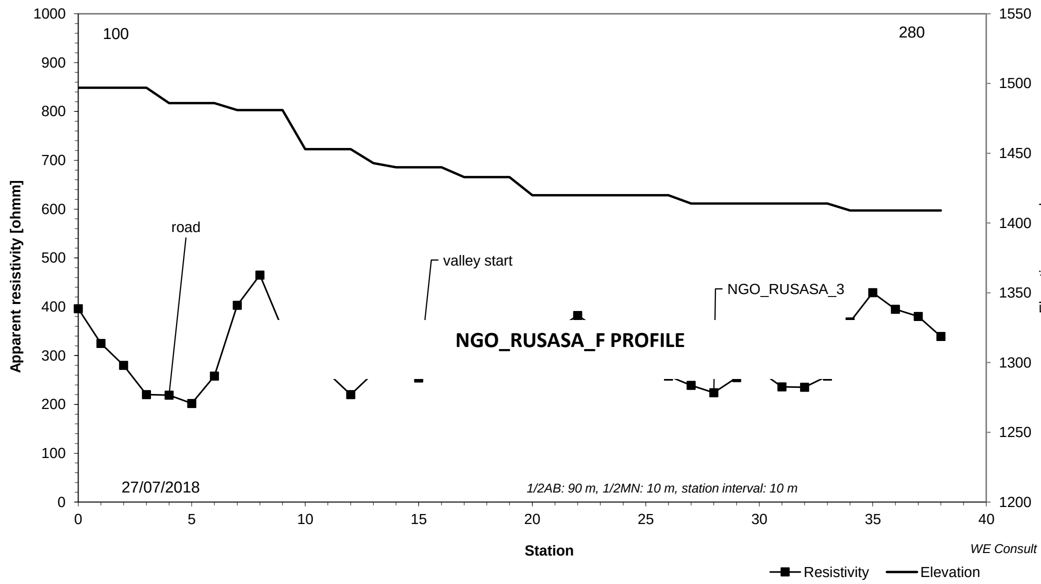


NGO_RUSASA_C PROFILE

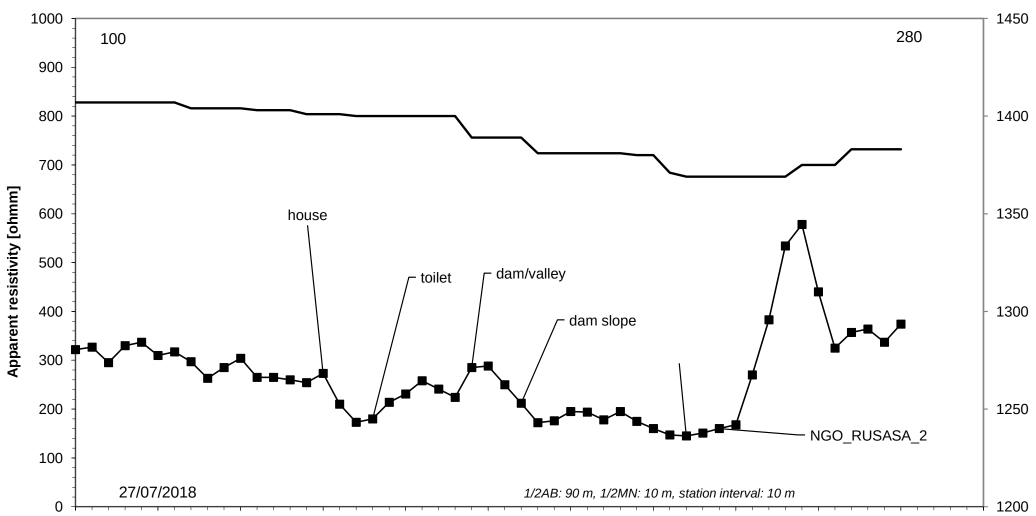




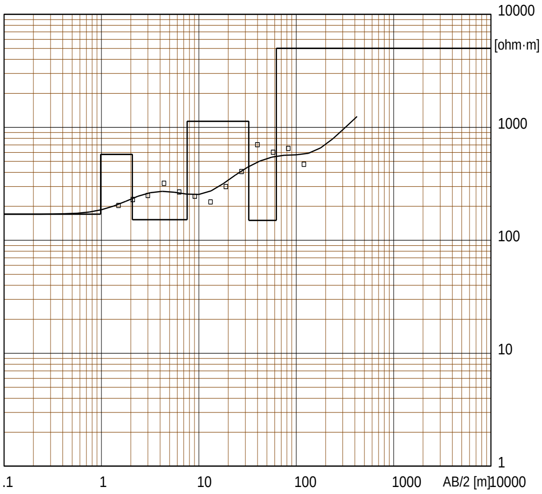
NGO_RUSASA_E PROFILE



NGO_RUSASA_F PROFILE



ELECTICAL SOUNDING_SCHLUM
NGO_RUSASA_1



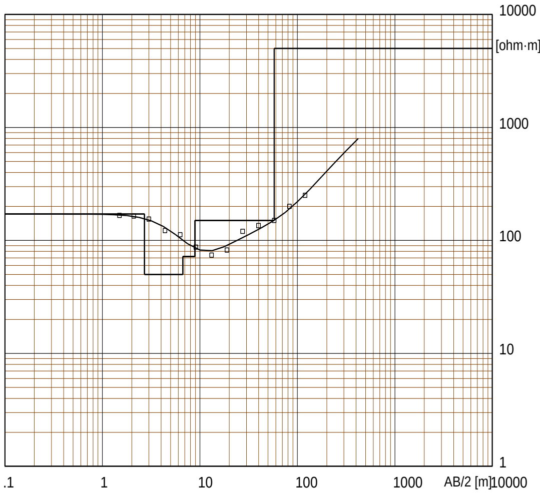
Location X = 225676 Y = 9761087 Z = 1471 Azim = 110-290

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
170	.98		1471
575	1.1	.98	1470
152	5.5	2.1	1468.9
1131	25	7.6	1463.4
150	30	33	1438
5000		63	1408

The VES was carried out on profile A station 23. The interpreted layers are: top soil,quatzites,sandy clay, laterites, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NGO_RUSASA_2



Location X = 223959 Y = 9765818 Z = 1388 Azim = 110-290

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
171	2.7		1388
50	4	2.7	1385.3
72	2.2	6.7	1381.3
150	49	8.9	1379.1
5000		58	1330

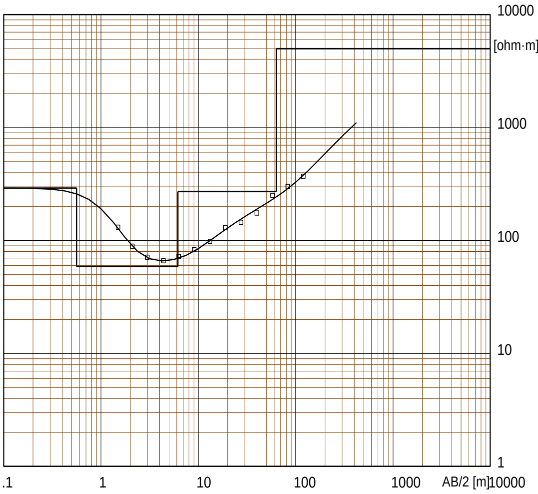
The VES was carried out on profile A station 37. The interpreted layers are: top soil,clay, sandy clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NGO_RUSASA_3

Electrical sounding Schlumberger - VES-1.WS3

VES-1

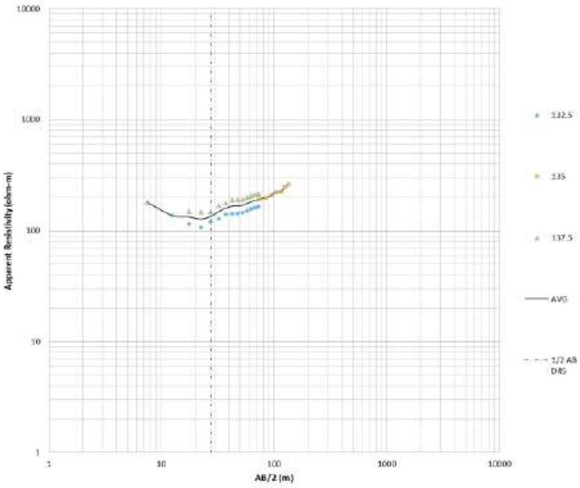


Location X = 225280 Y = 9765305 Z = 1389 Azim = 100-280

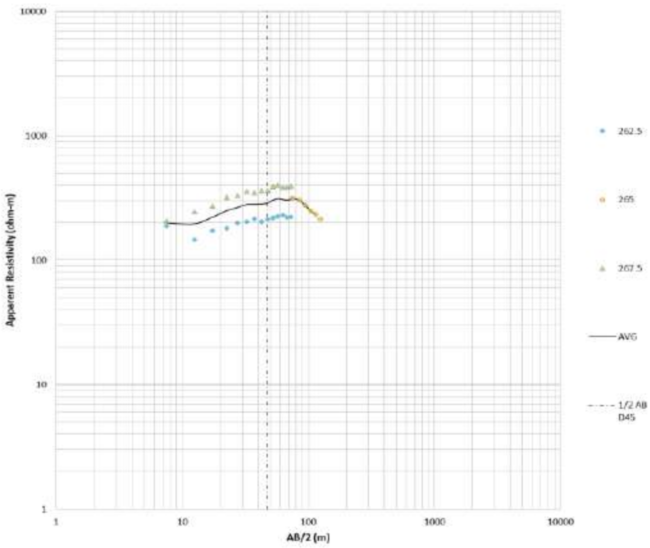
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
291	.56		1389
59	5.6	.56	1388.4
271	57	6.2	1382.8
5000		63	1326

The VES was carried out on profile A station 28. The interpreted layers are: top soil,sandy clay,weathered layer and hard rock.

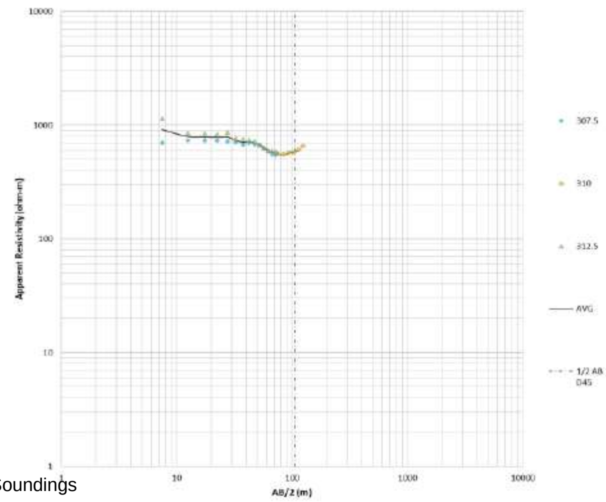
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NGO_RUSASA_A EX_1 (135 m)
IN SOFT FORMATION



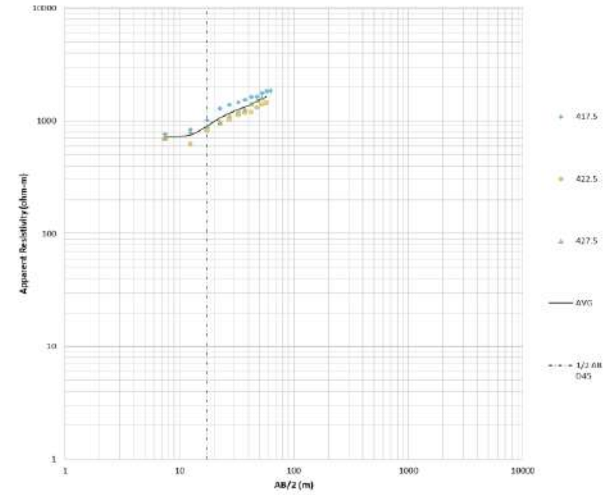
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NGO_RUSASA_A EX_2 (265 m)
ON SOFT TO HARD INTERFASE
SIMILAR RESULTS RWA_GAHENGERI_1



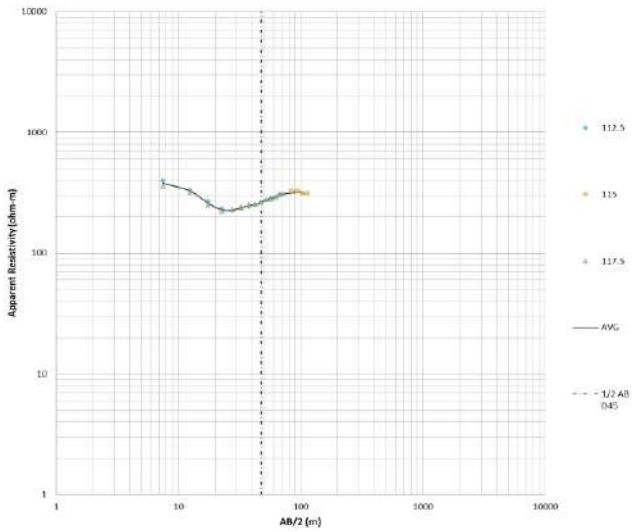
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NGO_RUSASA_A EX_3 (310 m)
BEGINNING OF SLOPE



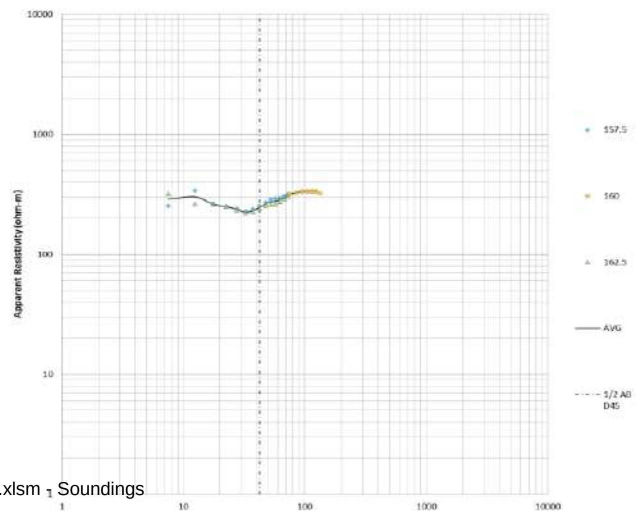
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NGO_RUSASA_A EX_3 (310 m)
HIGH UP SLOPE



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NGO_RUSASA_B EX_4 (310 m)
NGO_RUSSASA_1 (DIFFERENT)

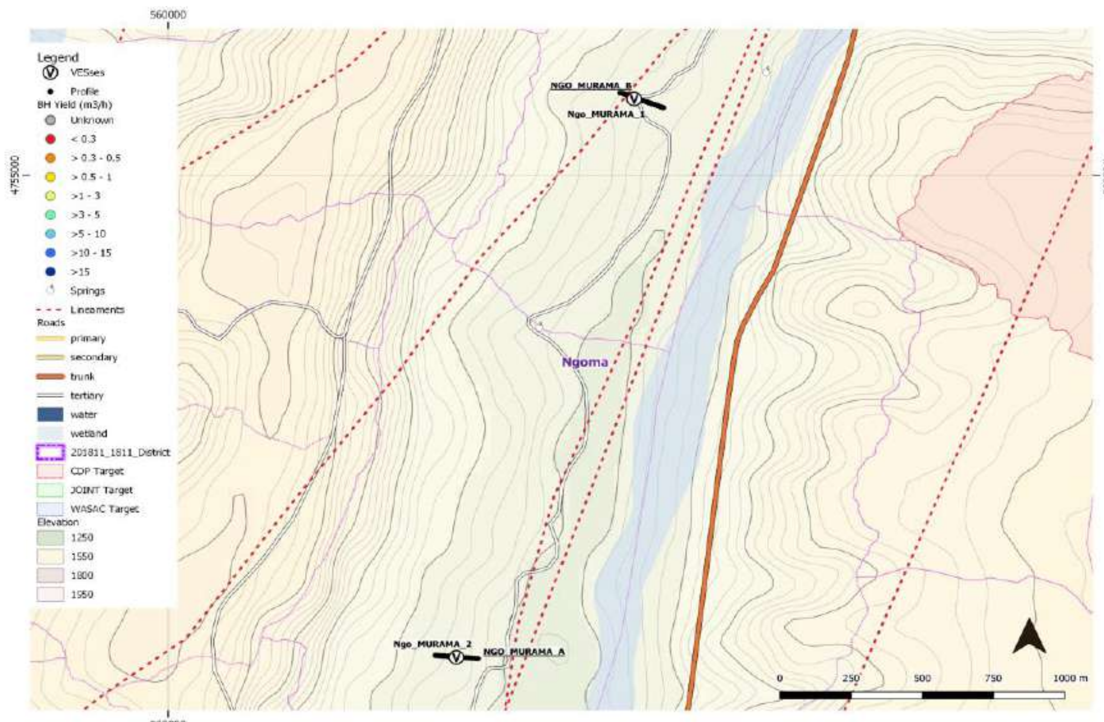


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NGO_RUSASA_A EX_3 (310 m)
ON ANOMALY



Location:	NGO_MURAMA				14
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Expected Formation:		Schists and sediments		Accessibility Village:	Good
Int yield (l/h) :	4,369	SWL (m asl):	1,374	Target:	None
Remarks:	Both boreholes perfectly line up with a major valley, and show almost identical VESes on top of that. This indicates that we can also use this information for confirmation of type 2 main valleys on top of callibrating boreholes. Both boreholes do not line up on anomalies on the profiles, but the resistivity differences are not that considerable anyway. When looking at the map at large, it becomes apparent that more boreholes are on this exact line next to the valley. Both boreholes having a yield north of 3m3/h, means that this valley has good potential if it is to be used for small solar powered systems, like WASAC is focussing on at the moment. Besides the boreholes, the valley is littered with high yielding springs.				

Location map geophysical measurements

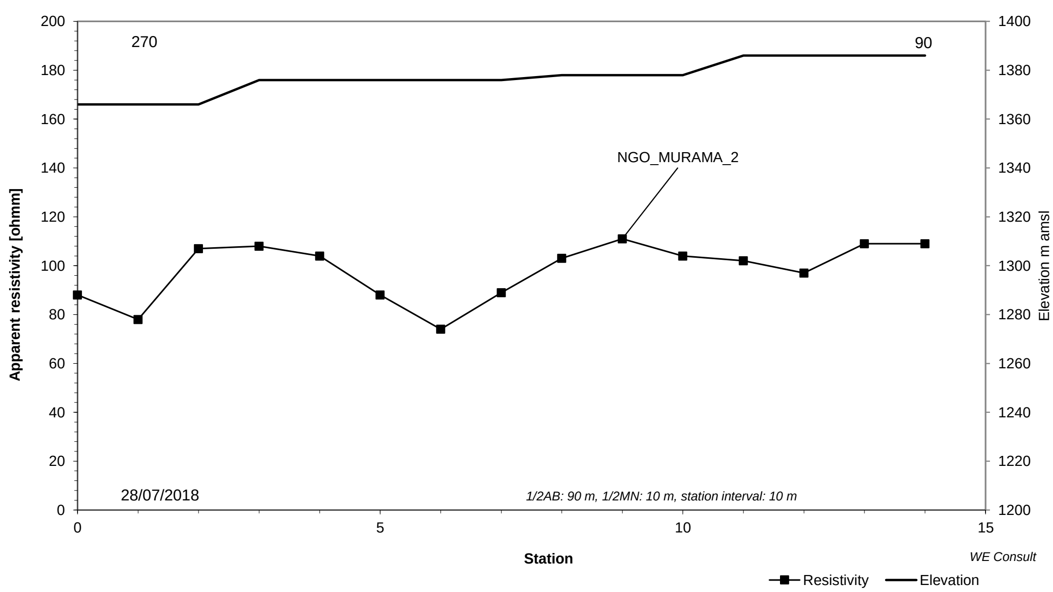


Site	14		Village	Kabahushi		
Cell	Sakara		Sector	Murama		
			District	Ngoma		
Rating per site (max. 100 points):							

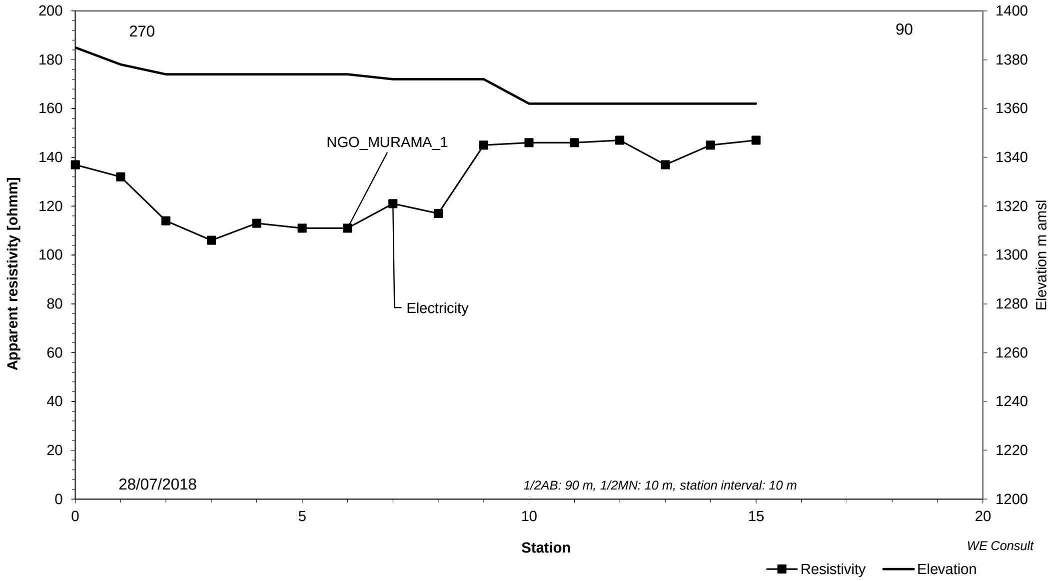
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							

Geophysical measurements

NGO_MURAMA_A PROFILE



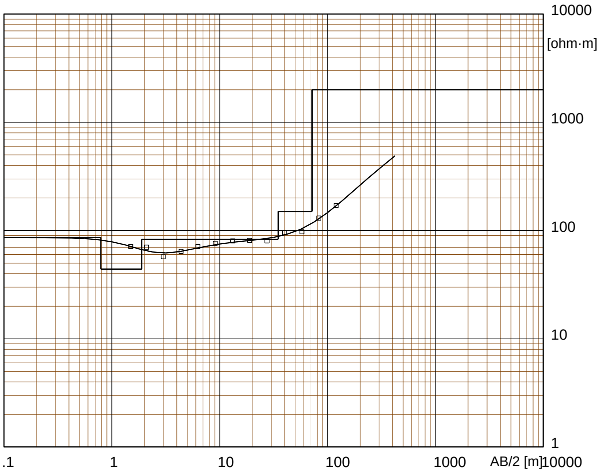
NGO_MURAMA_B PROFILE



ELECTICAL SOUNDING_SCHLUM
NGO_MURAMA_1
EXISTING BH YIELD 3 m3/h | SWL 28 m bgl
FUNCTIONAL

Electrical sounding Schlumberger - BH292.WS3

BH292



Location X = 227336 Y = 9753020 Z = 1398 Azim = 0-180

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
86	.79		1398
44	1.1	.79	1397.2
83	33	1.9	1396.1
150	37	35	1363
2000		72	1326

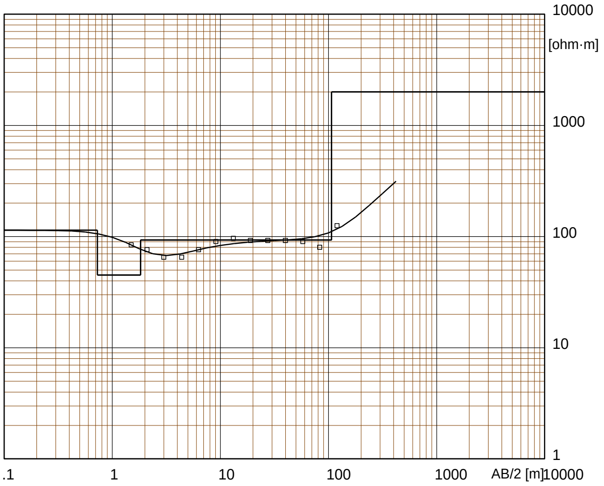
The VES was carried out on BH292. The interpreted layers are: top soil, clay, sandy clay weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NGO_MURAMA_2
EXISTING BH YIELD 5 m3/h | SWL 4 m bgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - BH291.WS3

BH291



Location X = 227956 Y = 9755151 Z = 1377 Azim = 10-190

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
114	.73		1377
45	1.1	.73	1376.3
93	105	1.8	1375.2
2000		107	1270

The VES was carried out on BH291. The interpreted layers are: top soil, clay, sandy clay and hard rock.

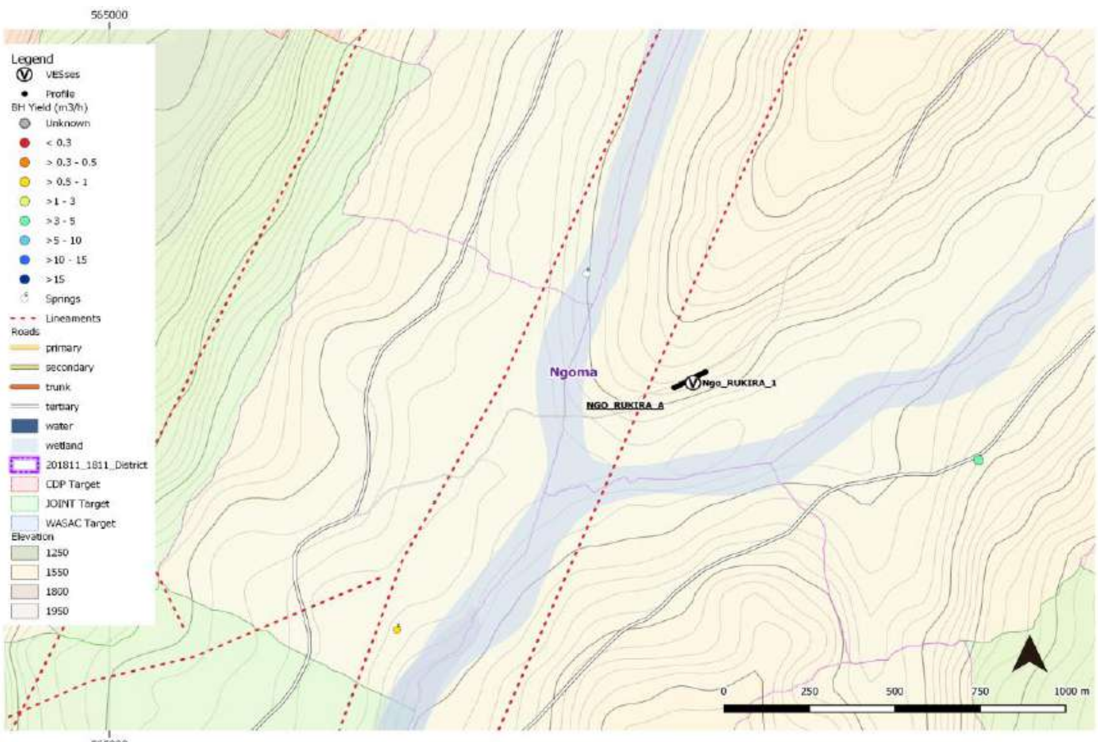
W-GeoSoft / WinSev 6.3

Location:	NGO_RUKIRA					15
Recommended Site:		32-	coordinate (E)	#N/A	coordinate (N)	#N/A
Expected DTB (m):			Altitude (amsl)			
Recommended Depth (m):			Accessibility Site:		Accessible	
Alternative Site:		32-	coordinate (E)	#N/A	coordinate (N)	#N/A
Expected DTB (m):			Altitude (amsl)			
Recommended Depth (m):			Accessibility Site:			
Expected Formation:		Schists and sediments	Accessibility Village:		Good	
Int yield (l/h) :	4,125	SWL (m asl): 1,474	Target:		None	

Remarks:

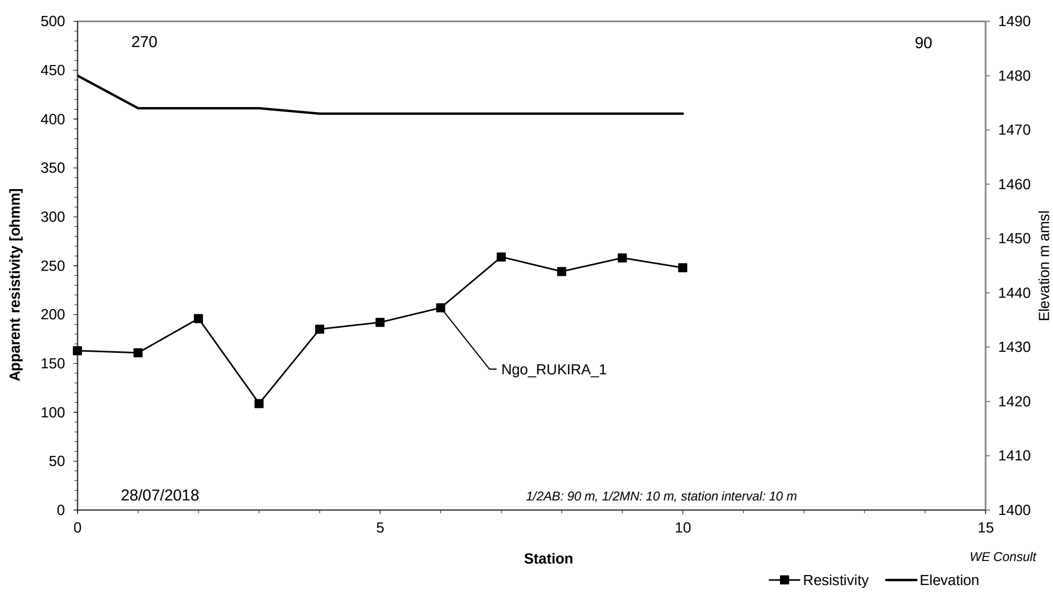
VES_1 is taken on top of the borehole that is on the fork which splits the valley from Site 14, where calibrations were done. The values on the profile are similar to Site 14, but the VES looks considerably different, showing a more traditional curve. The geology should be the same, but perhaps more influenced from the quartzites from the east can be noticed at this location. The boreholes and springs continue on both of the forked splits. The static water level is in fact quite deep, but this could be due to the fact that the borehole is quite high on the ridge. The yield range is the same as Site 14.

Location map geophysical measurements



Site	NGO_RUKIRA		Village			
Parish	Cell		Sector			
			District	#N/A		
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

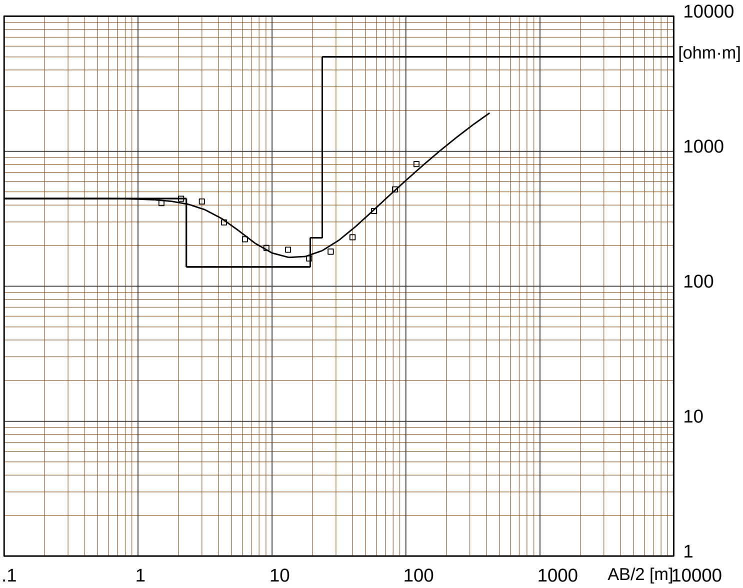
NGO_RUKIRA_A PROFILE



Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_SCHLUM
NGO_MURAMA_1
EXISTING BH YIELD 4 m3/h | SWL 43 m bgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - BH288.WS3



Location X = 233014 Y = 9763243 Z = 1452 Azim = 140-320

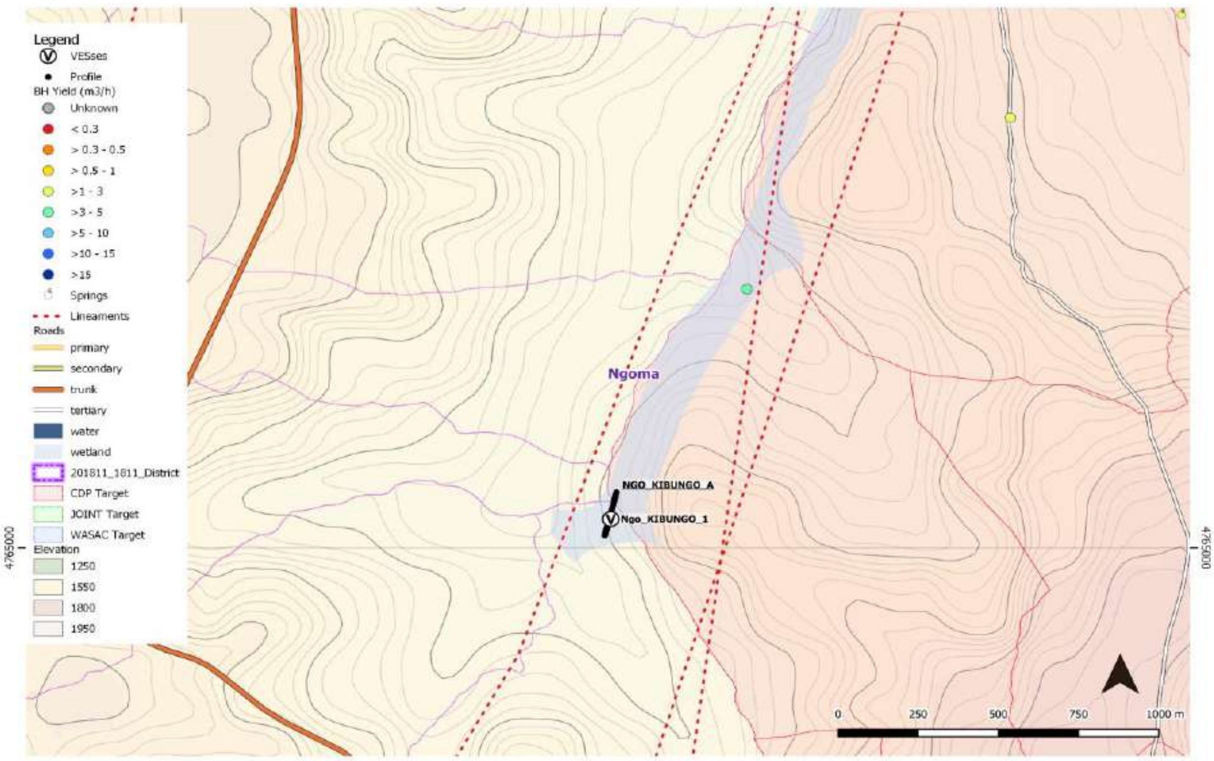
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
446	2.3		1452
139	17	2.3	1449.7
228	4.4	19	1433
5000		23	1429

The VES was carried out on BH288. The interpreted layers are: top soil, sandy clay, sand, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

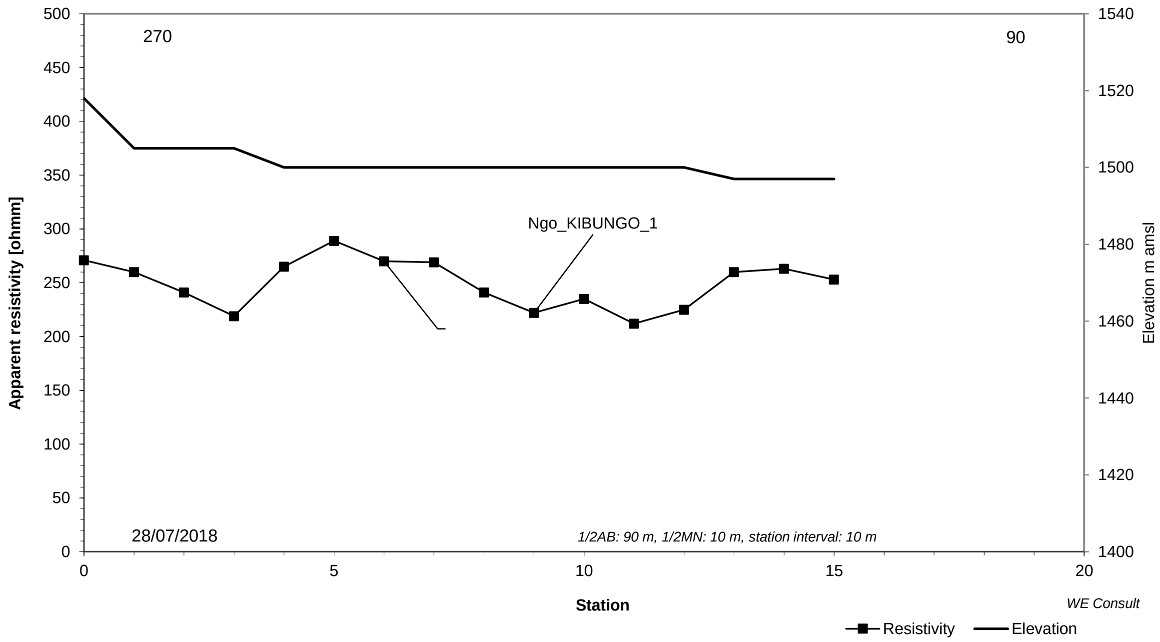
Location:	**NGO_KIBUNGO**				16
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Expected Formation:		Schists and sediments		Accessibility Village:	Good
Int yield (l/h) :	4,560	SWL (m asl):	1,502	Target:	
Remarks:	Multiple lineaments seems to coincide on this valley (depending on whether you look localized or more global). The resistivities on the profile are slightly higher than the close by Site 14 and 15, but this formation also signifies silt and sandstones which can account for that. However, when looking at the VES, this looks again almost identical to the calibrations done on Site 14. The static water level is extremely shallow (mere meters) and the yield is on the top of the range of the 2 previous sites. Taking into account Site 14, this kind of VES shape could signify shallow ground water as one of the Site 14 boreholes confirms. Site 15, with a deeper SWL shows a different curve. Boreholes in between that have not been calibrated also seem to fluctuate with their yield between 3 and 5 m3/h. The SWL is also very close to the surface for a lot of boreholes, as can be seen from the ground water flow map.				

Location map geophysical measurements



Site	16		Village	Gasoro			
Cell	Gahima		Sector	Kibungo			
			District	Ngoma			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

NGO_KIBUNGO_A PROFILE

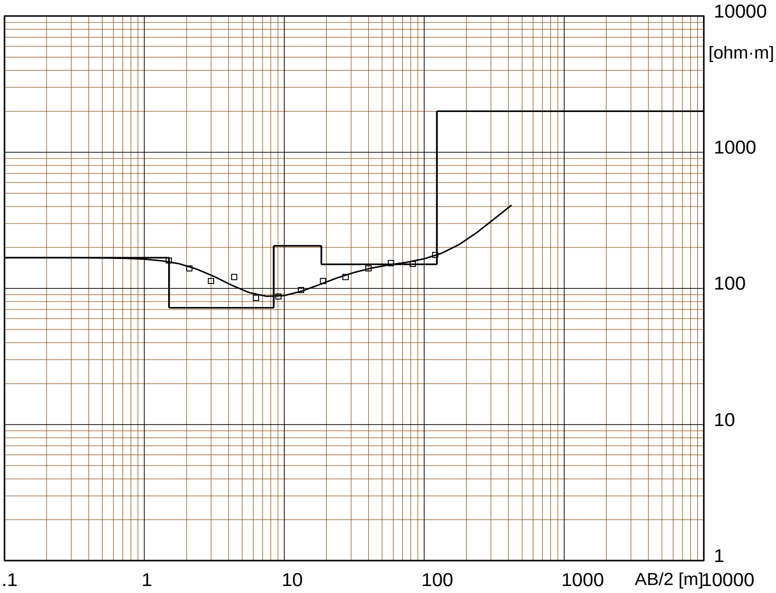


Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_SCHLUM
NGO_KIBUNGO_1
EXISTING BH YIELD 4,9 m3/h | SWL 3 m bgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - BH298.WS3

BH282



Location X = 228678 Y = 9764965 Z = 1464 Azim = 280-100

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
168	1.5		1464
72	6.9	1.5	1462.5
205	10	8.4	1455.6
150	105	18	1446
2000		123	1341

The VES was carried out on BH282. The interpreted layers are: top soil, sandy clay, sand, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

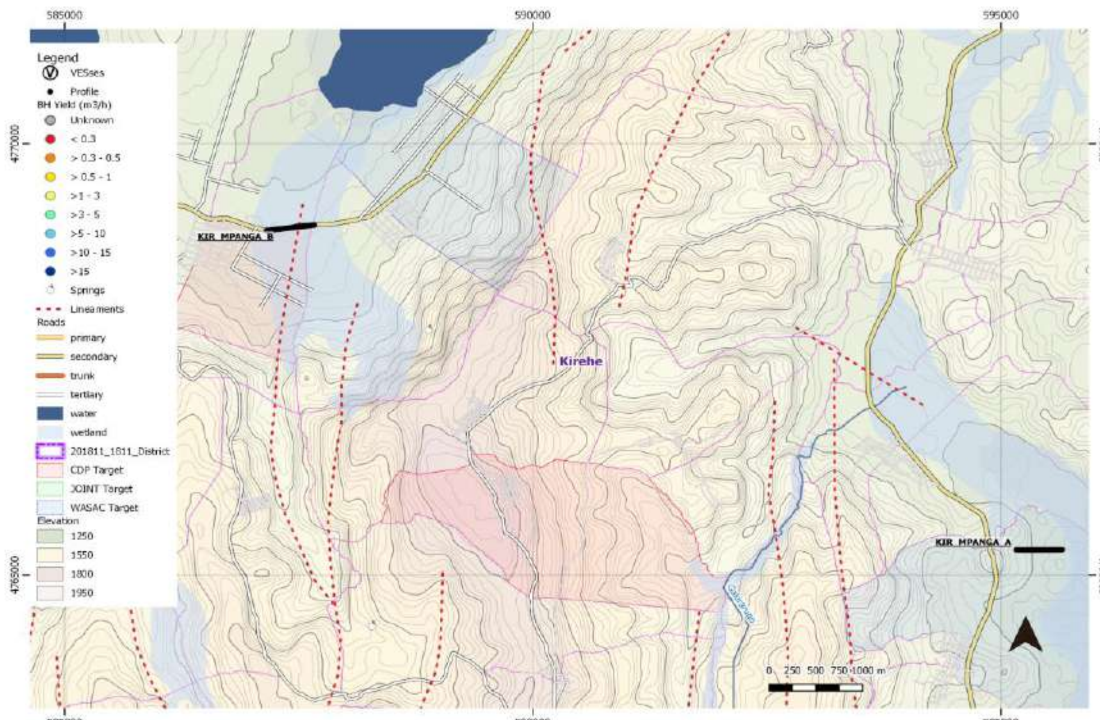
WE Consult

Location:	KIR_MPANGA				17
Recommended Site:		EX_7	coordinate (E) 587477	coordinate (N) 4769033	
Expected DTB (m):		-	Altitude (amsl)	1310	
Recommended Depth (m):		60	Accessibility Site:	Accessible	
Alternative Site:			coordinate (E)	coordinate (N)	
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:		
Expected Formation:		Sediments & Sandstone / Quartzite ridges	Accessibility Village:	Good	
Int yield (l/h) :	2,583	SWL (m asl): 1,303	Target:	CDP & WASAC	

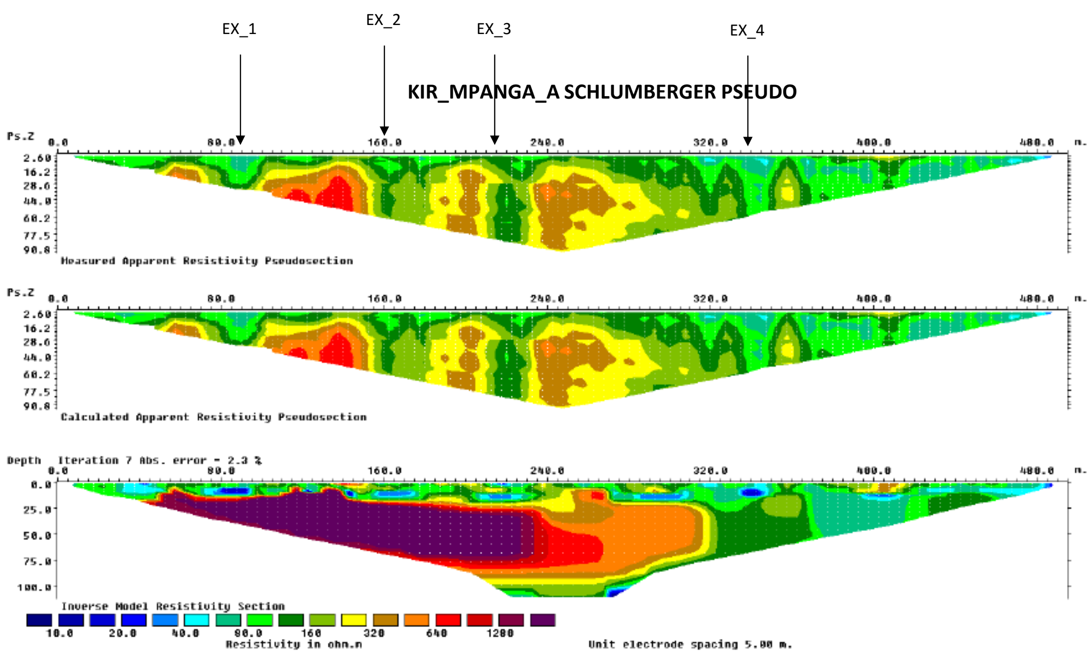
Remarks:

This is the first site in the Akagera formation which consists of consolidated clayey and sandy sediments. Profile A starts with quartzites to the west which are likely accountable for the high resistivities in the beginning of the profile. These high resitivities are however intermittend, causing multiple major anomalies on the line, clearly seen on the pseudo section and the 1D extraction. While resistivities go lower further along the profile, the anomalies in these apparent quarzites are interesting since they would signify weathering. However, the VESes extracted on those locations show that the curve bends off at a 45 degrees angle for hard rock, indicating that some masking might be at play here. These consolidated sediments seem to behave similarly to the schist-like layers found throughout the province, indicating that VESes are unlikely to give significant information on ground water potential. On profile B, seemingly in the same formation, the resistivities are considerably lower, siginifying that we are in fact in the alluvium with clay. The VES extractions will also not tell us anything here, however the profile still might. While normally in sediments, one looks for high resistivities signifying course material with high conductivity, here the low anomaly on EX_7 looks interesting. Since we know the Akagera formation is underlaying the sediments and the profile suposedly completely crosses the sediments, the anomaly is in fact not in the sediments but in the underlying formation, which would in turn signify conditions for ground water. Drilling up to 80 meters is recommended becasue the resistivities seem to be similar throughout a large portion of the underlying formation. If the first 10 meters in the new formation do not yield anything, then neither will the remaining meters. Water is likely to be here, it is a matter of finding a formation that conducts but not retains it.

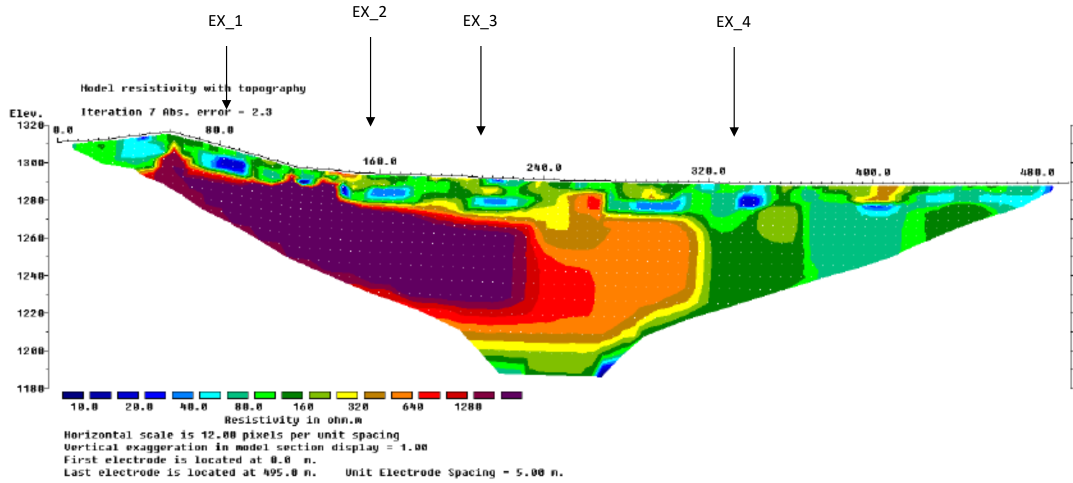
Location map geophysical measurements



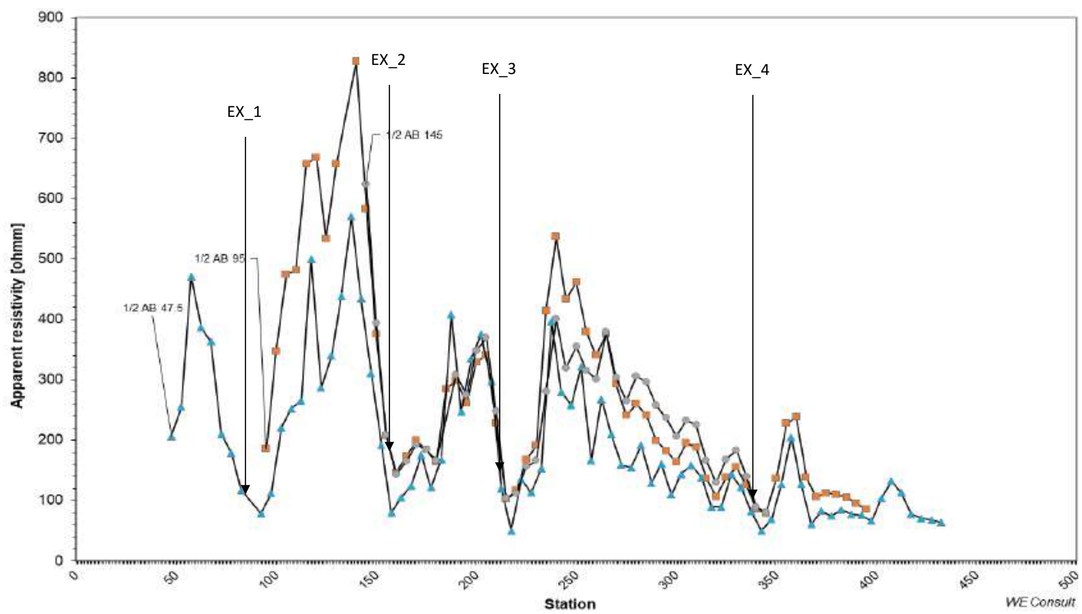
Site	17		Village	Agasasa			
Cell	Nasho		Sector	Mpanga			
			District	Kirehe			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							



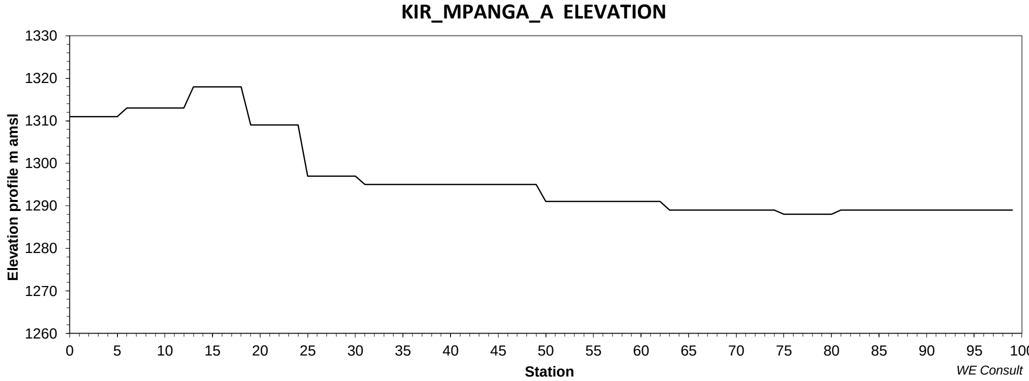
KIR_MPANGA_A SCHLUMBERGER TOPO

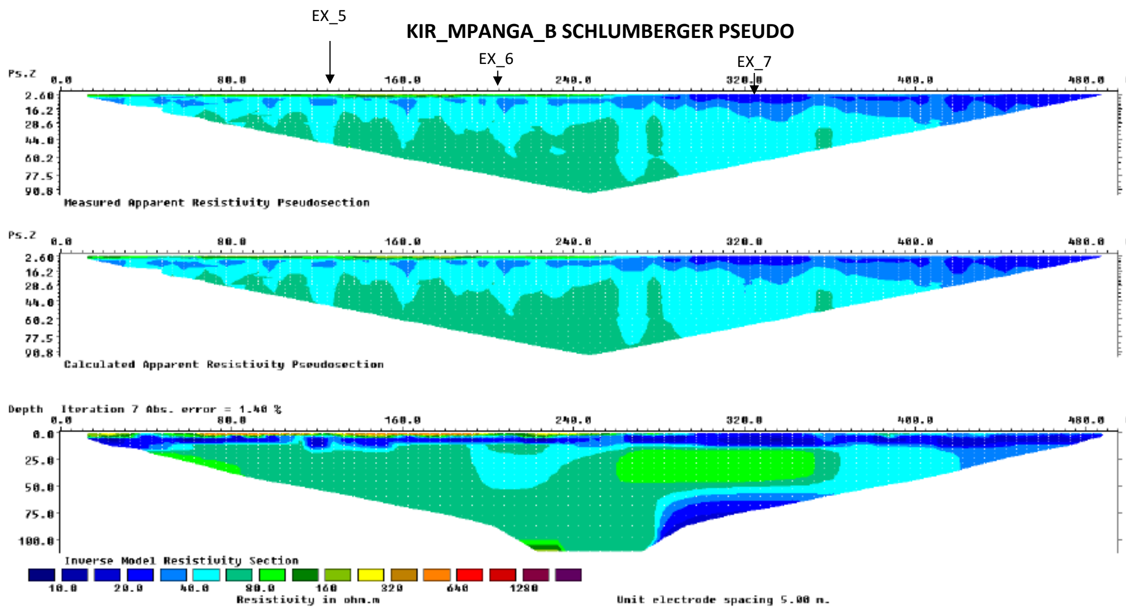


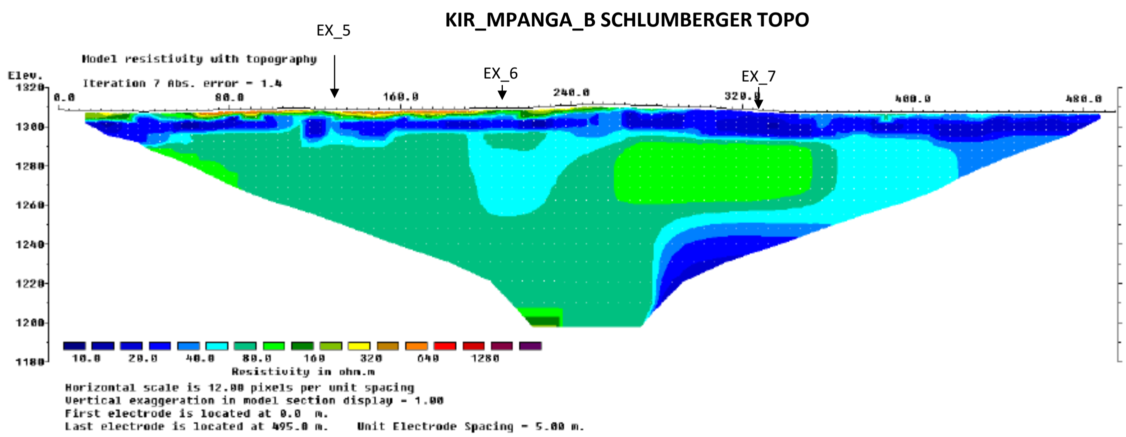
RWA_GAHENGERI_A SCHLUMBERGER 1D EXTRACTION



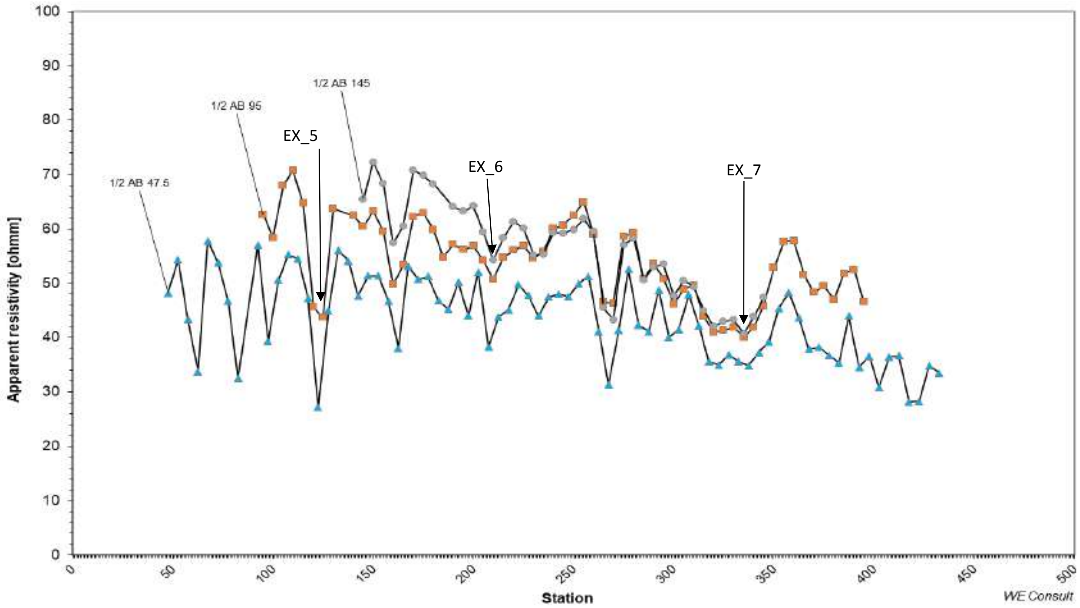
KIR_MPANGA_A ELEVATION



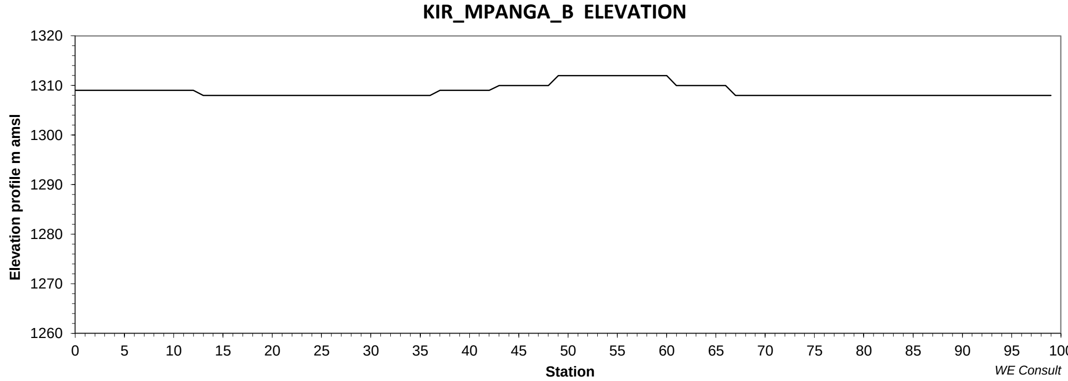

EX_5
KIR_MPANGA_B SCHLUMBERGER PSEUDO
EX_6
EX_7
Ps.Z
0.0
80.0
160.0
240.0
320.0
400.0
480.0
m.
2.60
16.2
28.6
44.0
60.2
77.5
90.8
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Depth
Iteration 7 Abs. error = 1.40 %
0.0
25.0
50.0
75.0
100.0
Inverse Model Resistivity Section
10.0
20.0
40.0
80.0
160
320
640
1280
Resistivity in ohm.m
Unit electrode spacing 5.00 m.


KIR_MPANGA_B SCHLUMBERGER TOPO
EX_5
Model resistivity with topography
Iteration 7 Abs. error = 1.4
EX_6
EX_7
Elev.
1320
1300
1280
1260
1240
1220
1200
1180
0.0
80.0
160.0
240.0
320.0
400.0
480.0
10.0
20.0
40.0
80.0
160
320
640
1280
Resistivity in ohm.m
Horizontal scale is 12.00 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 m.
Last electrode is located at 495.0 m.
Unit Electrode Spacing = 5.00 m.

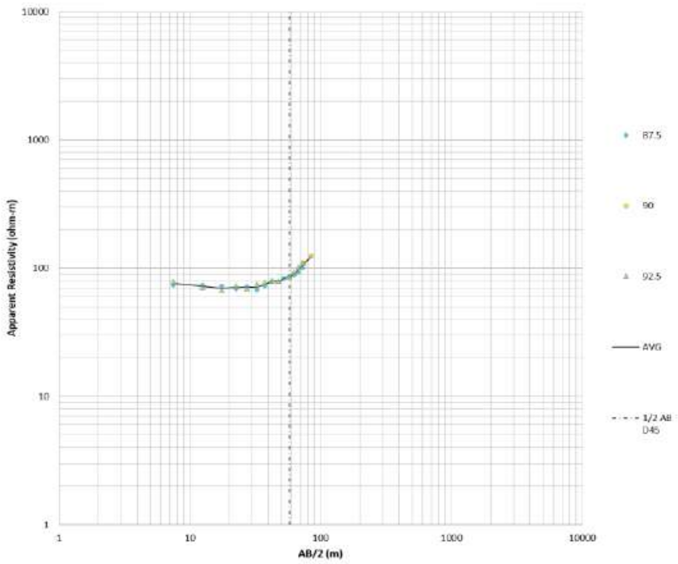
KIR_MPANGA_B SCHLUMBERGER 1D EXTRACTION



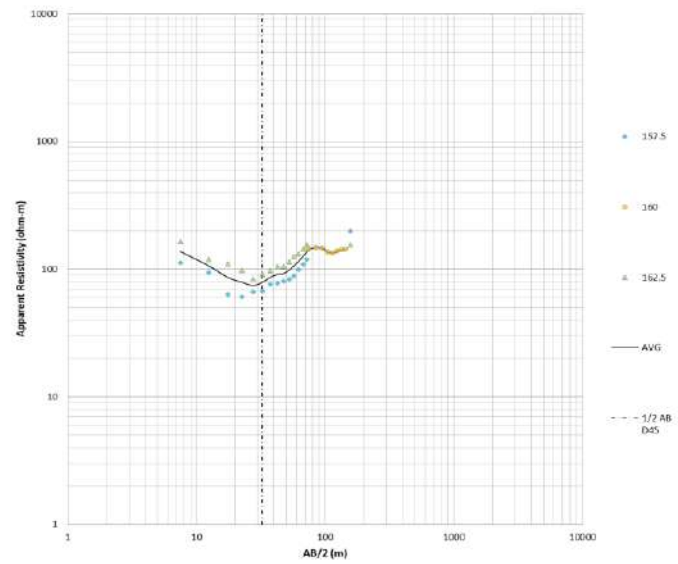
KIR_MPANGA_B ELEVATION



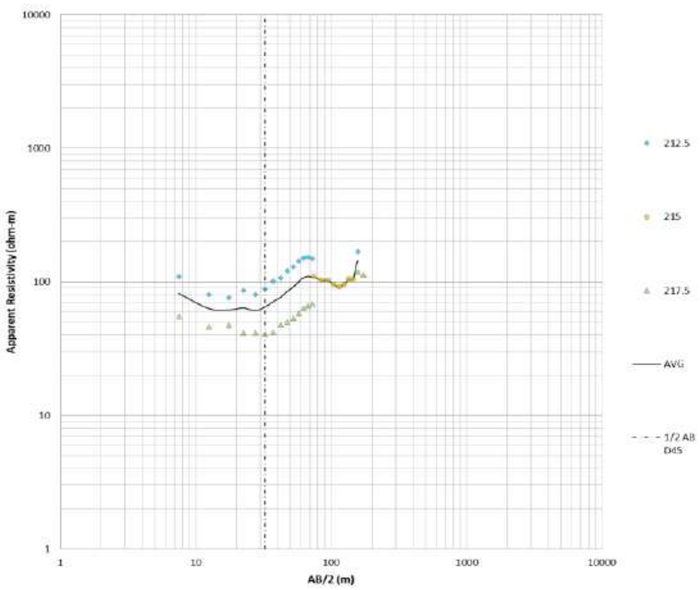
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_A_EX_1 (90 m)



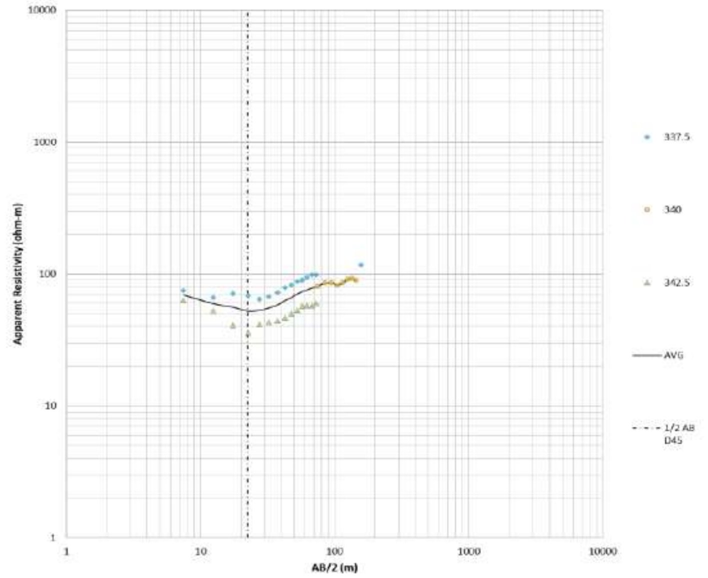
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_A_EX_2 (160 m)



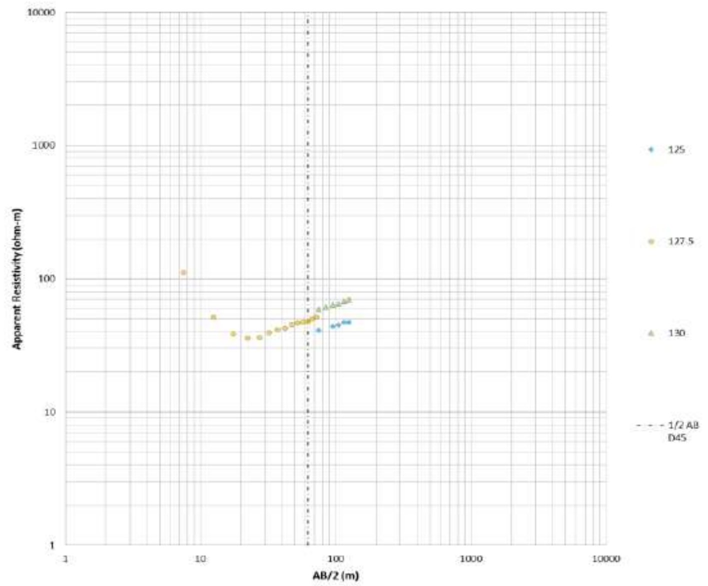
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_A_EX_3 (215 m)



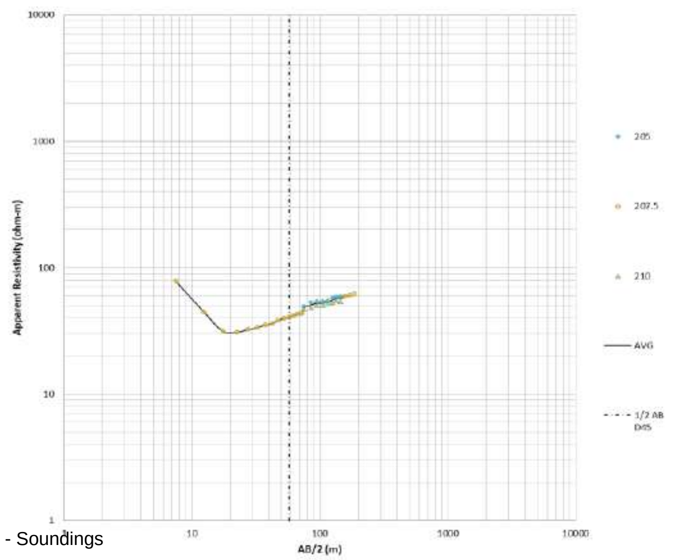
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_A_EX_4 (340 m)



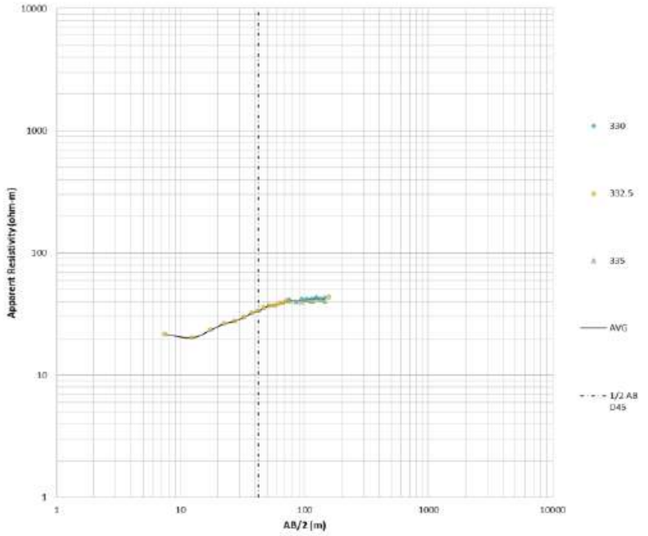
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_B_EX_5 (127.5 m)



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_B_EX_6 (207.5 m)

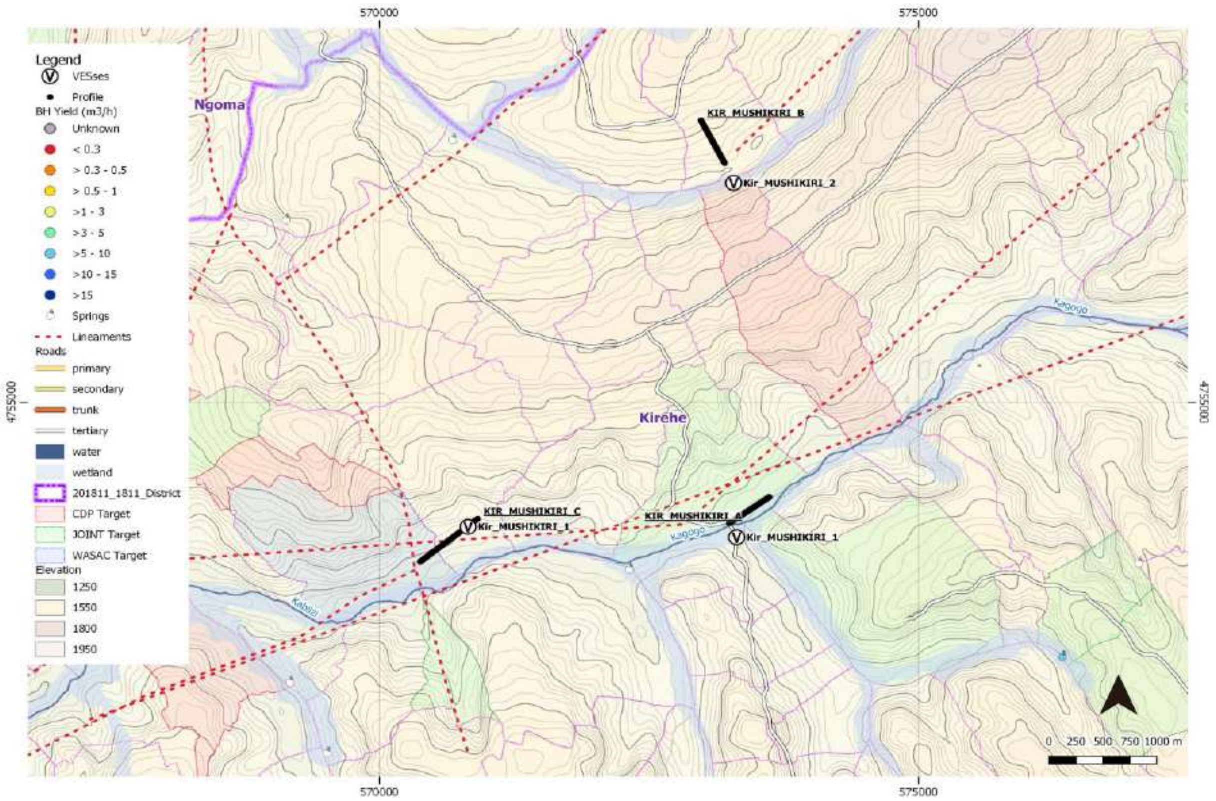


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MPANGA_C_EX_7 (325.5 m)



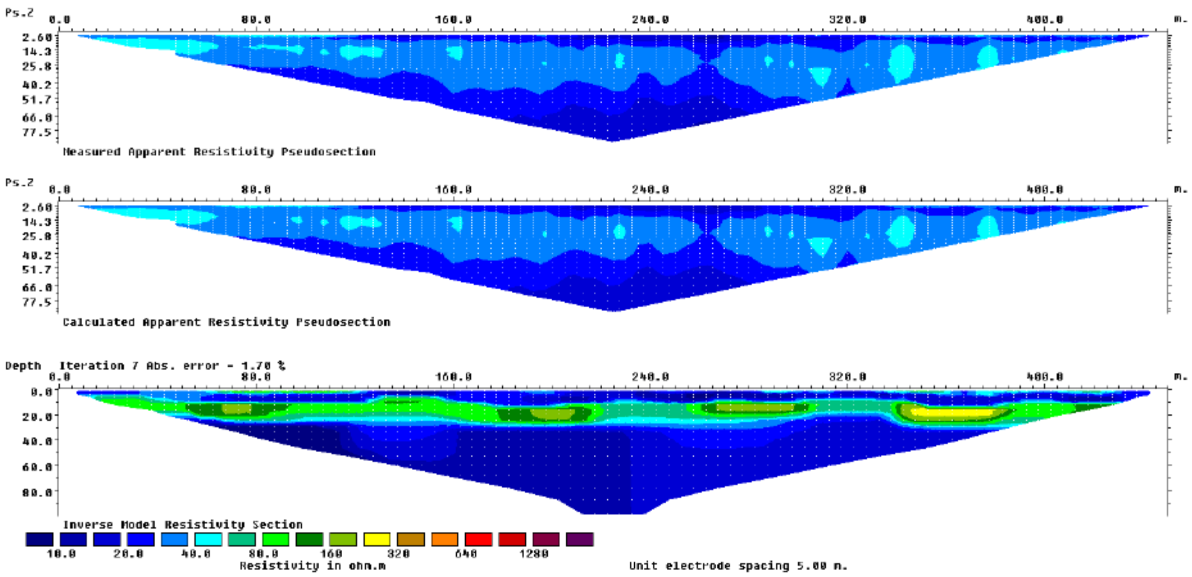
Location:	**KIR_MUSHIKIRI**					18
Recommended Site:		EX_3	coordinate (E)	573536	coordinate (N)	4753995
Expected DTB (m):			Altitude (amsl)		1025	
Recommended Depth (m):		40	Accessibility Site:		Accessible	
Alternative Site:		VES_2	coordinate (E)	573283	coordinate (N)	4757194
Expected DTB (m):		35	Altitude (amsl)		1500	
Recommended Depth (m):		70	Accessibility Site:		Accessible	
Expected Formation:		Sediments & Sandstone / Quartzite ridges	Accessibility Village:		Good	
Int yield (l/h) :	2,247	SWL (m asl): 1,443	Target:		CDP & WASAC	
Remarks:	This site focusses on the south-west edge of the quartzite formation in the middle of Kirehe. Profile A is done parallel to the main valley which contours the quartzite formation. The profiles shows very low restitivities which signify clay. But there is also a band of higher resistivities visible which shows coarser material which will have a higher conductivity then the clay layers. It is interesting to see that there is an elevation difference, since these results normally occur on flat plains. The elevation difference is likely due to the gradient of the river, which seems to be considerable. For this reason, it is advised to drill on EX_3, as the river flow speeds up afther this point meaning it will deposit less. Near this point there also seems to be somewhat of an obstruction which will cause more sediments to be deposited there (which is confirmed by the higher resititivty). This location can suffice for both handpump and production purposes. Profile B, while not functional in the sense of locating water, very effectively shows the effects from doing geophysics on top of a solid quartzite ridge. The resistivities are extremely high, but not erratic. This will show some anomalies, but they of course hold no relation to ground water, but rather dry fractures in the rock. It shows the ineffectiveness of siting on high elevated places with hardrock. VES_2 is done in the extension of the profile in the valley and shows potential in the valley, however without a profile it is risky to drill in these areas. A profile was not possible due to accesiblity and quality of measurement (no penetration through rock). VES_1 on profile C is located in a nice anomaly parallel to the valley, which will likely sustain a handpump. The verification on the borehole (VES_3) is near profile A but shows a different kind of formation being targeted there.					

Location map geophysical measurements

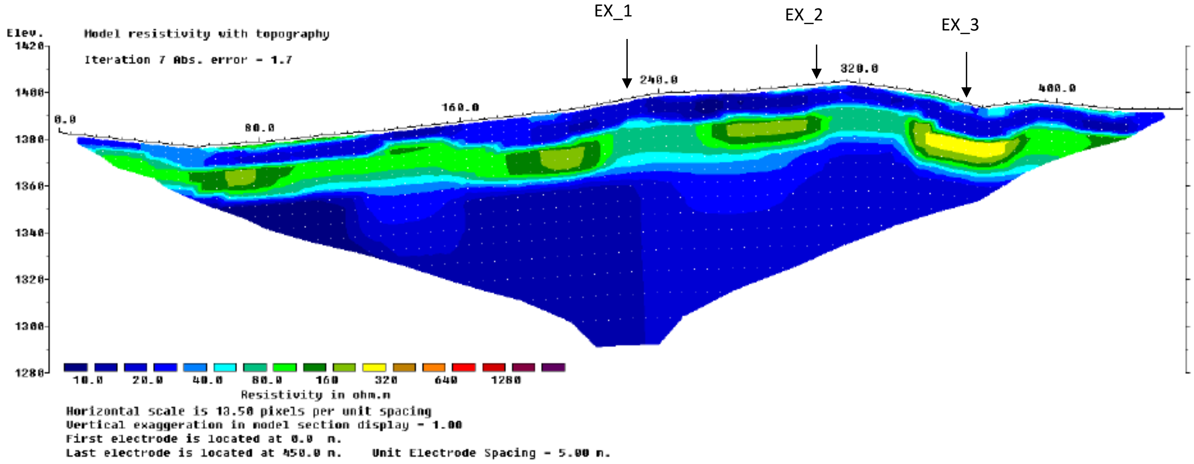


Site	18		Village	Isangano			
Cell	Bisagara		Sector	Mushikiri			
			District	Kirehe			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)		10					
Lineament (0-20 points)	2						
Anomaly (0-30 points)		4					
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	9.00	41.00					
Remarks							
Geophysical measurements							

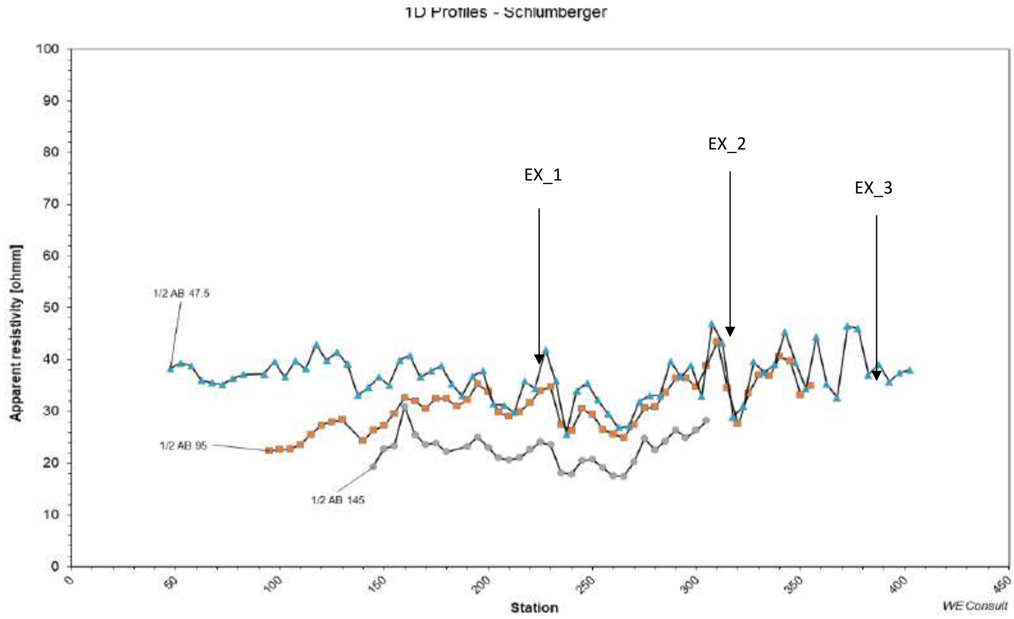
KIR_MUSHIKIRI_A SCHLUMBERGER PSEUDO



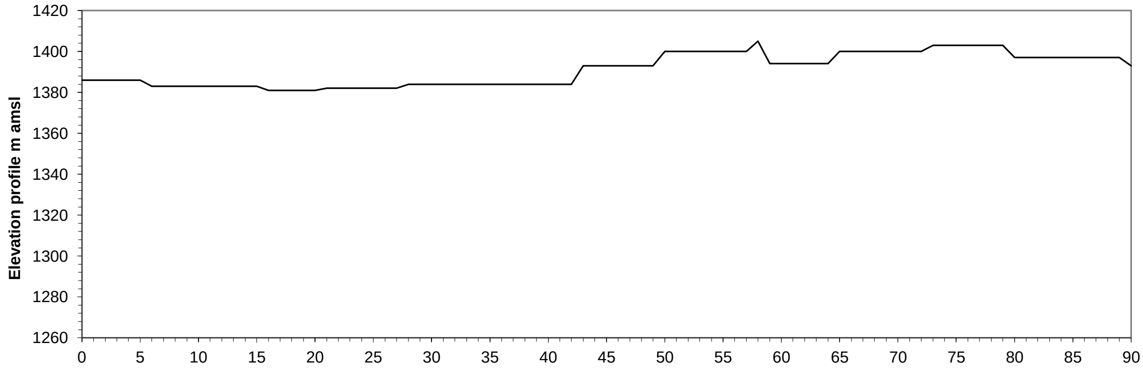
KIR_MUSHIKIRI_A SCHLUMBERGER TOPO



KIR_MUSHIKIRI_A SCHLUMBERGER 1D EXTRACTION



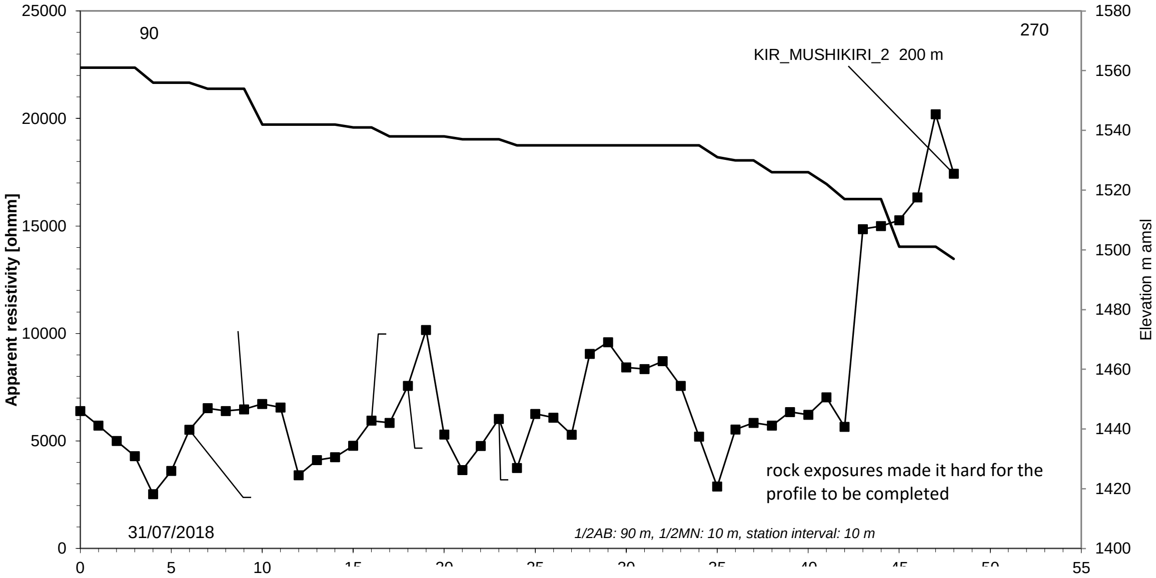
KIR_MUSHIKIRI_A ELEVATION



Station

WE Consult

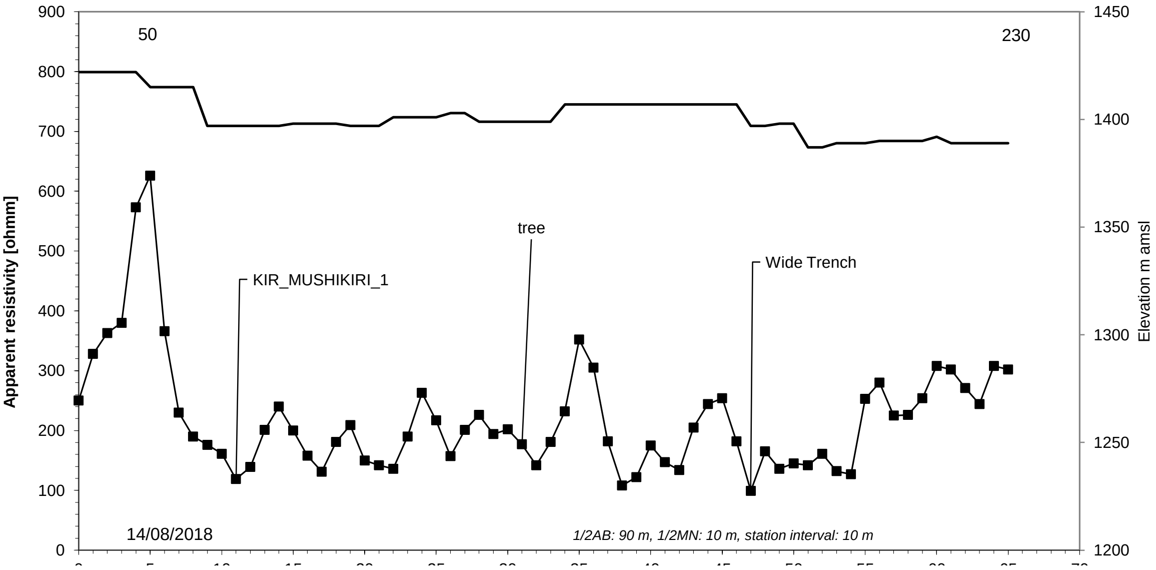
KIR_MUSHIKIRI_B PROFILE



KIR_MUSHIKIRI_C PROFILE

WE Consult

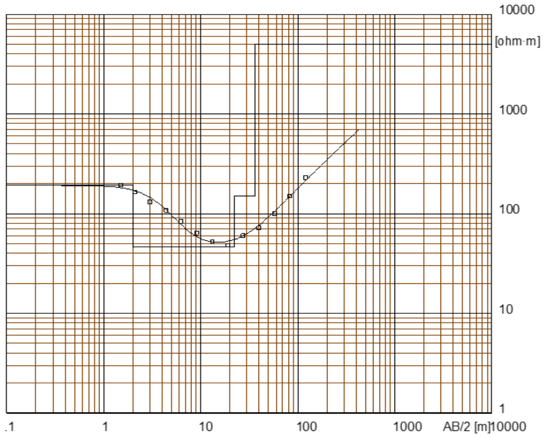
Elevation



Best VES: **CALIBRATION ONLY**

WE Consult

ELECTICAL SOUNDING_SCHLUM
KIR_MUSHIKIRI_1



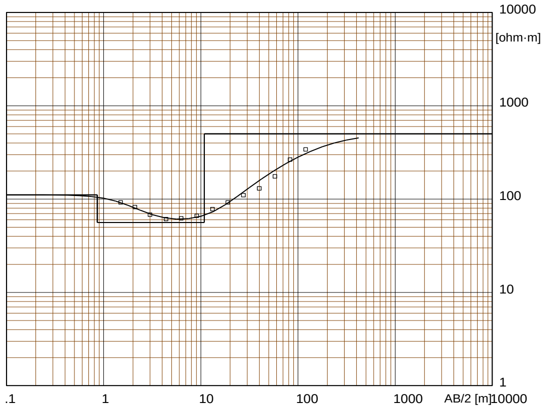
Location X = 237150 Y = 9753634 Z = 1416 Azim = 230-050

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
192	2		1416
46	20	2	1414
150	14	22	1394
5000		36	1380

The VES was carried out on station 11 of profile A (KIR_500). The interpreted layers are: top soil, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KIR_MUSHIKIRI_2



Location X = 239605 Y = 9757079 Z = 1492 Azim = 250-70

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
111	.86		1492
56	10	.86	1491.1
500		11	1481

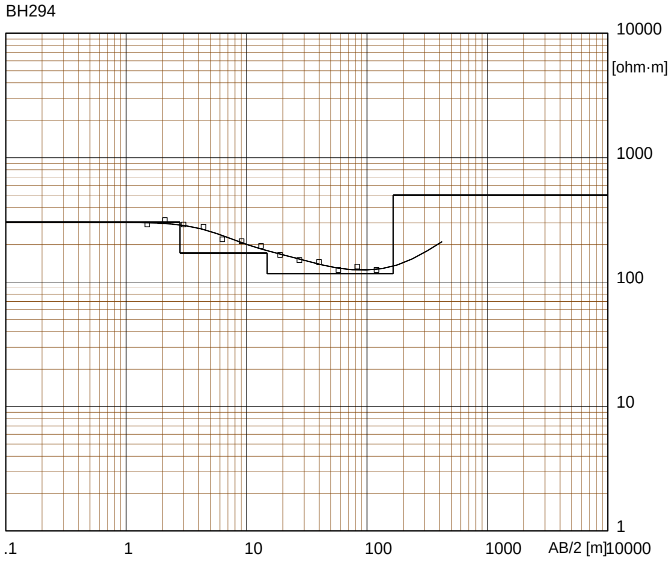
The VES was carried across the valley on profile KIR-6. The interpreted layers are: top soil, clay, and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MUSHIKIRI_3
EXISTING BH YIELD 2m3/h | SWL 10 m bgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - BH294.WS3

BH294



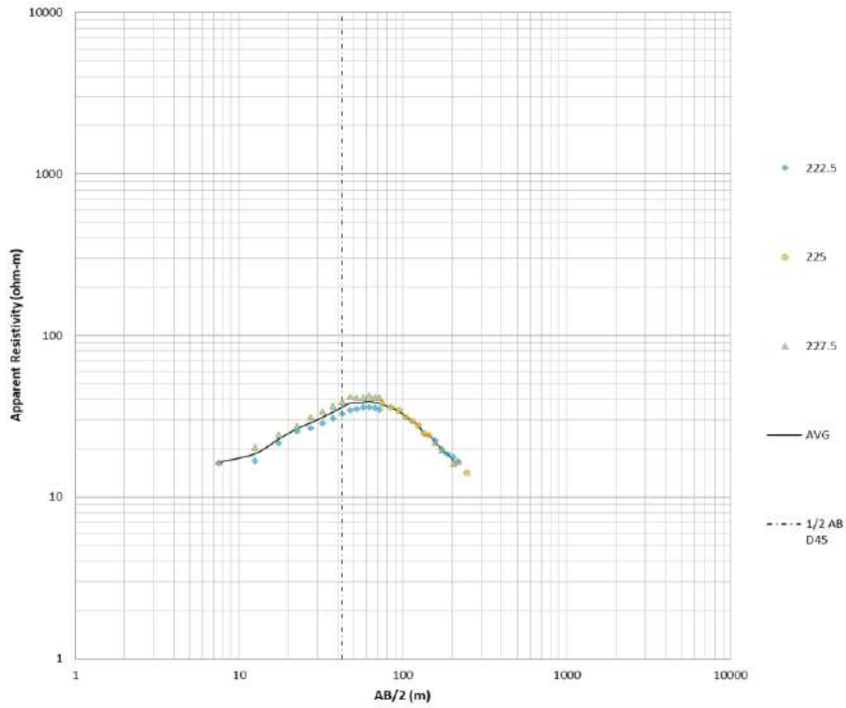
Location X = 239640 Y = 9753533 Z = 1369 Azim = 0-180

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
303	2.8		1369
171	12	2.8	1366.2
117	150	15	1354
500		165	1204

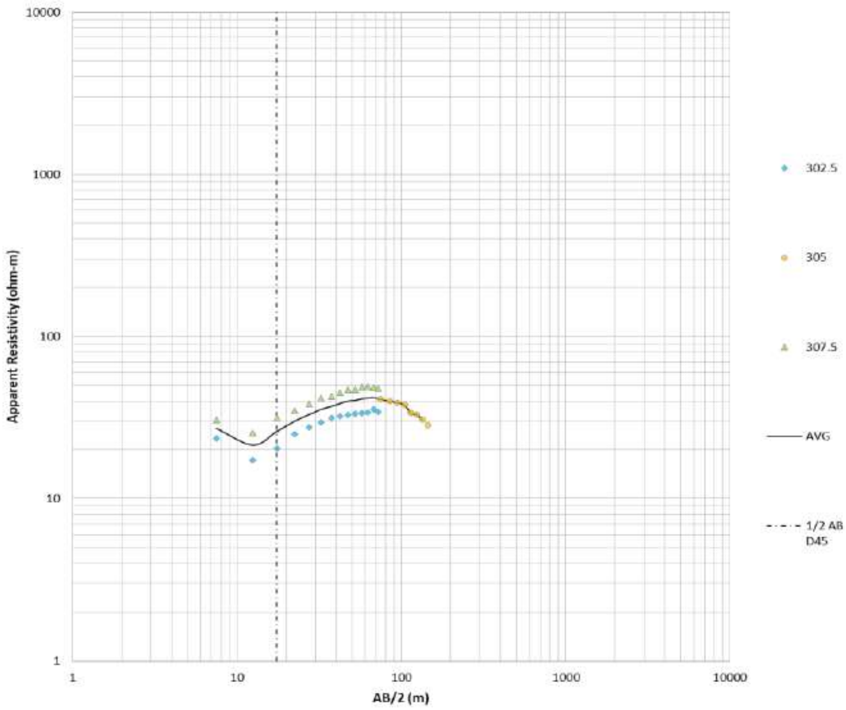
The VES was carried out on BH294. The interpreted layers are: top soil, sandy clay, sand and hard rock.

W-GeoSoft / WinSev 6.3

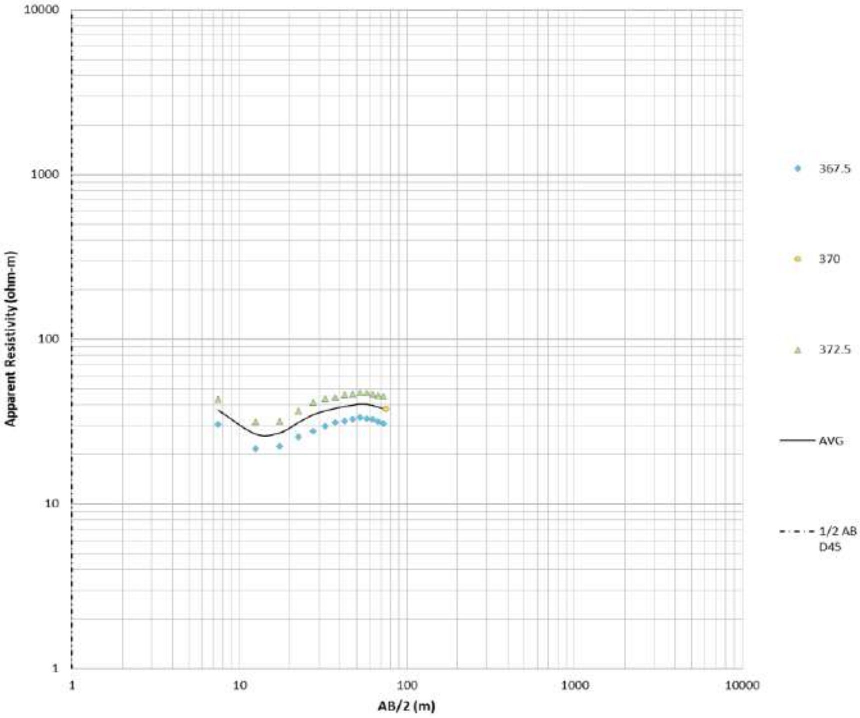
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MUSHIKIRI_A_EX_1 (225 m)



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MUSHIKIRI_A_EX_2 (305 m)

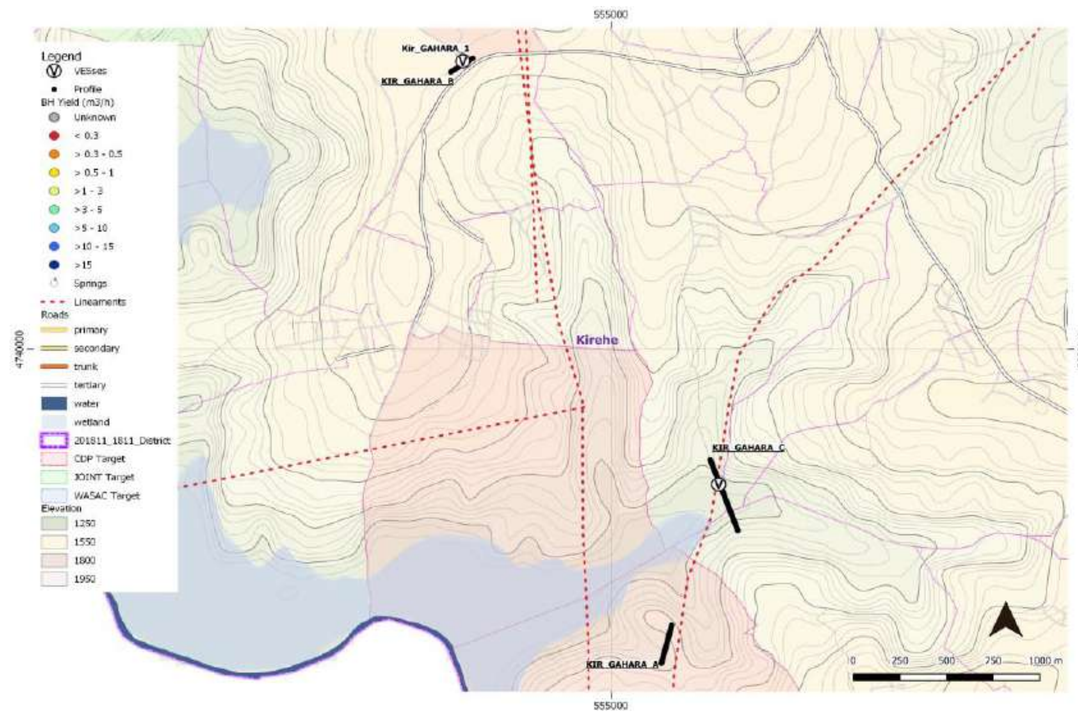


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KIR_MUSHIKIRI_A_EX_3 (370 m)



Location:	**KIR_GAHARA**				19
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Expected Formation:		Quartzites and schists		Accessibility Village:	
Int yield (l/h) :	2,110	SWL (m asl):	1,420	Target:	CDP
Remarks:	The main focus is to target the valley crossing through the quartzite vein. The quartzite is clearly visible on the left side, after which the resistivity values drop, to rise again on the right side of the profile. This is in the middle of the quartzite ridge where values in the faulted valley seem to drop considerably. VES_2 shows that values quite steadilly increase, signifying shallow bedrock, while weathered rock was expected. The VES was done close to the edge of the ridge where weathering does not seem to kick in. Due to accessibility issues no further VESes were conducted in the middle of the valley where anomalies are more interesting. Further investigation on this site is suggested as the anomalies and profile suggest potential, but the neccecary confirmation with VES could not be done. Further investigation with ERT could alleviate the issue. The verified borehole shows extremely high resitities and has a very deep static water level, which should not be targeted for new boreholes. However it does show how a VES can look like when you get water in sub optimal conditions at high elevation (which still under normal circumstances should not be considered, the borehole would not work for long). Profile A was prematurely abrubted because of accessibility issues				

Location map geophysical measurements



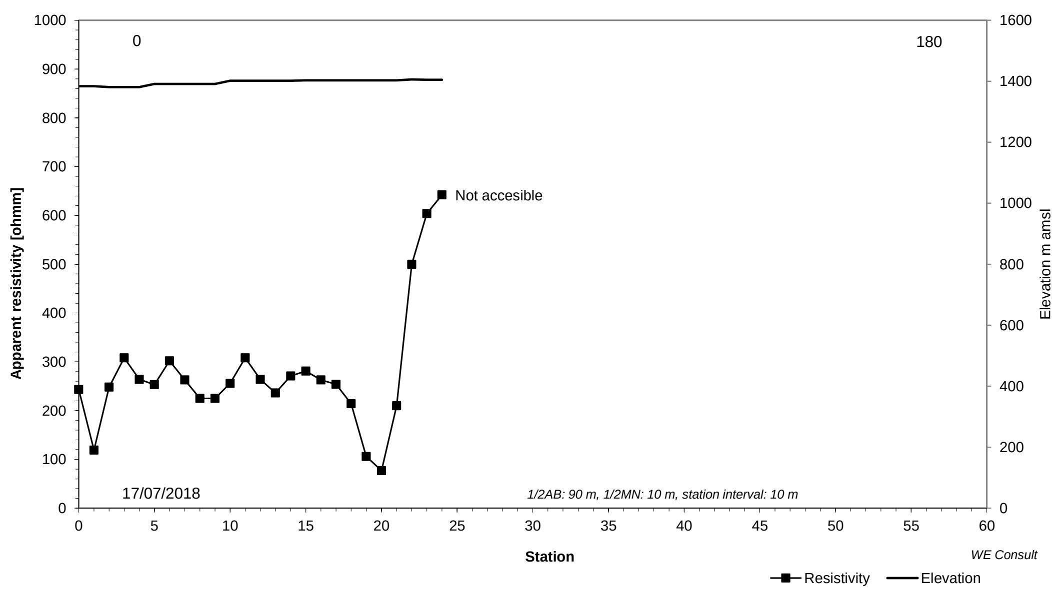
Site	19		Village	Nyamugari		
Cell	Murehe		Sector	Gahara		
			District	Kirehe		

Rating per site (max. 100 points):

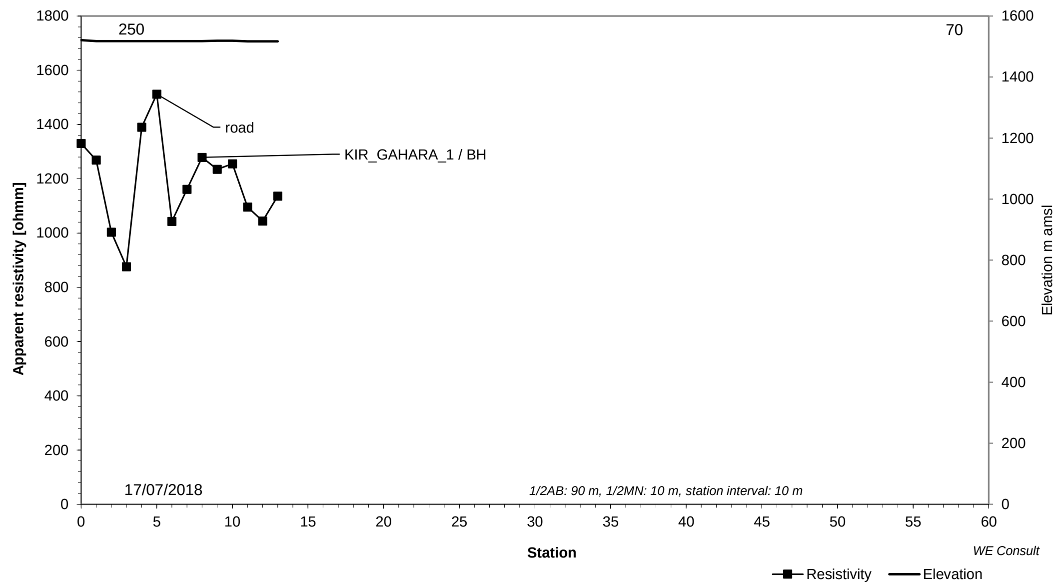
	1	2	3	4	5	6	7
Local topography (0-20 points)		25					
Lineament (0-20 points)		15					
Anomaly (0-30 points)		3					
VES (0 -15 points)							
Earlier results (0 - 15)							
Total		53					
Remarks							

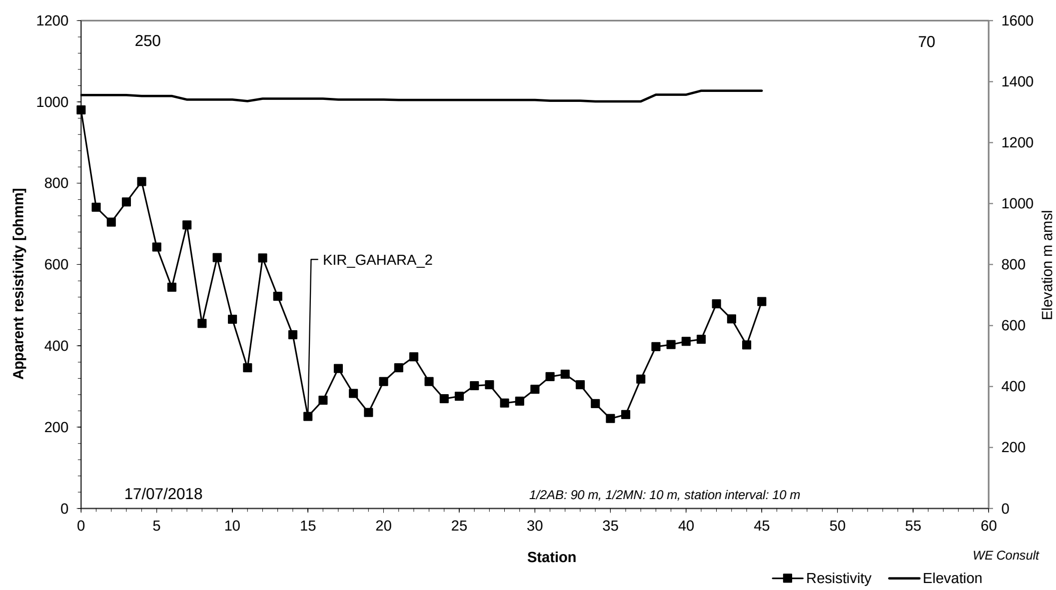
Geophysical measurements

KIR_GAHARA_A PROFILE



KIR_GAHARA_B PROFILE

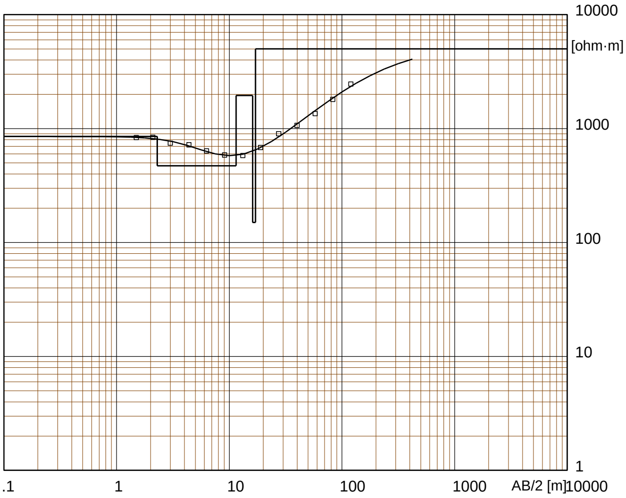




ELECTICAL SOUNDING_SCHLUM
KIR_GAHARA_1
EXISTING BOREHOLE 1,9 m3/h | SWL 94 m bgl
NOT FUNCTIONAL

Electrical sounding Schlumberger - BH297.WS3

BH297



Location X = 220551 Y = 9741509 Z = 1527 Azim = 180-0

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
850	2.3		1527
471	9.2	2.3	1524.7
1949	4.6	12	1515
150	1	17	1510
5000		18	1509

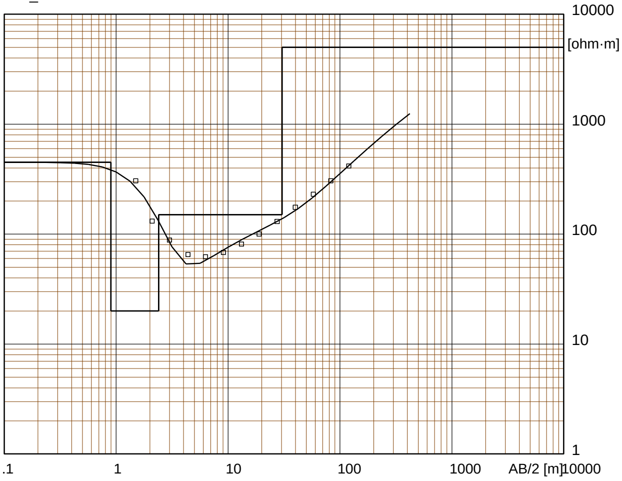
The VES was carried out on BH297. The interpreted layers are: top soil, coarse gravel,laterites, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KIR_GAHARA_2

Electrical sounding Schlumberger - 201811_KIR_501-1.WS3

KIR_501-1



Location X = 221926 Y = 9739055 Z = 1357 Azim = 150/330

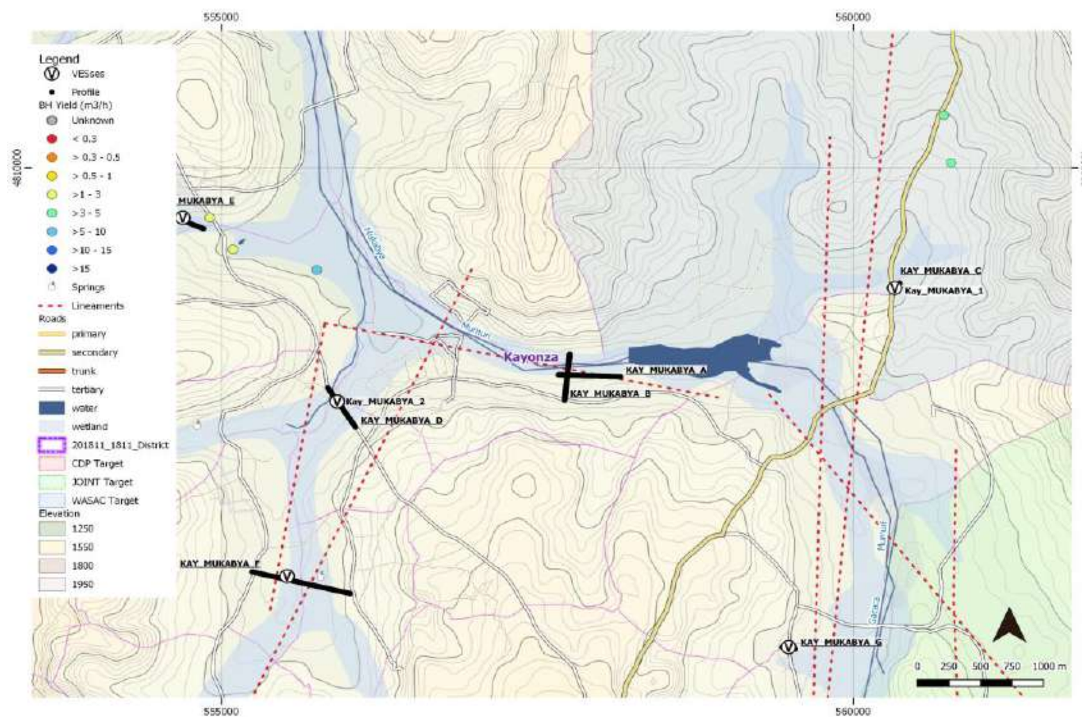
Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
450	.9		1357
20	1.5	.9	1356.1
150	28	2.4	1354.6
5000		30	1327

The VES was carried out on station 15 of profile A (KIR_501). The interpreted layers are: top soil, clay, weathered rock and hard rock.

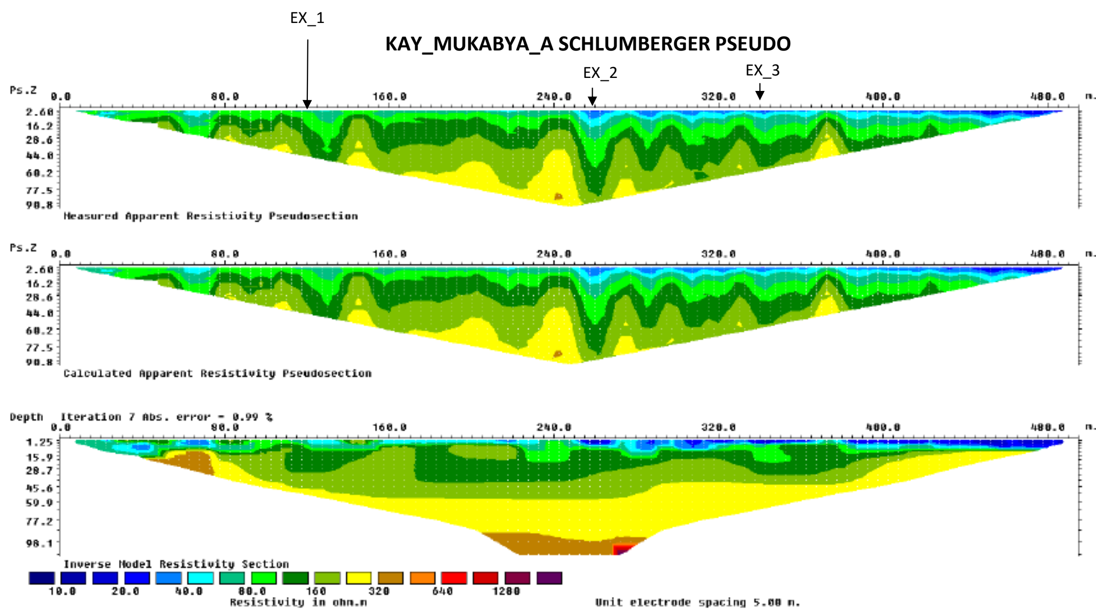
W-GeoSoft / WinSev 6.3

Location:	**KAY_MUKABYA**						20
Recommended Site:		EX_2		coordinate (E)	557897	coordinate (N)	4808217
Expected DTB (m):		UNKNOWN (masked)		Altitude (amsl)		1352	
Recommended Depth (m):		80		Accessibility Site:		Accessible	
Alternative Site:		VES_4		coordinate (E)	#N/A	coordinate (N)	#N/A
Expected DTB (m):		20		Altitude (amsl)		1018	
Recommended Depth (m):		70		Accessibility Site:			
Expected Formation:		Quartzite Schists and Sediments		Accessibility Village:		Good	
Int yield (l/h) :	4,055	SWL (m asl):	1,372	Target:		CDP	
Remarks:	This site focusses on the the Mukabya steam valley which crosses through quartzite veins in multiple locations. Main quartzite vein locations to consider are EX_2 (Profile A, perpendicular to the quartzite vein) where a very pronounced anomaly singifies deep weathering on the vein. Since we are dealing with sediments on this location, the VES extractions do not show anything significant due to masking. Profile B was done perpendicular to the valley but in the soft formation, so not enough contrast was found to pinpoint the ideal location. The 1D profiles done show results typical for sediments. The one VES done outside of calibrations matches nicely with the calibrated boreholes (some of extremely high yield), if not showing a better curve. It is located in between two artisian wells with similar VES curves. It is recommended for drilling, but only if development of the existing artesian wells does not work out.						

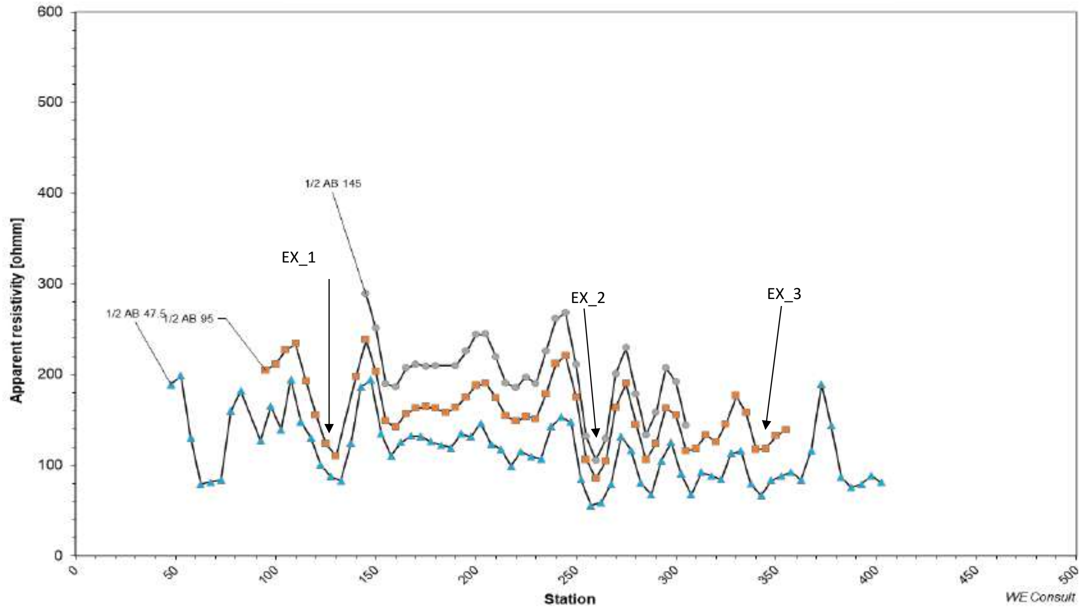
Location map geophysical measurements



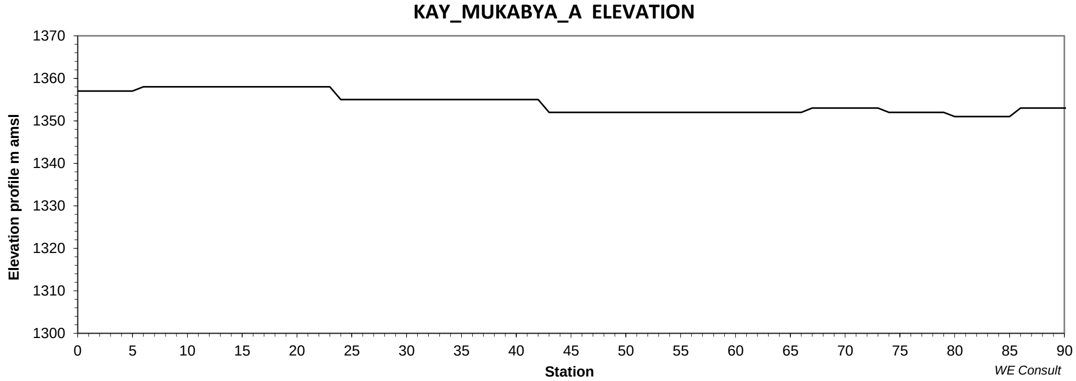
Site	KAY_MUKABYA		Village				
Parish	Cell		Sector				
			District	#N/A			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)				20			
Lineament (0-20 points)							
Anomaly (0-30 points)				7			
VES (0 -15 points)				4			
Earlier results (0 - 15)				14.00			
Total				61.00			
Remarks							
Geophysical measurements							



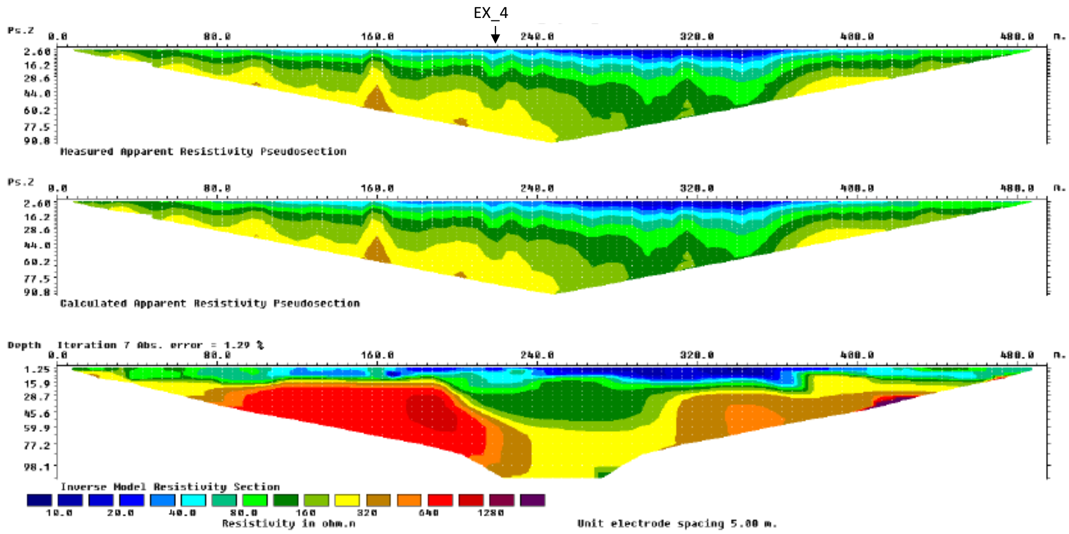
KAY_MUKABYA_A SCHLUMBERGER 1D EXTRACTION



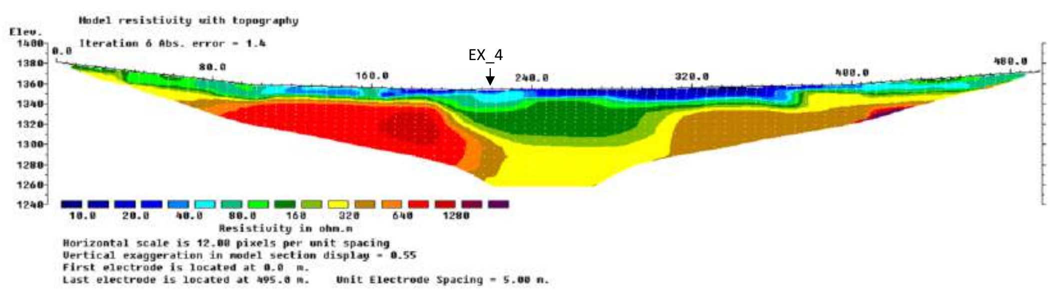
KAY_MUKABYA_A ELEVATION



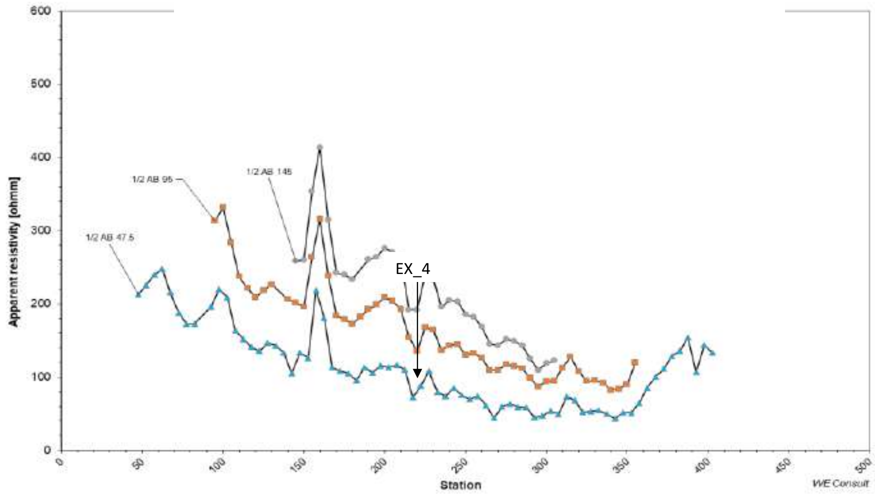
KAY_MUKABYA_B SCHLUMBERGER PSEUDO



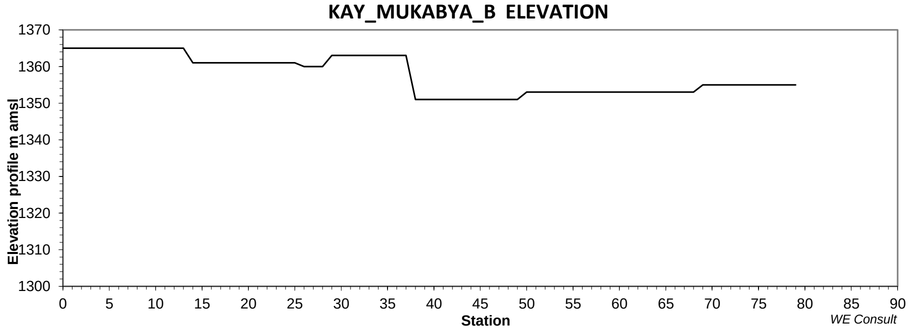
KAY_MUKABYA_B SCHLUMBERGER TOPO



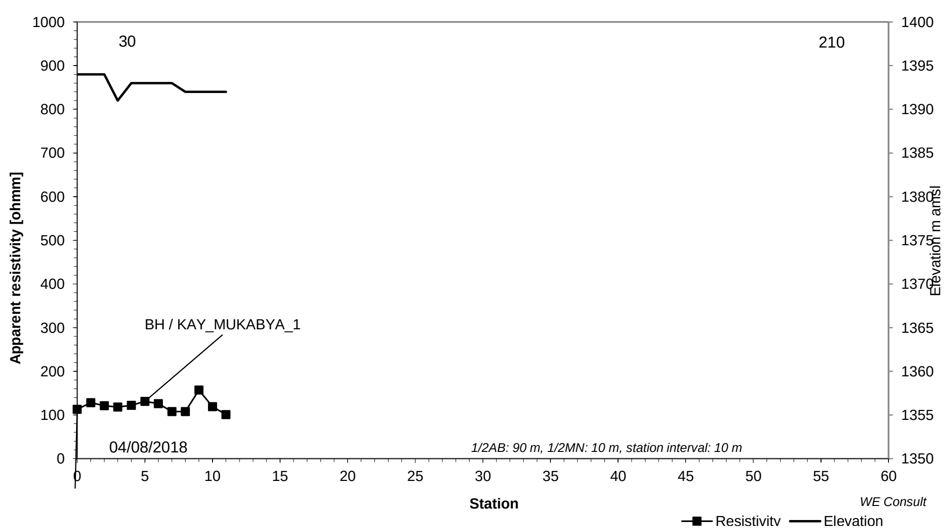
KAY_MUKABYA_B SCHLUMBERGER 1D EXTRACTION



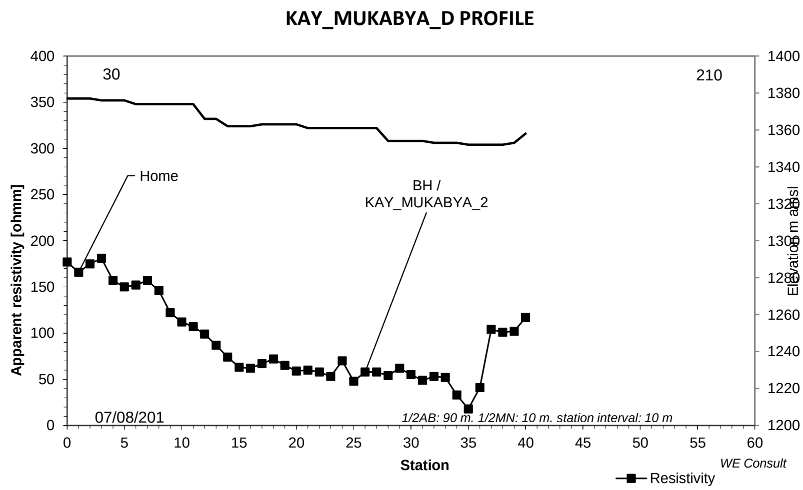
KAY_MUKABYA_B ELEVATION

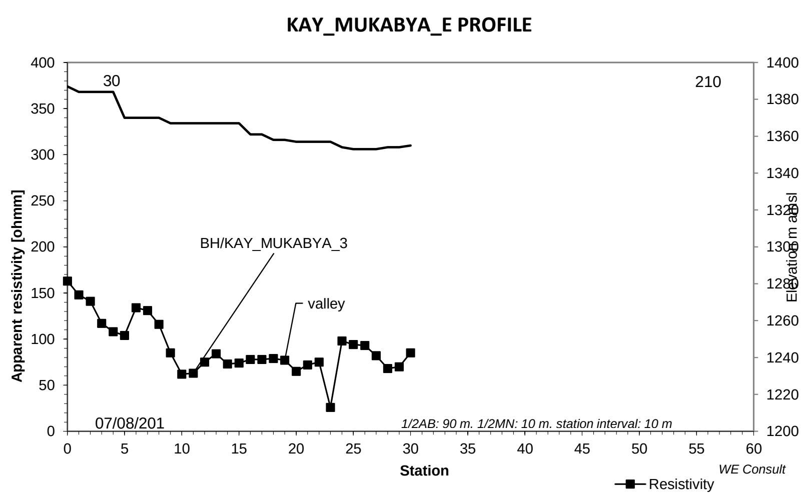


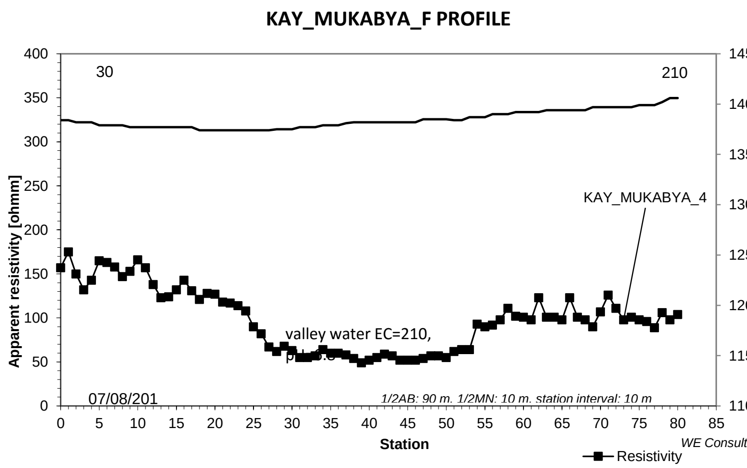
KAY_MUKABYA_C PROFILE

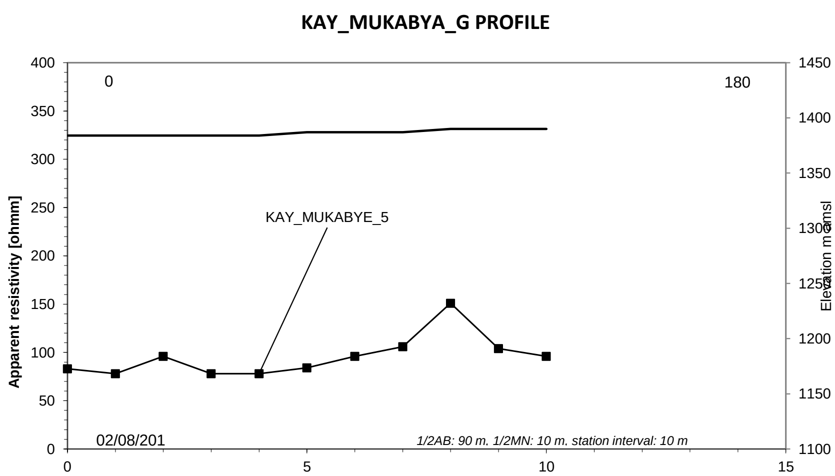


Resistivity Elevation





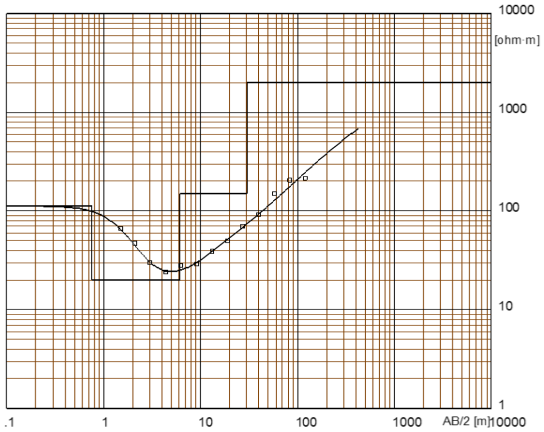

KAY_MUKABYA_F PROFILE
30
210
KAY_MUKABYA_4
valley water EC=210,
07/08/201
1/2AB: 90 m. 1/2MN: 10 m. station interval: 10 m
Apparent resistivity [ohmm]
Elevation m amsl
Station
WE Consult
Resistivity


KAY_MUKABYA_G PROFILE
0
180
KAY_MUKABYE_5
02/08/201
1/2AB: 90 m. 1/2MN: 10 m. station interval: 10 m
Apparent resistivity [ohmm]
Elevation m amsl

Best VES: **EX_2**

WE Consult

ELECTICAL SOUNDING_SCHLUM
KAY_MUKABYA_1
EXISTING BH | UNKNOWN CHARACTERISTICS
FUNCTIONAL



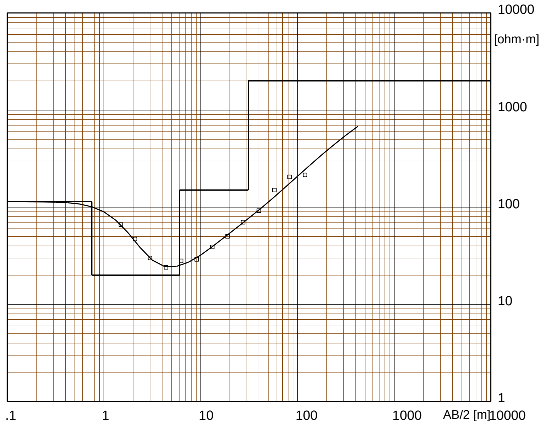
Location X = 226549 Y = 9808859 Z = 1390 Azim = 0 - 180

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
112	.76		1390
20	5.4	.76	1389.2
150	24	6.2	1383.8
2000		30	1360

The VES was carried on an existing borehole. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KAY_MUKABYA_2
EXISTING BH 12 m3/h | ARTESIAN
NOT FUNCTIONAL
TESTPUMPED UNDER THIS PROJECT



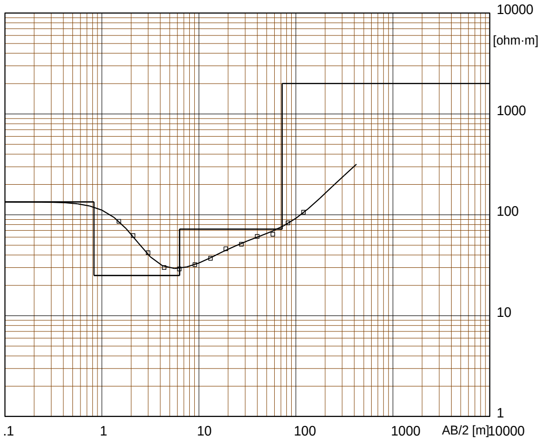
Location X = 222138 Y = 9807876 Z = 1348 Azim = 170 - 350

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
114	.75		1348
20	5.3	.75	1347.2
150	25	6	1342
2000		31	1317

The VES was carried on an existing borehole in Nyabugando village. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KAY_MUKABYA_3
EXISTING BH UNKNOWN YIELD| ARTESIAN
NOT FUNCTIONAL
TESTPUMPED UNDER THIS PROJECT



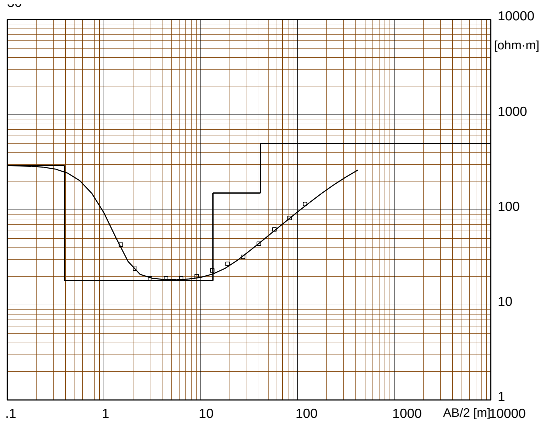
Location X = 220912 Y = 9809454 Z = 1384 Azim = 170 - 350

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
134	.83		1384
25	5.5	.83	1383.2
72	66	6.3	1377.7
2000		72	1312

The VES was carried on an existing borehole in Karambi village. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KAY_MUKABYA_4



Location X = 221743 Y = 9806376 Z = 1378 Azim = 10 - 190

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
292	.39		1378
18	13	.39	1377.6
150	28	13	1365
500		41	1337

The VES was carried on profile A (number 36) station 73. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

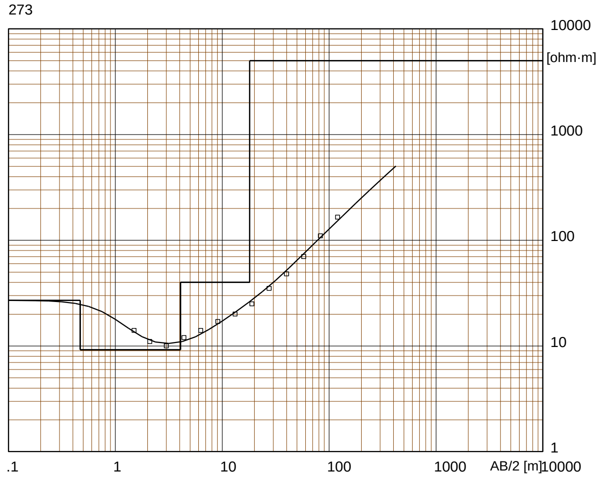
Best VES: **EX_2**

WE Consult

Best VES: **EX_2**

ELECTICAL SOUNDING_SCHLUM
KAY_MUKABYA_5
EXISTING BH | YIELD: 1 m3/h
NOT FUNCTIONAL

Electrical sounding Schlumberger - 273.WS3



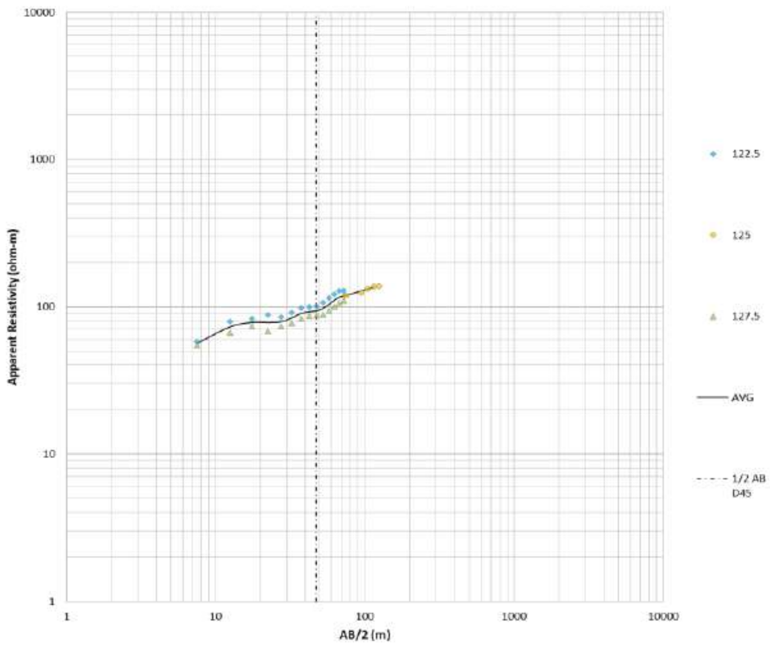
Location X = 225714 Y = 9805772 Z = 1392 Azim = 10 - 190

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
27	.47		1392
9.2	3.6	.47	1391.5
40	14	4.1	1387.9
5000		18	1374

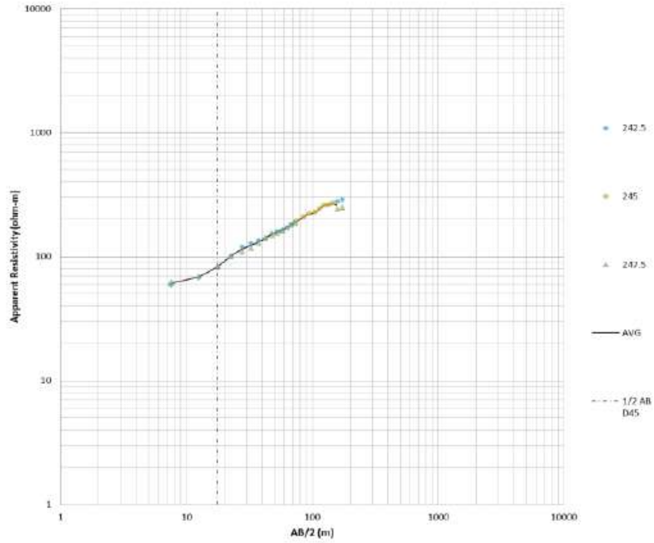
The VES was carried on borehole 273. The interpreted layers are: top soil, saturated sediments, clay, and hard rock.

W-GeoSoft / WinSev 6.3

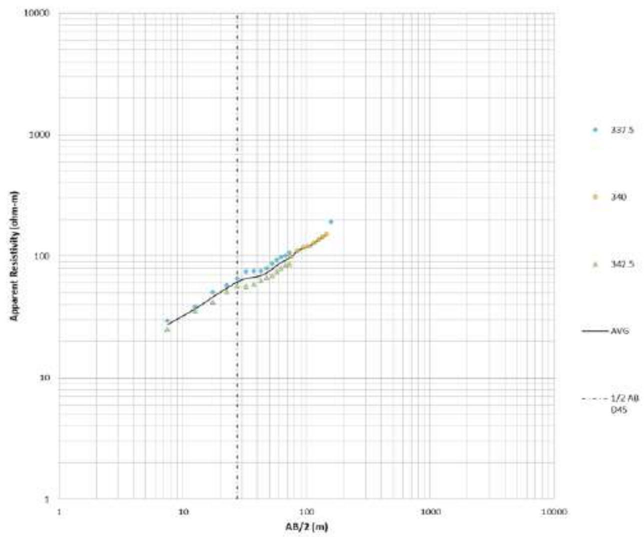
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MUKABYA_A_EX_1 (125 m)



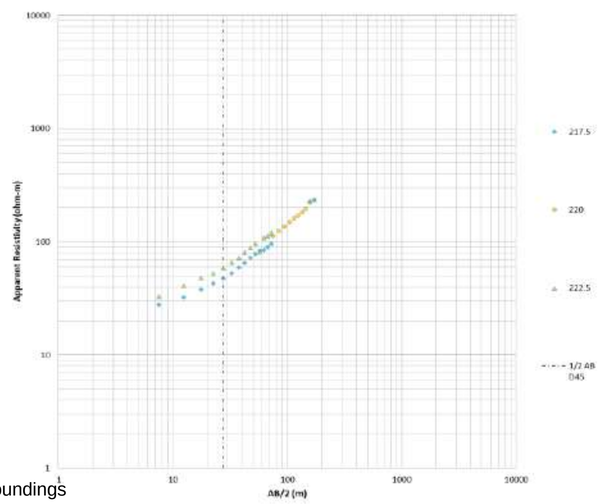
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MUKABYA_A_EX_2 (245 m)



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MUKABYA_A_EX_3 (340 m)

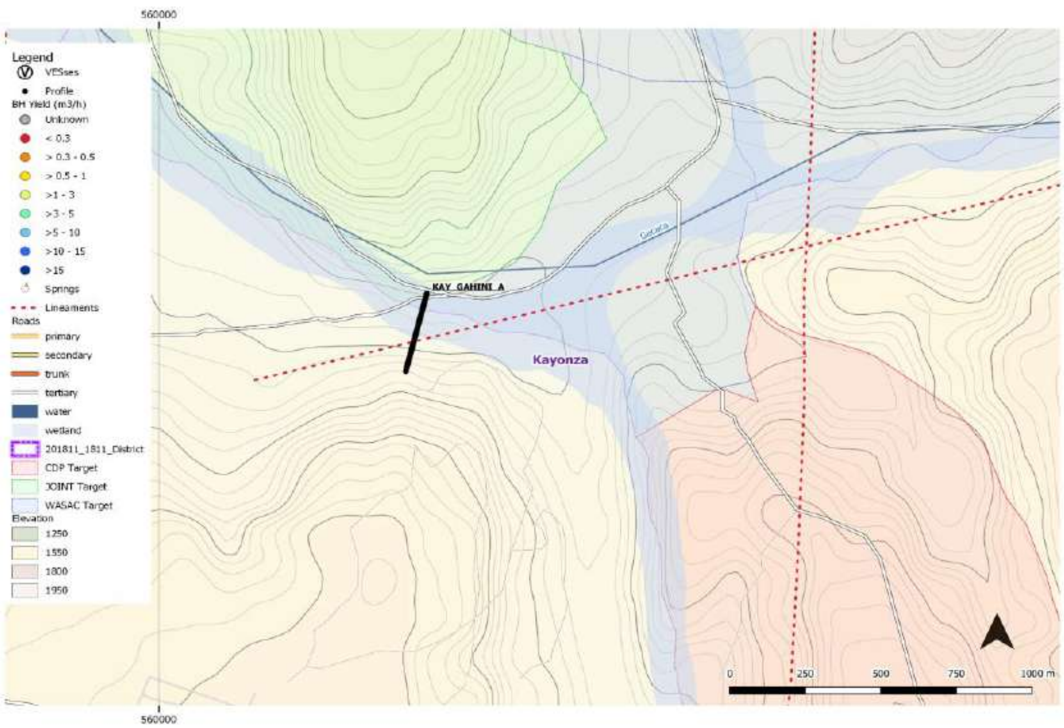


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MUKABYA_B_EX_4 (220 m)
(MASKED) - FURTHER VESSES ALSO MASKED



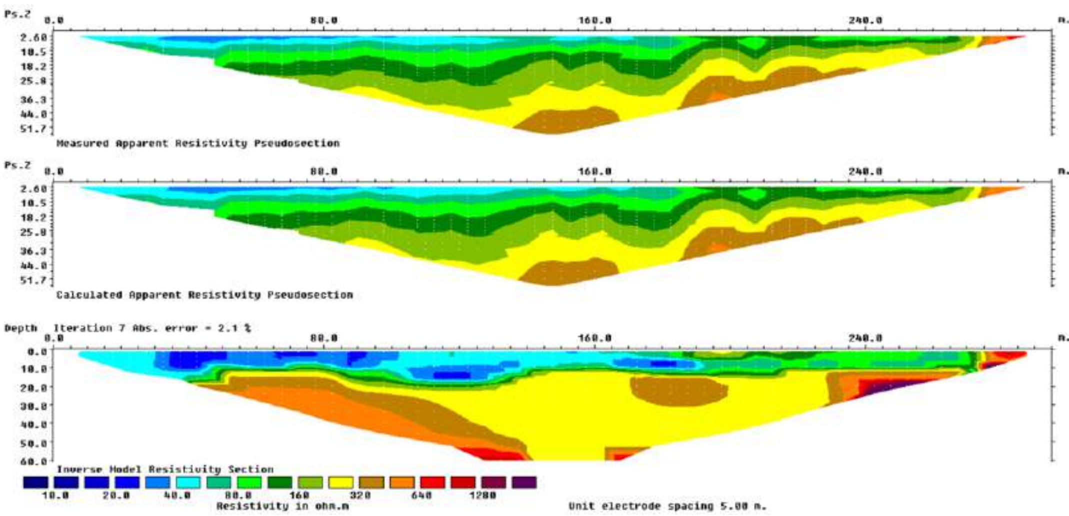
Location:	**KAY_GAHINI**				21
Recommended Site:		EX_1	coordinate (E) 560848	coordinate (N)	4797203
Expected DTB (m):			Altitude (amsl)	1437	
Recommended Depth (m):			Accessibility Site:	Accessible	
Alternative Site:			coordinate (E)	coordinate (N)	
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:		
Expected Formation:		Quartzite Schists and Sediments	Accessibility Village:		
Int yield (l/h) :	2,134	SWL (m asl): 1,432	Target:	JOINT	
Remarks:	This site was intended for confirmation of a class 1 quartzite ridge target, but the site was inaccesible. An attempt was made to run the profile just west of the ridge in the softer formations, but as expected the results lack the contrast needed to make conclusive argumentations. The VES extractions are masked by the sediment clay, which make it difficult to get useful information from them. The anomaly on EX_1 is good and its location would at least lend itself to a handpump borehole, even without the additional information from the VES.				

Location map geophysical measurements

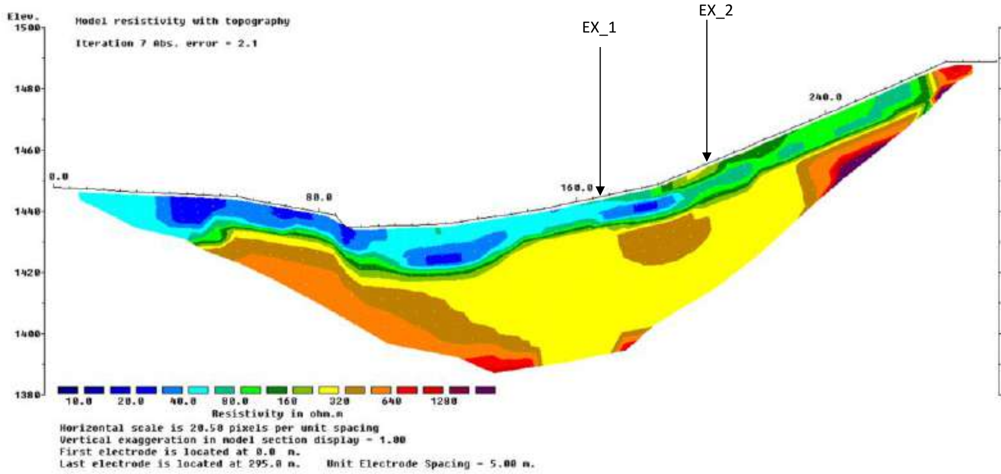


Site	21		Village	Nyagahandagaza			
Cell	Juru		Sector	Gahini			
			District	Kayonza			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

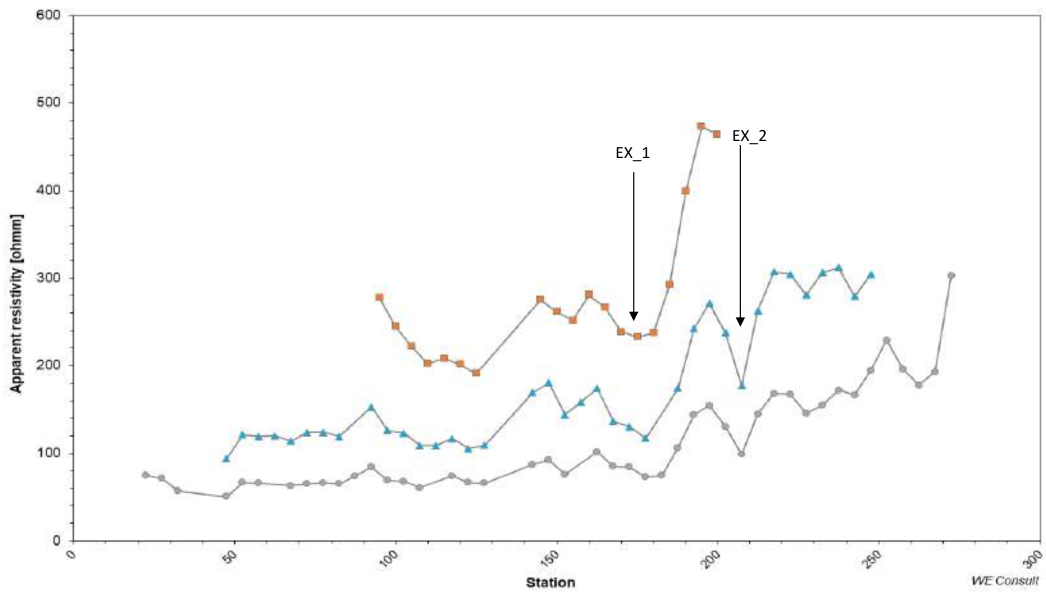
KAY_GAHINI_A SCHLUMBERGER PSEUDO



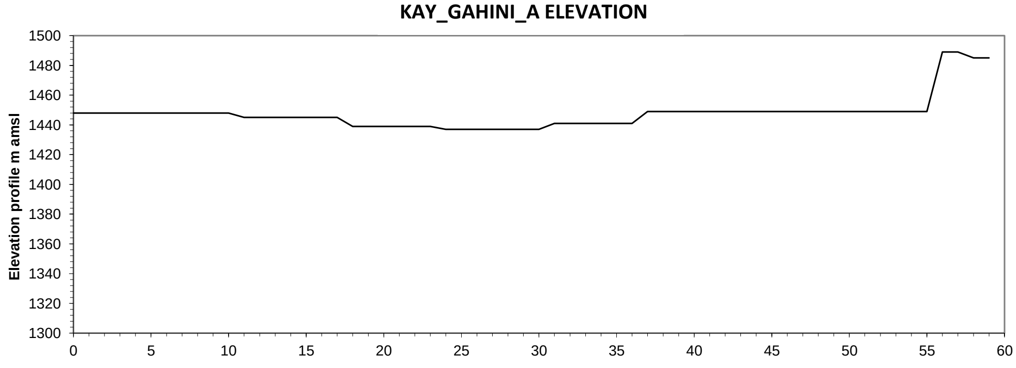
KAY_GAHINI_A SCHLUMBERGER TOPO



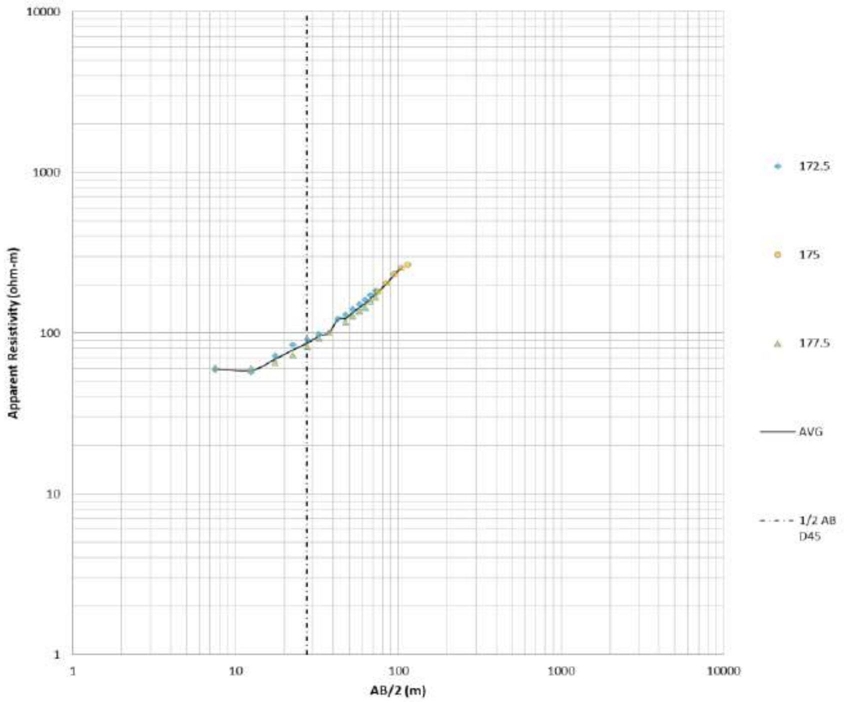
KAY_GAHINI_A SCHLUMBERGER 1D EXTRACTION



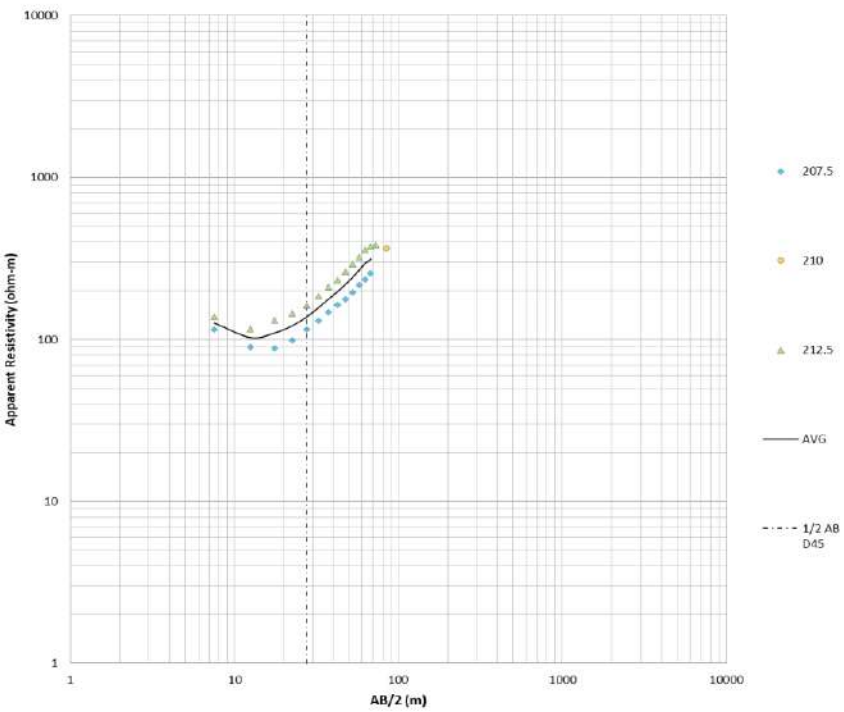
KAY_GAHINI_A ELEVATION



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_GAHINI_A_EX_1 (175 m)
(MASKED

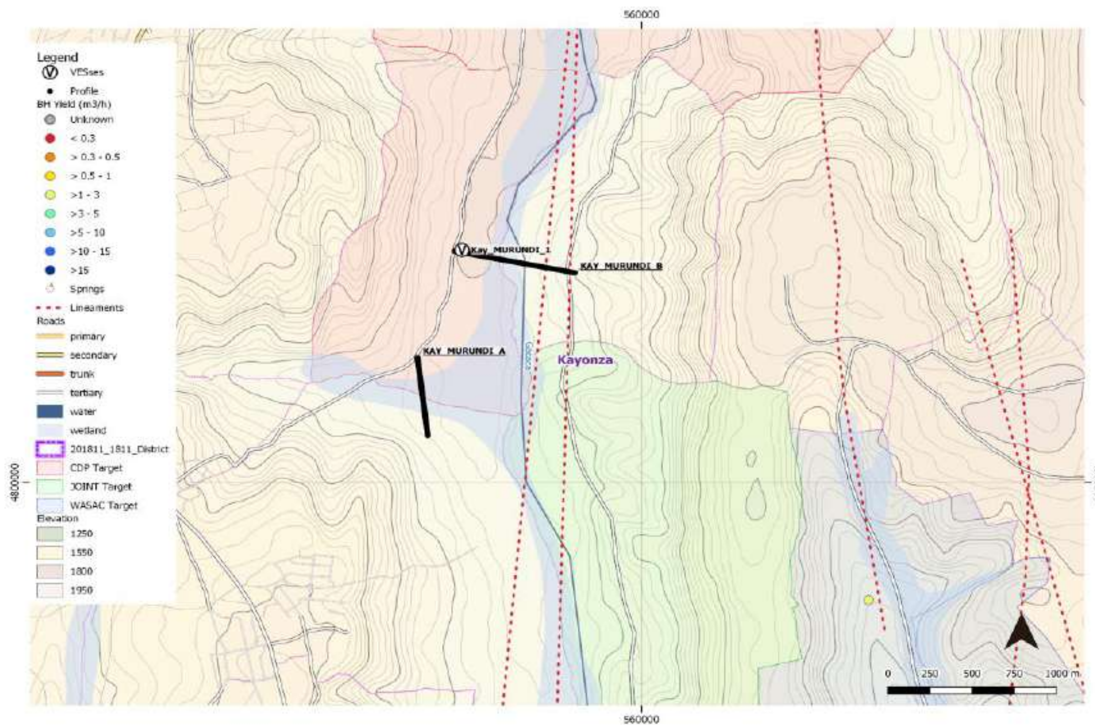


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_GAHINI_A_EX_2 210 m)
(MASKED)



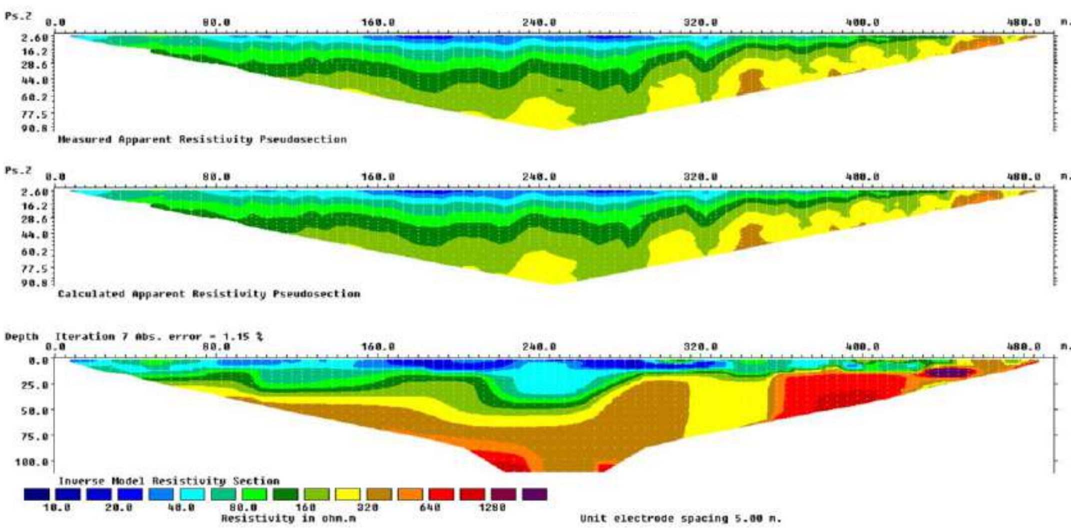
Location:	KAY_MURUNDI				22
Recommended Site:	EX_2	coordinate (E)	558709	coordinate (N)	4800480
Expected DTB (m):		Altitude (amsl)		1414	
Recommended Depth (m):		Accessibility Site:		Accessible	
Alternative Site:		coordinate (E)		coordinate (N)	
Expected DTB (m):		Altitude (amsl)			
Recommended Depth (m):		Accessibility Site:			
Expected Formation:	Quartzite Schists and Sediments	Accessibility Village:		Good	
Int yield (l/h) : 1,978	SWL (m asl): 1,413	Target:		CDP	
Remarks:	Profile A is targeting a class 1 quartzite ridge valley where an anomaly is visible in the valley on the profile. The extracted VES shows only masked results. The anomaly is likely at the weakest point in the valley where more weathering is expected. Profile B was done in a main valley but the results do not show significant potential.				

Location map geophysical measurements

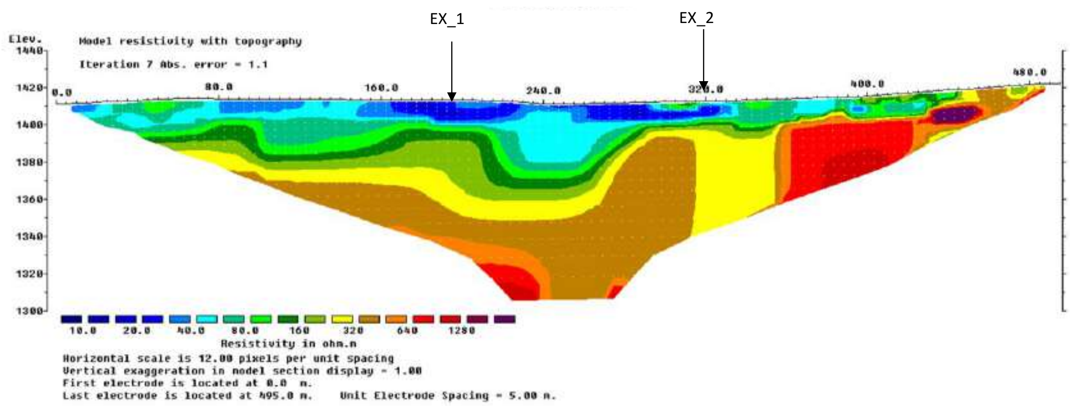


Site	22		Village	Kanyegera			
Cell	Ryamanyoni		Sector	Murundi			
			District	Kayonza			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	10						
Lineament (0-20 points)	10						
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	27						
Remarks							
Geophysical measurements							

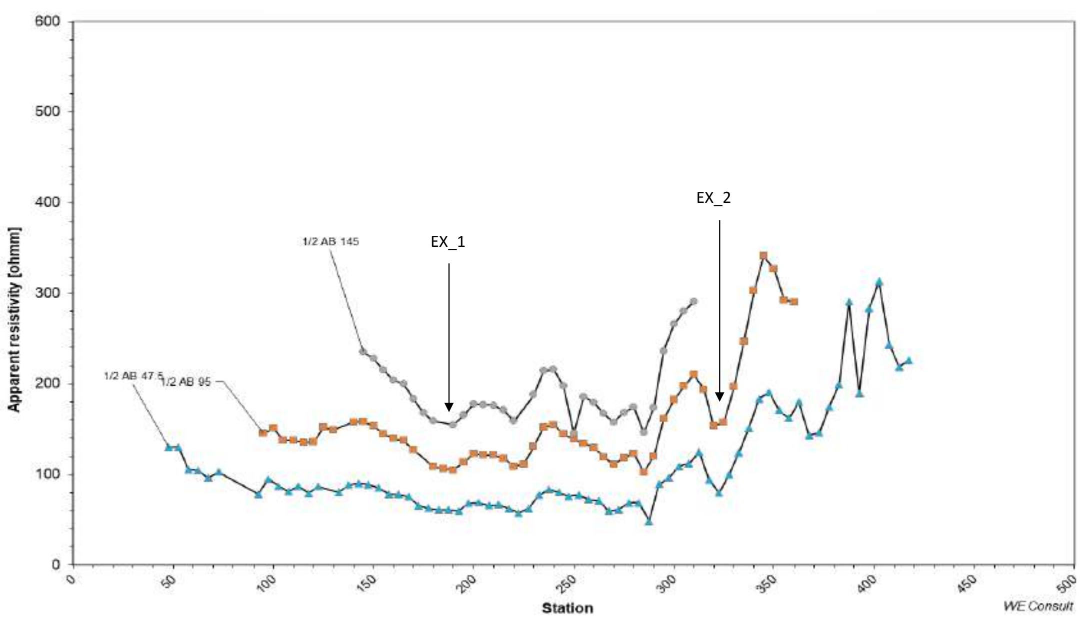
KAY_MURUNDI_A SCHLUMBERGER PSEUDO



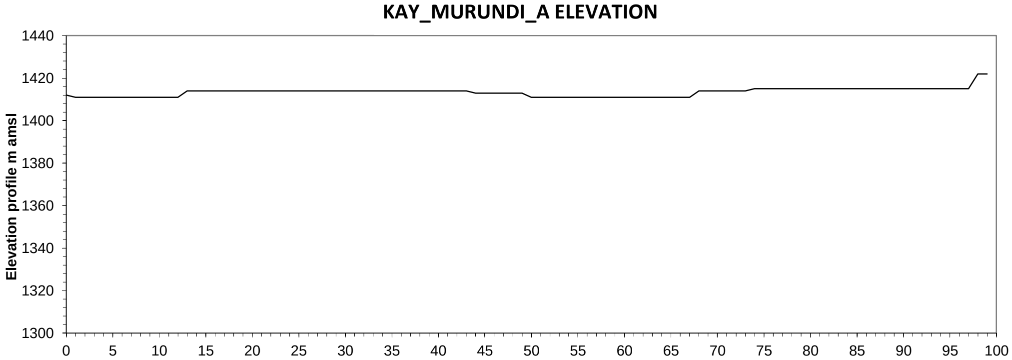
KAY_MURUNDI_A SCHLUMBERGER TOPO



KAY_MURUNDI_A SCHLUMBERGER 1D EXTRACTION

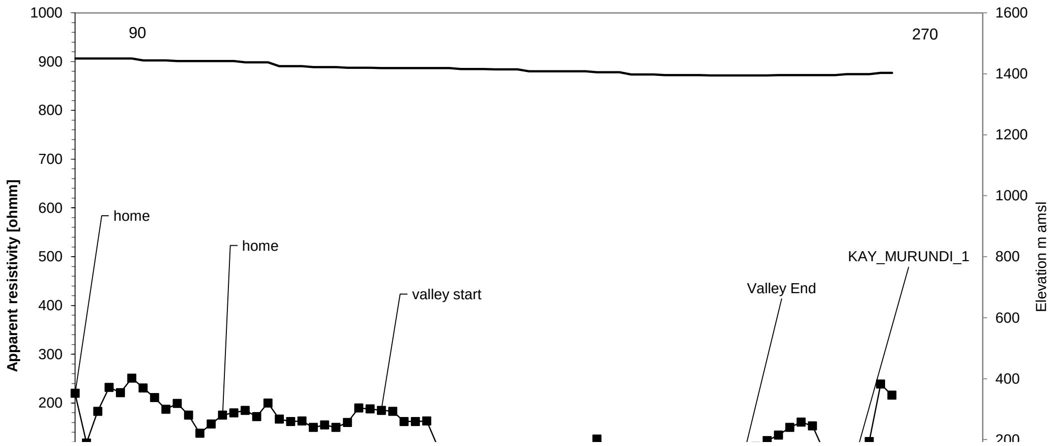


KAY_MURUNDI_A ELEVATION



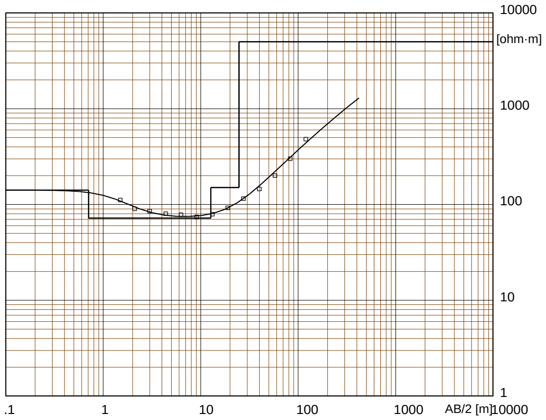
Station

WE Consult



Best VES: **EX_2**

ELECTICAL SOUNDING_SCHLUM
KAY_MURUNDI_1



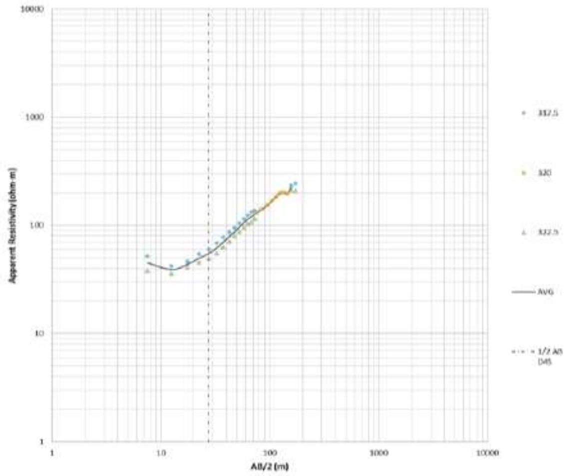
Location X = 225167 Y = 9801380 Z = 1417 Azim = 10 - 190

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
141	.71		1417
72	12	.71	1416.3
150	12	13	1404
5000		25	1392

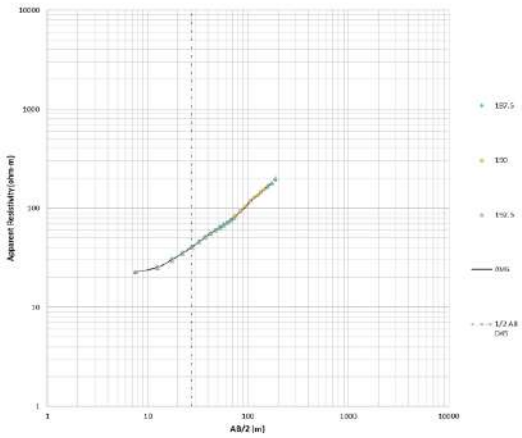
The VES was carried on profile A (Kay-46) at station 68. The interpreted layers are: top soil, sandy clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MURUNDI_A_EX_1 (320 m)
(MASKED)

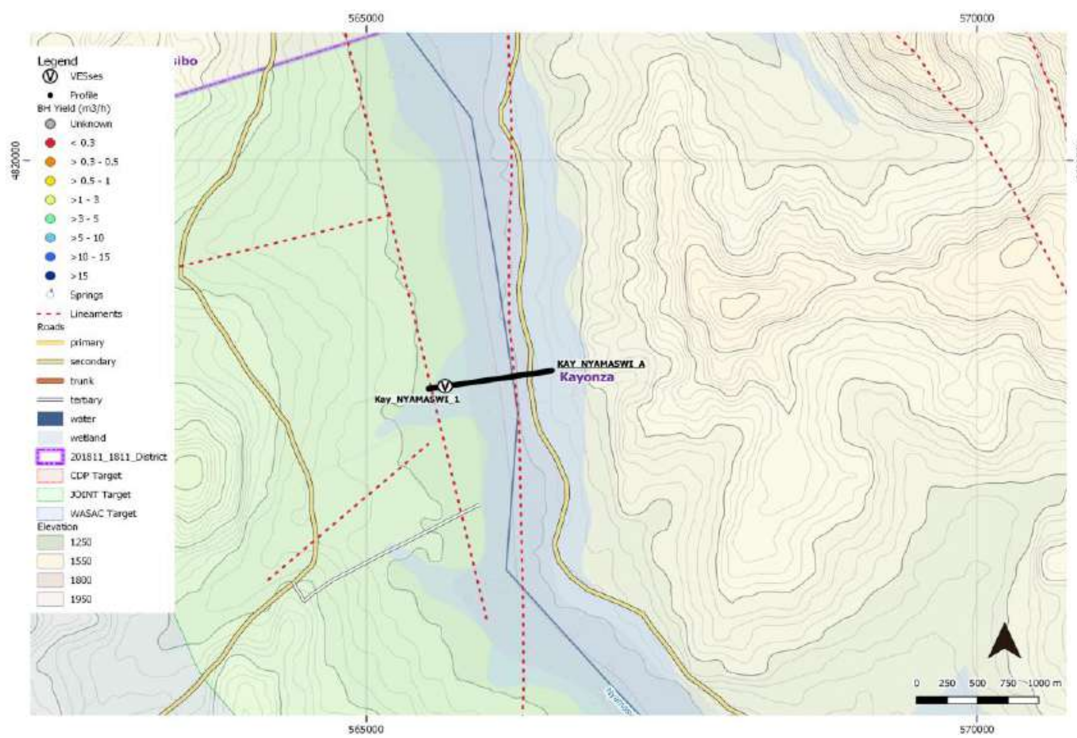


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MURUNDI_A_EX_2 (190 m)
(MASKED)



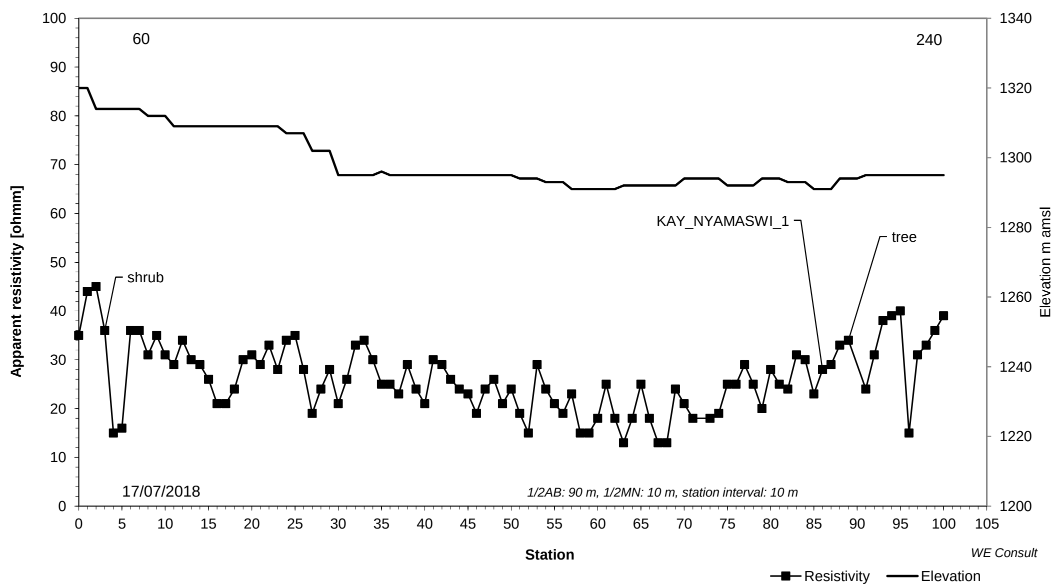
Location:	KAY_NYAMASWI				23
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	1025
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	1018
Recommended Depth (m):				Accessibility Site:	None
Expected Formation:		Schists & Sediments		Accessibility Village:	None
Int yield (l/h) :	2,728	SWL (m asl):	1,365	Target:	JOINT
Remarks:	Results homogeneous throughout and VES results are masked. No conclusions can be attached to this site.				

Location map geophysical measurements



Site	23		Village	Gakoma			
Cell	Buhabwa		Sector	Murundi			
			District	Kayonza			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	10						
Lineament (0-20 points)	10						
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	20						
Remarks							
Geophysical measurements							

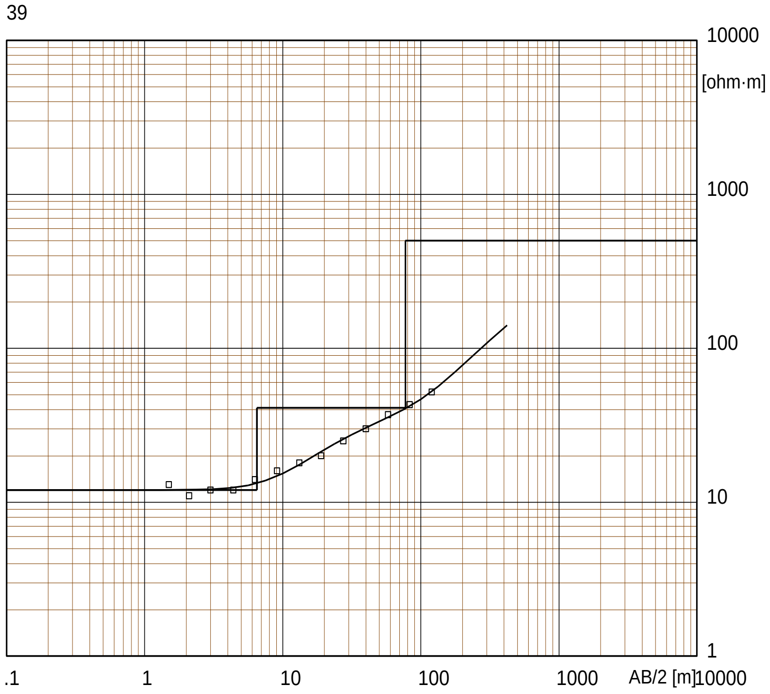
BUG_NYARUGENGE_A PROFILE



Best VES: **VES_1**

ELECTICAL SOUNDING_SCHLUM
KAY_NYAMASWI_1

Electrical sounding Schlumberger - 39.WS3



Location X = 231855 Y = 9817956 Z = 1288 Azim = 0 - 180

Model Resistivity	**Thickness**	**Depth**	**Altitude**
[ohm·m]	[m]	[m]	[m]
12	6.5		1288
41	71	6.5	1281.5
500		78	1210

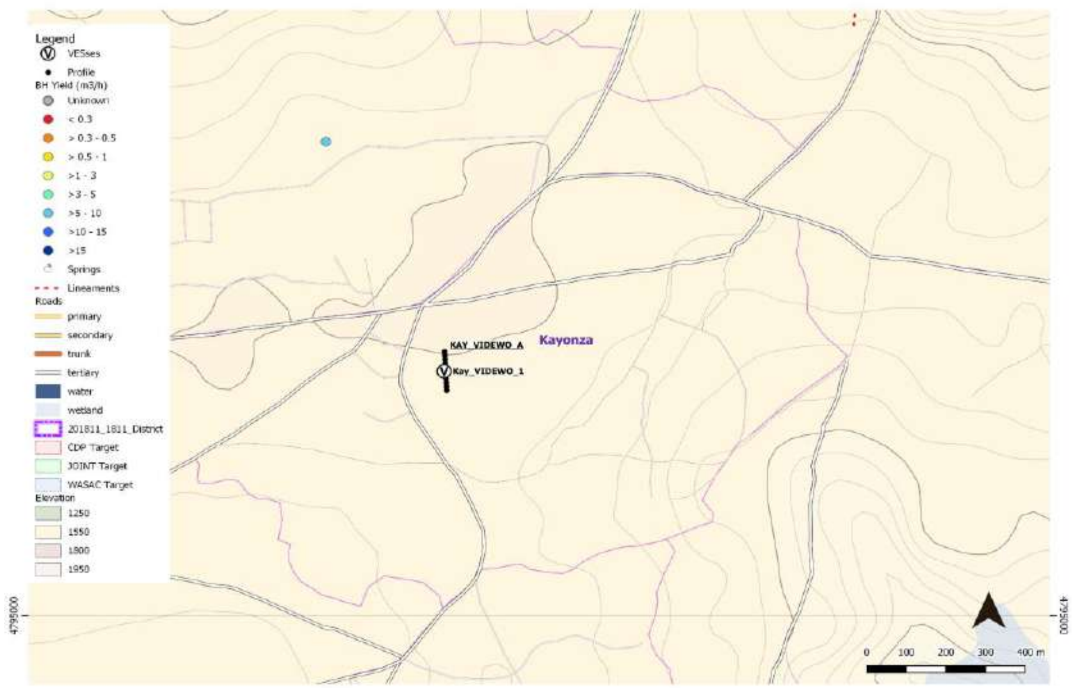
The VES was carried on profile A (number 39) station 86. The interpreted layers are: top soil, clay, and hard rock.

W-GeoSoft / WinSev 6.3

WE Consult

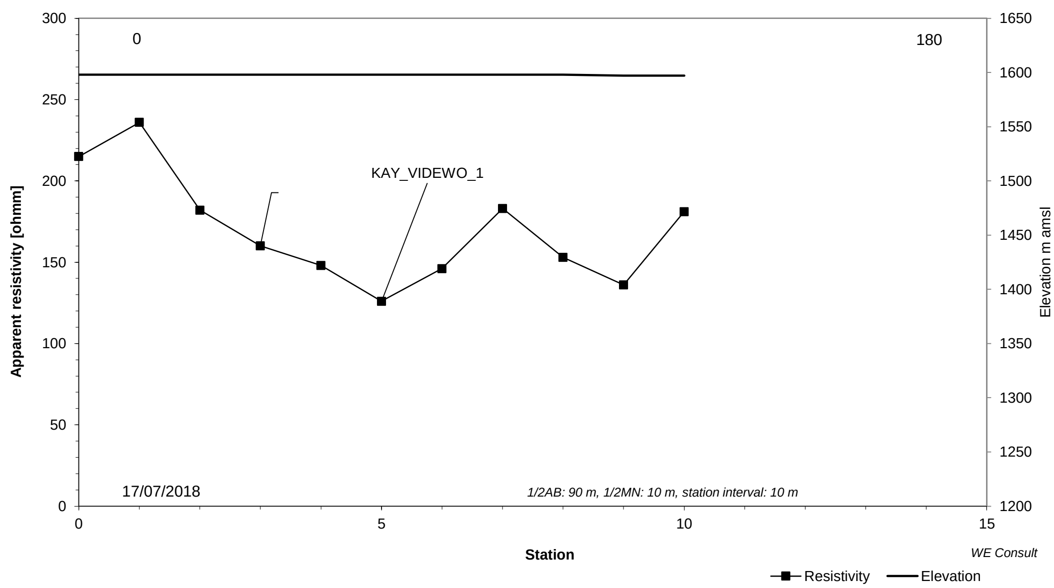
Location:	KAY_VIDEWO					24
Recommended Site:				coordinate (E)	coordinate (N)	
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:	Accessible	
Alternative Site:				coordinate (E)	coordinate (N)	
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:	None	
Expected Formation:		Schists		Accessibility Village:	None	
Int yield (l/h) :	3,258	SWL (m asl):	1,515	Target:	NONE	
Remarks:	Calibration of existing borehole. Low yielding with deep SWL. Depression in VES looks similar to other calibrations with the depression (likely water strike) deeper (the other calibrations had shallow ground water).					

Location map geophysical measurements



Site	24		Village	1			
Parish	Cell		Sector				
			District	#N/A			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

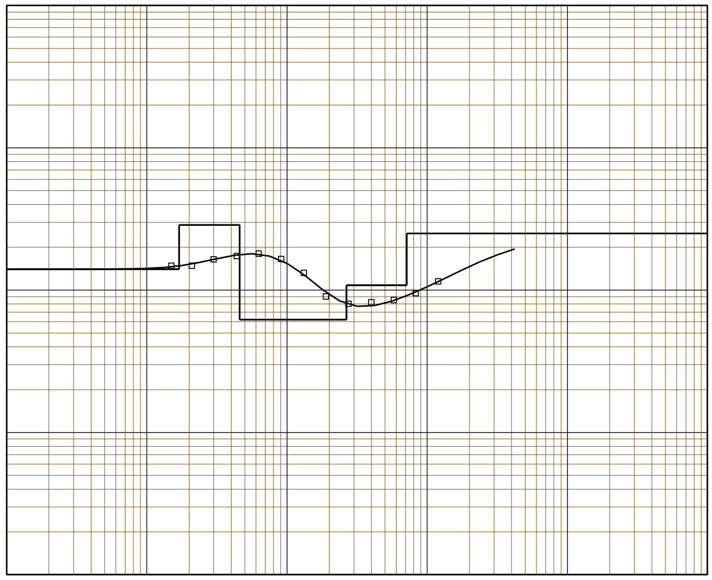
KAY_VIDEWO_A PROFILE



Best VES: **VES_1**

ELECTICAL SOUNDING_SCHLUM
KAY_VIDEWO_1
EXISTING BH: 1 m3/h | SWL 86 mblg

Electrical sounding Schlumberger - 265.WS3



Location X = 224205 Y = 97995528 Z = 1607 Azim = 10 - 190

Model Resistivity	**Thickness**	**Depth**	**Altitude**
[ohm·m]	[m]	[m]	[m]
140	1.7		1607
287	2.9	1.7	1605.3
62	22	4.6	1602.4
108	45	27	1580
250		72	1535

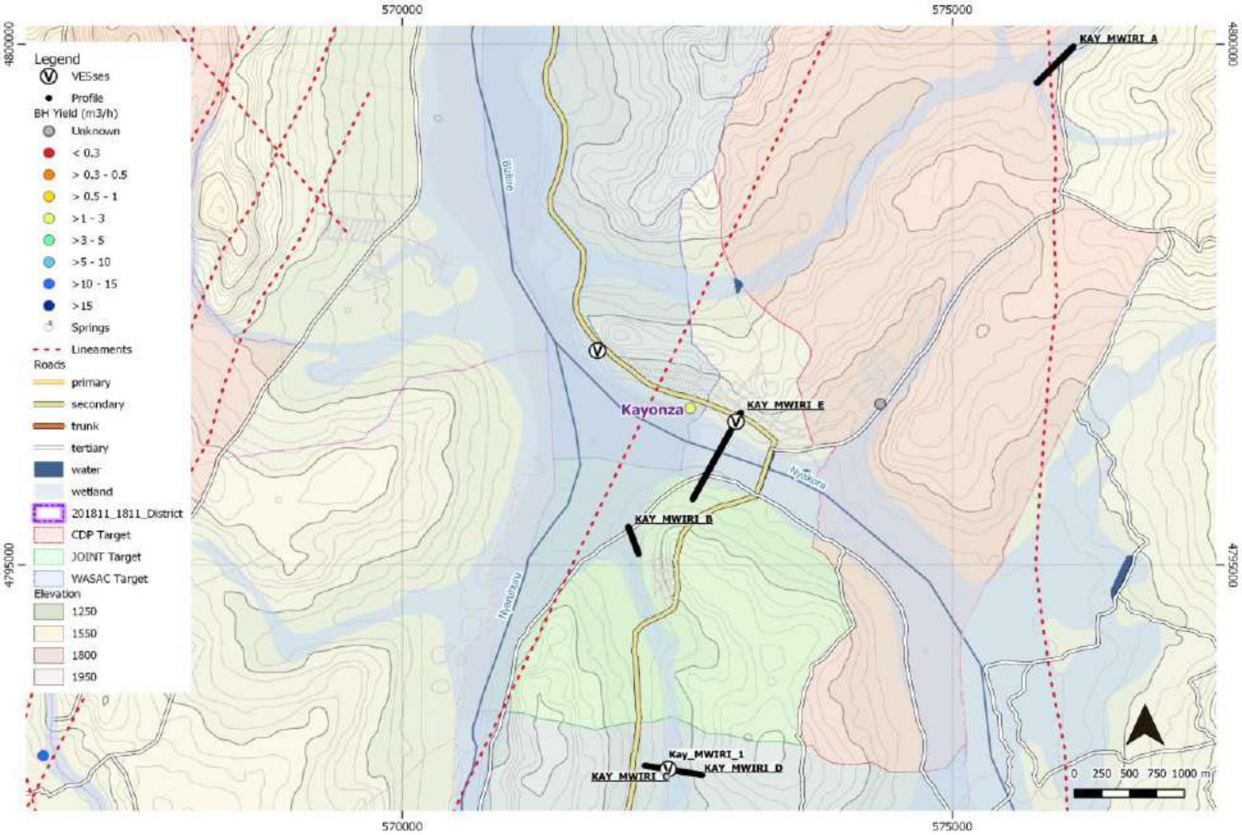
The VES was carried on borehole 265. The interpreted layers are: top soil, sand, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

WE Consult

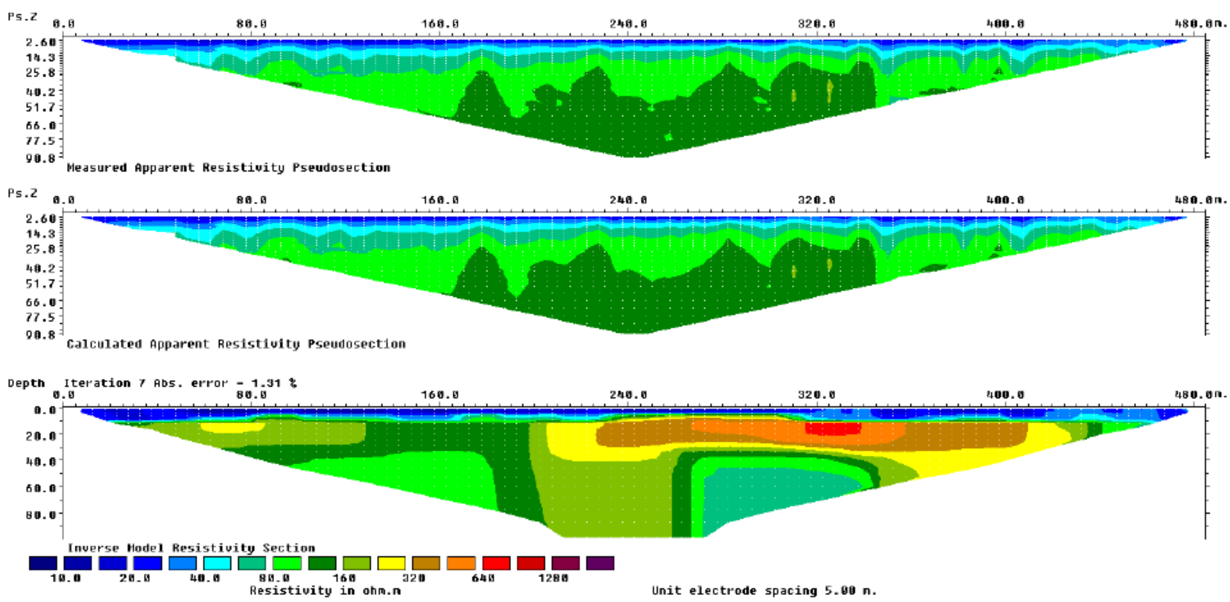
Location:	**KAY_MWIRI**						25
Recommended Site:		EX_1		coordinate (E)	575940	coordinate (N)	4799809
Expected DTB (m):				Altitude (amsl)		1377	
Recommended Depth (m):				Accessibility Site:		Accessible	
Alternative Site:		VES_1		coordinate (E)	572416	coordinate (N)	4793043
Expected DTB (m):				Altitude (amsl)		1336	
Recommended Depth (m):				Accessibility Site:			
Expected Formation:		Quartzite Schists and Sediment		Accessibility Village:		Good	
Int yeild (l/h) :	2,130	SWL (m asl):	1,341	Target:		CDP	
Remarks:	Targeting potential sites in water stressed areas. Profile E is crossing a Class 2 major valley target, while Profile A is focussing on a Class 1 quartzite valley. The other profiles are focussing on more unlikely targets. 1D profile VESes (1 and 2) show higher resistivities than the nearby calibration, and the profiles are very unpronounced, except profile D which nicely shows a side valley. VES_1 is recommended for a hand pump borehole. The 1D extraction of Profile A shows that the deep resistivities almost match the shallower ones, signifying that in fact we are measuring in the softer surrounding formations and not the quartzite. With that noted, EX_1 still shows potential for a hand pump borehole, just not for production.						

Location map geophysical measurements

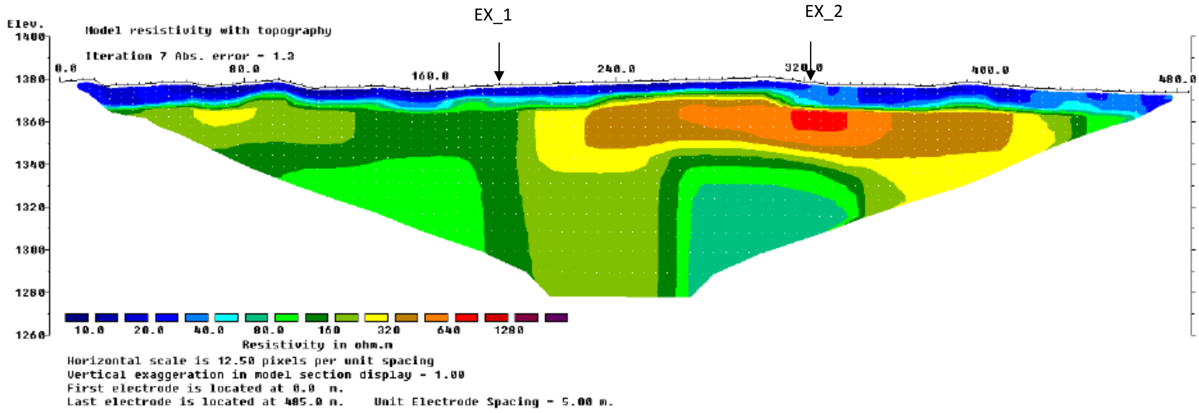


Site	KAY_MWIRI		Village	1			
Parish	Cell		Sector				
			District	#N/A			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	18	19					
Lineament (0-20 points)	5	5					
Anomaly (0-30 points)	9						
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	47	31					
Remarks							
Geophysical measurements							

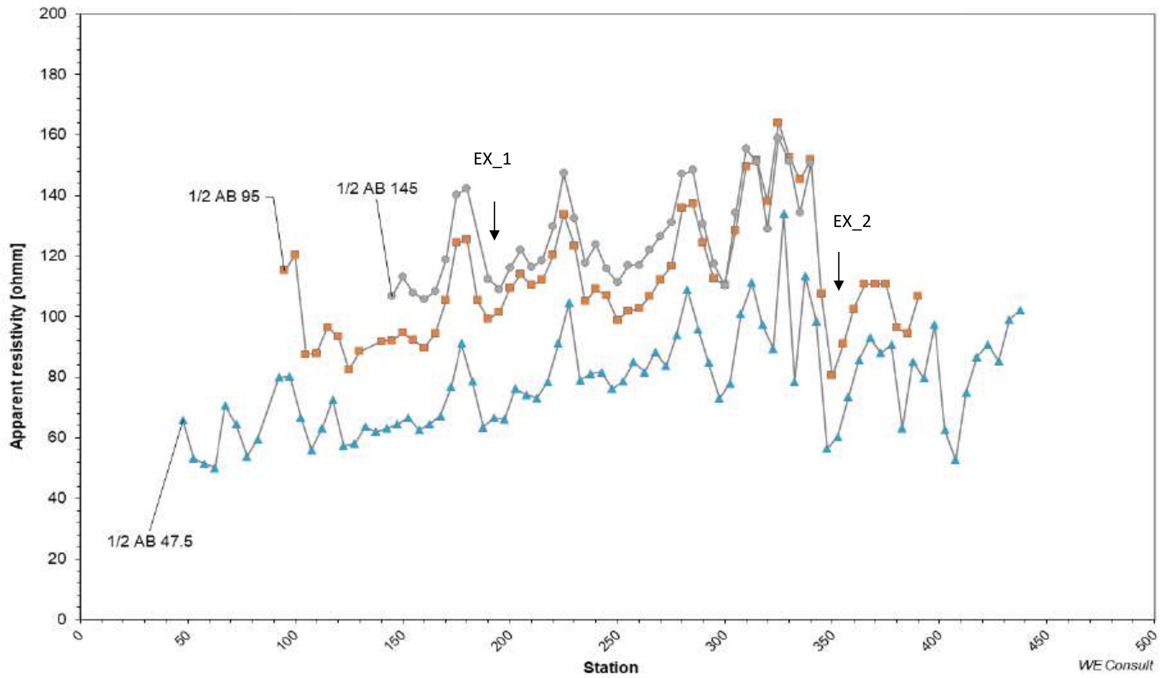
KAY_MWIRI_A SCHLUMBERGER PSEUDO



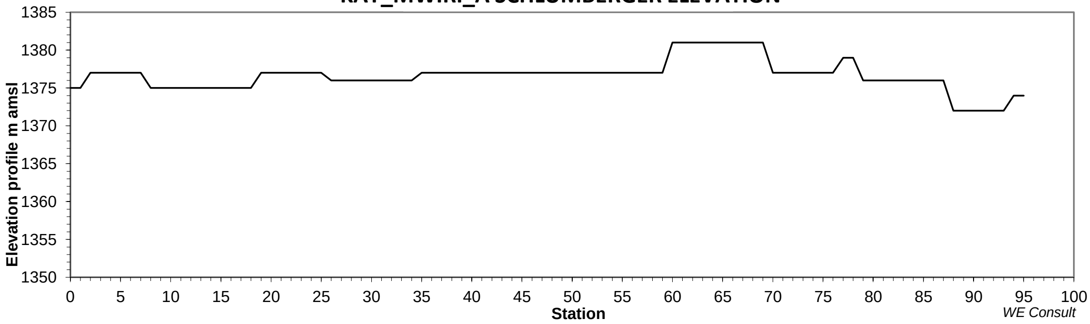
KAY_MWIRI_A SCHLUMBERGER TOPO



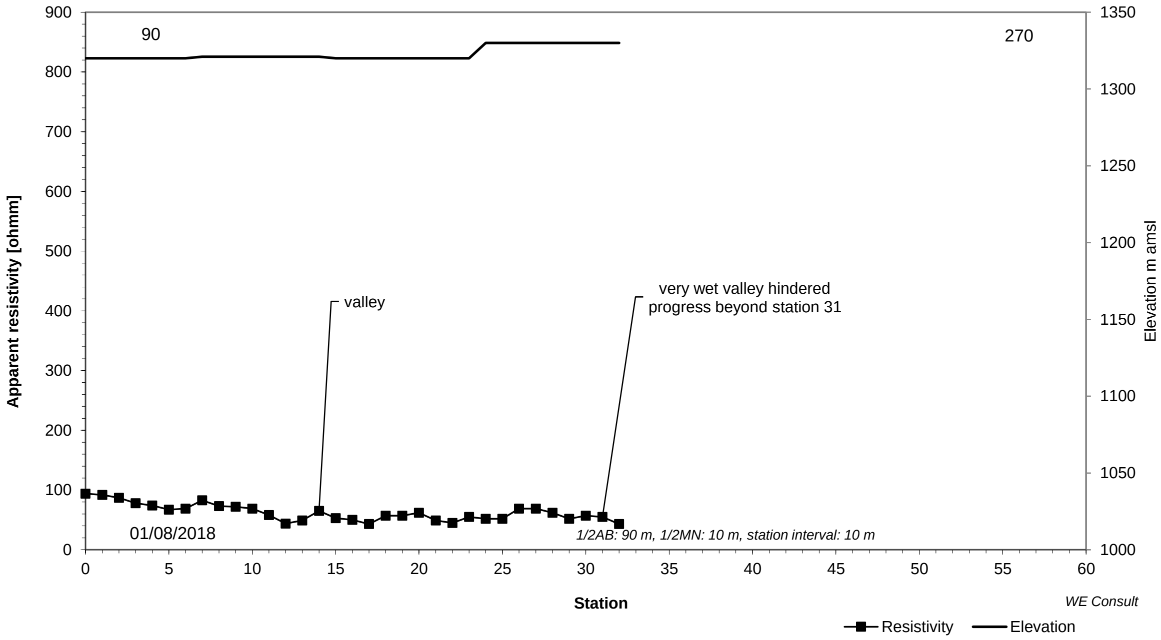
KAY_MWIRI_A SCHLUMBERGER 1D EXTRACTION



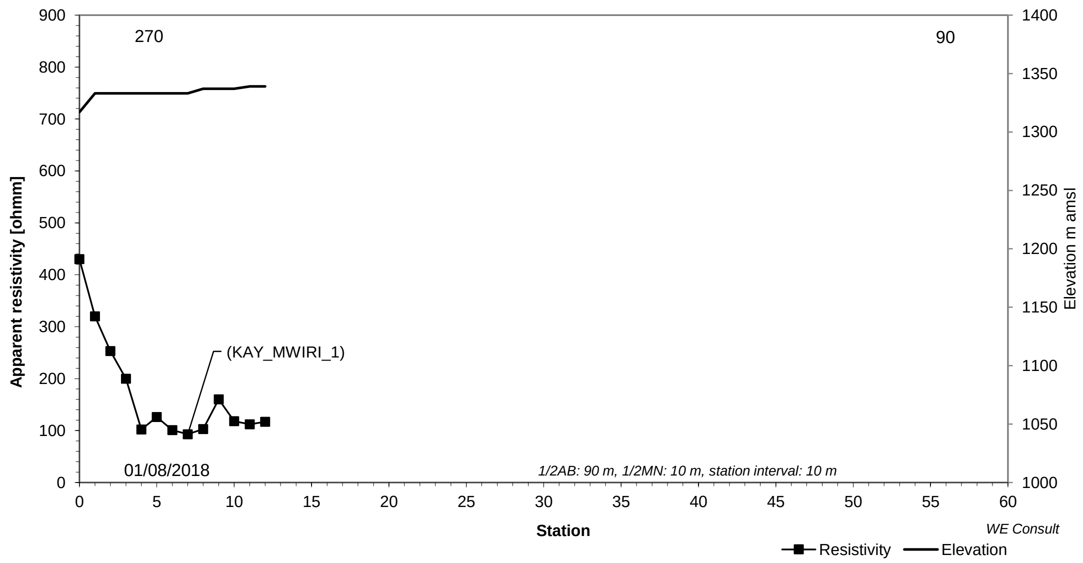
KAY_MWIRI_A SCHLUMBERGER ELEVATION



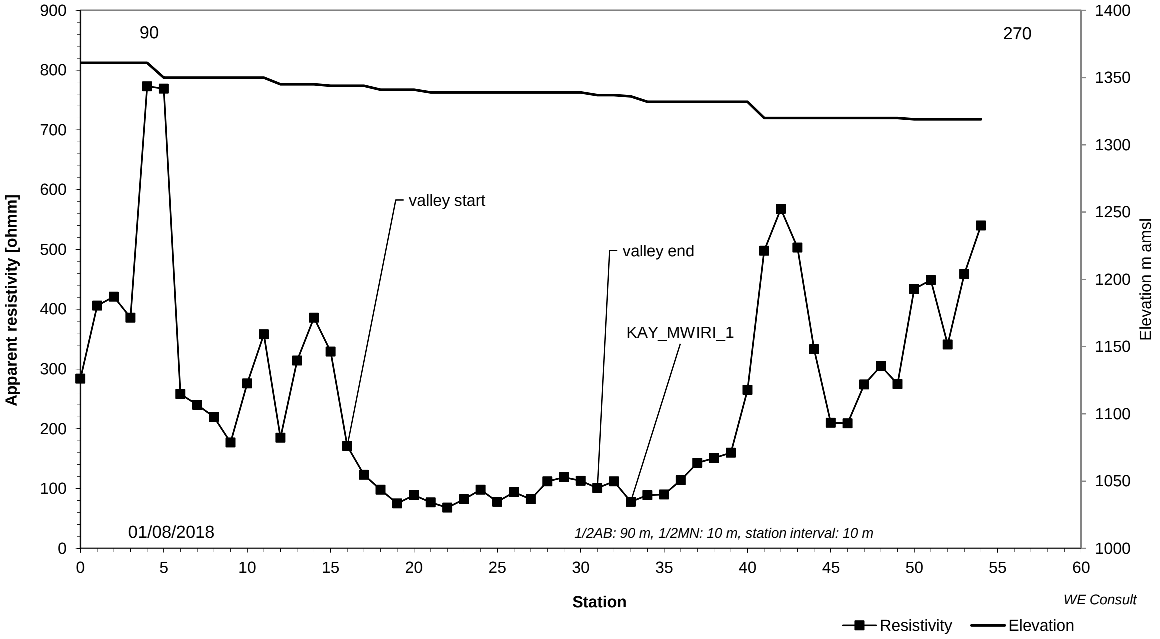
KAY_MWIRI_B PROFILE



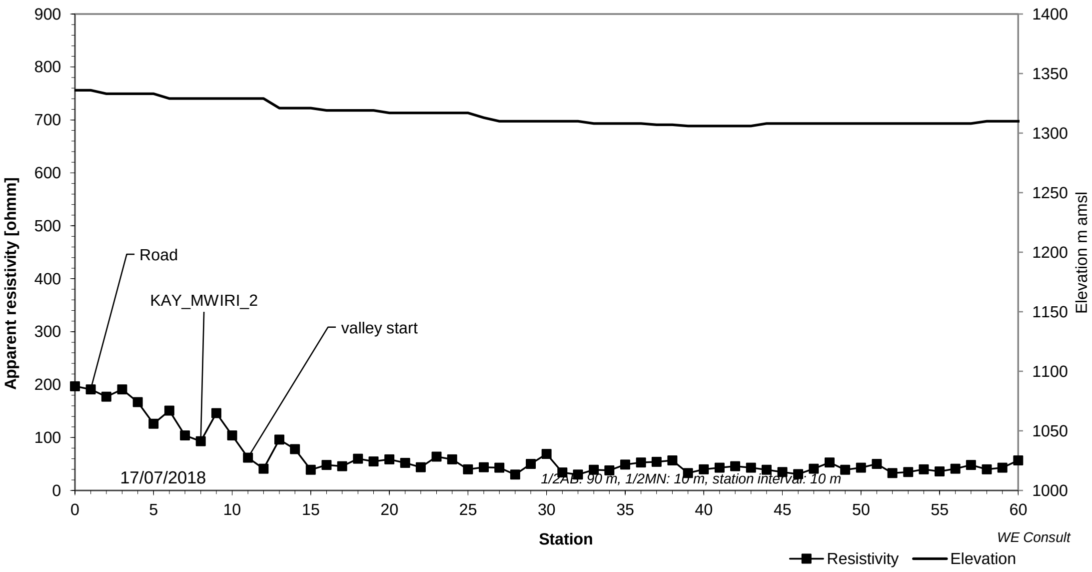
KAY_MWIRI_C PROFILE



KAY_MWIRI_D PROFILE



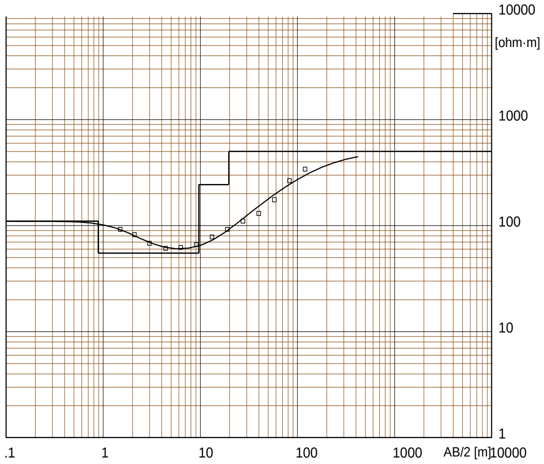
KAY_MWIRI_E PROFILE



Best VES:

WE Consult

ELECTICAL SOUNDING_SCHLUM
KAY_MWIRI_1



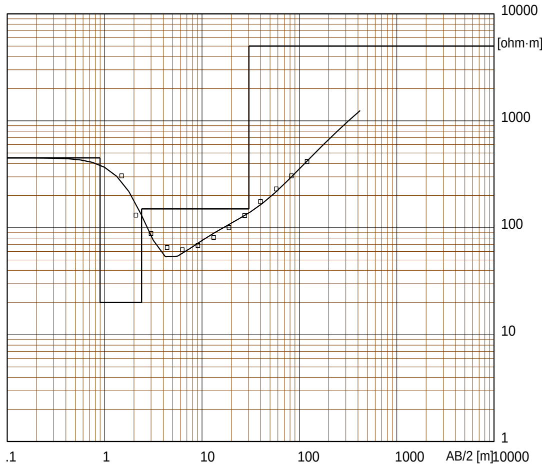
Location X = 238671 Y = 9792943 Z = 1314 Azim = 20-200

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
110	.89		1314
55	8.8	.89	1313.1
244	9.9	9.7	1304.3
500		20	1294

The VES was carried on profile A (Kay-49) at station 33. The interpreted layers are: top soil, clay, sandy clay and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KAY_MWIRI_2



Location X = 239282 Y = 9796280 Z = 1476 Azim = 20/200

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
450	.9		1476
20	1.5	.9	1475.1
150	28	2.4	1473.6
5000		30	1446

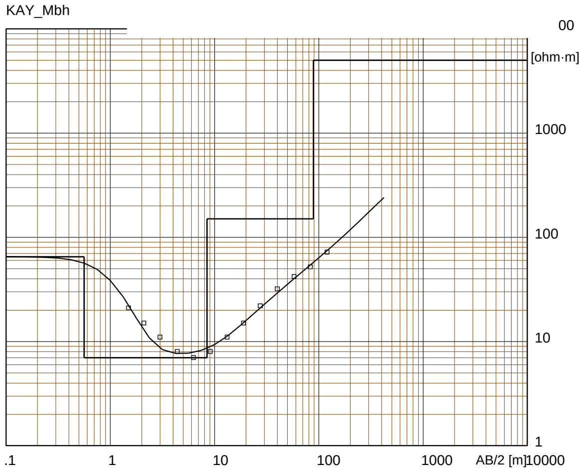
The VES was carried out on station 8 of profile A (KAY_48). The interpreted layers are: top soil, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
KAY_MWIRI_3
EXISTING BH: APPARENT MONITORING BH

Electrical soundi

KAY_Mbh



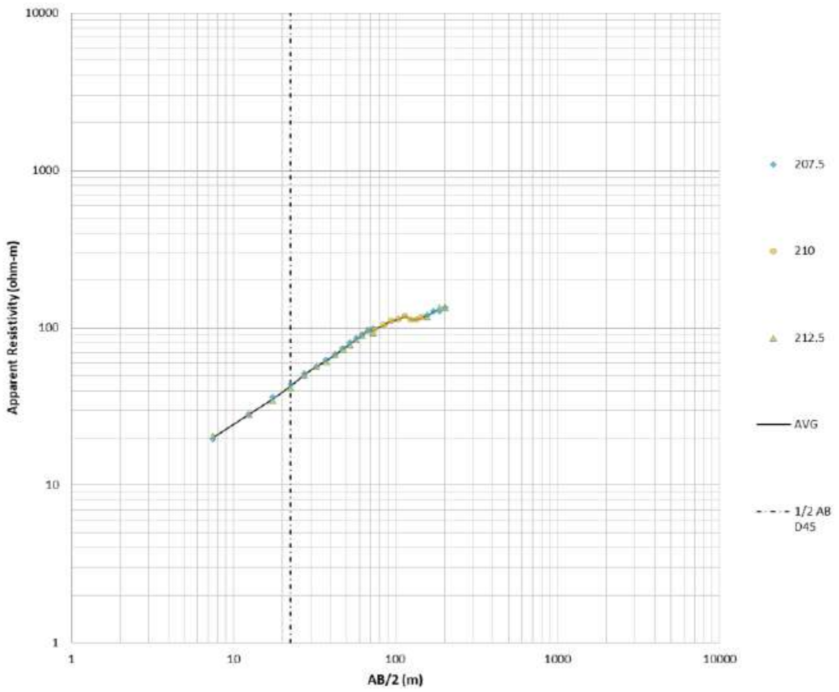
Location X = 238021 Y = 9796960 Z = 1308 Azim = 20/200

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
65	.56		1308
7	7.9	.56	1307.4
150	80	8.5	1299.5
5000		88	1220

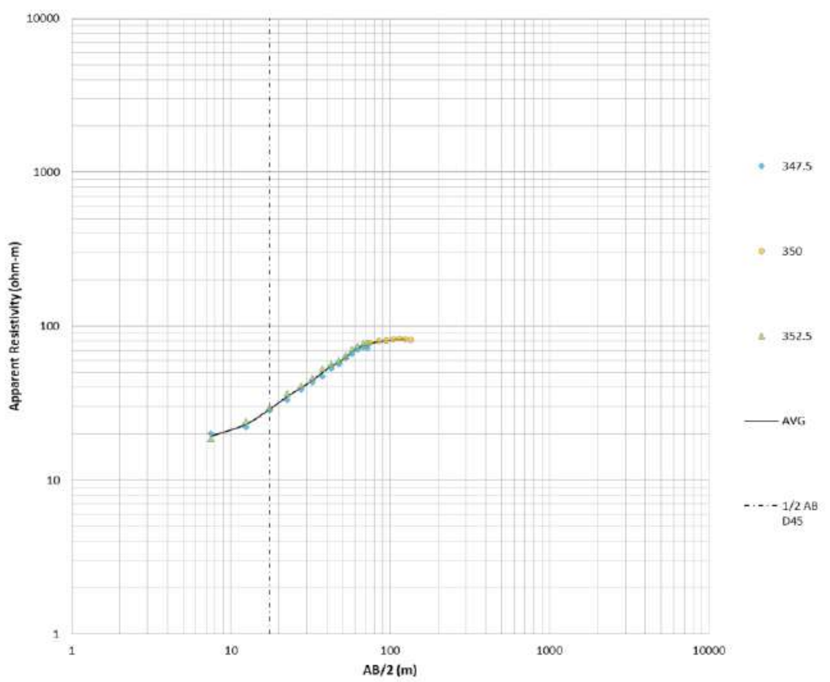
The VES was carried out on a monitoring bh in Kayonza district. The interpreted layers are: top soil, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MWIRI_EX_1 (210 m)
IN DEPRESSION OF RESISTIVITY VALUES
MASKED

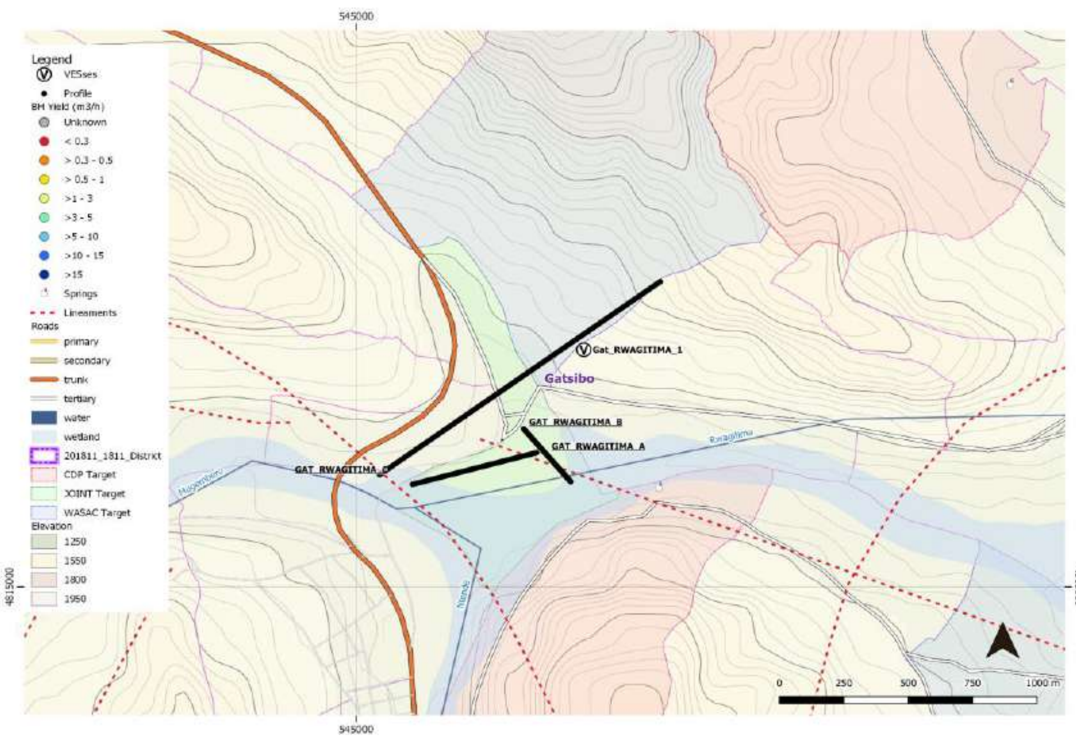


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
KAY_MWIRI_A_EX_2 (350 m)
IN ANOMALY ON 1D EXTRACTION
MASKED



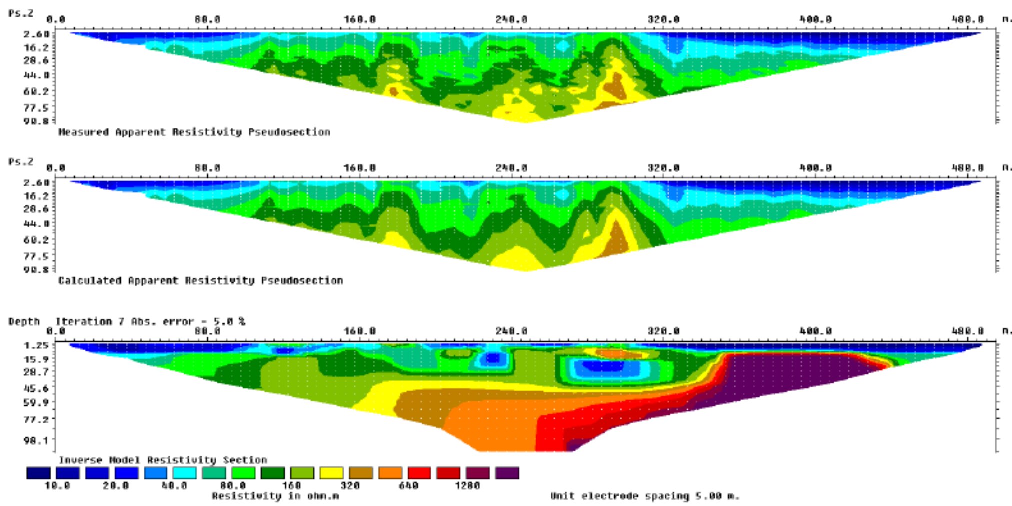
Location:	GAT_RWAGITIMA					26
Recommended Site:		EX_1		coordinate (E) 545446	coordinate (N)	4815482
Expected DTB (m):		50		Altitude (amsl)	1353	
Recommended Depth (m):		70		Accessibility Site:	Accessible	
Alternative Site:				coordinate (E)	coordinate (N)	
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:		
Expected Formation:		Quartzite Schists and Sediments		Accessibility Village:	Good	
Int yield (l/h) :	4,296	SWL (m asl):	1,358	Target:	JOINT	
Remarks:	There are some major uartzite valleys and main valley targets clustered around this point. The problem is however that most of it is overlain by cotton soils which makes readings almost indistinguishable. The readings for Profile B are typical for cotton soil masking, there is not much you can derive from it. Profile A going perpendicular however does show some good anomalies to focus on. It would seem that this profile is going perpendicular to the quartzite vein which is making these anomalies visible in the middle of the profile. EX_1 at 265 meters shows the most promise. EX_1 be able to suffice for a hand pump borehole or a solar powered small system. VES_1 shows a very shallow D45 which is not suprising with the masking effect from the cotton soil.					

Location map geophysical measurements

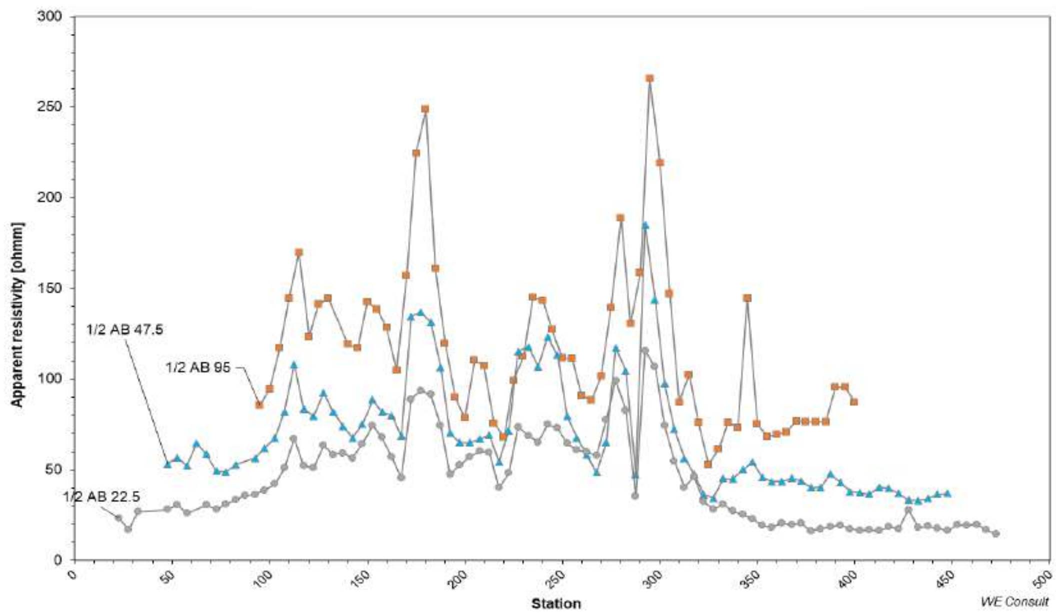


Site	26		Village	Isangano			
Cell	Kiburara		Sector	Rwimbogo			
			District	Gatsibo			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	20.00						
Lineament (0-20 points)	10						
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	30.00						
Remarks							
Geophysical measurements							

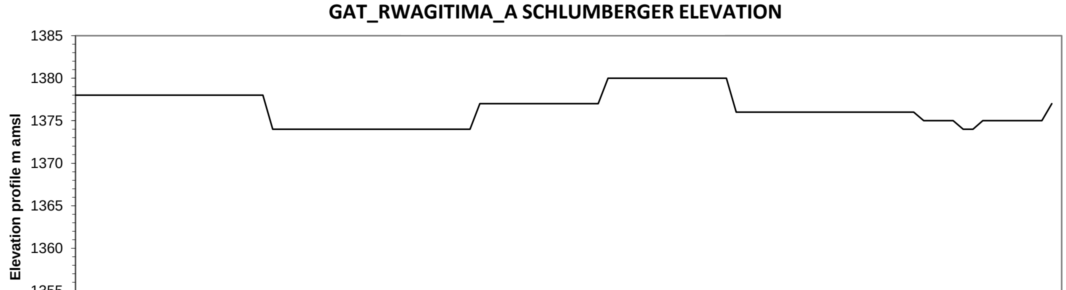
GAT_RWAGITIMA_A SCHLUMBERGER PSEUDO



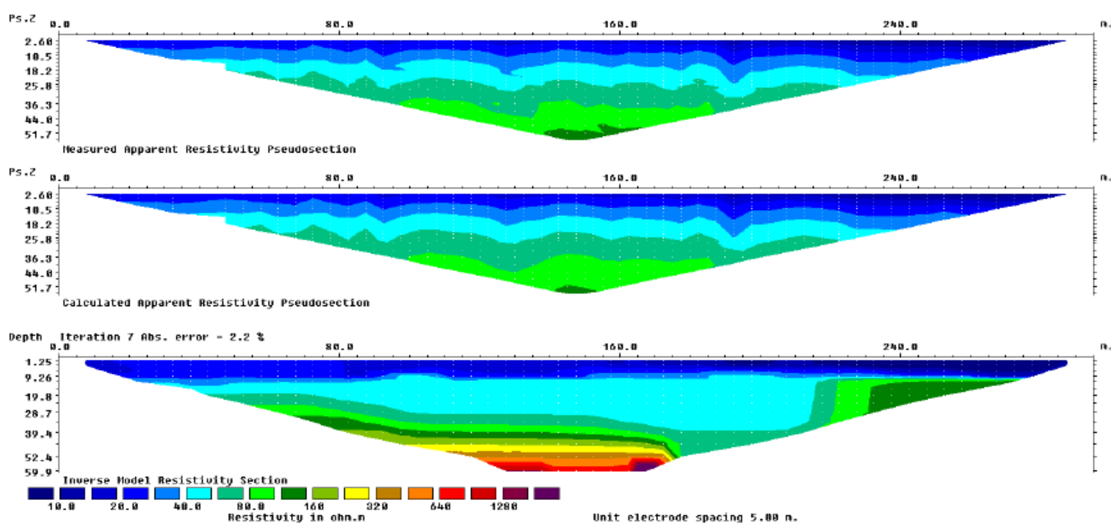
GAT_RWAGITIMA_A SCHLUMBERGER 1D EXTRACTION



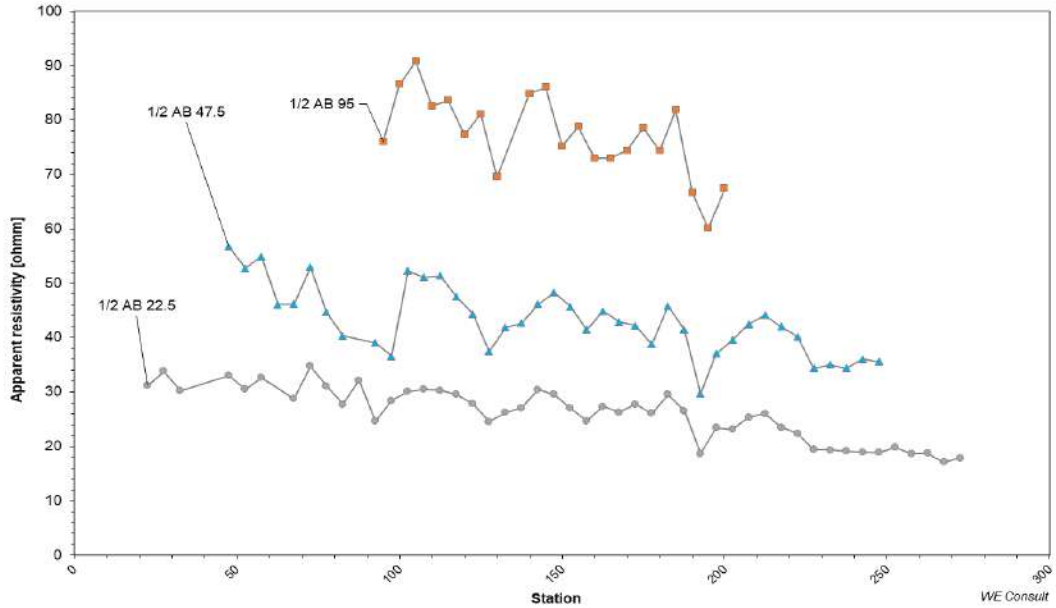
GAT_RWAGITIMA_A SCHLUMBERGER ELEVATION



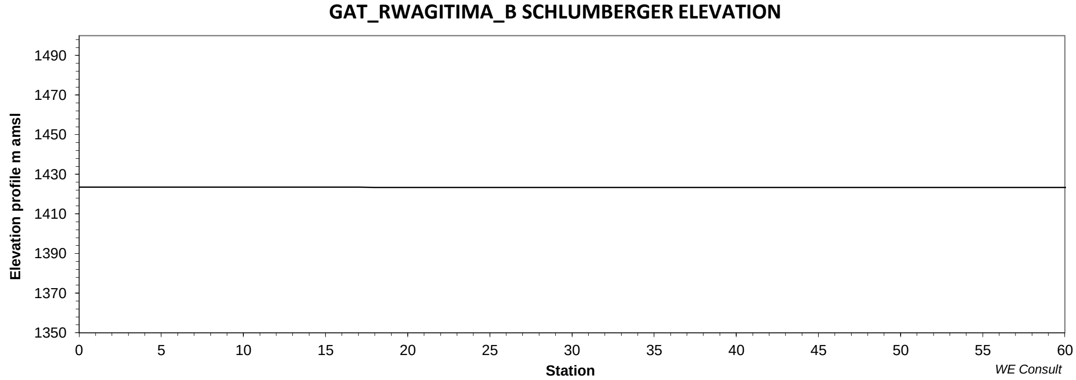
GAT_RWAGITIMA_B SCHLUMBERGER PSEUDO



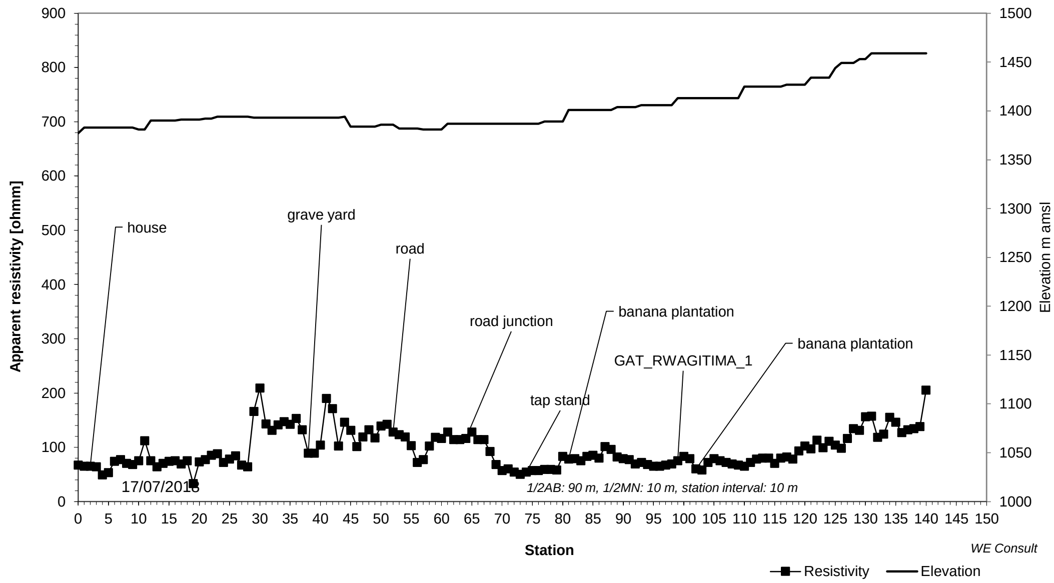
GAT_RWAGITIMA_B SCHLUMBERGER 1D EXTRACTION



GAT_RWAGITIMA_B SCHLUMBERGER ELEVATION



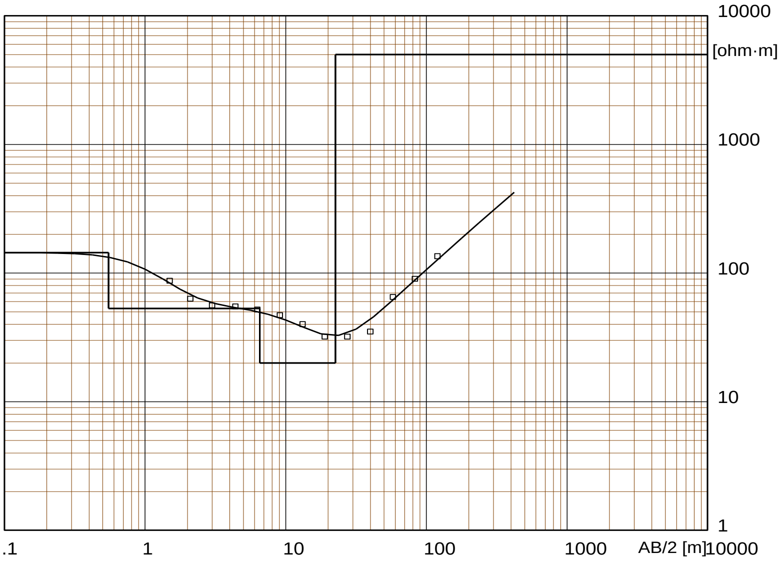
GAT_RWAGITIMA_C PROFILE



Best VES: **EX_1**

ELECTICAL SOUNDING_SCHLUM
GAT_RWAGITIMA_1

Electrical sounding Schlumberger - 29.WS3



Location X = 212085 Y = 9815844 Z = 1406 Azim = 350 - 170

Model Resistivity	**Thickness**	**Depth**	**Altitude**
[ohm·m]	[m]	[m]	[m]
144	.55		1406
53	6	.55	1405.4
20	16	6.6	1399.4
5000		23	1383

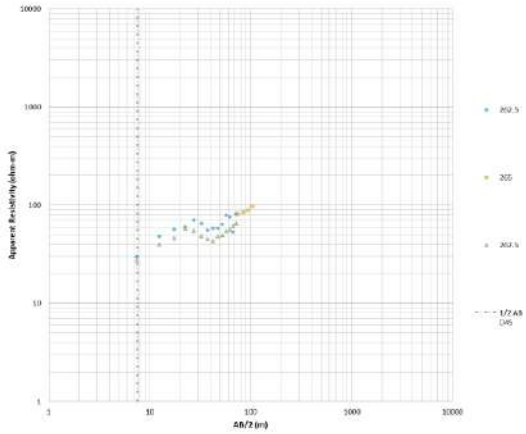
The VES was carried on an profile A (proposed profile 29) at station 99. The interpreted layers are: top soil,sandy clay, clay, and hard rock.

W-GeoSoft / WinSev 6.3

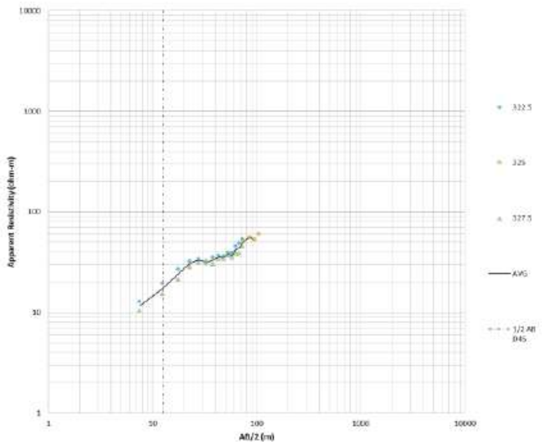
WE Consult

Best VES: **EX_1**

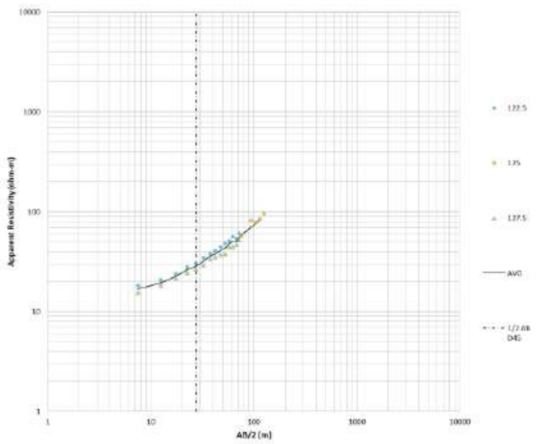
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
GAT_RWAGITIMA_A_EX_1 (210 m)
ANOMALY 1D EXTRACTION



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
GAT_RWAGITIMA_A_EX_2 (325 m)
LOW RESISTIVITY ANOMALY 1D EXTRACTION

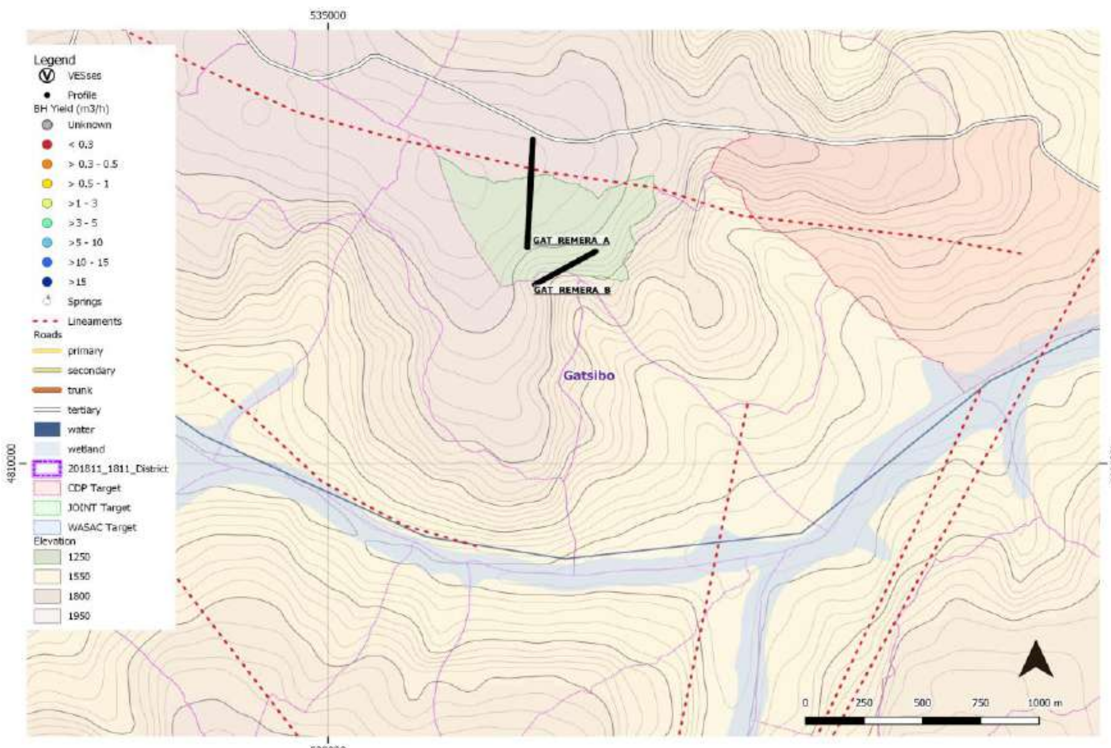


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
GAT_RWAGITIMA_B_EX_2 (125 m)
ANOMALY 1D EXTRACTION
WHOLE PROFLIE VESSES MASKED



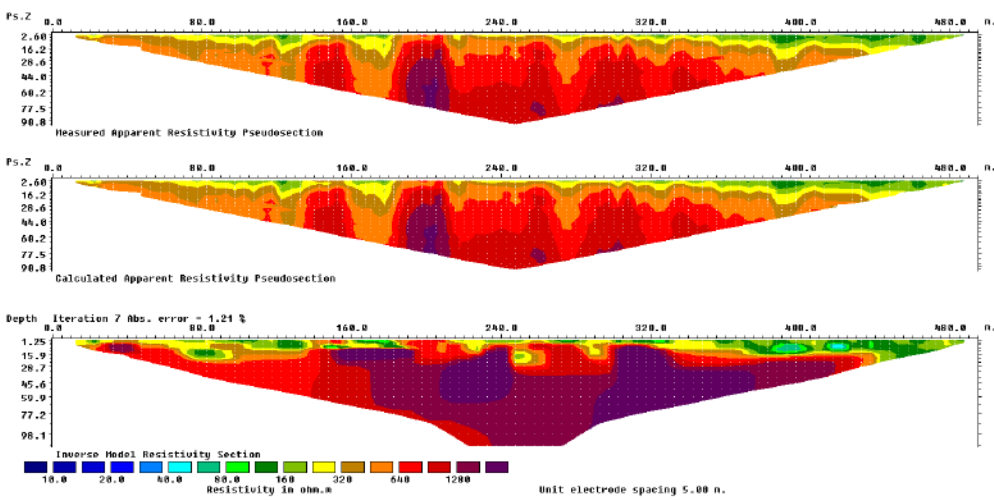
Location:	GAT_REMERA					27
Recommended Site:				coordinate (E)	coordinate (N)	
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:	Accessible	
Alternative Site:				coordinate (E)	coordinate (N)	
Expected DTB (m):				Altitude (amsl)		
Recommended Depth (m):				Accessibility Site:		
Expected Formation:		Quartzites / Schists		Accessibility Village:	Good	
Int yield (l/h) :	5,410	SWL (m asl):	1,749	Target:		
Remarks:	The purpose of this site is not to find ground water specifically, but rather show what the oposite looks like. The sites are highly elevated and are in an area considered in the ground water potential map without any potential, due to the deep ground water flow which cannnot be reached on top of the hill. Knowing all this, the results, while high in resistivity, show very nice anomalies and VES shapes that would make you think you can drill for water. Which of course you can, but it will be extremely deep and no handpump will be able to pump it. Profile A is right on top of teh hill while profile B is sloping down from the hill and coming up the other. This effectively makes your half A/B smaller which means that though EX_3 looks very good considering you are on a hill, it is not usable since your setup of electrodes and lenghts the currents travel is effectively halfway folder up, creating shorter distances between the electrodes at either ends. For serving communities on top of hills like this, consider building small or big systems that supply from the abundant aquifers below. Siting on top of locations like this will always result in ambiguous results and dry boreholes will be the outcome. When considering underserved population on these hills don't consider geophysics or boreholes on top of the hills but rather supply them from below.					

Location map geophysical measurements

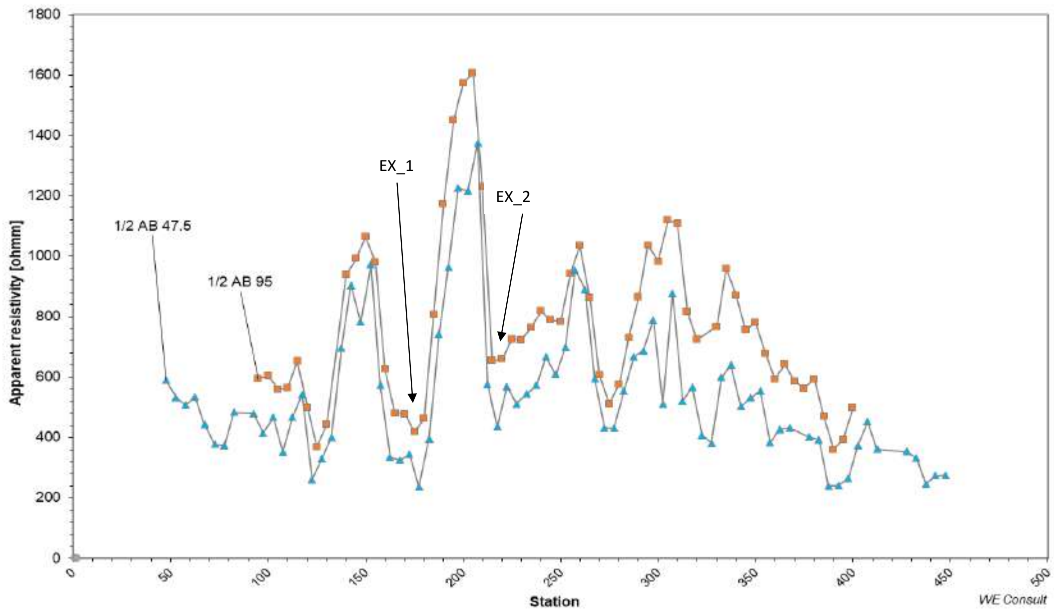


Site	27		Village	Rugarama			
Cell	Rurenge		Sector	Remera			
			District	Gatsibo			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

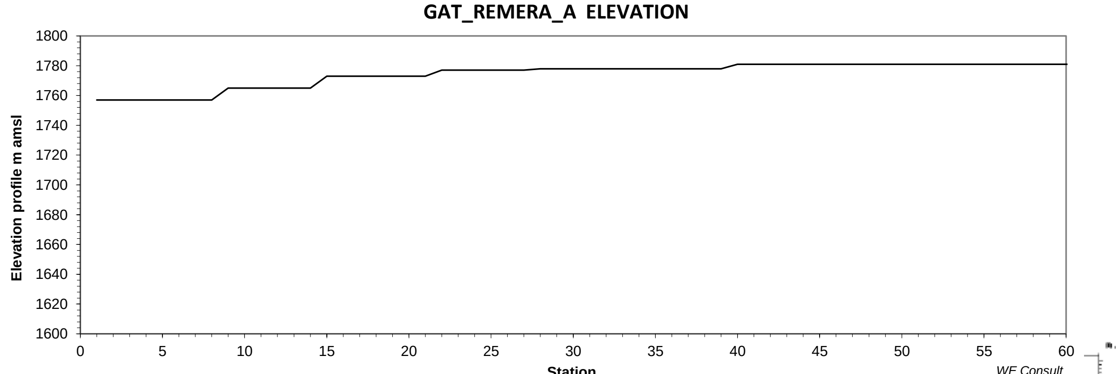
GAT_REMERA_A SCHLUMBERGER PSEUDO

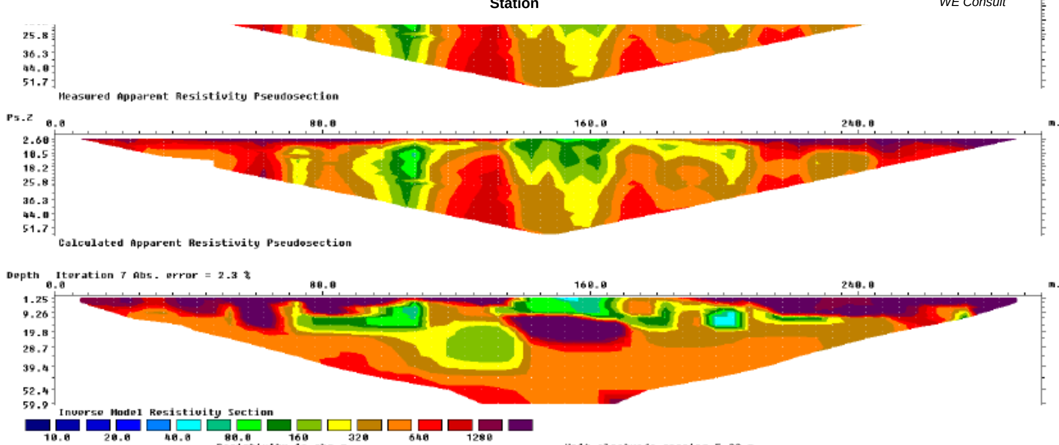


GAT_REMERA_A SCHLUMBERGER 1D EXTRACTION

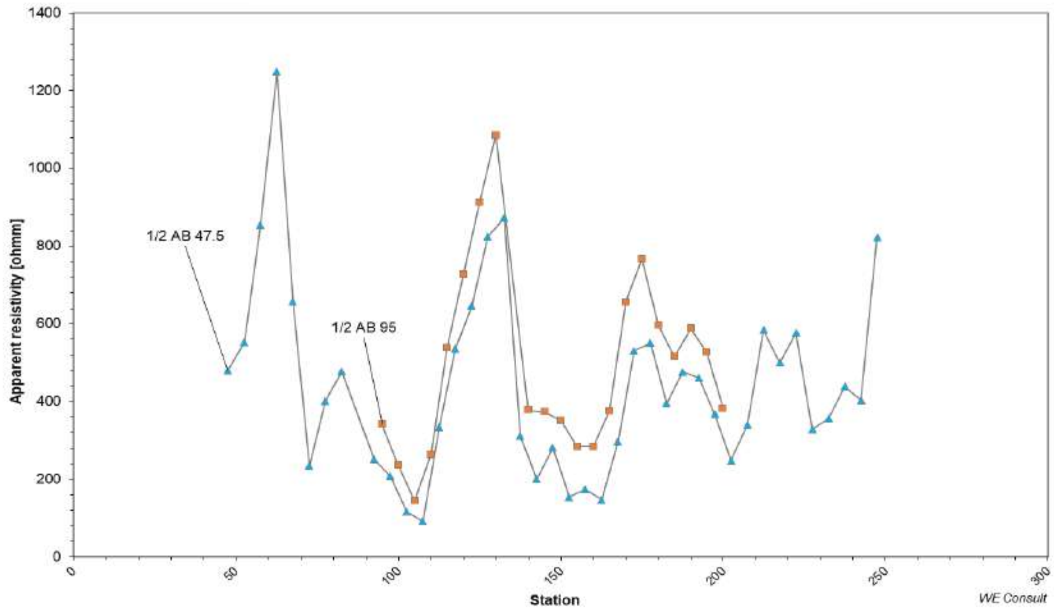


GAT_REMERA_A ELEVATION

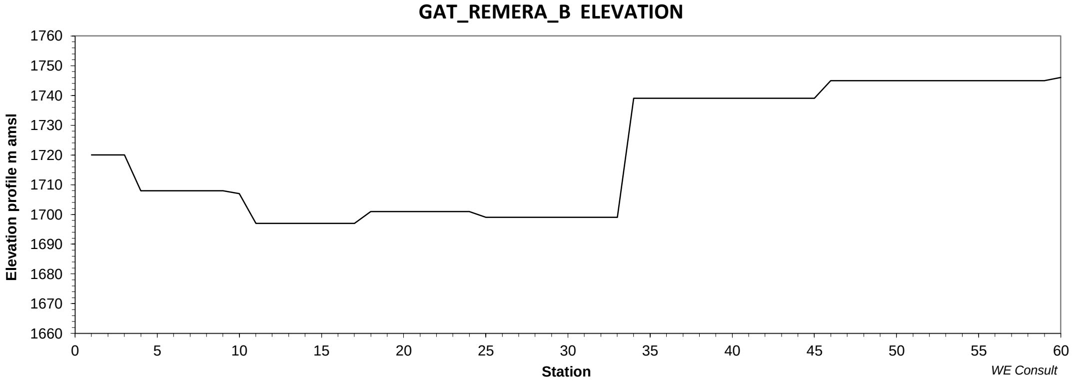




GAT_REMERA_B SCHLUMBERGER 1D EXTRACTION

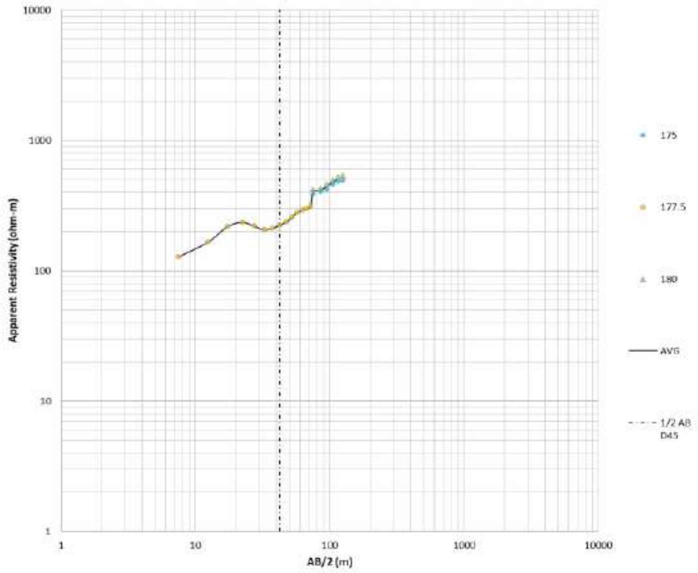


GAT_REMERA_B ELEVATION

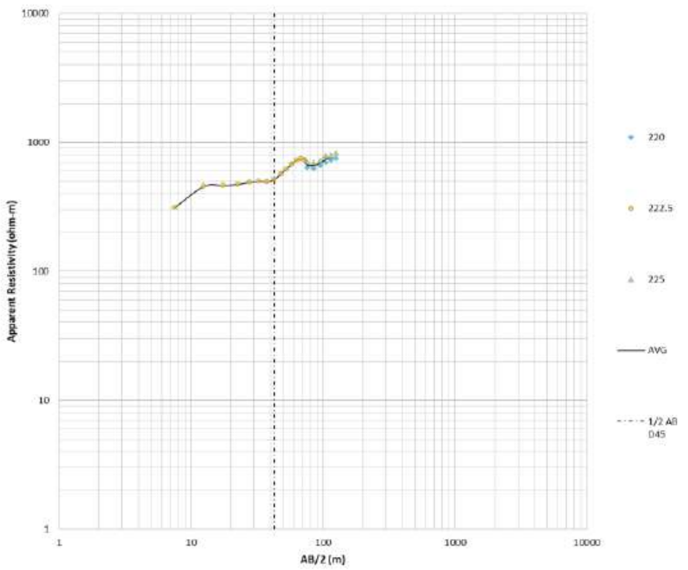


Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
GAT_REMERA_EX_1 (175 m)
ANOMALY ON PROFILE

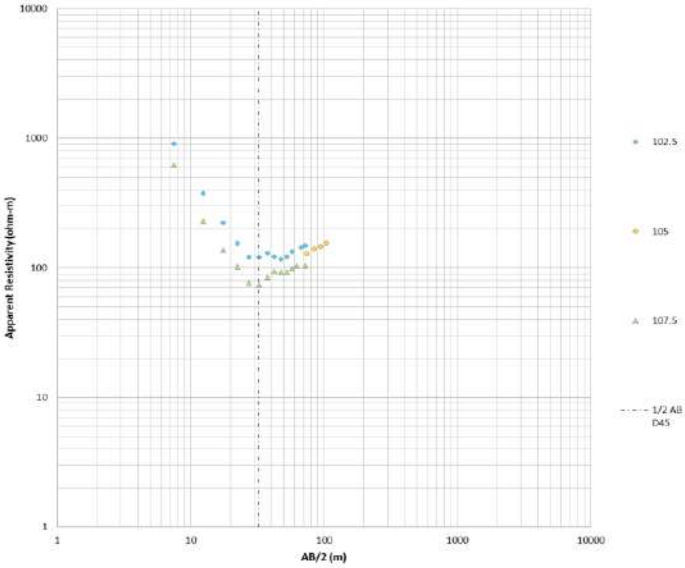


ELECTICAL SOUNDING_EXTRACTION_SCHLUM
GAT_REMERA_EX_2 (225 m)
ANOMALY ON PROFILE



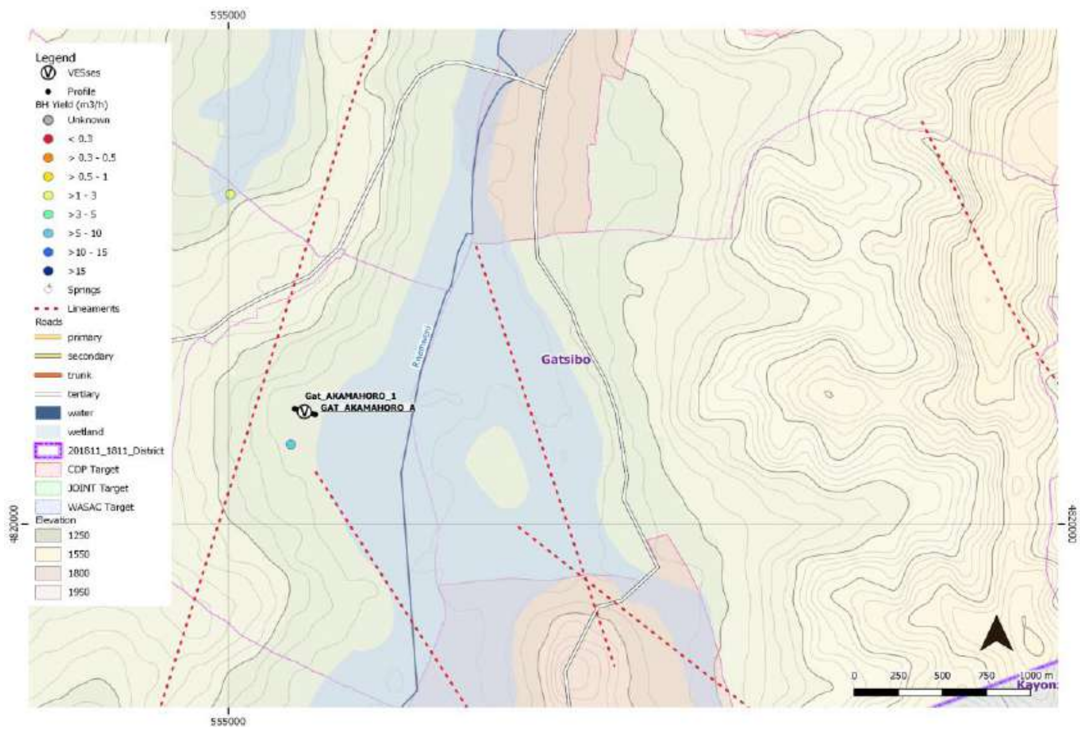
Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_EXTRACTION_SCHLUM
GAT_REMERA_B_EX_3 (105 m)
ANOMALY ON PROFILE



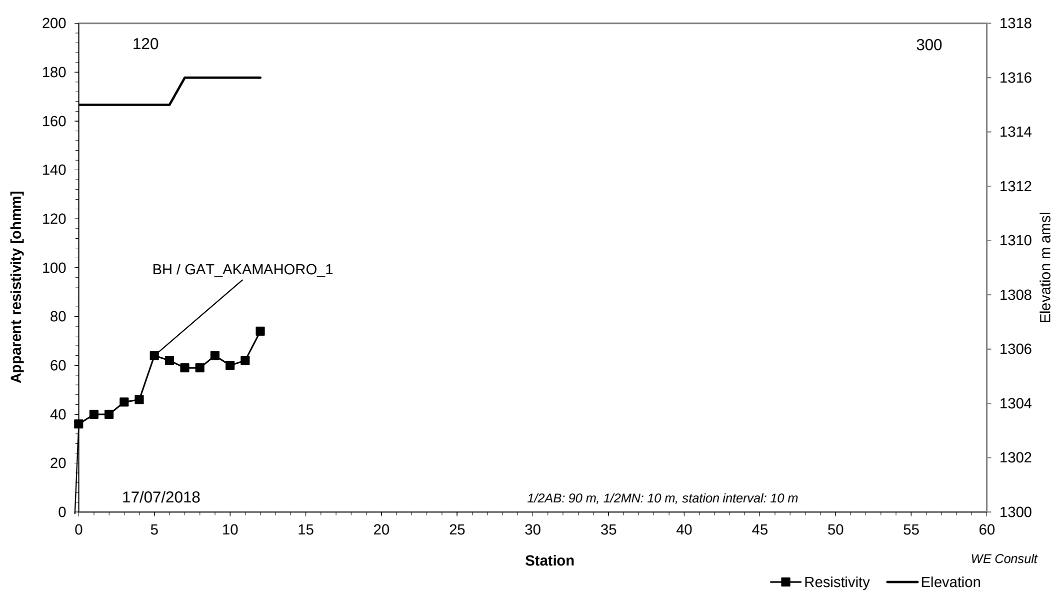
Location:	GAT_AKAMAHORO				28
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	None
Expected Formation:		Schists		Accessibility Village:	None
Int yield (l/h) :	6,702	SWL (m asl):	1,374	Target:	NONE
Remarks:	Borehole confirmation in sediments and schists. Sounding shows very low resistivities and a wide VES shape. There seems to be no specific relation to an anomaly on the profile.				

Location map geophysical measurements



Site	28		Village	Akamahoro			
Cell	Rwikiniro		Sector	Rwimbogo			
			District	Gatsibo			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

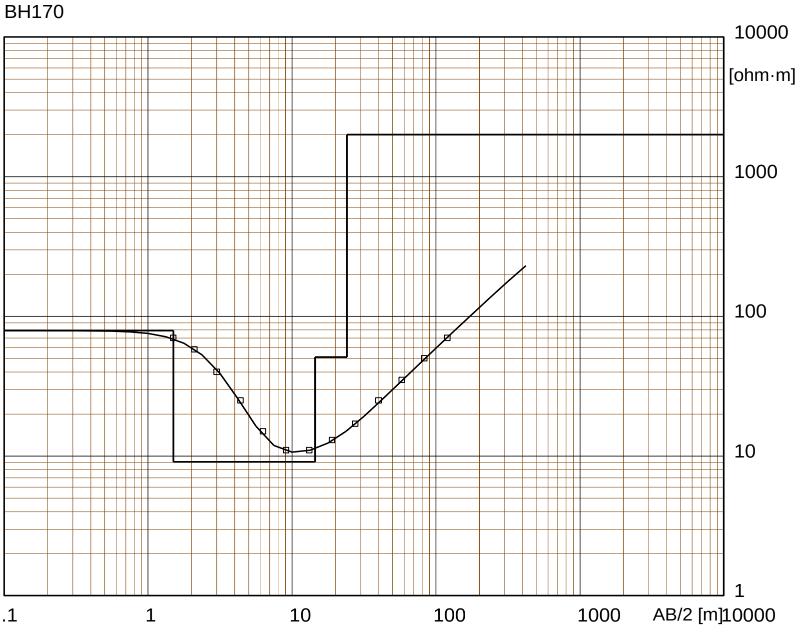
GAT_AKAMAHORO_A PROFILE



Best VES: **VES_1**

ELECTICAL SOUNDING_SCHLUM
GAT_AKAMAHORO_1
EXISTING BOREHOLE | UNKNOWN CHARACTERISTICS

Electrical sounding Schlumberger - BH170.WS3



Location X = 221633 Y = 9820564 Z = 1333 Azim = 50 - 230

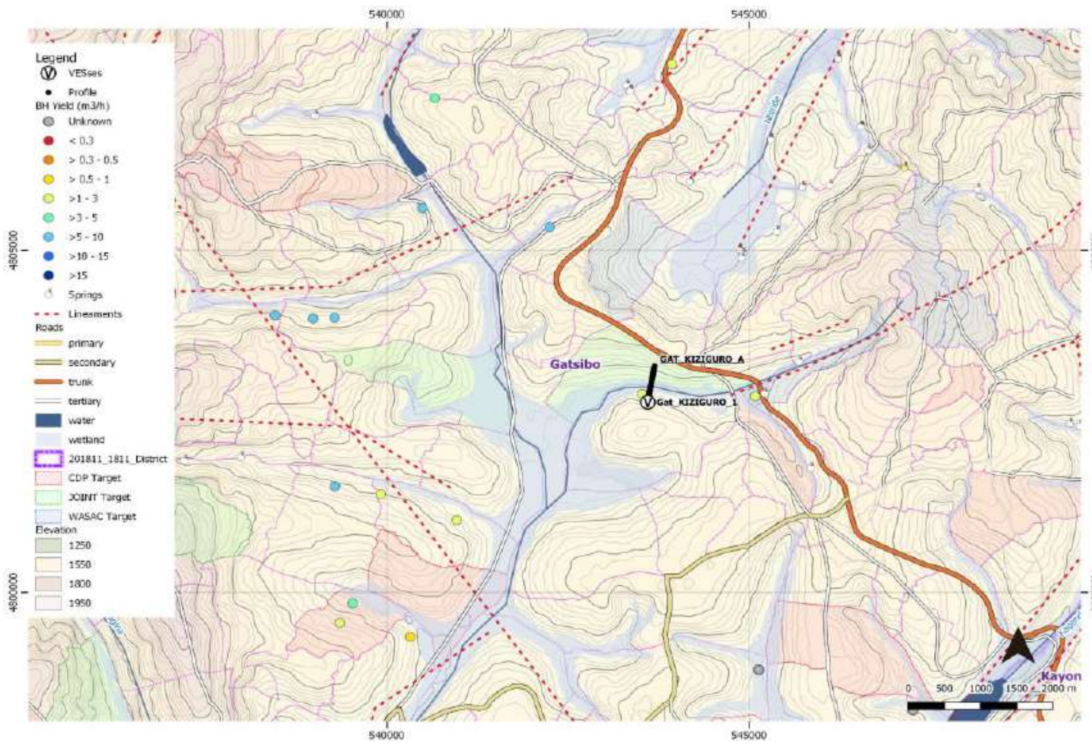
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
79	1.5		1333
9.1	13	1.5	1331.5
51	9.5	14	1319
2000		24	1309

The VES was carried on an existing borehole (170). The interpreted layers are: top soil,clay, sandy clay and hard rock.

W-GeoSoft / WinSev 6.3

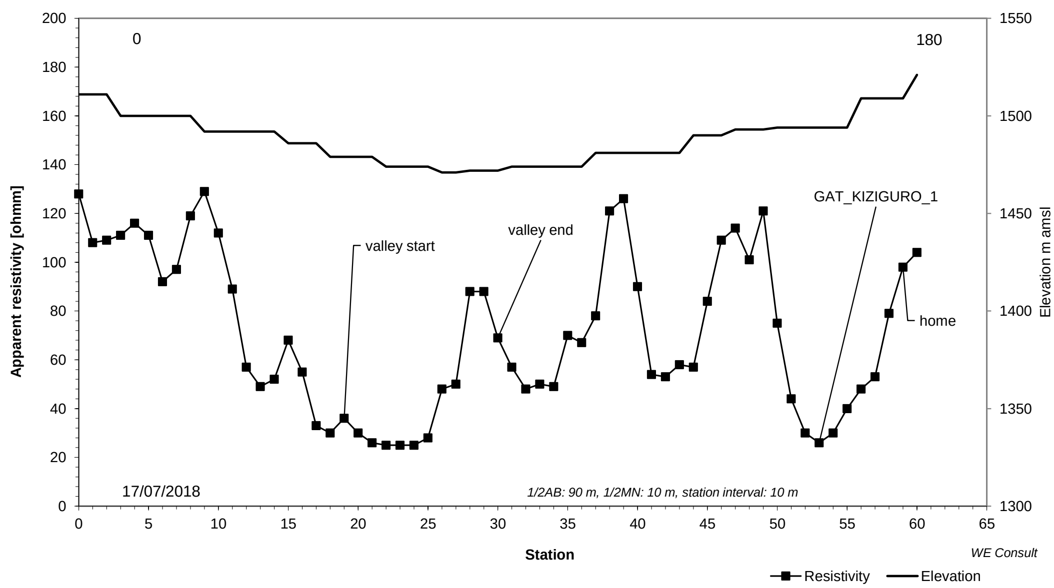
Location:	GAT_KIZIGURU			29
Recommended Site:	VES_1	coordinate (E) 543600	coordinate (N) 4802782	
Expected DTB (m):		Altitude (amsl)	1500	
Recommended Depth (m):		Accessibility Site:	Accessible	
Alternative Site:		coordinate (E)	coordinate (N)	
Expected DTB (m):		Altitude (amsl)	1018	
Recommended Depth (m):		Accessibility Site:	None	
Expected Formation:	Schists & Sediments	Accessibility Village:	None	
Int yield (l/h) : 1,520	SWL (m asl): 1,488	Target:	JOINT	
Remarks:	The profile is run in a sediment valley in granites. The anomaly for VES_1 is very pronounced with the VES showing only hitting bedrock beyond 100 1/2AB. This signifies that in fact it is not underlain by granites but rather schists coming in from the east. Based on the VES, the ground water potential would be indicated as low. However, with the anomaly shape and its pronounciation, within a valley signifies that there is at least the possiblity for a hand pump.			

Location map geophysical measurements



Site	29		Village	Isangano			
Cell	Agakomeye		Sector	Kiziguro			
			District	Gatsibo			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	18						
Lineament (0-20 points)	3						
Anomaly (0-30 points)	22						
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	43						
Remarks							
Geophysical measurements							

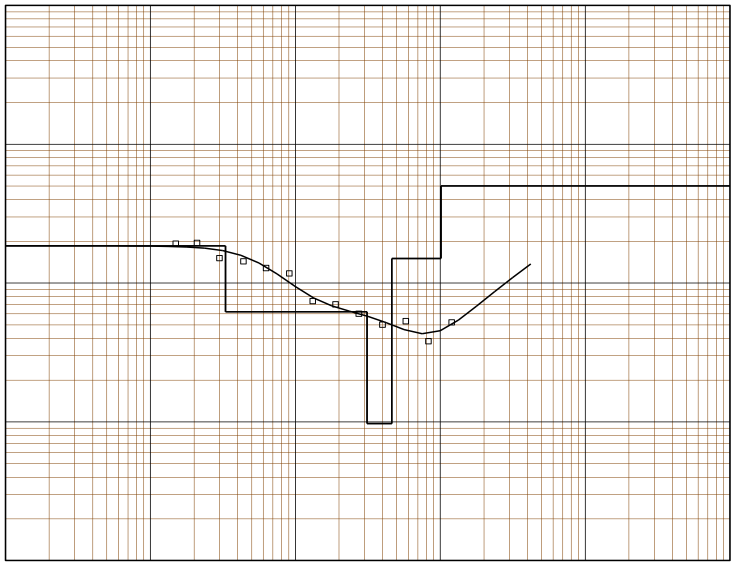
GAT_KIZIGURO_A PROFILE



Best VES: **VES_1**

ELECTICAL SOUNDING_SCHLUM
GAT_KIZIGURO_1

Electrical sounding Schlumberger - 32.WS3



Location X = 209822 Y = 9802640 Z = 1507 Azim = 0 - 180

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
185	3.3		1507
62	28	3.3	1503.7
9.7	15	31	1476
150	55	46	1461
500		101	1406

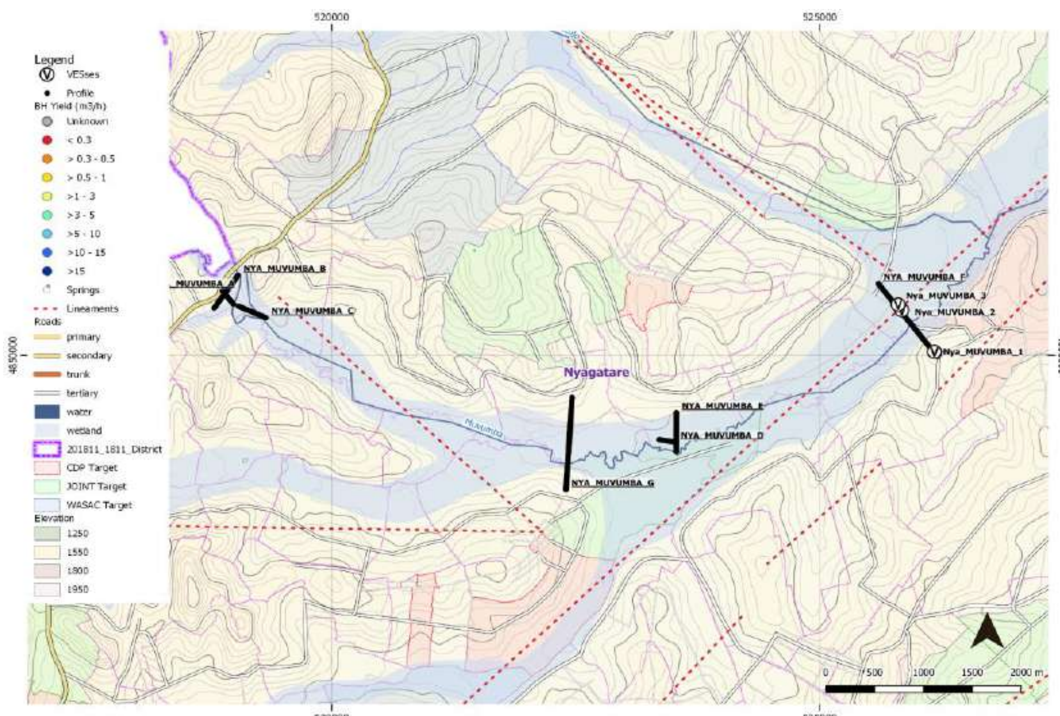
The VES was carried on an profile A (proposed profile 32) at station 53. The interpreted layers are: top soil,sandy clay, clay, weathered rock and hard rock.

W-GeoSoft / WinSev 6.3

WE Consult

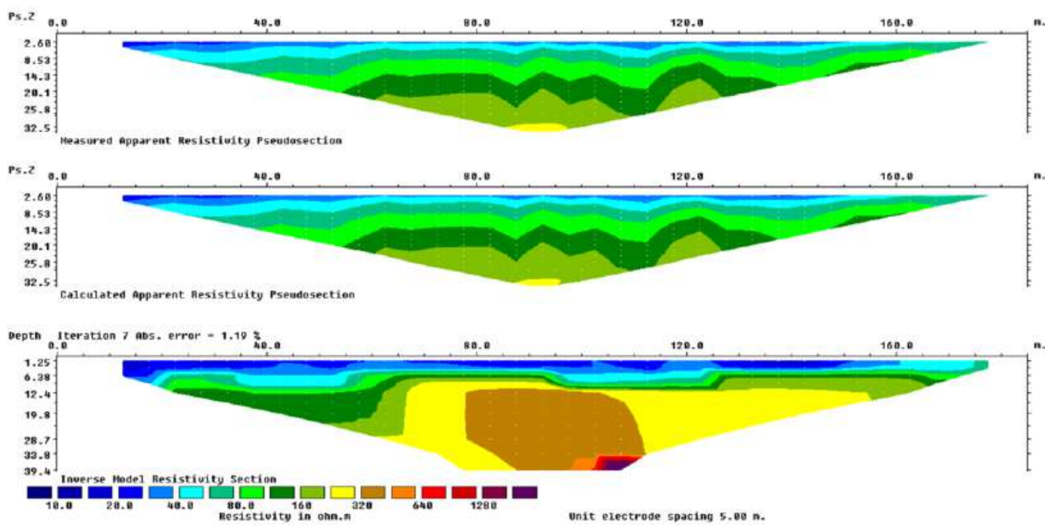
Location:	NYA_MUVUMBA					31
Recommended Site:		VES_6	coordinate (E)	522440	coordinate (N)	4849204
Expected DTB (m):			Altitude (amsl)		1428	
Recommended Depth (m):			Accessibility Site:		Accessible	
Alternative Site:			coordinate (E)		coordinate (N)	
Expected DTB (m):			Altitude (amsl)			
Recommended Depth (m):			Accessibility Site:			
Expected Formation:		Quartzite Schists and Sediment	Accessibility Village:		Good	
Int yield (l/h) :	897	SWL (m asl): 1,424	Target:		CDP	
Remarks:	The main target of this excersise was to find coarse sedimentary aquifers that would match the ones found in Bugesera and Kirehe in characteristics. This was thought to be possible since the rivers seem to meander quite a bit, and coarse gravel deposits are seen on the surface. However, when looking at the ERT measurements throughout, and the 1D measurements with VESes, the results are nothing similar, while with their own potential all together. In general the underlying granite seems to be more prominent in this part of the province, with it being quite shallow. This however means with the rivers meandering over it, it is subjected to weathering over time. Instead of looking for low resistivities, we are here in fact looking for weathered hard rock. Profile B 160 m, Profile C 120m, Profile E 250 m all show potential. The extracted VESes, due to the sediments are masked and not usable. The 1D profiles, are not very pronounced and most VESes are masked except VES_6. This, together with the ERT results, provides plenty of opportunities to drill at least hand pump boreholes with the potential for higher yields.					

Location map geophysical measurements

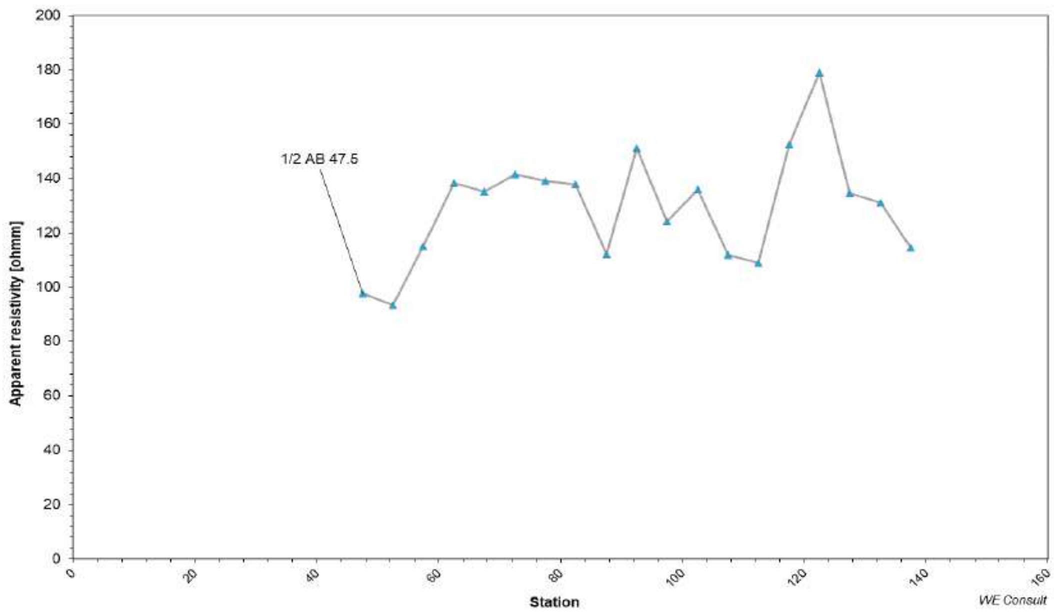


Site	31			Village	Rutoma		
Parish	Ndego			Sector	Karama		
				District	Nyagatare		
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	17	17	17	17	17	17	17
Lineament (0-20 points)	10	10	10	10	10	10	10
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	34	34	37	34	36	42	36
Remarks							
Geophysical measurements							

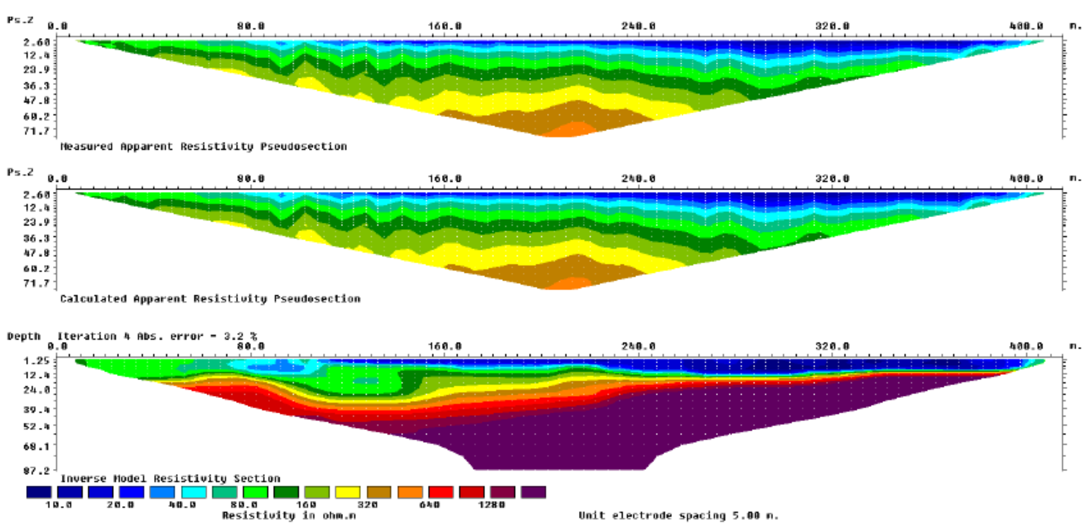
NYA_MUVUMBA_A SCHLUMBERGER PSEUDO



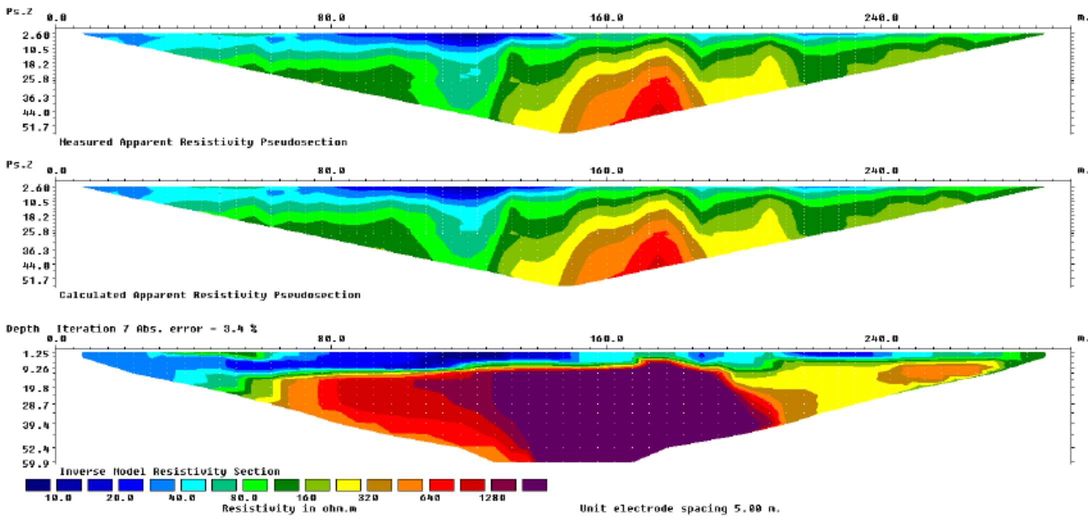
NYA_MUVUMBA_A SCHLUMBERGER 1D EXTRACTION



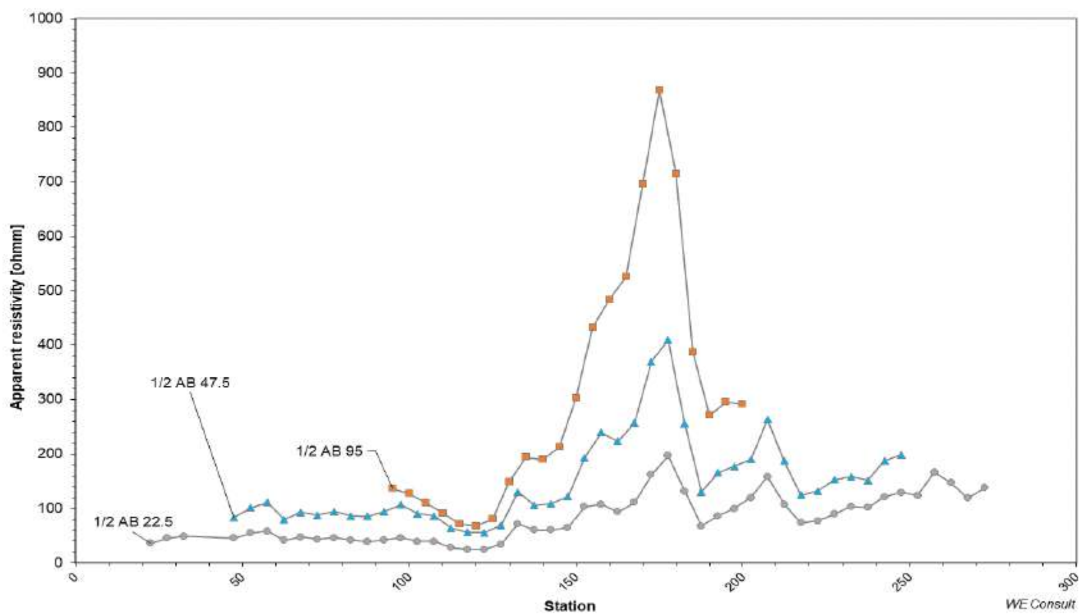
NYA_MUVUMBA_B SCHLUMBERGER PSEUDO



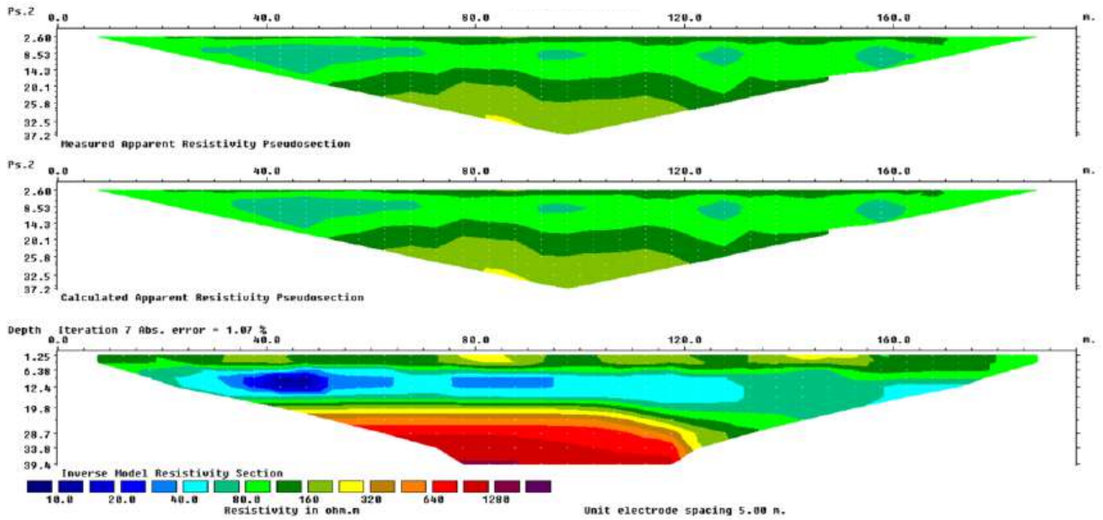
NYA_MUVUMBA_C SCHLUMBERGER PSEUDO



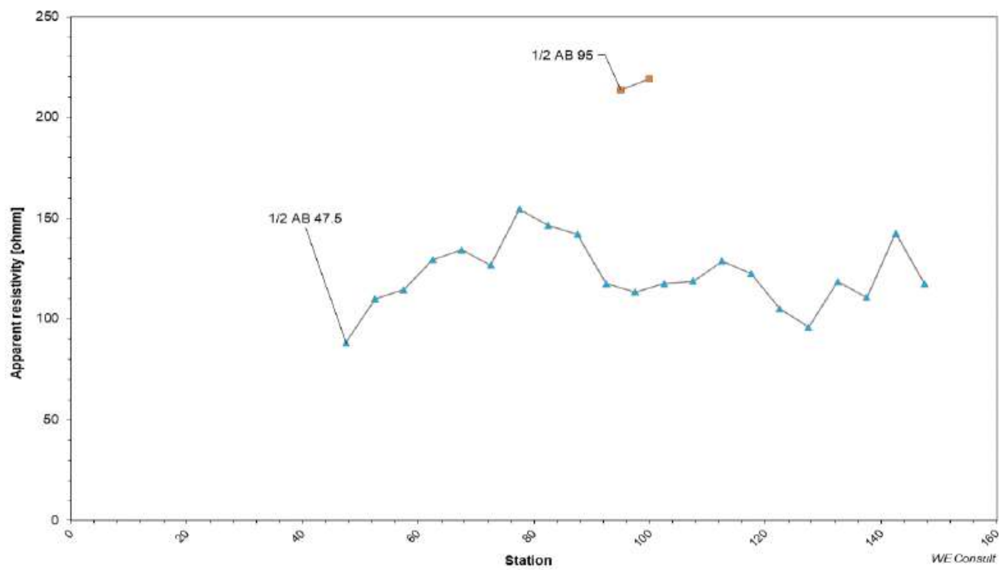
NYA_MUVUMBA_C 1D EXTRACTION



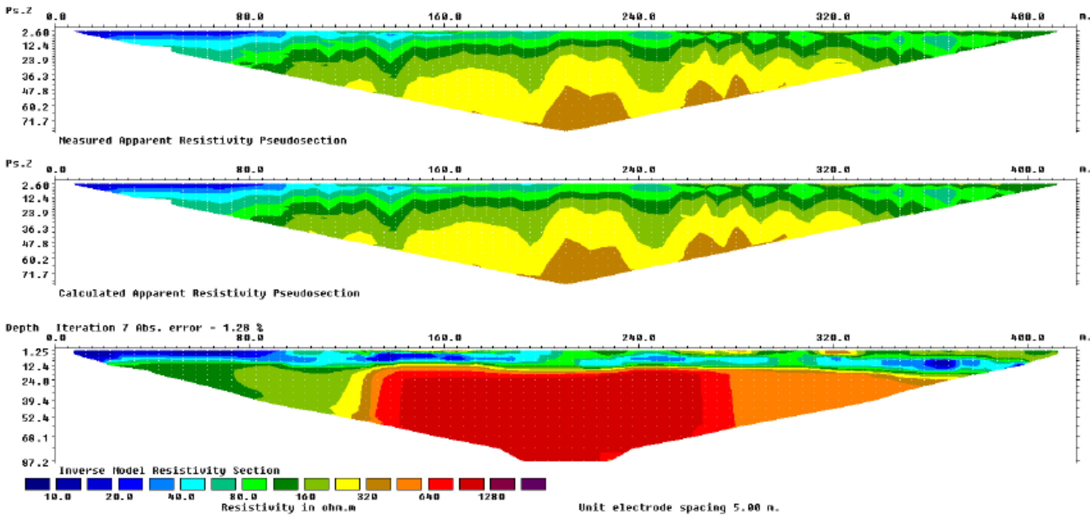
NYA_MUVUMBA_D SCHLUMBERGER PSEUDO



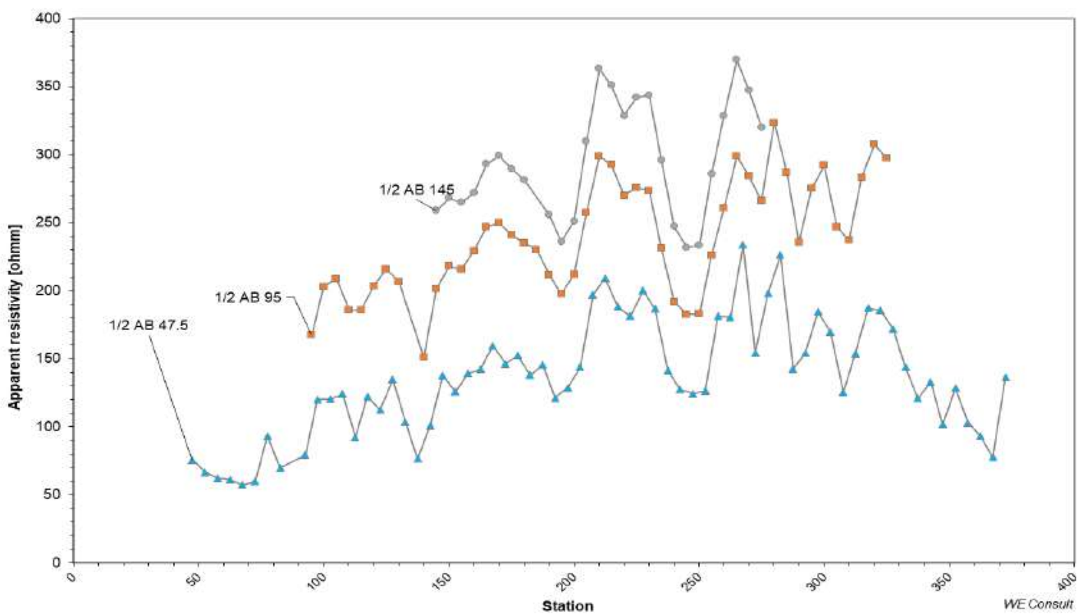
NYA_MUVUMBA_D 1D EXTRACTION



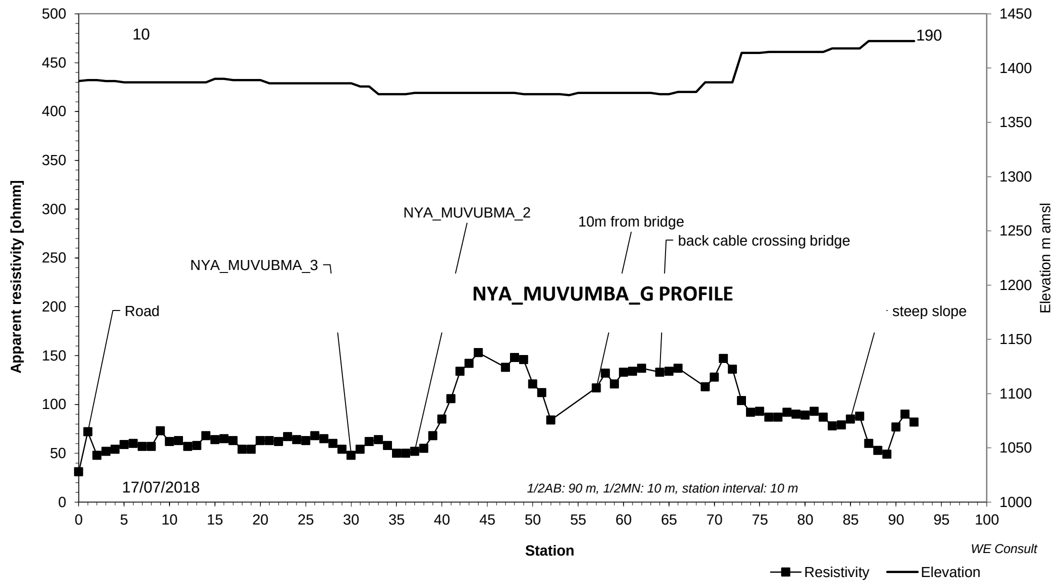
NYA_MUVUMBA_E SCHLUMBERGER PSEUDO



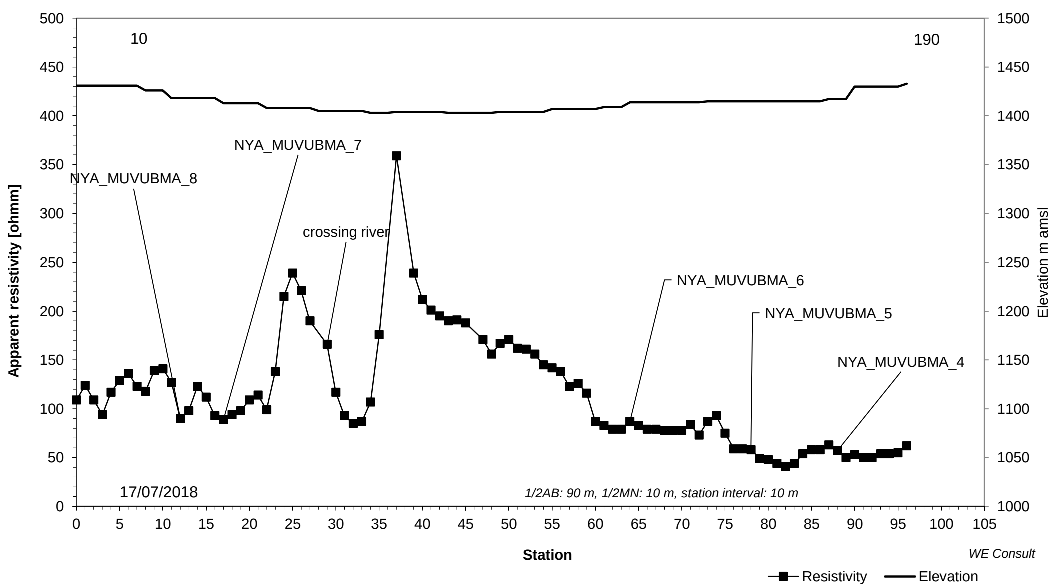
NYA_MUVUMBA_E 1D EXTRACTION



NYA_MUVUMBA_F PROFILE

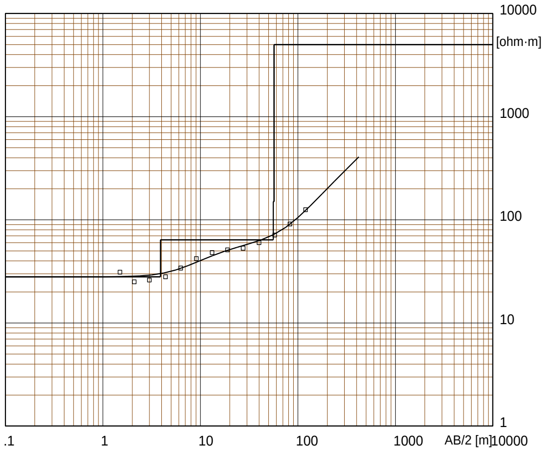


NYA_MUVUMBA_G PROFILE



Best VES: **CALIBRATION ONLY**

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_1



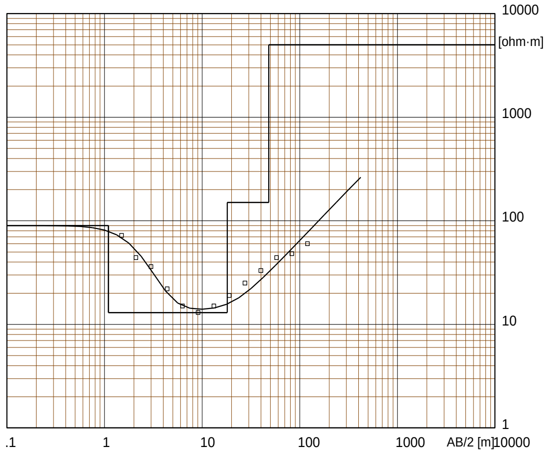
Location X = 192314 Y = 9849909 Z = 1395 Azim = 190 - 10

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
28	3.9		1395
64	52	3.9	1391.1
150	1	56	1339
5000		57	1338

The VES was carried on station 94 of NYA-4. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_2



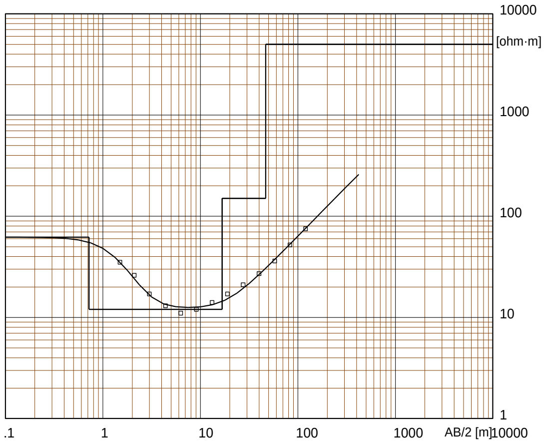
Location X = 191978 Y = 9850360 Z = 1382 Azim = 190 - 10

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
90	1.1		1382
13	17	1.1	1380.9
150	30	18	1364
5000		48	1334

The VES was carried on station 37 of NYA-4. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_3



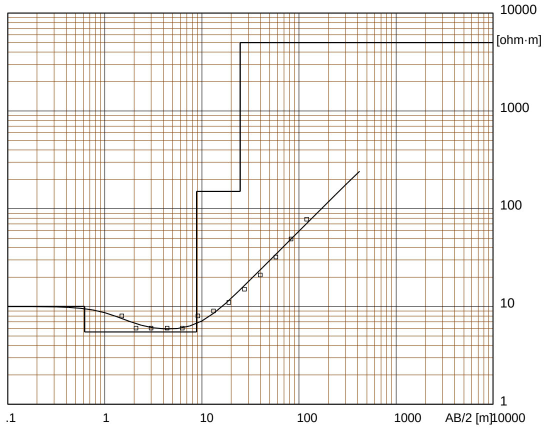
Location X = 191940 Y = 9850420 Z = 1387 Azim = 190 - 10

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
62	.72		1387
12	16	.72	1386.3
150	30	17	1370
5000		47	1340

The VES was carried on station 30 of NYA-4. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_4



Location X = 188576 Y = 9849183 Z = 1417 Azim = 10 - 190

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
10	.62		1417
5.5	8.2	.62	1416.4
150	16	8.8	1408.2
5000		25	1392

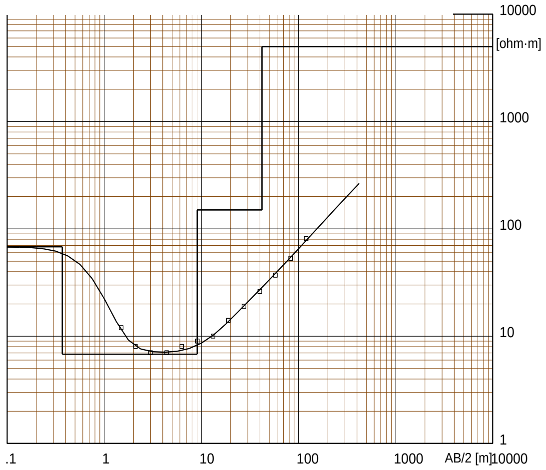
The VES was carried on an station 88 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

Best VES: **CALIBRATION ONLY**

Best VES:

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_5



Location X = 188593 Y = 9849091 Z = 1535 Azim = 10 - 190

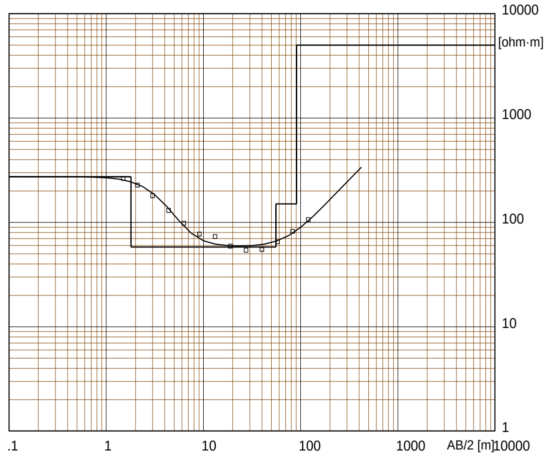
Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
68	.37		1535
6.8	8.7	.37	1534.6
150	33	9.1	1525.9
5000		42	1493

The VES was carried on an station 78 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_6



Location X = 188581 Y = 9848946 Z = 1415 Azim = 10 - 190

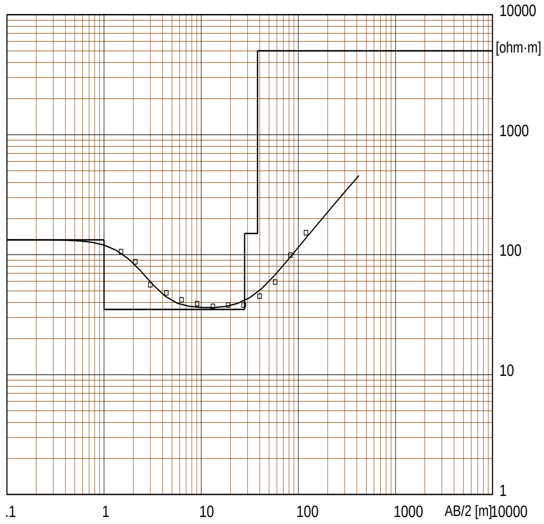
Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
274	1.8		1415
58	54	1.8	1413.2
150	35	56	1359
5000		91	1324

The VES was carried on an station 64 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_7

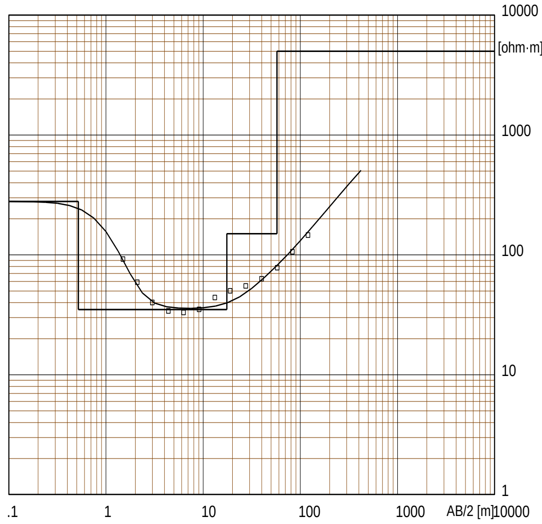


Location X = 188548 Y = 9848478 Z = 1494 Azim = 10 - 190

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
133	1		1494
35	27	1	1493
150	10	28	1466
5000		38	1456

ELECTICAL SOUNDING_SCHLUM
NYA_MUVUBMA_8



Location X = 188534 Y = 9848436 Z = 1458 Azim = 10 - 190

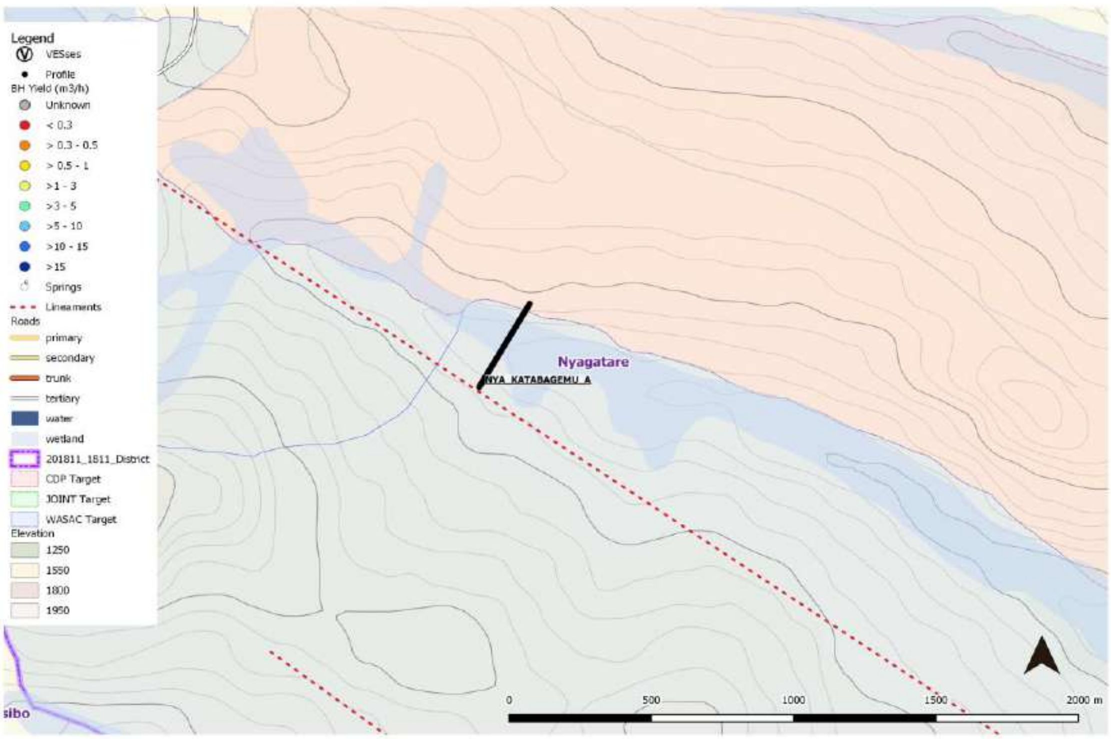
Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
279	.52		1458
35	17	.52	1457.5
150	40	18	1440
5000		58	1400

The VES was carried on an station 12 of profile A. The interpreted layers are: top soil, clay

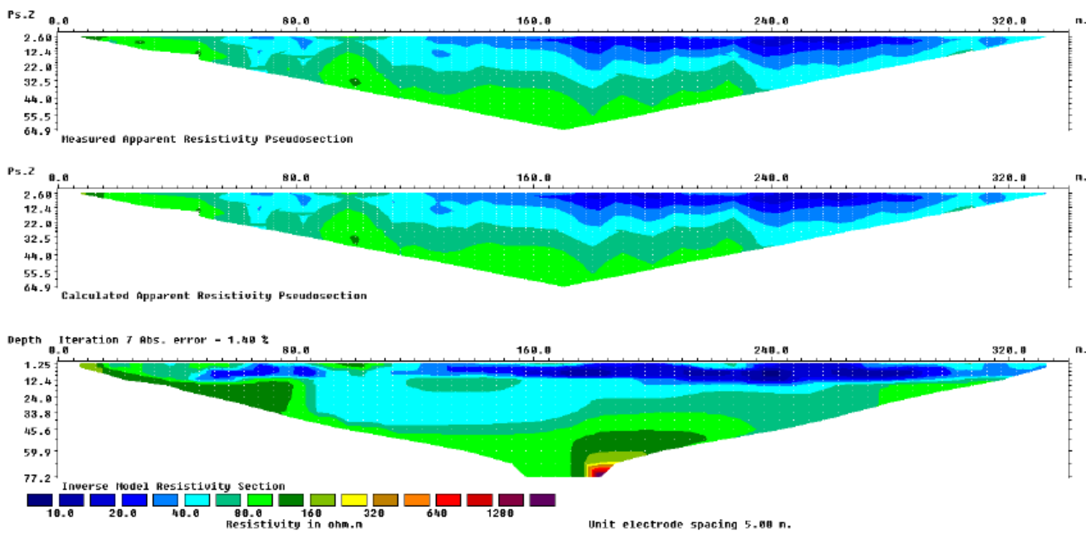
Location:	NYA_KATABAGEMU					32
Recommended Site:		EX_3	coordinate (E)	532909	coordinate (N)	4833436
Expected DTB (m):		40	Altitude (amsl)		1421	
Recommended Depth (m):		60	Accessibility Site:		Accessible	
Alternative Site:			coordinate (E)		coordinate (N)	
Expected DTB (m):			Altitude (amsl)			
Recommended Depth (m):			Accessibility Site:			
Expected Formation:		Quartzite Schists and Sedimen	Accessibility Village:		Good	
Int yield (l/h) :	1,937	SWL (m asl): 1,416	Target:		CDP	
Remarks:	This site was picked since it was selected to find water for irrigation on this location, while it also gave the opportunity to verify an additional borehole on the side valleys as found in Ngarama. These valley showed different results and it is interesting to see that the results of the valley closest to this one are similar. This means that while the valleys look similar there is a different underground situation going on. In any case there are 3 anomalies that are interesting enough to consider. The first anomaly shows a VES (EX_1) that shows a deeper depth to bedrock than the previous borehole attempted (approx 25 m). The values for EX_2 are largely masked but still show a similar deep depth to bedrock. EX_3 shows a VES more consistent with weathering in granite formations. Both EX_1 and EX_3 would suffice, however the expectation is that the yield will not be very high (not high enough for irrigation purposes). The main idea is to target the weathered interface, which is where the water is expected to be.					

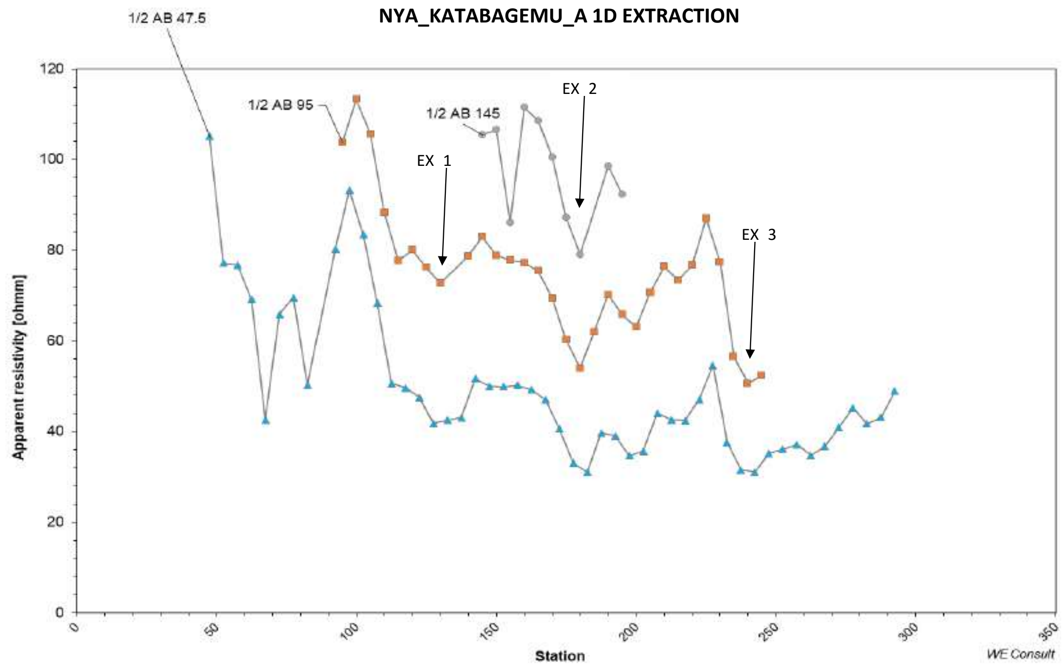
Location map geophysical measurements

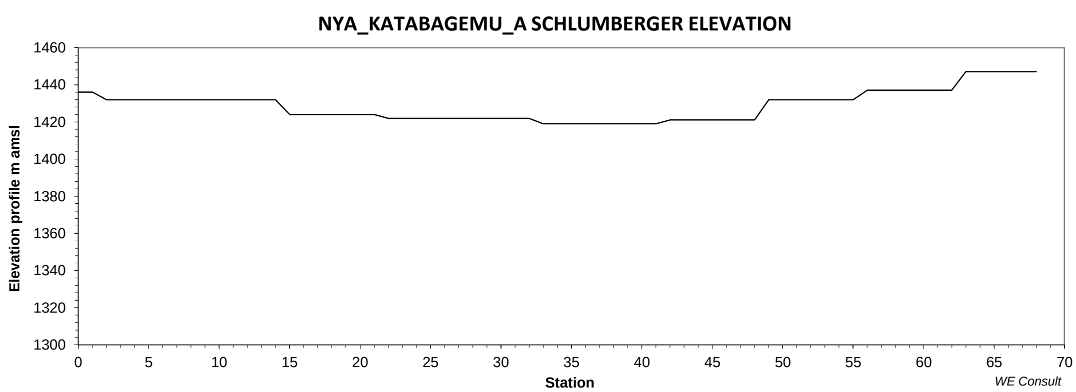


Site	32		Village	Burera			
Cell	Rugazi		Sector	Katabagemu			
			District	Nyagatare			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							
Geophysical measurements							

NYA_KATABAGEMU_A SCHLUMBERGER PSEUDO

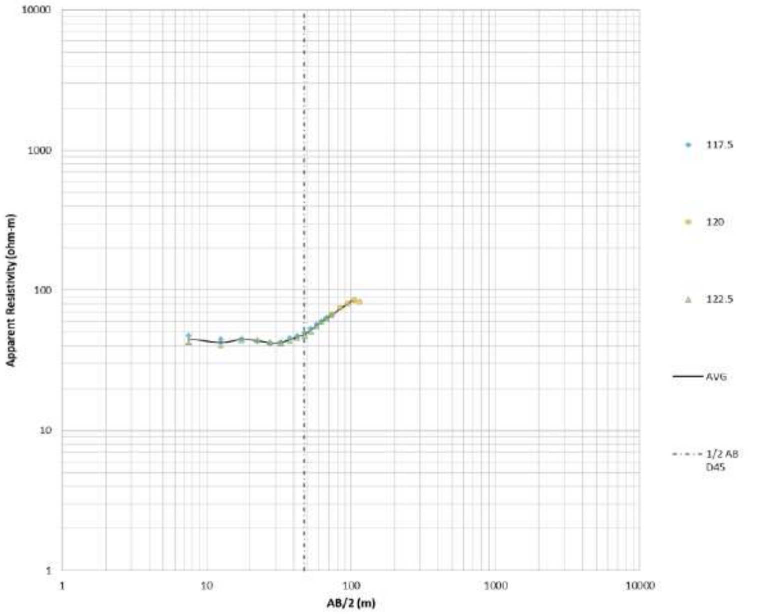



NYA_KATABAGEMU_A 1D EXTRACTION
1/2 AB 47.5
1/2 AB 95
1/2 AB 145
EX 1
EX 2
EX 3
Apparent resistivity [ohmm]
Station
WE Consult

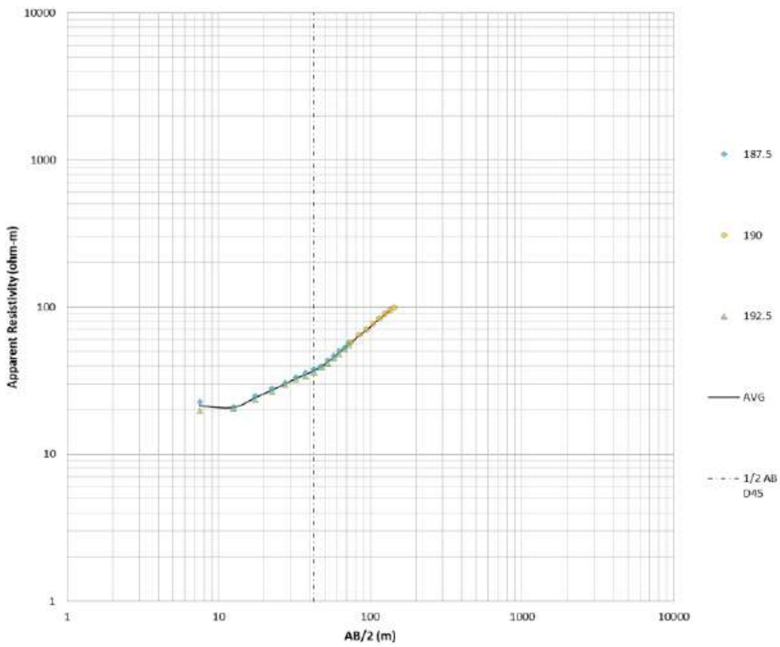

NYA_KATABAGEMU_A SCHLUMBERGER ELEVATION
Elevation profile m amsl
Station
WE Consult

Best VES: **CALIBRATION ONLY**

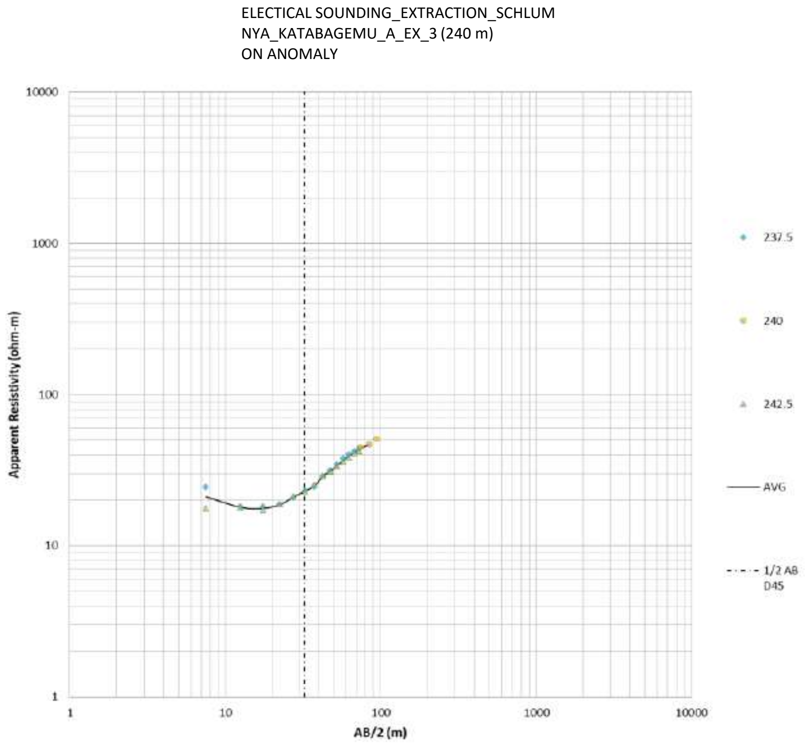
ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NYA_KATABAGEMU_A_EX_1 (120 m)
ON ANOMALY



ELECTICAL SOUNDING_EXTRACTION_SCHLUM
NYA_KATABAGEMU_A_EX_2 (190 m)
ON ANOMALY

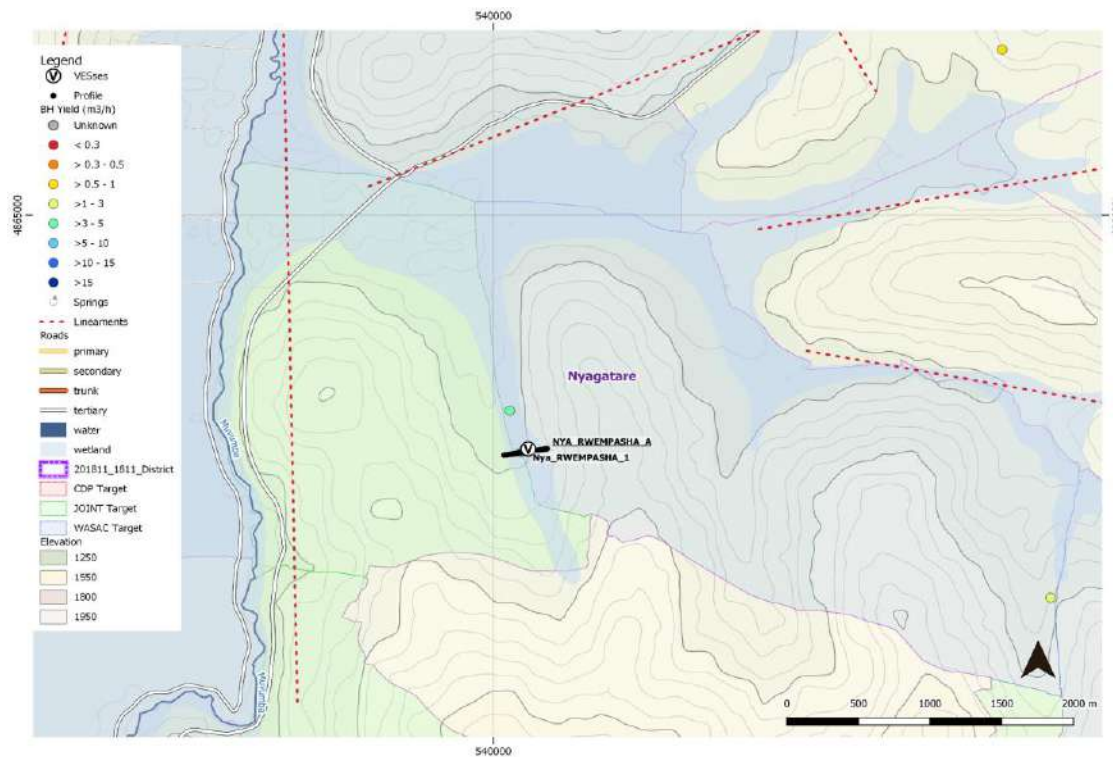


Best VES: **CALIBRATION ONLY**



Location:	NYA_RWEMPASHA				33
Recommended Site:			coordinate (E)	coordinate (N)	
Expected DTB (m):			Altitude (amsl)	1025	
Recommended Depth (m):			Accessibility Site:	Accessible	
Alternative Site:			coordinate (E)	coordinate (N)	
Expected DTB (m):			Altitude (amsl)		
Recommended Depth (m):			Accessibility Site:	None	
Expected Formation:		Granites	Accessibility Village:	None	
Int yield (l/h) :	3,980	SWL (m asl): 1,391	Target:	NONE	
Remarks:	Calibration of existing borehole. Values for the VES and Profile are very low suggesting that in fact sediments are overlaying the granites as opposed of the representation of only granites on the geological map. The VES shows a very thick overburden wiith a slow rise to 45 degrees which points to a thicker layer of weathering.				

Location map geophysical measurements

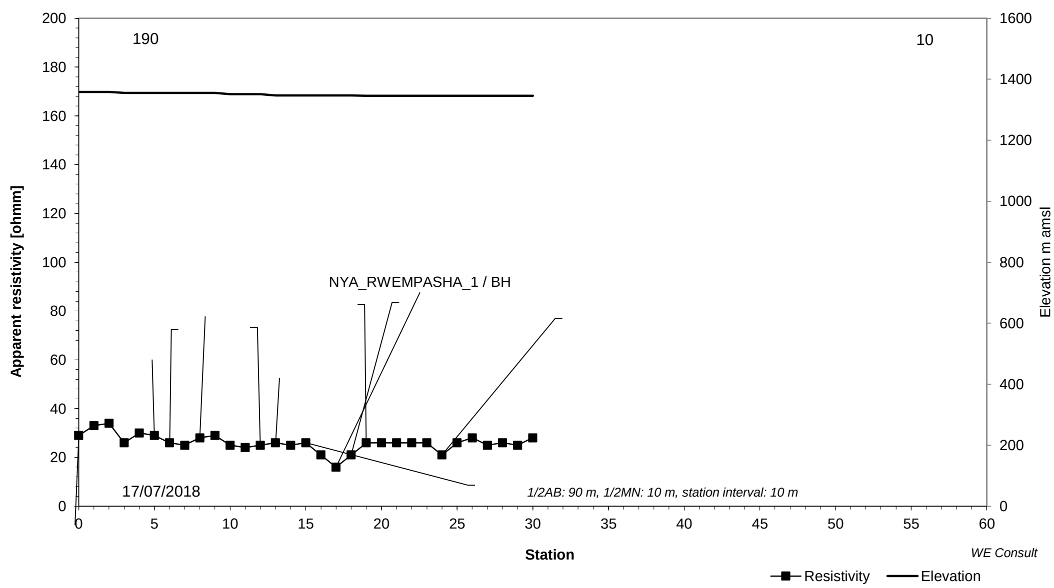


Site	NYA_RWEMPASHA	Village				
Parish	Cell	Sector				
		District	#N/A			
Rating per site (max. 100 points):							

	1	2	3	4	5	6	7
Local topography (0-20 points)							
Lineament (0-20 points)							
Anomaly (0-30 points)							
VES (0 -15 points)							
Earlier results (0 - 15)							
Total							
Remarks							

Geophysical measurements

NYA_RWEMPASHA_A PROFILE

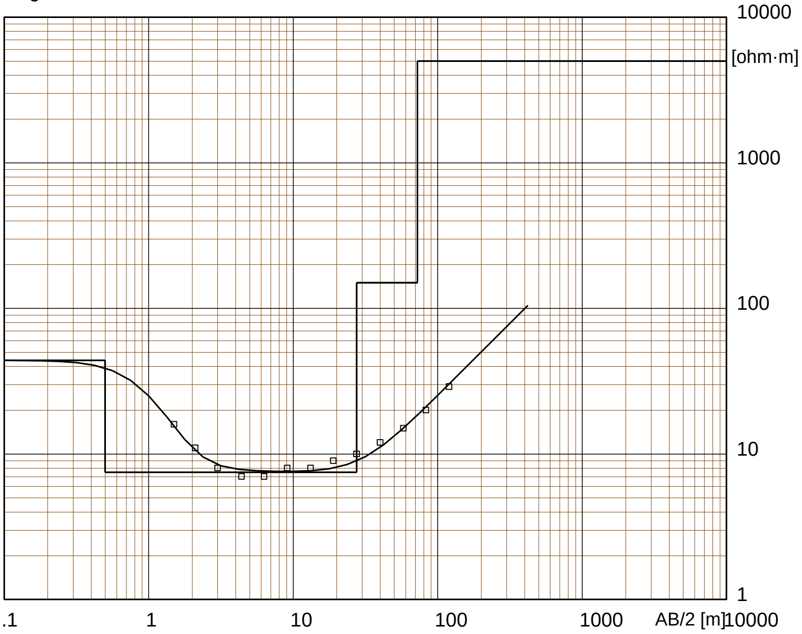


Best VES: **CALIBRATION**

ELECTICAL SOUNDING_SCHLUM
NYA_RWEMPASHA_1

Electrical sounding Schlumberger - 201811_NagatareII.WS3

Nagatare II



Location X = 206377 Y = 9863181 Z = 1476 Azim = 1180 - 360

Model Resistivity	**Thickness**	**Depth**	**Altitude**
[ohm·m]	[m]	[m]	[m]
44	.5		1476
7.5	27	.5	1475.5
150	45	28	1448
5000		73	1403

The VES was carried on an existing bh in nyagatare. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

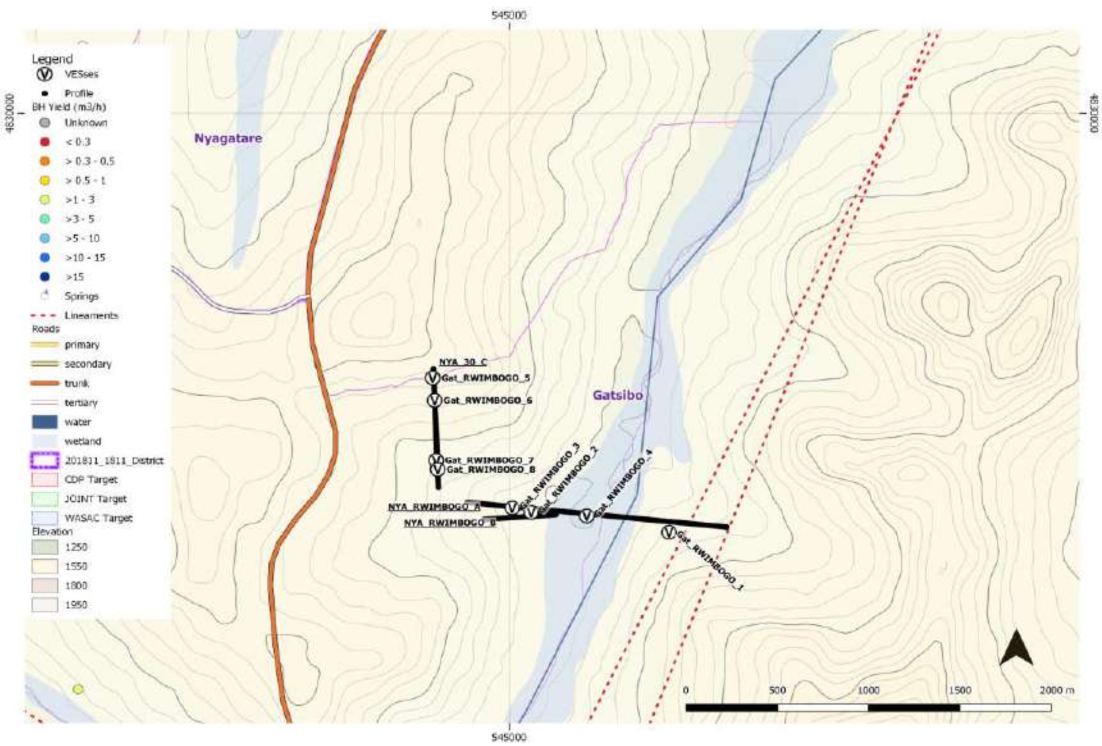
WE Consult

Best VES: **CALIBRATION**

WE Consult

Location:	NYA_RWIMBOGO					34
Recommended Site:		VES_8		coordinate (E) 544607	coordinate (N)	4827935
Expected DTB (m):		60		Altitude (amsl)	1442	
Recommended Depth (m):		80		Accessibility Site:	Accessible	
Alternative Site:		VES_3		coordinate (E) 545015	coordinate (N)	4827712
Expected DTB (m):		40		Altitude (amsl)	1408	
Recommended Depth (m):		80		Accessibility Site:	Accessible	
Expected Formation:		Granites		Accessibility Village:	None	
Int yield (l/h) :	2,494	SWL (m asl):	1,426	Target:	PRODUCTION	
Remarks:	This survey was done to provide water supply for the sub station being built, and to get an overview on (estimated) low potential granite valleys common in Nyagatare and Gatsibo. VES-3 is on a pronounced anomaly on the profile representing a discontinuation of the bedrock at a depth of 60m on location. The VES shape is wide, and unlike the failed attempts previously made. The wide shape and late rising to 45 degrees indicates a thick overburden with higher chances of getting water before bedrock and a thicker weathered layer also indicated by the anomaly on the profile. Solid bedrock is expected beyond 80 meters and it is not recommended to drill beyond it. VES-8 is close to a valley and is on a visible anomaly on the profile. It is not as pronounced, both in VES and profile as VES-3, but shows the potential for similar subsurface conditions in a valley perpendicular to the one crossed by the profile with VES-3. Solid bedrock is expected at 60 meters since it is at a lower elevation than VES-8, so the bedrock will be reached sooner. It is not recommended to continue beyond 60 meters unless solid bedrock has not yet been encountered (solid bedrock is recognizable by slow progress in drilling and dust instead of rough cuttings when using DTH drilling techniques.					

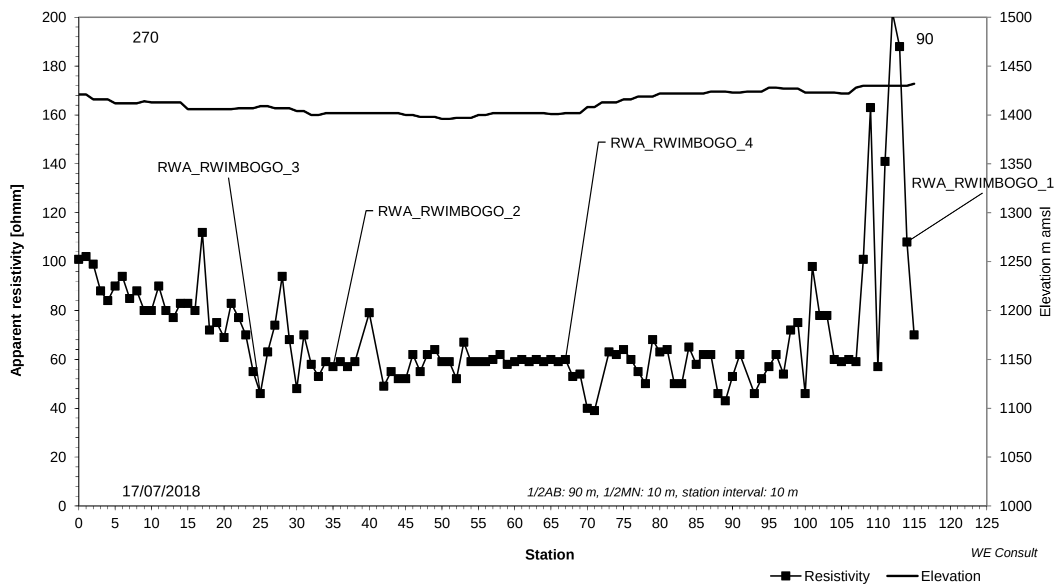
Location map geophysical measurements



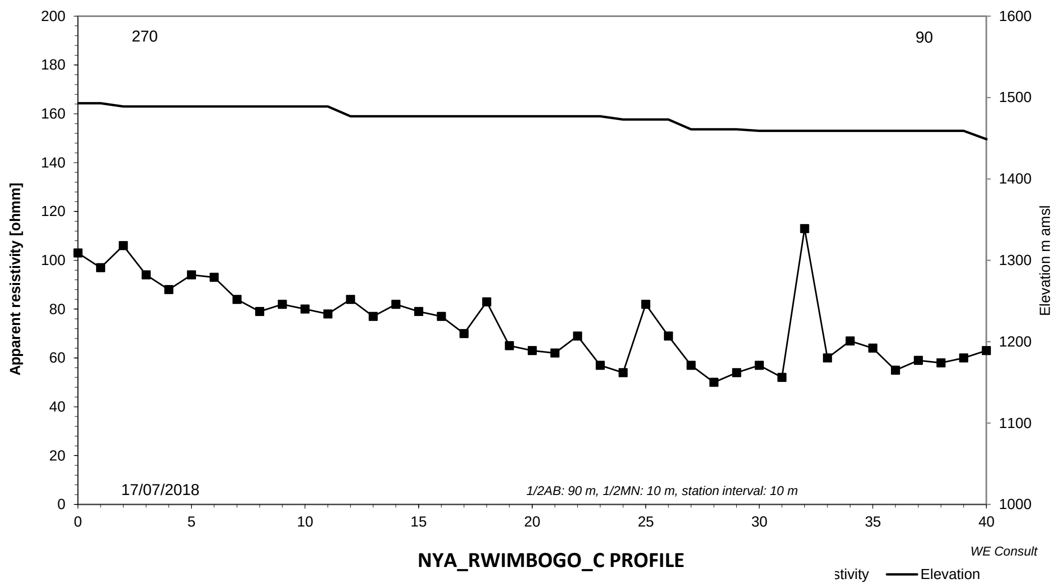
Site	34		Village	Ngarama		
Cell	Nyabikiri		Sector	Kabarore		
			District	Gatsibo		

Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	5	15	15	15	5	5	10
Lineament (0-20 points)	5	5	5	5			
Anomaly (0-30 points)			5		5	2	2
VES (0 -15 points)							
Earlier results (0 - 15)							
Total	15	25	48	25	33	27	32
Remarks							
Geophysical measurements							

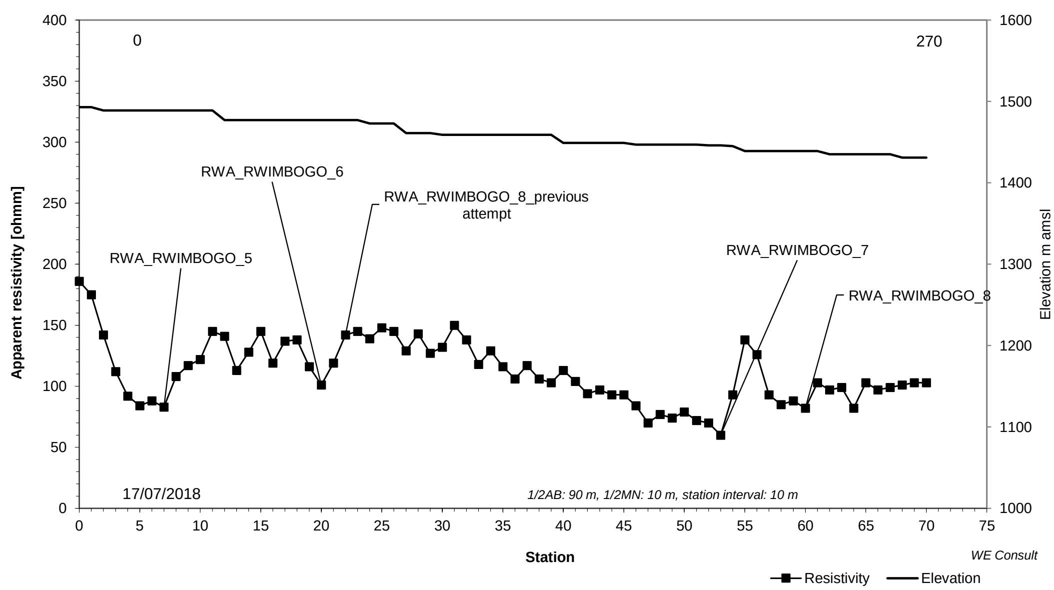
NYA_RWIMBOGO_A PROFILE



NYA_RWIMBOGO_B PROFILE



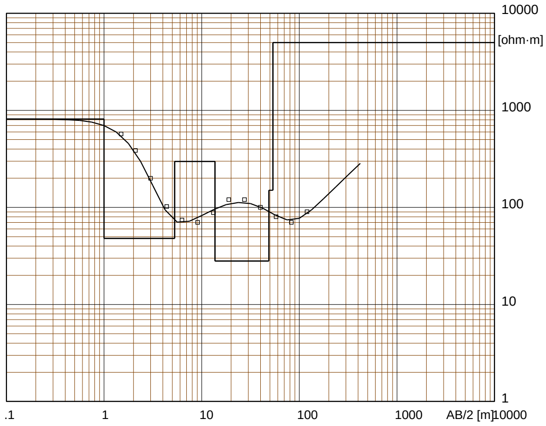
NYA_RWIMBOGO_C PROFILE



Best VES: **VES_3**

WE Consult

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_1



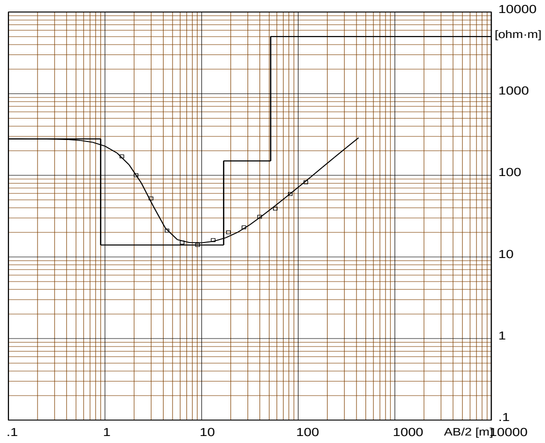
Location X = 212059 Y = 9827450 Z = 1426 Azim = 90 - 270

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
812	1		1426
48	4.3	1	1425
298	8.4	5.3	1420.7
28	35	14	1412
150	5	49	1377
5000		54	1372

The VES was carried on station 114 of profile A. The interpreted layers are: top soil, clay, sandy clay, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_2



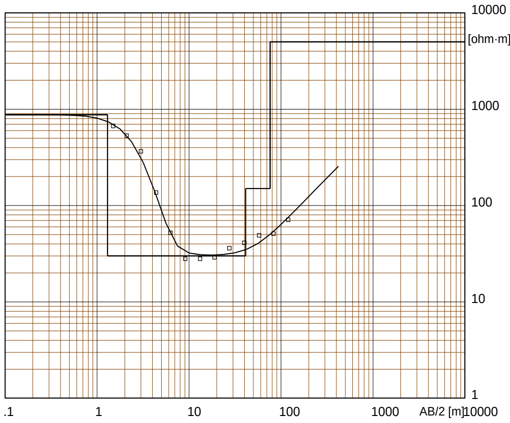
Location X = 211304 Y = 9827565 Z = 1450 Azim = 90 - 270

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
279	.9		1450
14	16	.9	1449.1
150	35	17	1433
5000		52	1398

The VES was carried on station 35 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_3



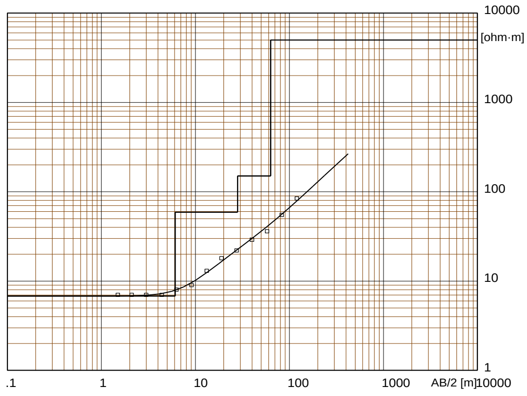
Location X = 211200 Y = 9827590 Z = 1454 Azim = 90 - 270

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
876	1.3		1454
30	40	1.3	1452.7
150	35	41	1413
5000		76	1378

The VES was carried on station 25 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_4



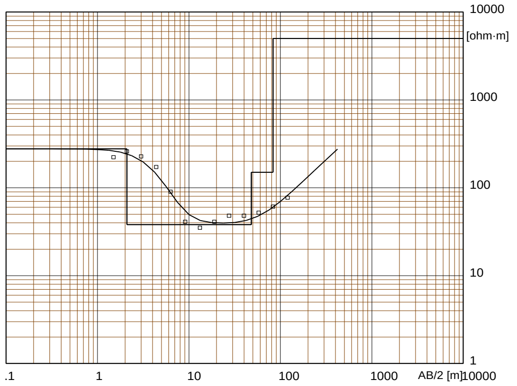
Location X = 211608 Y = 9827544 Z = 1404 Azim = 90 - 270

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
6.8	6.1		1404
59	22	6.1	1397.9
150	35	28	1376
5000		63	1341

The VES was carried on station 67 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_5



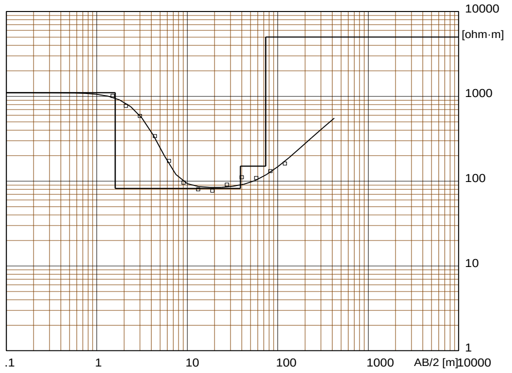
Location X = 210763 Y = 9828344 Z = 1490 Azim = 180 - 0

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
277	2.1		1490
38	46	2.1	1487.9
150	35	48	1442
5000		83	1407

The VES was carried on station 7 of profile C. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_6



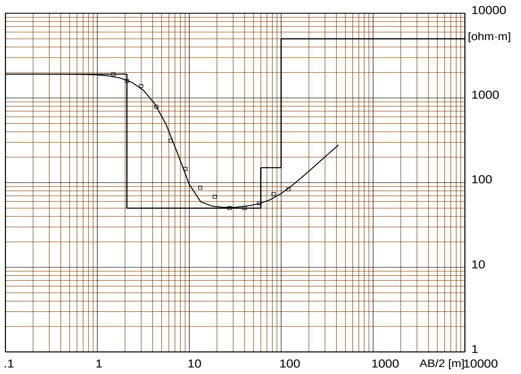
Location X = 210774 Y = 9828214 Z = 1482 Azim = 180 - 0

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1102	1.6		1482
82	37	1.6	1480.4
150	35	39	1443
5000		74	1408

The VES was carried on station 20 of profile C. The interpreted layers are: top soil, sandy clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_7



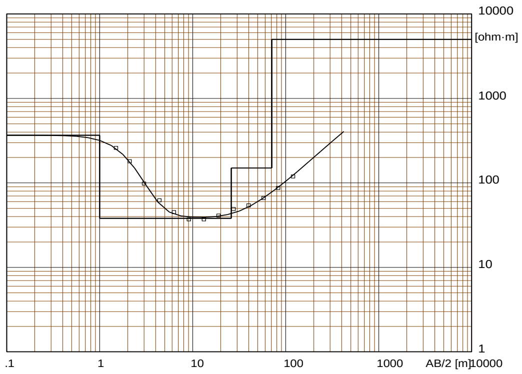
Location X = 210783 Y = 9827866 Z = 1461 Azim = 180 - 0

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1911	2.1		1461
50	58	2.1	1458.9
150	40	60	1401
5000		100	1361

The VES was carried on station 53 of profile C. The interpreted layers are: top soil, sandy clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_8



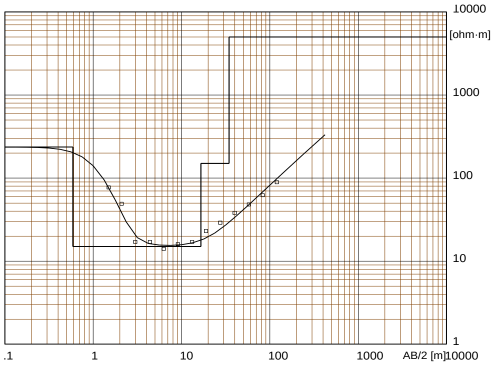
Location X = 210791 Y = 9827813 Z = 1445 Azim = 180 - 0

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
366	1		1445
38	25	1	1444
150	45	26	1419
5000		71	1374

The VES was carried on station 60 of profile C. The interpreted layers are: top soil, Clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_RWIMBOGO_9



Location X = 211260 Y = 9827547 Z = 1415 Azim = 90 - 270

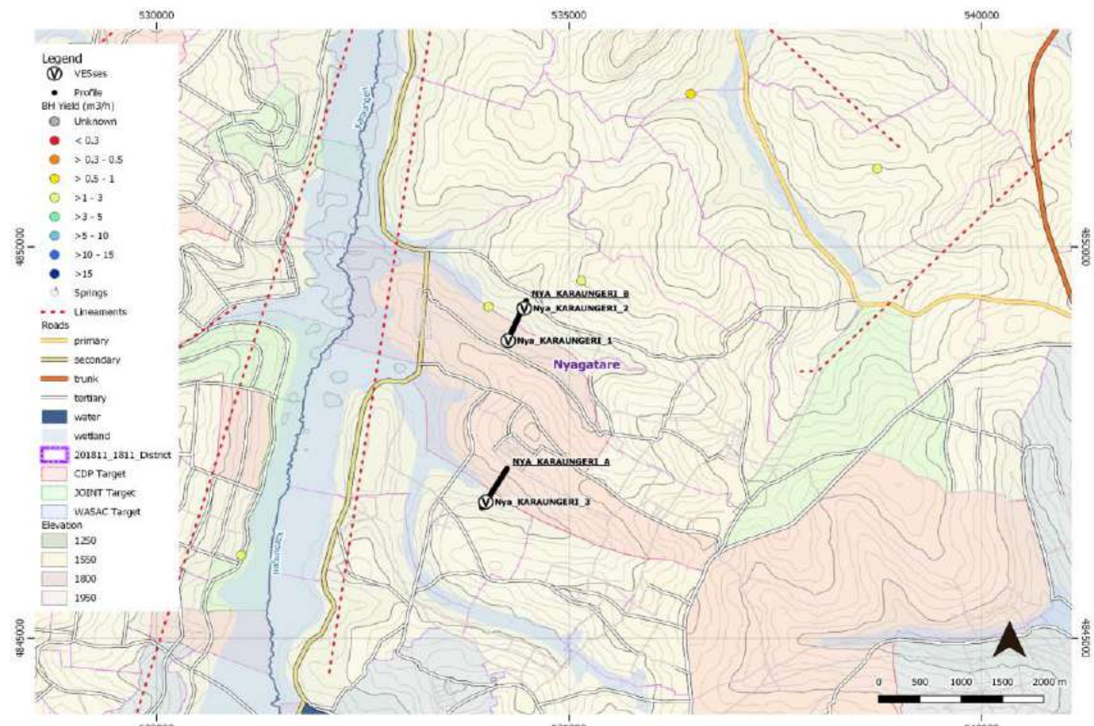
Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
236	.59		1415
15	16	.59	1414.4
150	18	17	1398
5000		35	1380

The VES was carried on an station 22 of profile C. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

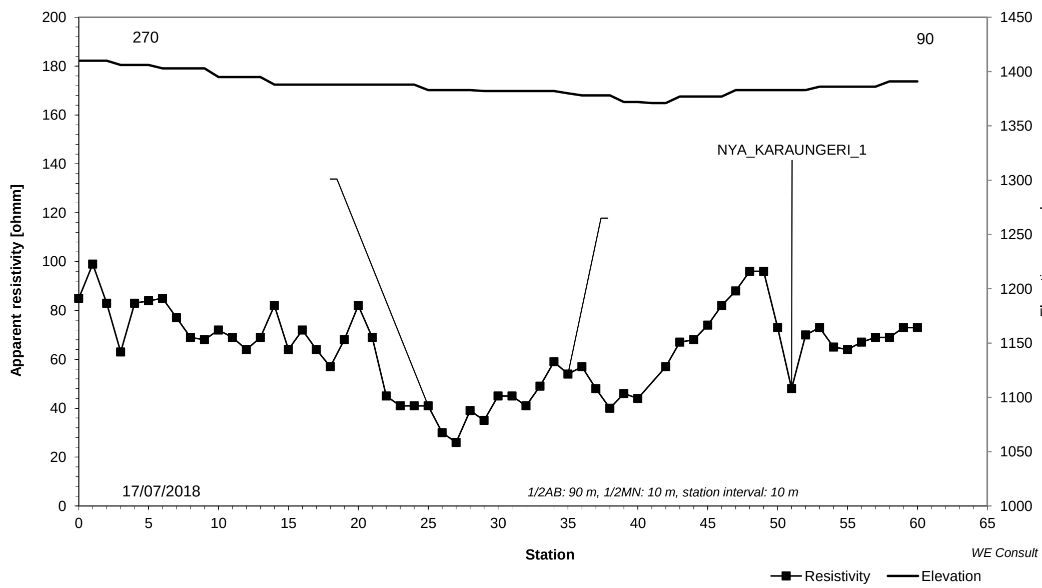
Location:	NYA_KARAUNGERI						35
Recommended Site:		VES_4		coordinate (E)	533989	coordinate (N)	4846741
Expected DTB (m):		20		Altitude (amsl)		1383	
Recommended Depth (m):		60		Accessibility Site:		Accessible	
Alternative Site:				coordinate (E)		coordinate (N)	
Expected DTB (m):				Altitude (amsl)			
Recommended Depth (m):				Accessibility Site:			
Expected Formation:		Granites & Sediments		Accessibility Village:		None	
Int yield (l/h) :	2,241	SWL (m asl):	1,378	Target:		CDP	
Remarks:	This survey was done to confirm Class 2 major valleys in Granites. VES_1 and VES_3 show a deep depth to bedrock indicating a thick overburden and more intensive weathering then on VES_4. The calibration however shows that the depth to bedrock is not deep on the existing borehole. In fact, the VES shape for VES_4 is almost identical. For this reason, since the borehole is in very close proximity it is suggested to drill on VES_4. However, since the characteristics of the borehole are not known, and the VES shape is not very convincing, only hand pump capacity is expected.						

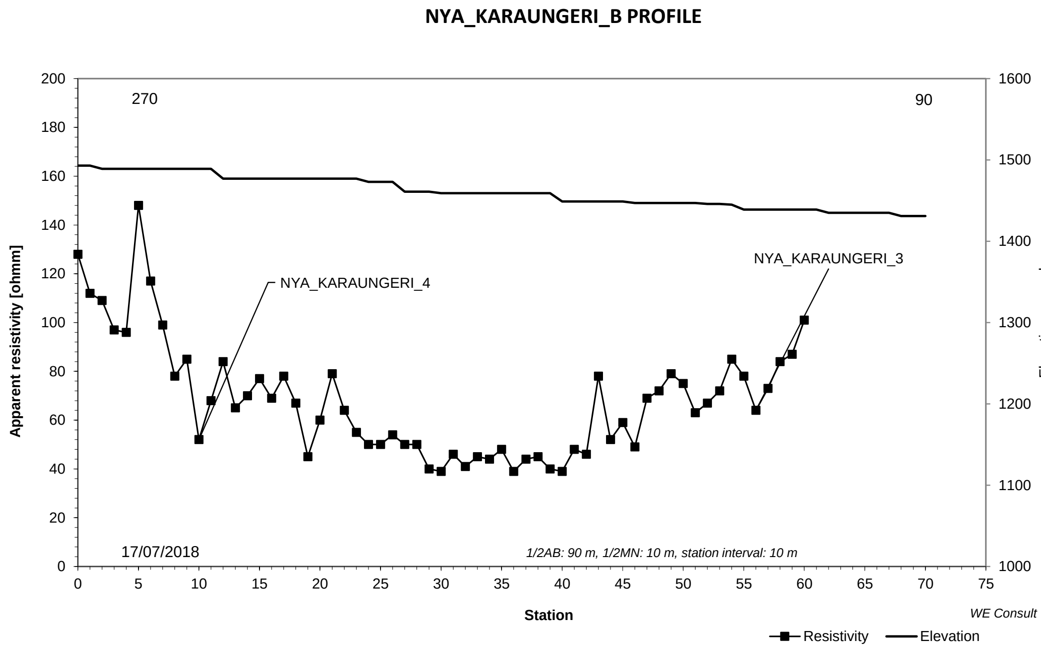
Location map geophysical measurements



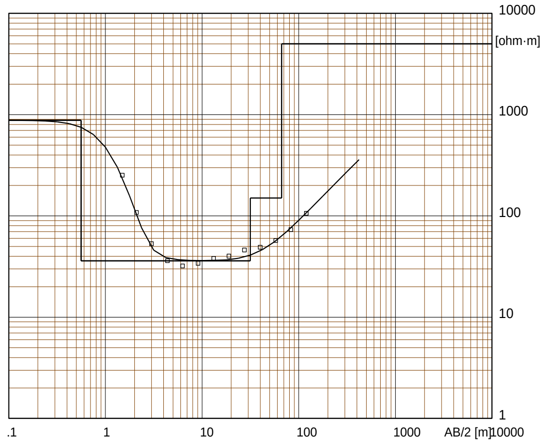
Site	34		Village	Mihingo			
Cell	Gakirage		Sector	Nyagatare			
			District	Nyagatare			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	10		10	10			
Lineament (0-20 points)							
Anomaly (0-30 points)	2						
VES (0 -15 points)							
Earlier results (0 - 15)				5			
Total	26		26	32			
Remarks							
Geophysical measurements							

NYA_KARAUNGERI_A PROFILE




NYA_KARAUNGERI_B PROFILE
270
90
NYA_KARAUNGERI_4
NYA_KARAUNGERI_3
Apparent resistivity [ohmm]
Elevation m amsl
17/07/2018
1/2AB: 90 m, 1/2MN: 10 m, station interval: 10 m
Station
WE Consult
Resistivity
Elevation

ELECTICAL SOUNDING_SCHLUM
NYA_KARAUNGERI_1



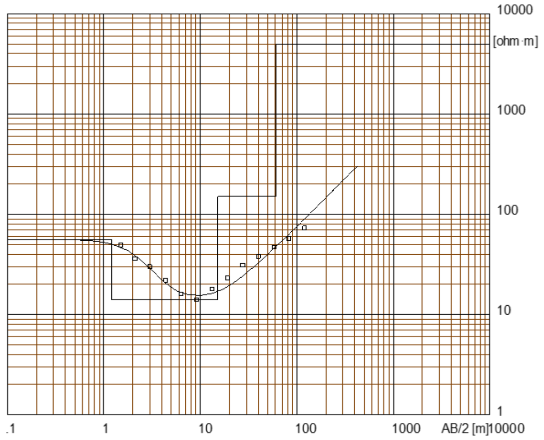
Location X = 200140 Y = 9846619 Z = 1382 Azim = 180 - 0

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
878	.56		1382
36	31	.56	1381.4
150	35	32	1350
5000		67	1315

The VES was carried on station 51 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_KARAUNGERI_2
EXISTING_BH
UNKNOWN CHARACTERISTICS



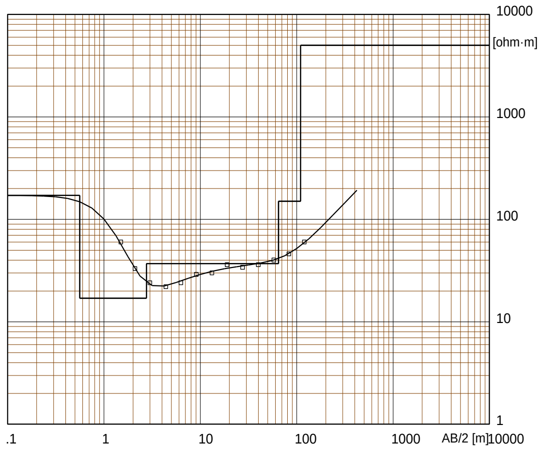
Location X = 200136 Y = 9846756 Z = 1377 Azim = 180 - 0

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
56	1.2		1377
14	14	1.2	1375.8
150	45	15	1362
5000		60	1317

The VES was carried on an existing bh. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_KARAUNGERI_3



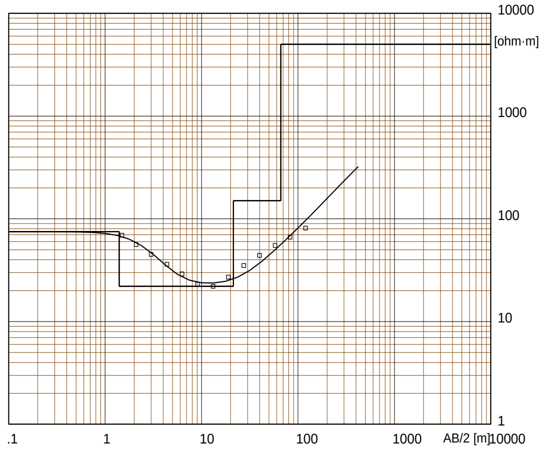
Location X = 200409 Y = 9848682 Z = 1377 Azim = 170 - 350

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
171	.56		1377
17	2.2	.56	1376.4
37	62	2.8	1374.2
150	45	65	1312
5000		110	1267

The VES was carried on an station 56 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_KARAUNGERI_4



Location X = 200602 Y = 9849095 Z = 1465 Azim = 170 - 350

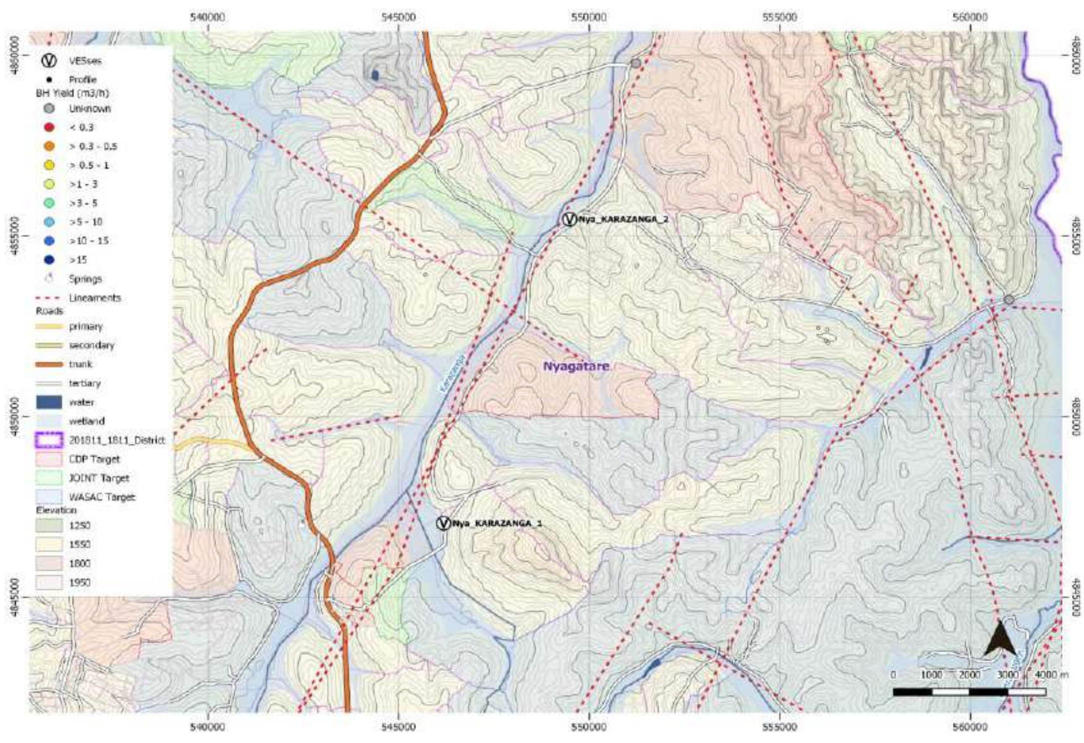
Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
75	1.4		1465
22	20	1.4	1463.6
150	45	21	1444
5000		66	1399

The VES was carried on an station 10 of profile A. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

Location:	NYA_KARANZANGA				36
Recommended Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	Accessible
Alternative Site:				coordinate (E)	coordinate (N)
Expected DTB (m):				Altitude (amsl)	
Recommended Depth (m):				Accessibility Site:	
Expected Formation:		Granites & Sediments		Accessibility Village:	
Int yield (l/h) :	2,241	SWL (m asl):	1,311	Target:	
Remarks:	This survey was done to confirm/calibrate existing high yielding boreholes in the Nyagatare Granites. However, due to the difficulty of interpreting VES results in clayey sediments, it is difficult to see the characteristics of the underground situation of said boreholes. The resistivities are extremely low and consecutive values are masked. However, the VESes do seem to confirm to some extent that the water is likely gotten from the granites (rather than it being schists or other soft rocks), giving hope for fractured aquifers in the granite in valleys if geohphysical investigations are done.				

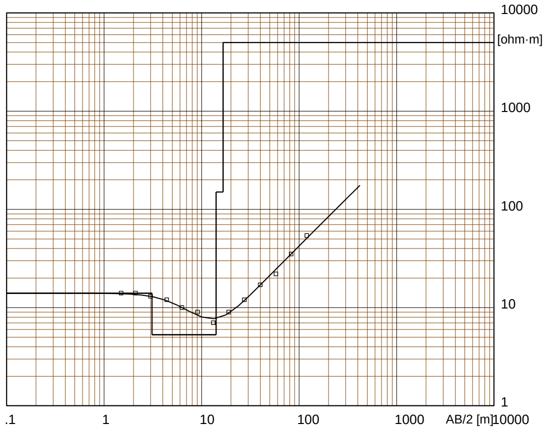
Location map geophysical measurements



Site	34		Village	Mihingo			
Cell	Gakirage		Sector	Nyagatare			
			District	Nyagatare			
Rating per site (max. 100 points):							
	1	2	3	4	5	6	7
Local topography (0-20 points)	10		10	10			
Lineament (0-20 points)							
Anomaly (0-30 points)	2						
VES (0 -15 points)							
Earlier results (0 - 15)				5			
Total	26		26	32			
Remarks							
Geophysical measurements							

Best VES: **CALIBRATION**

ELECTICAL SOUNDING_SCHLUM
NYA_KARAZANGA_1
EXISTING_BH 25 m3/h



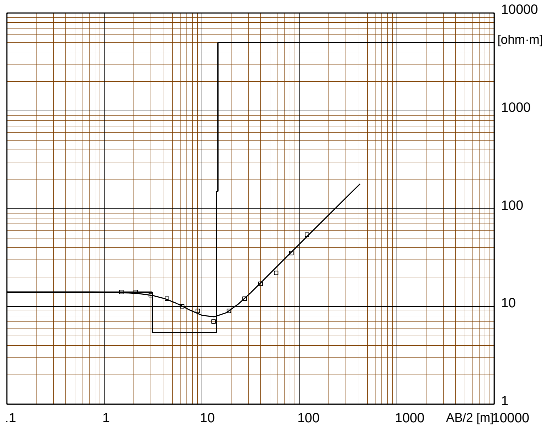
Location X = 212340 Y = 9846941 Z = 1345 Azim = 160 - 240

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
14	3.1		1345
5.3	11	3.1	1341.9
150	2.5	14	1331
5000		16	1329

The VES was carried on an existing bh at Kirebe diary. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_KARAZANGA_2
EXISTING_BH 5,5 m3/h



Location X = 215638 Y = 9855364 Z = 1328 Azim = 60 - 240

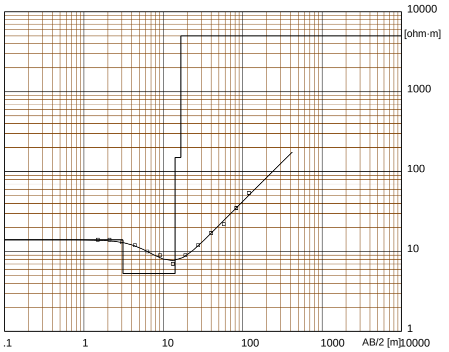
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
14	3.1		1328
5.4	11	3.1	1324.9
150	.5	14	1314
5000		14	1314

The VES was carried on an existing bh at Kirebe diary. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

Best VES: **CALIBRATION**

ELECTICAL SOUNDING_SCHLUM
NYA_KARAZANGA_1
EXISTING_BH 25 m3/h



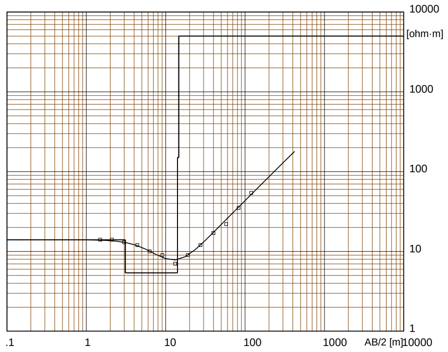
Location X = 212340 Y = 9846941 Z = 1345 Azim = 160 - 240

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
14	3.1		1345
5.3	11	3.1	1341.9
150	2.5	14	1331
5000		16	1329

The VES was carried on an existing bh at Kirebe diary. The interpreted layers are: top soil, clay, weathered layer and hard rock.

W-GeoSoft / WinSev 6.3

ELECTICAL SOUNDING_SCHLUM
NYA_KARAZANGA_2
EXISTING_BH 5,5 m3/h



Location X = 215638 Y = 9855364 Z = 1328 Azim = 60 - 240

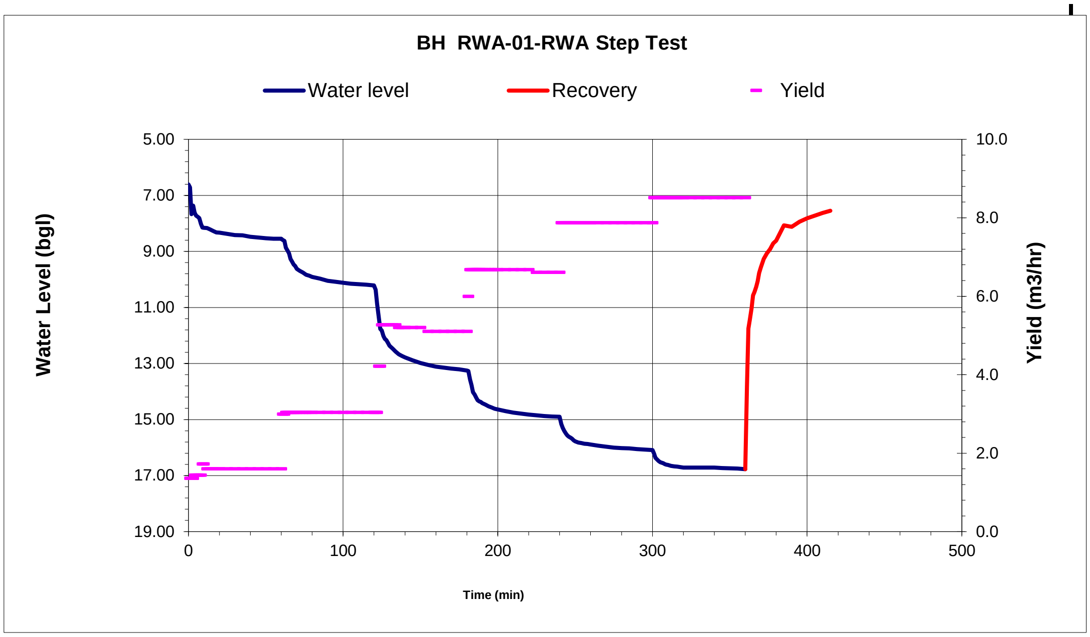
Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
14	3.1		1328
5.4	11	3.1	1324.9
150	.5	14	1314
5000		14	1314

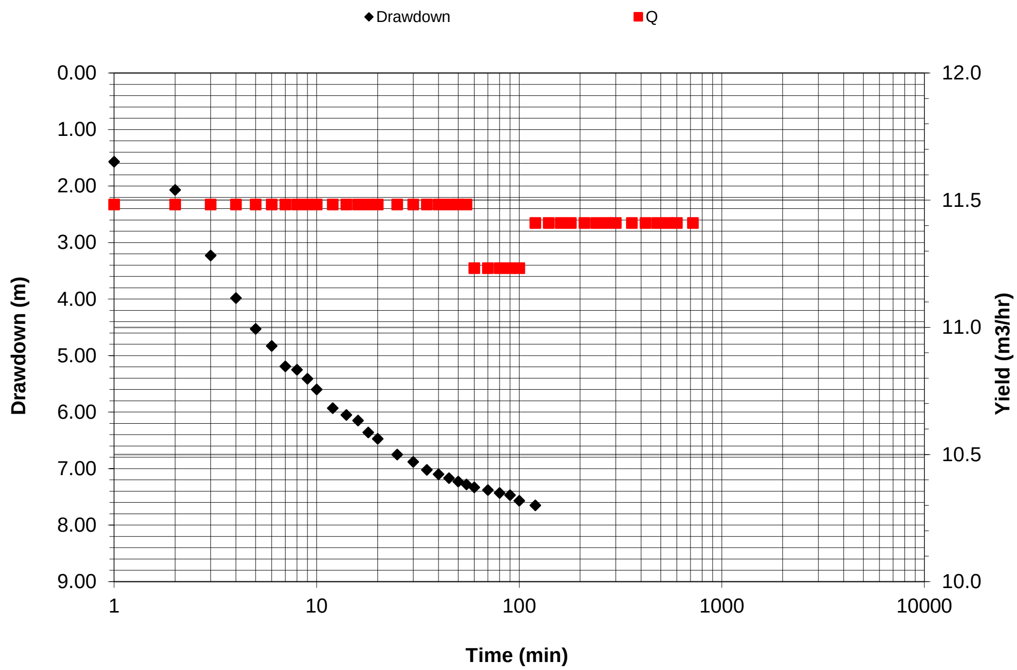
The VES was carried on an existing bh at Kirebe diary. The interpreted layers are: top soil, clay, weathered layer and hard rock.

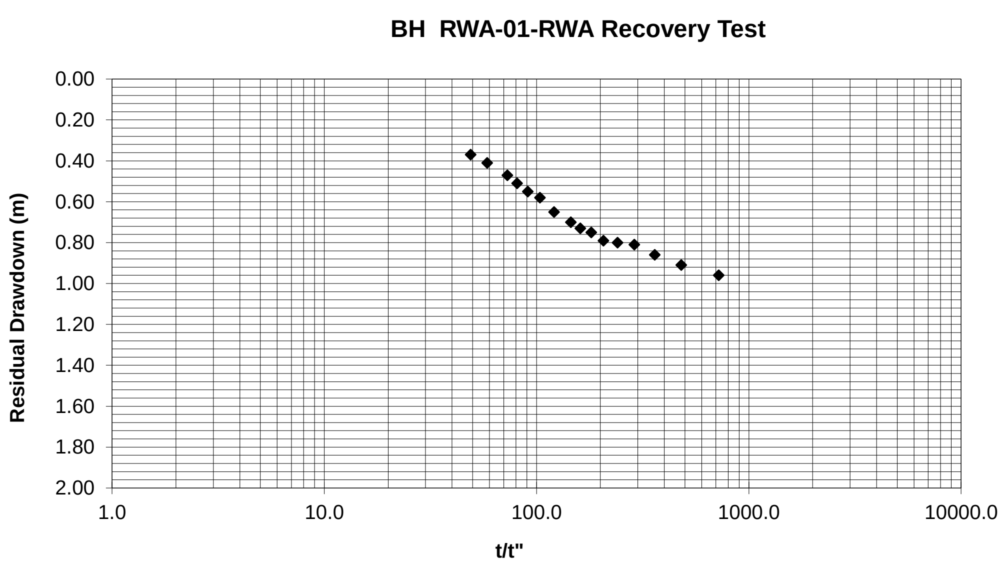
W-GeoSoft / WinSev 6.3

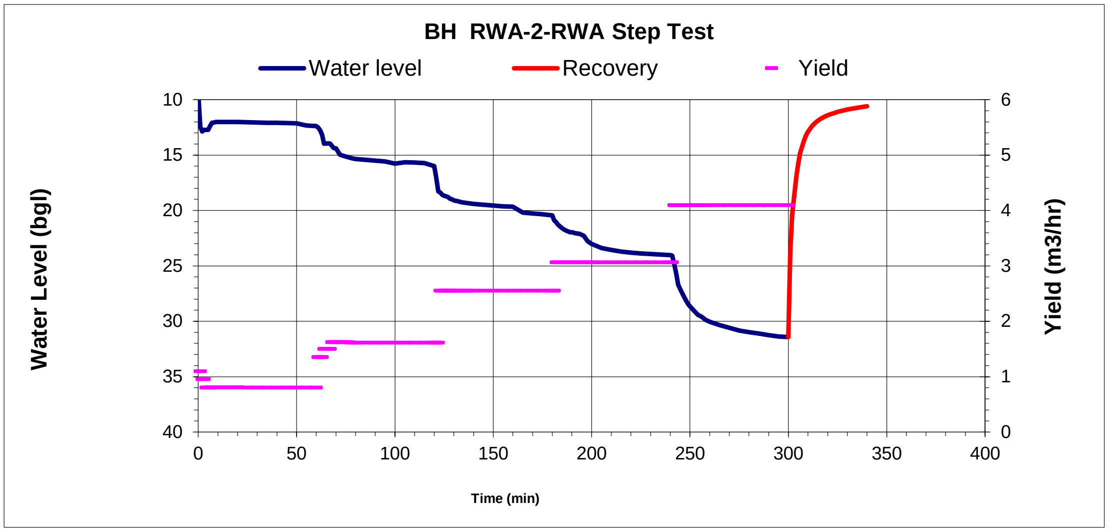
WE Consult

Annex 3. Results Test pumping

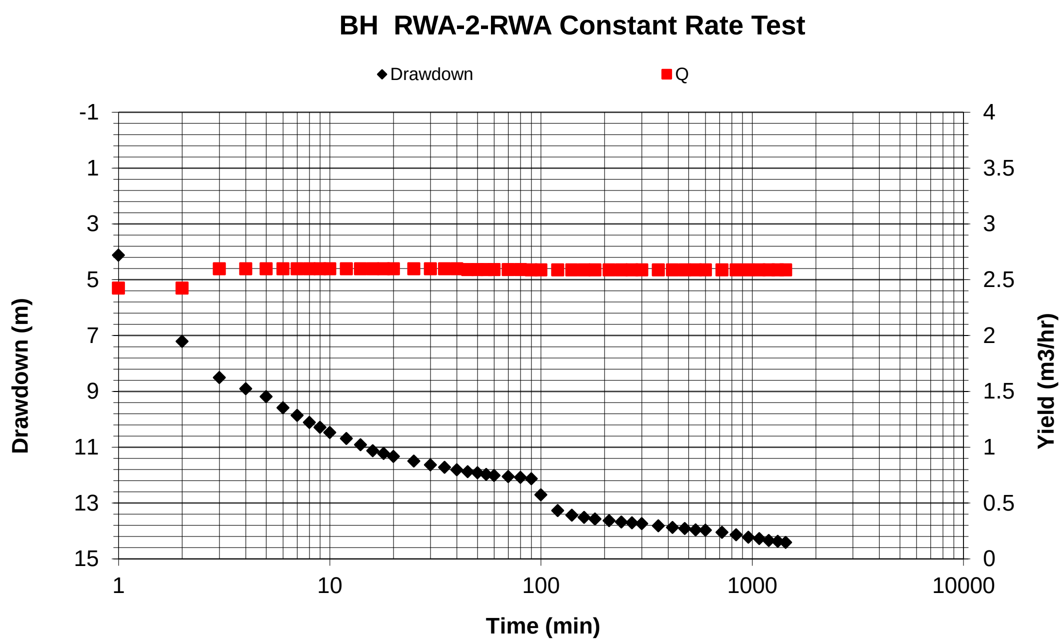

BH RWA-01-RWA Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)


Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)

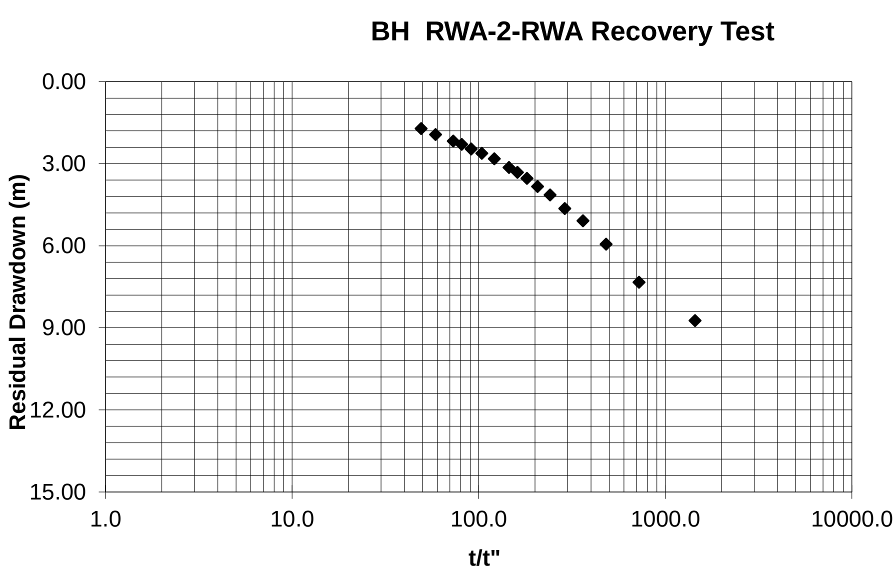

BH RWA-01-RWA Recovery Test
Residual Drawdown (m)
t/t"



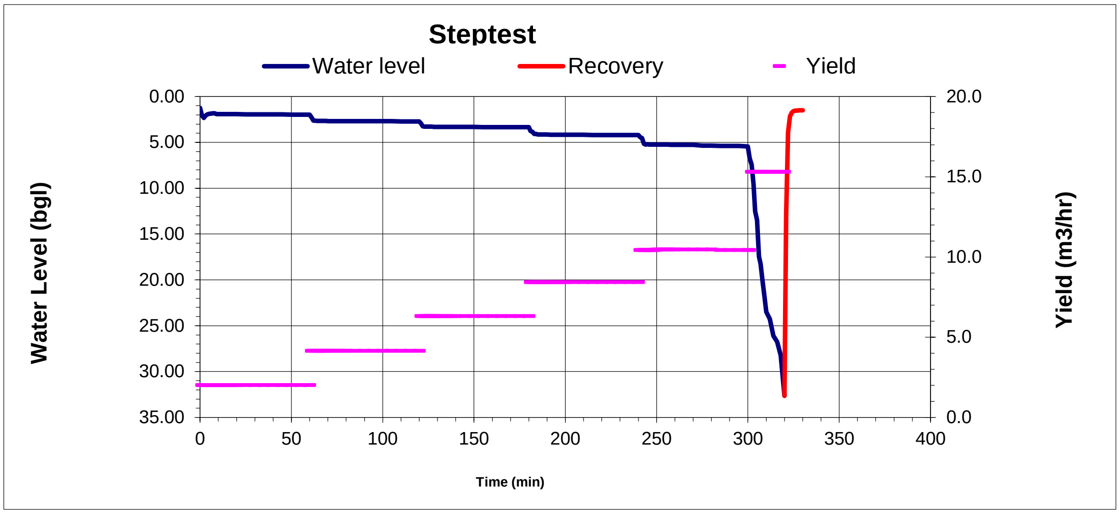
BH RWA-2-RWA Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
10
15
20
25
30
35
40
6
5
4
3
2
1
0
0
50
100
150
200
250
300
350
400



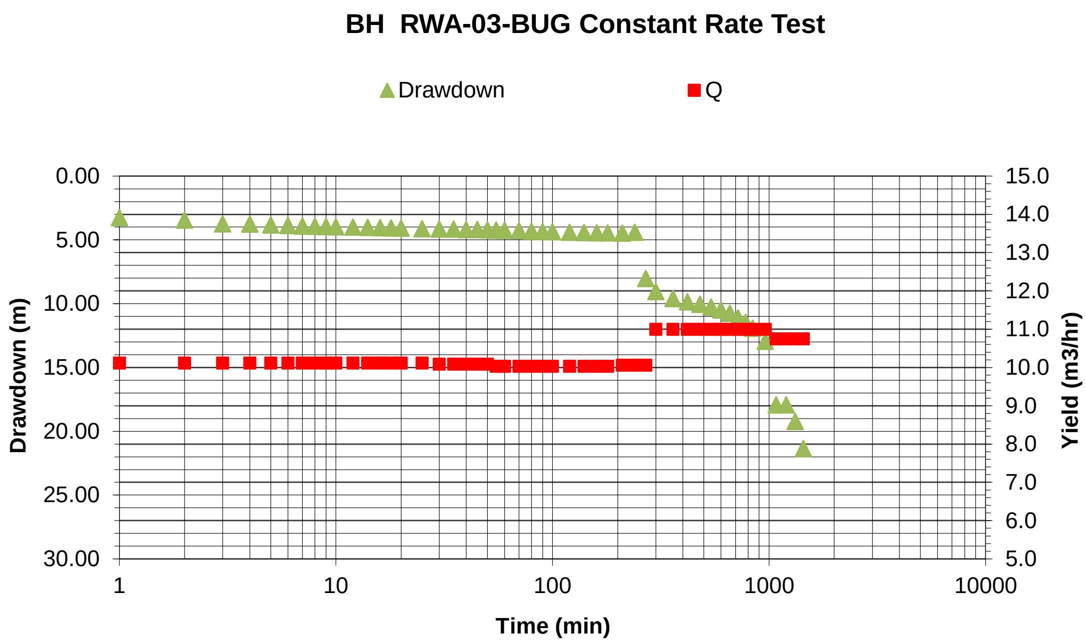
BH RWA-2-RWA Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
-1
1
3
5
7
9
11
13
15
4
3.5
3
2.5
2
1.5
1
0.5
0
1
10
100
1000
10000



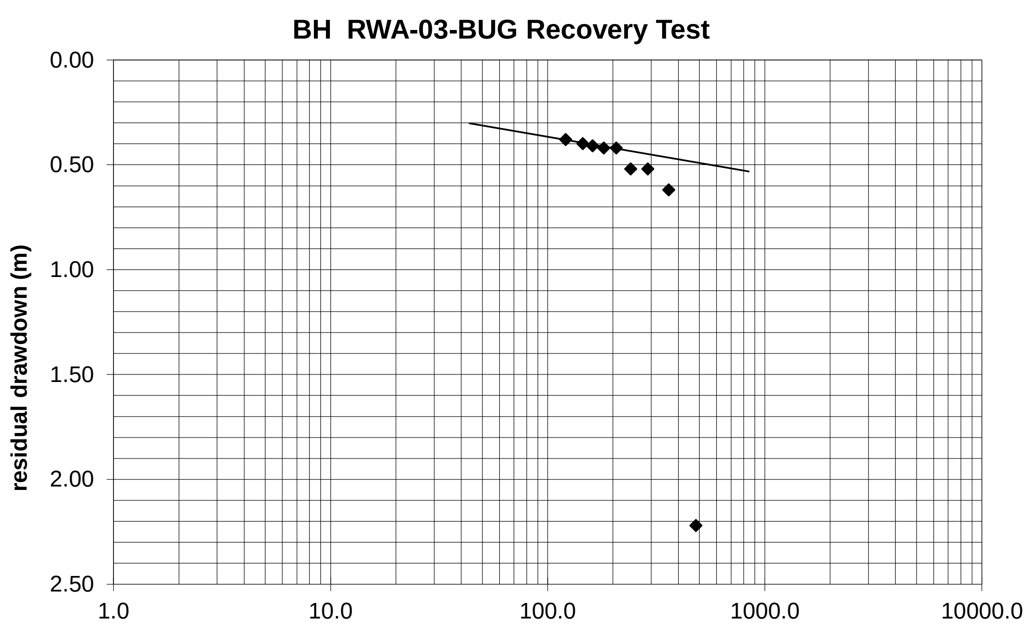
BH RWA-2-RWA Recovery Test
Residual Drawdown (m)
t/t"
0.00
3.00
6.00
9.00
12.00
15.00
1.0
10.0
100.0
1000.0
10000.0



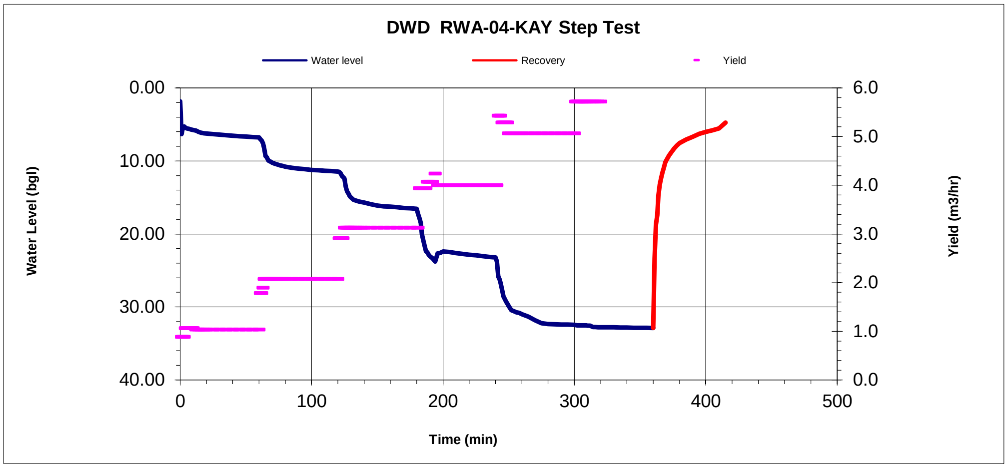
Steptest
Water level
Recovery
Yield
Water Level (bgl)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Yield (m3/hr)
20.0
15.0
10.0
5.0
0.0
0
50
100
150
200
250
300
350
400
Time (min)

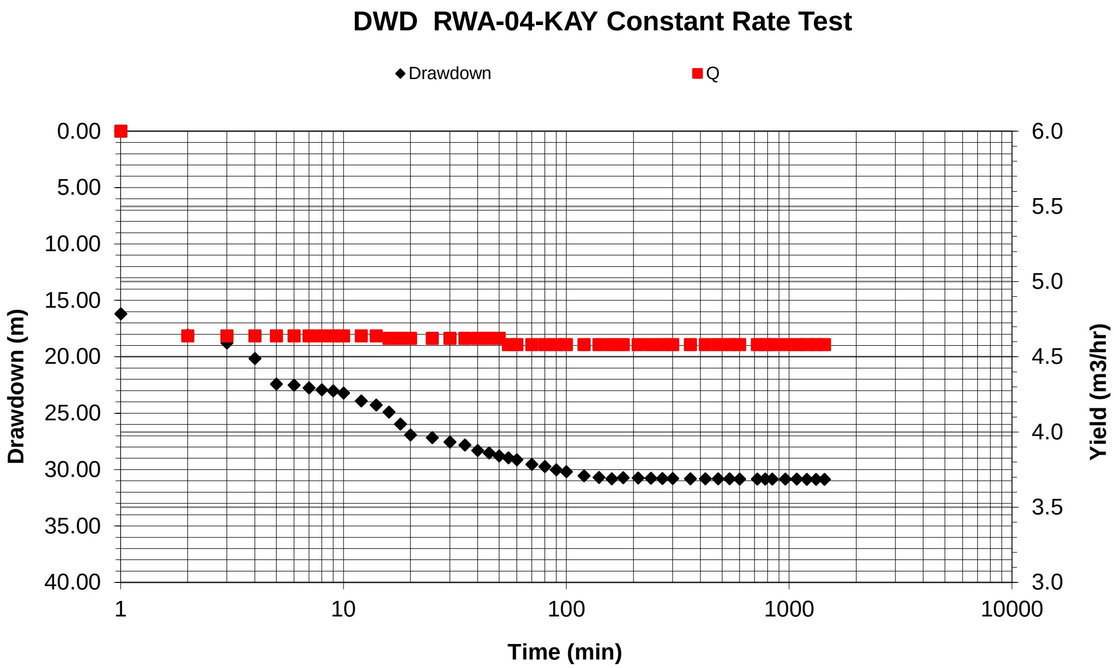


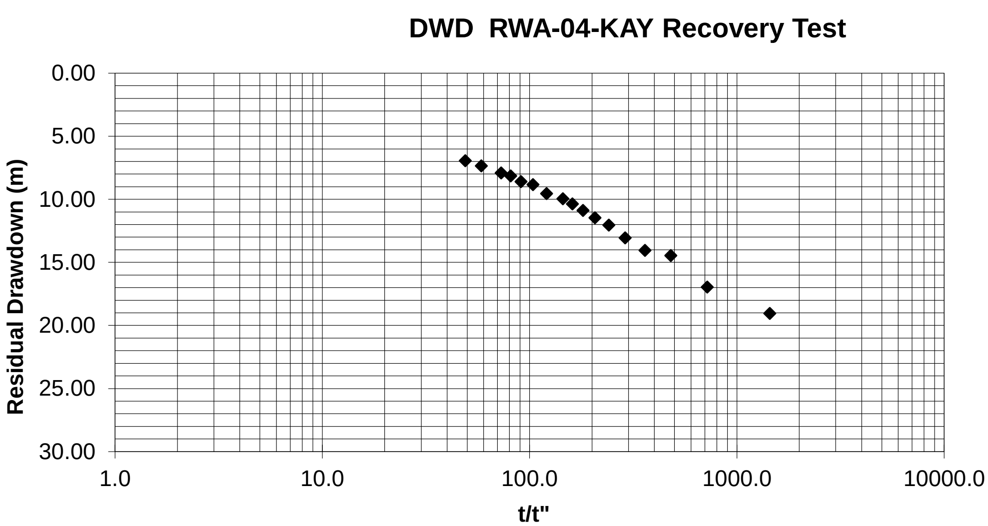
BH RWA-03-BUG Constant Rate Test
Drawdown
Q
Drawdown (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Yield (m3/hr)
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
1
10
100
1000
10000
Time (min)

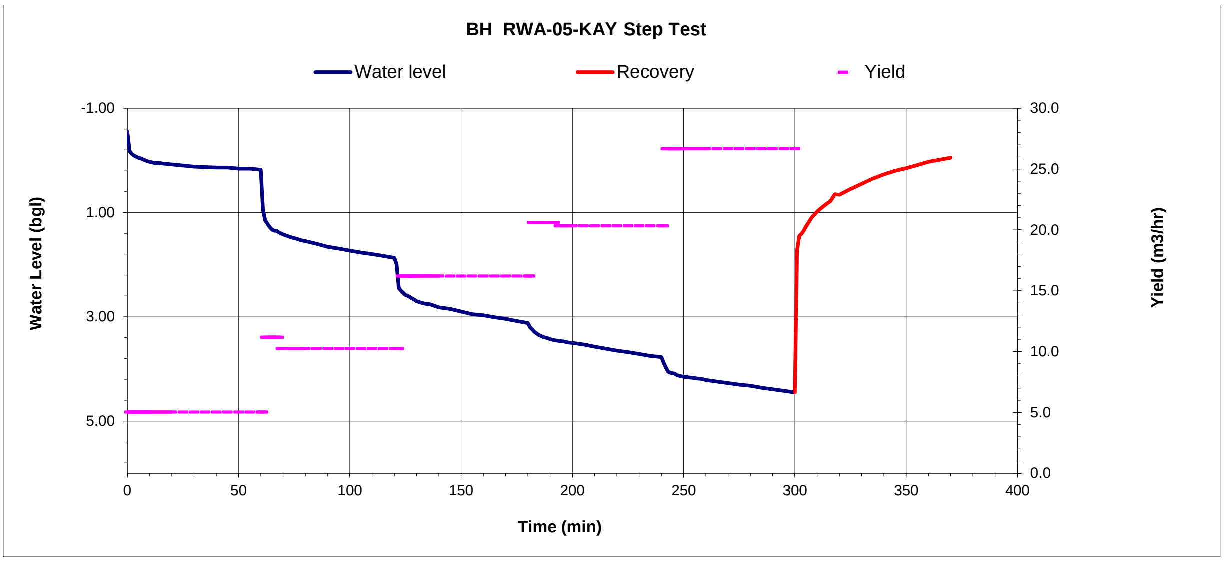


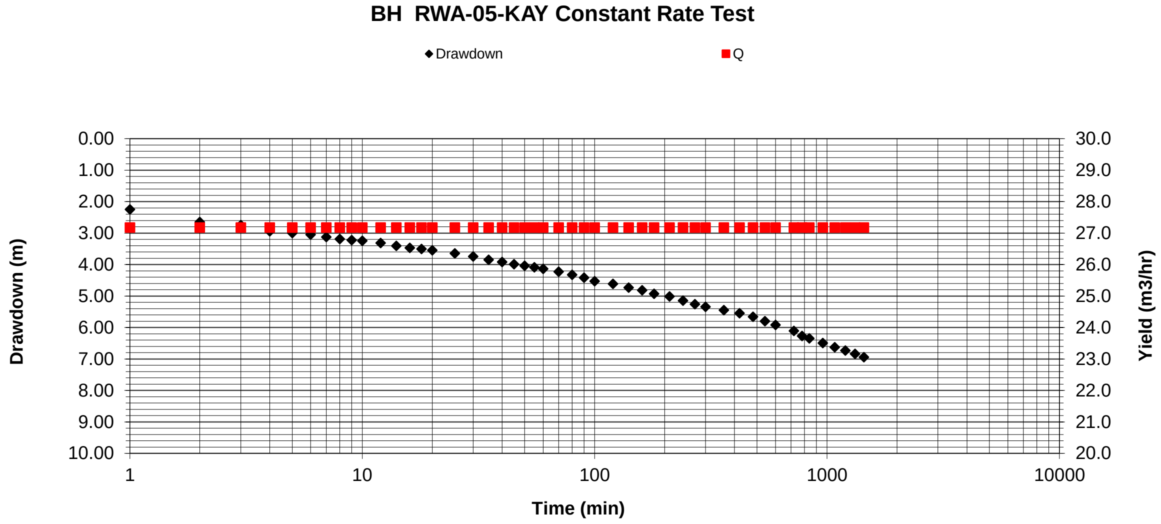
BH RWA-03-BUG Recovery Test
residual drawdown (m)
0.00
0.50
1.00
1.50
2.00
2.50
1.0
10.0
100.0
1000.0
10000.0

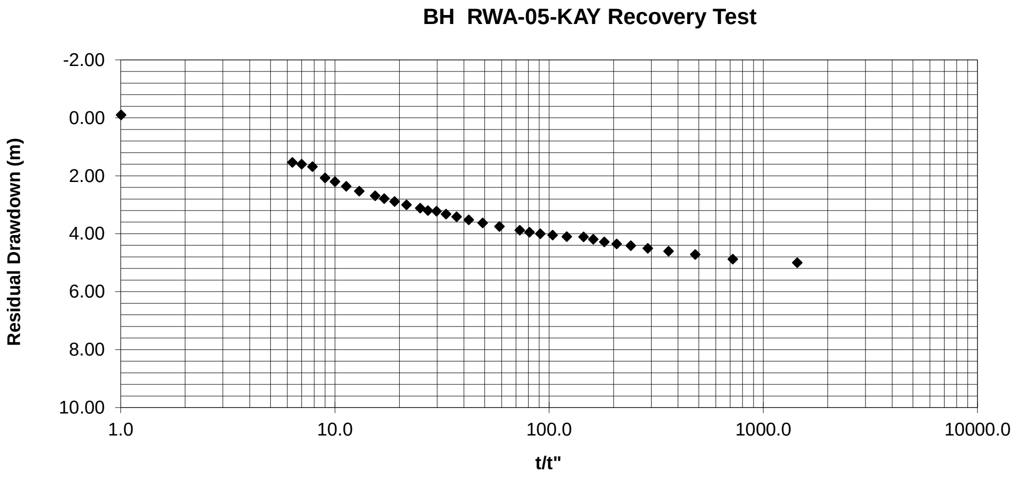

DWD RWA-04-KAY Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
0.00
10.00
20.00
30.00
40.00
0
100
200
300
400
500
6.0
5.0
4.0
3.0
2.0
1.0
0.0

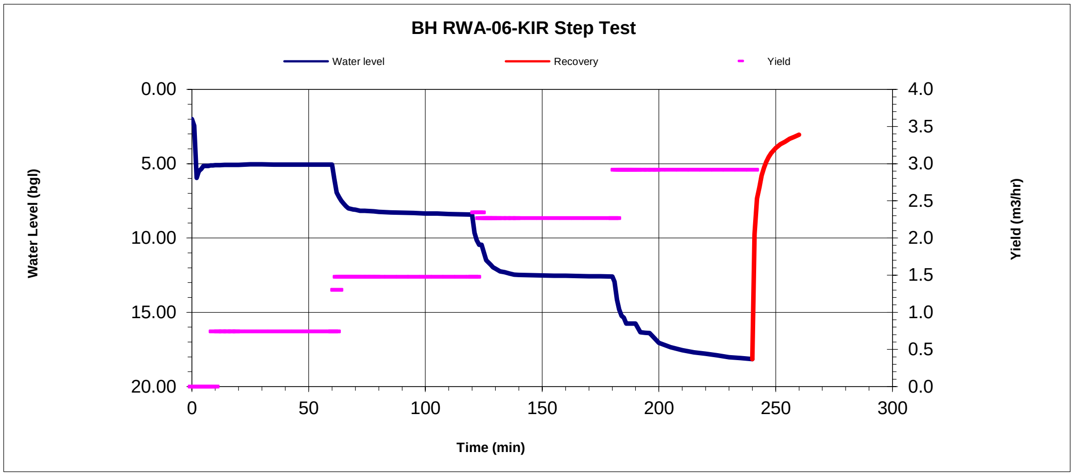

DWD RWA-04-KAY Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1
10
100
1000
10000
6.0
5.5
5.0
4.5
4.0
3.5
3.0

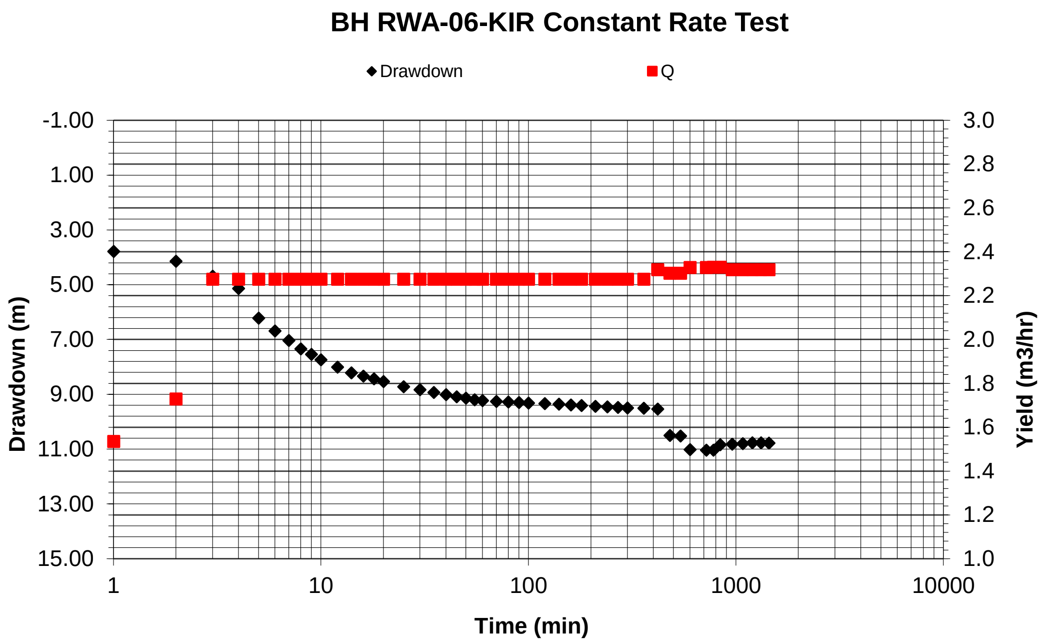

DWD RWA-04-KAY Recovery Test
Residual Drawdown (m)
t/t"
0.00
5.00
10.00
15.00
20.00
25.00
30.00
1.0
10.0
100.0
1000.0
10000.0

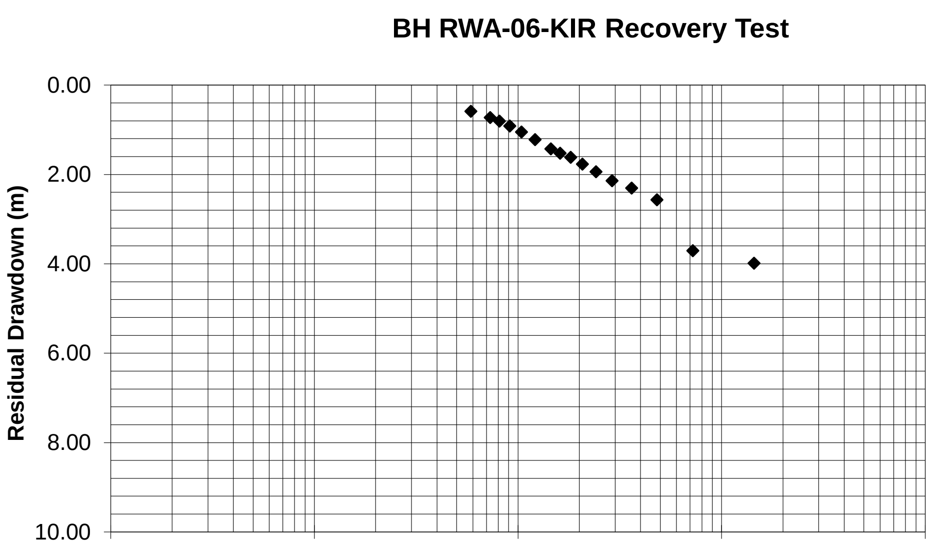

BH RWA-05-KAY Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
-1.00
1.00
3.00
5.00
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
50
100
150
200
250
300
350
400

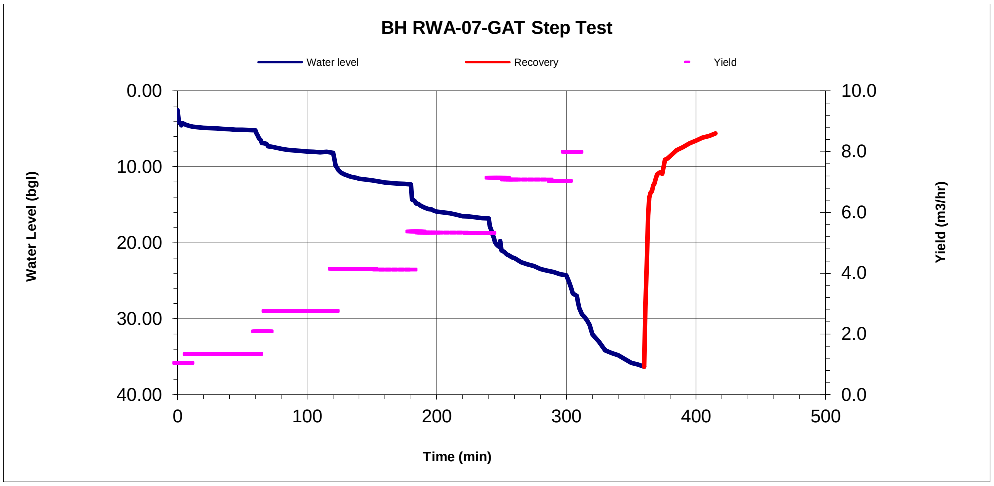

BH RWA-05-KAY Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
1
10
100
1000
10000

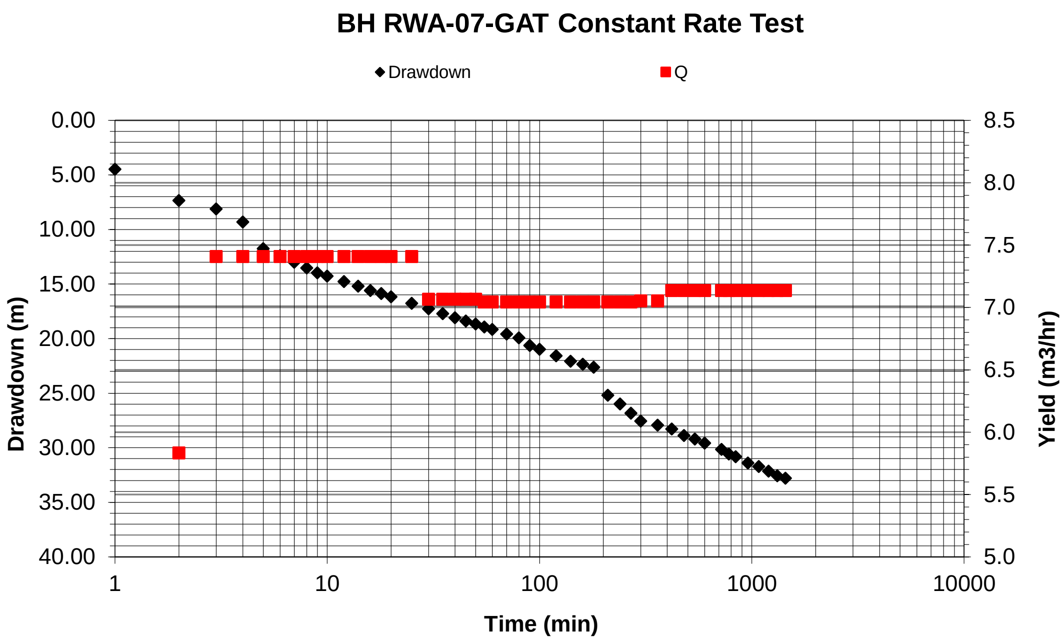

BH RWA-05-KAY Recovery Test
Residual Drawdown (m)
t/t"
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
1.0
10.0
100.0
1000.0
10000.0

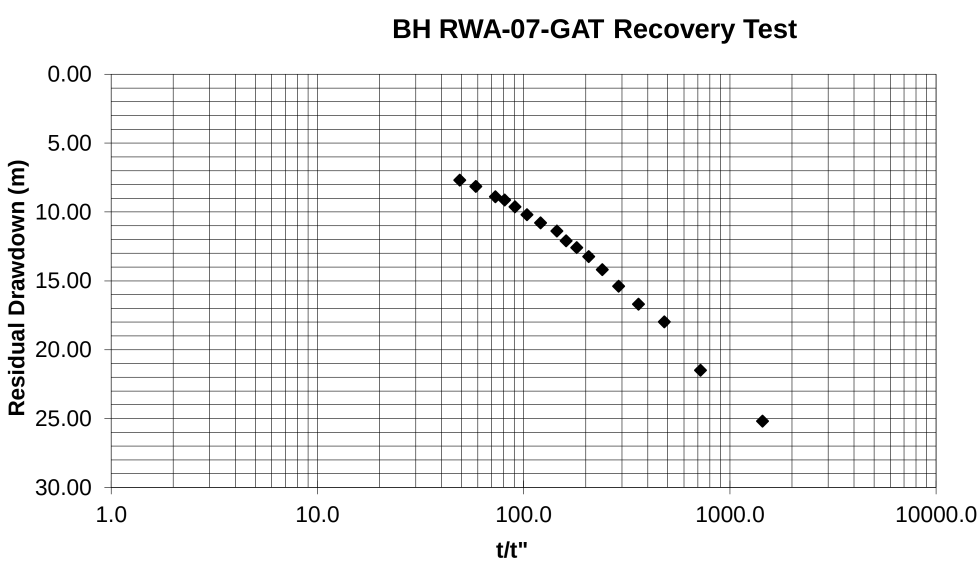

BH RWA-06-KIR Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
0.00
5.00
10.00
15.00
20.00
0
50
100
150
200
250
300
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

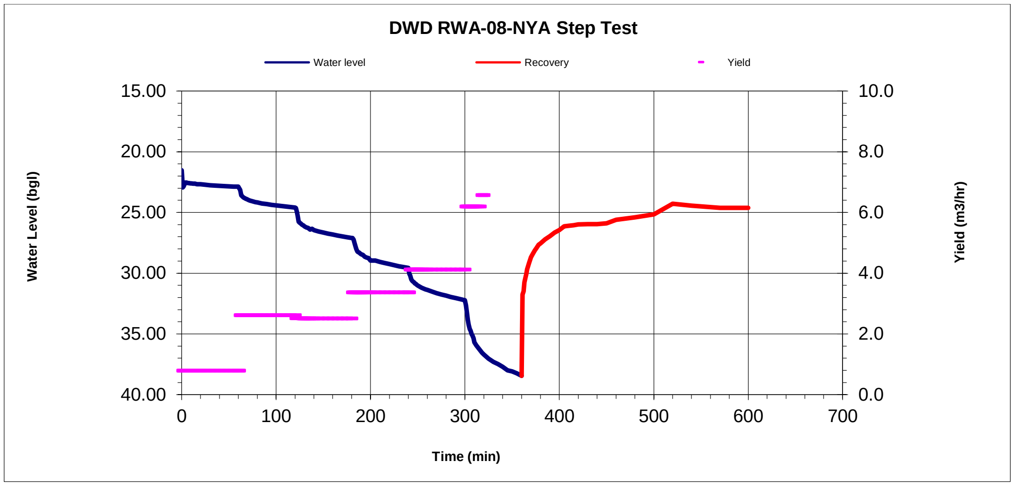

BH RWA-06-KIR Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
-1.00
1.00
3.00
5.00
7.00
9.00
11.00
13.00
15.00
1
10
100
1000
10000
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0

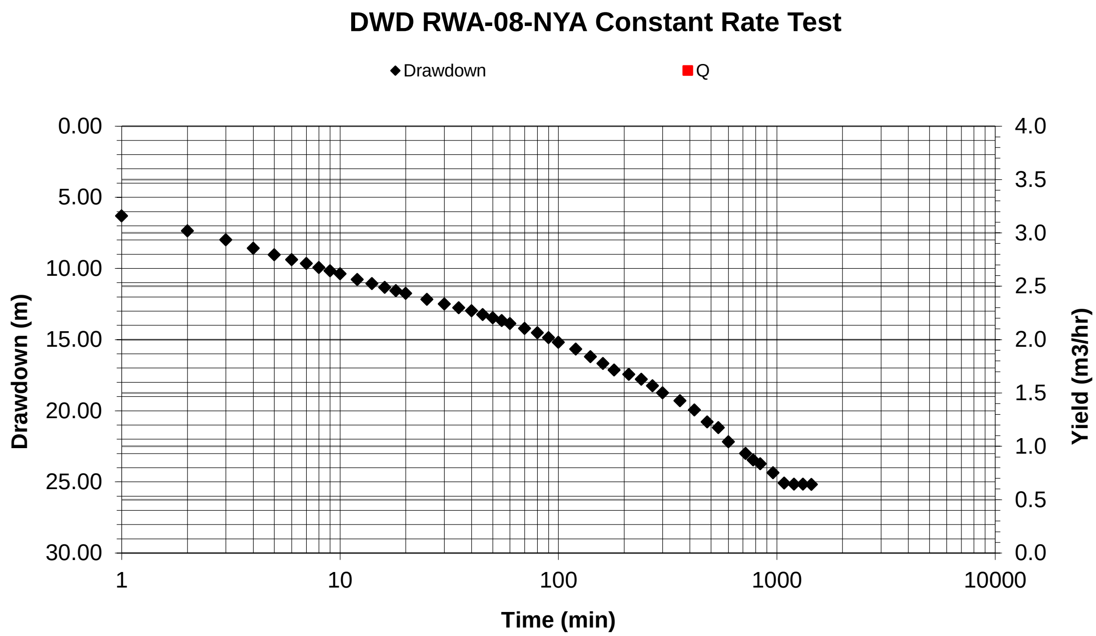

BH RWA-06-KIR Recovery Test
Residual Drawdown (m)
0.00
2.00
4.00
6.00
8.00
10.00

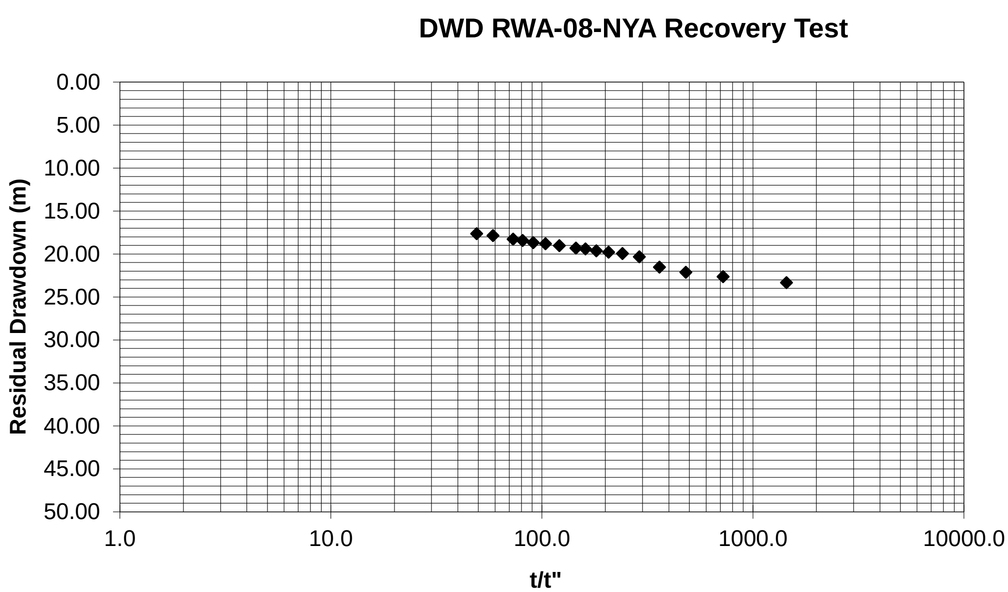

BH RWA-07-GAT Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
0.00
10.00
20.00
30.00
40.00
0
100
200
300
400
500
10.0
8.0
6.0
4.0
2.0
0.0

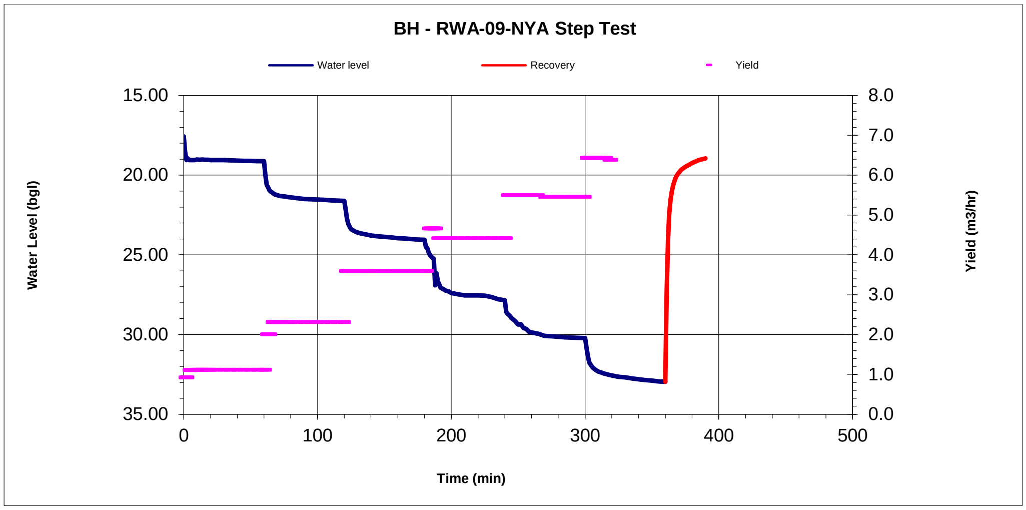

BH RWA-07-GAT Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
1
10
100
1000
10000
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0

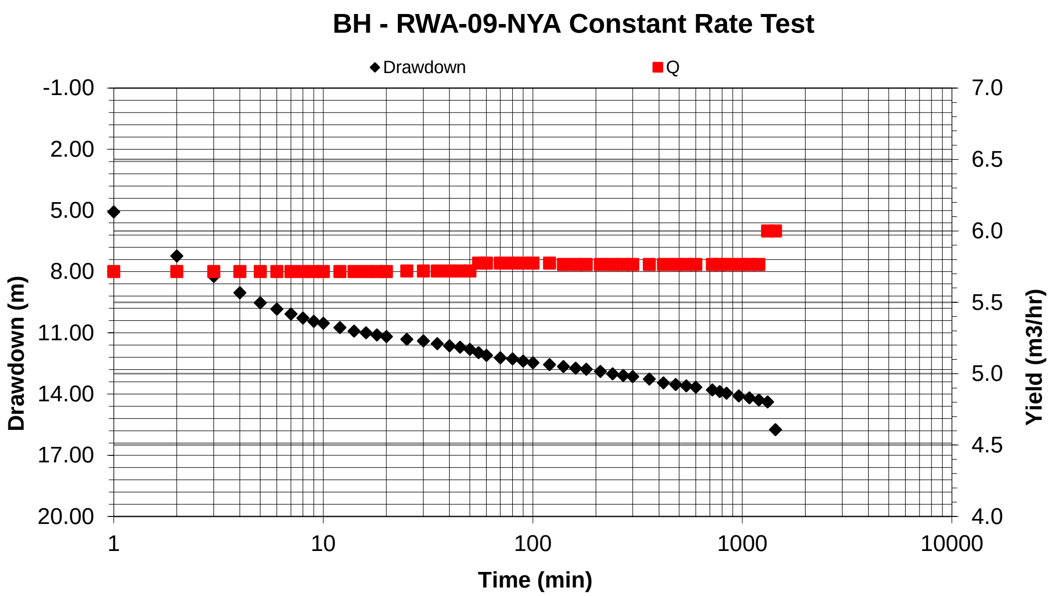

BH RWA-07-GAT Recovery Test
Residual Drawdown (m)
t/t"
0.00
5.00
10.00
15.00
20.00
25.00
30.00
1.0
10.0
100.0
1000.0
10000.0

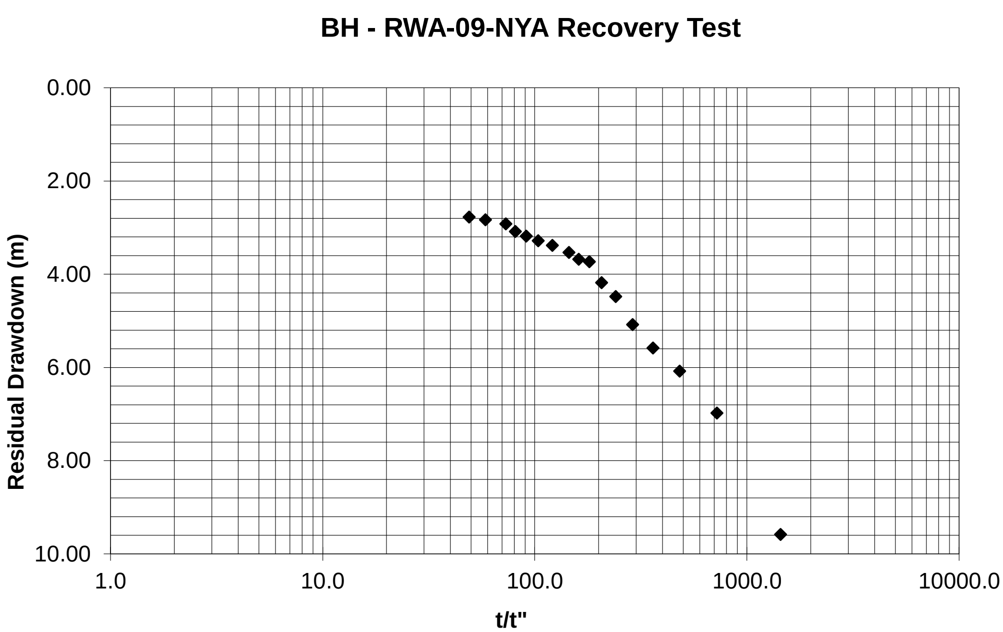

DWD RWA-08-NYA Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)

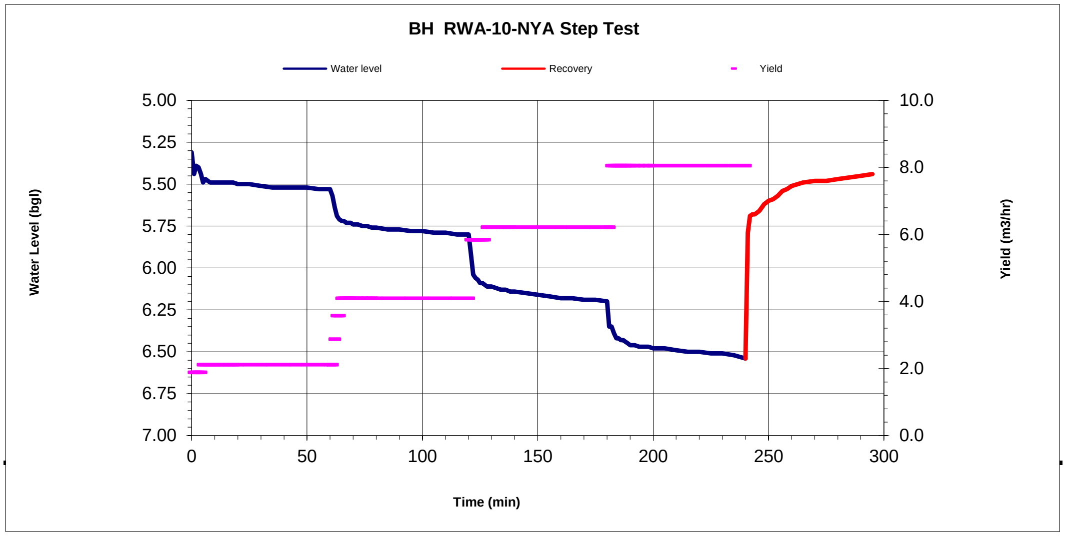

DWD RWA-08-NYA Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)

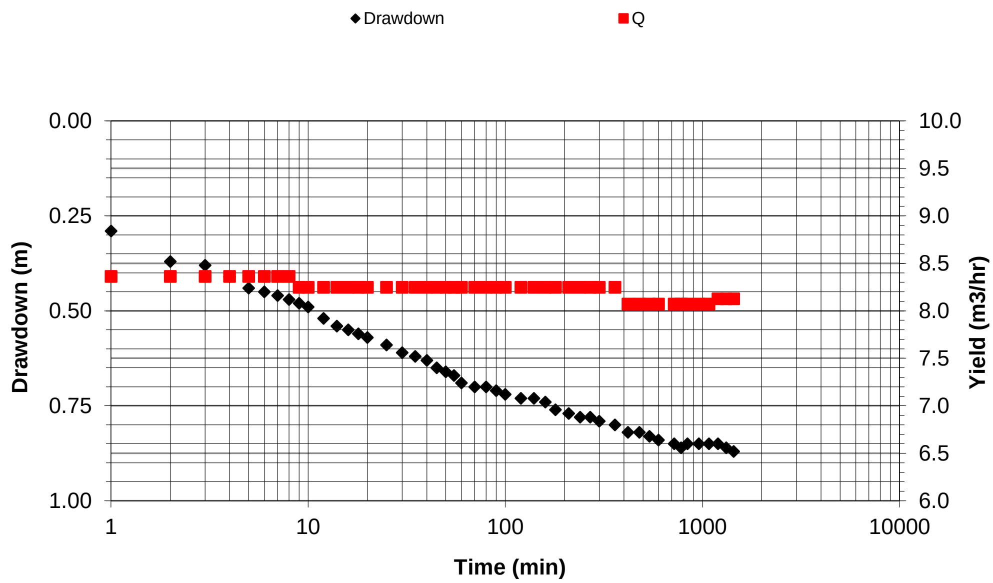

DWD RWA-08-NYA Recovery Test
Residual Drawdown (m)
t/t"

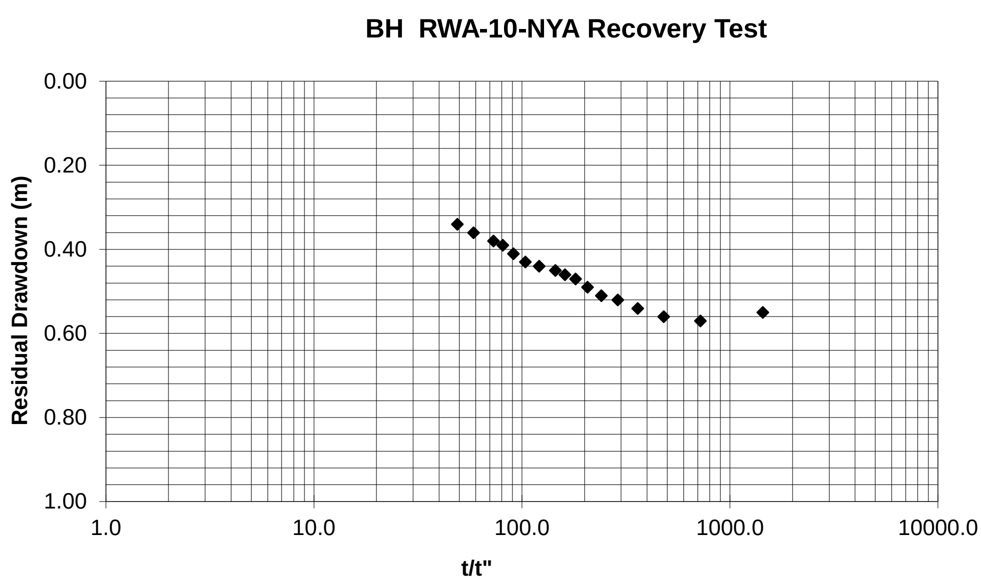

BH - RWA-09-NYA Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
15.00
20.00
25.00
30.00
35.00
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
100
200
300
400
500


BH - RWA-09-NYA Constant Rate Test
Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
-1.00
2.00
5.00
8.00
11.00
14.00
17.00
20.00
7.0
6.5
6.0
5.5
5.0
4.5
4.0
1
10
100
1000
10000


BH - RWA-09-NYA Recovery Test
Residual Drawdown (m)
t/t"
0.00
2.00
4.00
6.00
8.00
10.00
1.0
10.0
100.0
1000.0
10000.0


BH RWA-10-NYA Step Test
Water level
Recovery
Yield
Water Level (bgl)
Yield (m3/hr)
Time (min)
5.00
5.25
5.50
5.75
6.00
6.25
6.50
6.75
7.00
10.0
8.0
6.0
4.0
2.0
0.0
0
50
100
150
200
250
300


Drawdown
Q
Drawdown (m)
Yield (m3/hr)
Time (min)
0.00
0.25
0.50
0.75
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
1
10
100
1000
10000


BH RWA-10-NYA Recovery Test
Residual Drawdown (m)
t/t"
0.00
0.20
0.40
0.60
0.80
1.00
1.0
10.0
100.0
1000.0
10000.0

CONSTANT RATE TEST
DATA SHEET

Water, Environment & Geo Services Ltd

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Borehole Nr.	RWA-01-RWA
UTM X	197708
UTM Y	9786893
Location/Village	Cyagakwerere
Parish	Gahengeri
Sub-County	Karambo
County	Eastern
District	Rwamagana
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	5.2	Q-planned	8		Q-actual	7	
Supervisor		Micheal Kazinda					
Date start :		01/08/2018	Time:	03:40	Top of screen 1	27.75	mbgl
Date end :		02/08/2018	Time:	15:40	Top of screen 2	23.47	mbgl
Casing inner diameter		99.00		mm	Available drawdown PID/SWL	13.36	m
Total depth of well:		29.00		m	datum level (dl)	0.53	magl
Depth of pump intake:		23.47		mbgl	reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		7.11		mbgl	3		mbgl
DWL:		9.57		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		7.11		m³/hr	
1	0:01	9.21	6.27	11.48	
2	0:02	9.71		11.48	
3	0:03	10.87		11.48	
4	0:04	11.62		11.48	
5	0:05	12.17		11.48	
6	0:06	12.47	6.27	11.48	
7	0:07	12.83		11.48	
8	0:08	12.89		11.48	
9	0:09	13.05		11.48	
10	0:10	13.24		11.48	
12	0:12	13.57		11.48	
14	0:14	13.69		11.48	
16	0:16	13.79		11.48	
18	0:18	14.00		11.48	
20	0:20	14.11		11.48	
25	0:25	14.39		11.48	
30	0:30	14.52		11.48	
35	0:35	14.66		11.48	
40	0:40	14.74		11.48	
45	0:45	14.81		11.48	
50	0:50	14.87		11.48	
55	0:55	14.92		11.48	
60	1:00	14.97	6.41	11.23	
70	1:10	15.02		11.23	
80	1:20	15.07		11.23	
90	1:30	15.11		11.23	
100	1:40	15.21		11.23	
120	2:00	15.29	6.31	11.41	
140	2:20			11.41	
160	2:40			11.41	
180	3:00			11.41	
210	3:30			11.41	
240	4:00			11.41	
270	4:30			11.41	
300	5:00			11.41	
360	6:00			11.41	
420	7:00			11.41	
480	8:00			11.41	
540	9:00			11.41	
600	10:00			11.41	Reddish turbid discharge
720	12:00			11.41	Sand in discharge, hence the pump was switched off

RECOVERY TEST
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Borehole Nr.	RWA-01-RWA
UTM X	197708
UTM Y	9786893
Location/Village	Cyagakwerere
Parish	Gahengeri
Sub-County	Karambo
County	Eastern
District	Rwamagana
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	5.2	Q-planned	8.0		Q-actual	7.0	
Supervisor		Micheal Kazinda					
Date start :		02/08/2018	Time:	15:40	Top of screen 1	27.75	mbgl
Date end :		02/08/2018	Time:		Top of screen 2	23.47	mbgl
Casing inner diameter		99	mm		Available drawdown PID/SWL		m
Total depth of well:		29.00	m		datum level (dl)	0.53	magl
Depth of pump intake:		23.47	mbgl		reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		7.11	mbgl		3		mbgl
DWL:		9.57	mbgl		4		mbgl
Yield indicator:		20	liters		5		mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
		9.57	2.46		
1441	1.00	9.27	2.16	12%	
1442	2.00	8.07	0.96	61%	
1443	3.00	8.02	0.91	63%	
1444	4.00	7.97	0.86	65%	
1445	5.00	7.92	0.81	67%	
1446	6.00	7.91	0.80	67%	
1447	7.00	7.90	0.79	68%	
1448	8.00	7.86	0.75	70%	
1449	9.00	7.84	0.73	70%	
1450	10.00	7.81	0.70	72%	
1452	12.00	7.76	0.65	74%	
1454	14.00	7.69	0.58	76%	
1456	16.00	7.66	0.55	78%	
1458	18.00	7.62	0.51	79%	
1460	20.00	7.58	0.47	81%	
1465	25.00	7.52	0.41	83%	
1470	30.00	7.48	0.37	85%	
1475	35.00	7.46	0.35	86%	
1480	40.00	7.45	0.34	86%	

STEP TEST
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Borehole Nr.	RWA-01-RWA
UTM X	197708
UTM Y	9786893
Location/Village	Cyagakwerere
Parish	Gahengeri
Sub-County	Karambo
County	Eastern
District	Rwamagana
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Micheal Kazinda					
Date start :	01/08/2018	Time:	07:40	Top of screen 1	27.75	mbgl
Date end :	01/08/2018	Time:	13:40	Top of screen 2	23.47	mbgl
Total depth of well:	29.00	m		Available drawdown PID/SWL	13.87	m
Depth of pump intake:	23.47	mbgl		datum level (dl)	0.53	magl
Type of pump:	SQ-5-70			reported water strikes: 1		mbgl
SWL:	6.60	mbgl		2		mbgl
DWL:	8.55	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**1.6**	Borehole nr.	**RWA-01-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	6.61				
1	6.72	53.00	1.36		
2	7.67		1.36		
3	7.37		1.36		
4	7.62	50.00	1.44		
5	7.72		1.44		
6	7.77		1.44		
7	7.81		1.44		
8	8.02		1.44		
9	8.15	41.66	1.73		
10	8.16		1.73		
12	8.17	45.00	1.60		
14	8.22		1.60		
16	8.27		1.60		
18	8.32		1.60		
20	8.33		1.60		
25	8.37	45.00	1.60		
30	8.42		1.60		
35	8.43		1.60		
40	8.48	45.00	1.60		
45	8.50		1.60		
50	8.53		1.60		
55	8.55		1.60		
60	8.55		1.60		
70					
80					
90					

Step Nr.	Step 2	Yield (m3/h)	3	Borehole nr.	RWA-01-RWA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	8.55		1.60		
1	8.59	24.00	3.00		
2	8.63		3.00		
3	8.87	23.70	3.04		
4	8.97		3.04		
5	9.07		3.04		
6	9.27		3.04		
7	9.37		3.04		
8	9.47		3.04		
9	9.52		3.04		
10	9.62	23.70	3.04		
12	9.69		3.04		
14	9.75		3.04		
16	9.83		3.04		
18	9.87		3.04		
20	9.91		3.04		
25	9.97		3.04		
30	10.05		3.04		
35	10.08		3.04		
40	10.12		3.04		
45	10.15		3.04		
50	10.17		3.04		
55	10.19		3.04		
60	10.21	23.70	3.04		
70					
80					
90					

Step Nr.	Step 3	Yield (m3/h)	5	Borehole nr.	RWA-01-RWA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	10.21	23.70	3.04		
1	10.37		3.04		
2	10.87		3.04		
3	11.36	17.07	4.22		
4	11.77		4.22		
5	11.82	13.65	5.27		
6	12.02		5.27		
7	12.12		5.27		
8	12.17		5.27		
9	12.27		5.27		
10	12.37		5.27		
12	12.47		5.27		
14	12.57		5.27		
16	12.67	13.83	5.21		
18	12.73		5.21		
20	12.78		5.21		
25	12.89		5.21		
30	12.98		5.21		
35	13.05	14.11	5.10		
40	13.11	10.78	5.10		
45	13.15		5.10		
50	13.18		5.10		
55	13.21		5.10		
60	13.25		5.10		
70					
80					
90					

Step Nr.	**Step 4**	Yield (m3/h)	**6.6**	Borehole nr.	**RWA-01-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	13.25		5.10		
1	13.27	12.00	6.00		
2	13.57	10.78	6.68		
3	13.77		6.68		
4	14.02		6.68		
5	14.11		6.68		
6	14.21		6.68		
7	14.31		6.68		
8	14.35	10.78	6.68		
9	14.37		6.68		
10	14.41		6.68		
12	14.47		6.68		
14	14.53		6.68		
16	14.57		6.68		
18	14.61		6.68		
20	14.64		6.68		
25	14.70		6.68		
30	14.75		6.68		
35	14.79		6.68		
40	14.82		6.68		
45	14.85	10.89	6.61		
50	14.87		6.61		
55	14.89		6.61		
60	14.90		6.61		
70					
80					
90					

Step Nr.	**Step 5**	Yield (m3/h)	**7.28**	Borehole nr.	**RWA-01-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	14.90		6.61		
1	15.16	9.14	7.88		
2	15.30		7.88		
3	15.40		7.88		
4	15.50		7.88		
5	15.57		7.88		
6	15.61		7.88		
7	15.65	9.14	7.88		
8	15.68		7.88		
9	15.74		7.88		
10	15.78	9.14	7.88		
12	15.82		7.88		
14	15.84		7.88		
16	15.86		7.88		
18	15.87		7.88		
20	15.89		7.88		
25	15.93		7.88		
30	15.97		7.88		
35	16.00		7.88		
40	16.02		7.88		
45	16.03	9.14	7.88		
50	16.05		7.88		
55	16.07		7.88		
60	16.09		7.88		
70					
80					
90					

Step Nr.	**Step 6**	Yield (m3/h)	**8.5**	Borehole nr.	**RWA-01-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.					
0	16.09		7.87746		
1	16.21	8.46	8.51		
2	16.37		8.51		
3	16.43		8.51		
4	16.48		8.51		
5	16.52		8.51		
6	16.54		8.51		
7	16.56		8.51		
8	16.59		8.51		
9	16.61		8.51		
10	16.62	8.46	8.51		
12	16.65		8.51		
14	16.67		8.51		
16	16.68		8.51		
18	16.70		8.51		
20	16.71		8.51		
25	16.71	8.46	8.51		
30	16.71		8.51		
35	16.71		8.51		
40	16.71		8.51		
45	16.73		8.51		
50	16.74		8.51		
55	16.75		8.51		
60	16.77	8.46	8.51		
70					
80					
90					

CONSTANT RATE TEST
DATA SHEET

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Borehole Nr.	RWA-2-RWA
UTM X	196195
UTM Y	9784416
Location/Village	Nyamirama
Parish	Murundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	2.3	Q-planned	3		Q-actual	2.6	
Supervisor		Michael Kazinda					
Date start :		03/08/2018	Time:	15:40	Top of screen 1		mbgl
Date end :		04/08/2018	Time:	15:40	Top of screen 2	34.57	mbgl
Casing inner diameter		114.30	mm		Available drawdown PID/SWL	22.14	m
Total depth of well:		42.85	m		datum level (dl)	0.43	magl
Depth of pump intake:		34.57	mbgl		reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		9.43	mbgl		3		mbgl
DWL:		24.27	mbgl		4		mbgl
Yield indicator:		20	liters		5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		9.90	32.51	2.21	
1	0:01	13.98	29.70	2.42	
2	0:02	17.07		2.42	
3	0:03	18.37	27.71	2.60	
4	0:04	18.77		2.60	
5	0:05	19.05		2.60	
6	0:06	19.45		2.60	
7	0:07	19.72		2.60	
8	0:08	19.97		2.60	
9	0:09	20.15		2.60	
10	0:10	20.33		2.60	
12	0:12	20.55		2.60	
14	0:14	20.77		2.60	
16	0:16	20.99		2.60	
18	0:18	21.08		2.60	
20	0:20	21.19		2.60	
25	0:25	21.36		2.60	
30	0:30	21.49		2.60	
35	0:35	21.58		2.60	
40	0:40	21.67		2.60	
45	0:45	21.74	27.80	2.59	
50	0:50	21.78		2.59	
55	0:55	21.83		2.59	
60	1:00	21.87		2.59	
70	1:10	21.91		2.59	
80	1:20	21.94		2.59	
90	1:30	21.99	27.83	2.59	
100	1:40	22.57		2.59	
120	2:00	23.13		2.59	
140	2:20	23.30		2.59	
160	2:40	23.37		2.59	
180	3:00	23.43		2.59	
210	3:30	23.49		2.59	
240	4:00	23.54		2.59	
270	4:30	23.57		2.59	
300	5:00	23.60		2.59	
360	6:00	23.68		2.59	
420	7:00	23.73		2.59	
480	8:00	23.77		2.59	
540	9:00	23.82		2.59	
600	10:00	23.83		2.59	
720	12:00	23.91		2.59	
840	14:00	24.00		2.59	
960	16:00	24.09		2.59	
1080	18:00	24.13		2.59	
1200	20:00	24.20		2.59	
1320	22:00	24.23		2.59	
1440	24:00	24.27		2.59	

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Borehole Nr.	RWA-2-RWA
UTM X	196195
UTM Y	9784416
Location/Village	Nyamirama
Parish	Murundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	2.3	Q-planned	3.0		Q-actual	2.6	
Supervisor		Michael Kazinda					
Date start :		04/08/2018	Time:	15:40	Top of screen 1		mbgl
Date end :		04/08/2018	Time:	16:40	Top of screen 2	34.57	mbgl
Casing inner diameter		114	mm		Available drawdown PID/SWL		m
Total depth of well:		42.85	m		datum level (dl)	0.43	magl
Depth of pump intake:		34.57	mbgl		reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		9.43	mbgl		3		mbgl
DWL:		24.27	mbgl		4		mbgl
Yield indicator:		20	liters		5		mbgl

Time elapsed		Water level	drawdown	recovery	Remarks
min.	min rec	mbgl	m	%	
		24.27	14.84		
1441	1	18.17	8.74	41%	
1442	2	16.77	7.34	51%	
1443	3	15.37	5.94	60%	
1444	4	14.52	5.09	66%	
1445	5	14.07	4.64	69%	
1446	6	13.57	4.14	72%	
1447	7	13.27	3.84	74%	
1448	8	12.97	3.54	76%	
1449	9	12.75	3.32	78%	
1450	10	12.57	3.14	79%	
1452	12	12.25	2.82	81%	
1454	14	12.05	2.62	82%	
1456	16	11.89	2.46	83%	
1458	18	11.72	2.29	85%	
1460	20	11.61	2.18	85%	
1465	25	11.37	1.94	87%	
1470	30	11.15	1.72	88%	
1475	35	11.07	1.64	89%	
1480	40	11.02	1.59	89%	
1485	45	10.93	1.50	90%	
1490	50	10.84	1.41	90%	
1495	55	10.78	1.35	91%	
1500	60	10.74	1.31	91%	

STEP TEST
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Borehole Nr.	RWA-2-RWA
UTM X	196195
UTM Y	9784416
Location/Village	Nyamirama
Parish	Murundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	03/08/2018	Time:	08:45	Top of screen 1		mbgl
Date end :	03/08/2018	Time:	13:45	Top of screen 2	34.57	mbgl
Total depth of well:	42.85	m		Available drawdown PID/SWL	14.59	m
Depth of pump intake:	34.57	mbgl		datum level (dl)	0.43	magl
Type of pump:	SQ-5-70			reported water strikes: 1		mbgl
SWL:	9.43	mbgl		2		mbgl
DWL:	31.42	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**0.8**	Borehole nr. **RWA-2-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	mbgl	Seconds	m3/h	
0	9.34			
1	12.45	65.46	1.10	
2	12.87	75.00	0.96	
3	12.71		0.96	
4	12.72	89.49	0.80	
5	12.72		0.80	
6	12.37		0.80	
7	12.09	89.02	0.81	
8	12.05		0.81	
9	12.02		0.81	
10	12.00		0.81	
12	12.00		0.81	
14	12.00		0.81	
16	12.00		0.81	
18	12.01		0.81	
20	12.02		0.81	
25	12.04	89.49	0.80	
30	12.07		0.80	
35	12.08		0.80	
40	12.09		0.80	
45	12.11		0.80	
50	12.13		0.80	
55	12.34		0.80	
60	12.38		0.80	
70				
80				
90				

Step Nr.	**Step 2**	Yield (m3/h)	**1.5**	Borehole nr.	**RWA-2-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	12.38		0.80		
1	12.49	53.00	1.36		
2	12.77		1.36		
3	13.20	53.00	1.36		
4	13.97	47.82	1.51		
5	13.95		1.51		
6	13.95		1.51		
7	13.95		1.51		
8	14.17	44.23	1.63		
9	14.37		1.63		
10	14.39		1.63		
12	14.96		1.63		
14	15.09		1.63		
16	15.18		1.63		
18	15.28	44.56	1.62		
20	15.36		1.62		
25	15.42		1.62		
30	15.49		1.62		
35	15.57		1.62		
40	15.77		1.62		
45	15.65		1.62		
50	15.67		1.62		
55	15.71	44.56	1.62		
60	15.98		1.62		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**2.5**	Borehole nr.	**RWA-2-RWA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	15.98		1.62		
1	16.97		1.62		
2	18.27		1.62		
3	18.37	28.15	2.56		
4	18.57		2.56		
5	18.67		2.56		
6	18.72		2.56		
7	18.78		2.56		
8	18.93		2.56		
9	18.99		2.56		
10	19.09		2.56		
12	19.17		2.56		
14	19.26		2.56		
16	19.32	28.15	2.56		
18	19.36		2.56		
20	19.41		2.56		
25	19.49		2.56		
30	19.56		2.56		
35	19.62		2.56		
40	19.65	23.46	2.56		
45	20.19		2.56		
50	20.27		2.56		
55	20.35		2.56		
60	20.45		2.56		
70					
80					
90					

Step Nr.	Step 4	Yield (m3/h)	3	Borehole nr.	RWA-2-RWA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	20.45		2.56		
1	20.87		2.56		
2	21.07	23.46	3.07		
3	21.29		3.07		
4	21.44		3.07		
5	21.60		3.07		
6	21.72		3.07		
7	21.82		3.07		
8	21.89		3.07		
9	21.96		3.07		
10	21.97		3.07		
12	22.05		3.07		
14	22.11		3.07		
16	22.27		3.07		
18	22.78		3.07		
20	23.01		3.07		
25	23.39		3.07		
30	23.57		3.07		
35	23.71		3.07		
40	23.80		3.07		
45	23.87	23.46	3.07		
50	23.92		3.07		
55	23.97		3.07		
60	24.02	23.46	3.07		

Step Nr.	Step 5	Yield (m3/h)	4	Borehole nr.	RWA-2-RWA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	24.02	23.46	3.07		
1	24.07		3.07		
2	24.78	17.57	4.10		
3	25.72		4.10		
4	26.71		4.10		
5	27.07		4.10		
6	27.41		4.10		
7	27.82		4.10		
8	28.14		4.10		
9	28.42		4.10		
10	28.65	17.57	4.10		
12	29.05		4.10		
14	29.42		4.10		
16	29.61		4.10		
18	29.87		4.10		
20	30.04		4.10		
25	30.33		4.10		
30	30.58		4.10		
35	30.83		4.10		
40	30.98		4.10		
45	31.11	17.57	4.10		
50	31.26		4.10		
55	31.37		4.10		
60	31.42		4.10		
70					
80					
90					

CONSTANT RATE TEST DATA SHEET

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Borehole Nr.	RWA-03-BUG
UTM X	180282
UTM Y	9762808
Location/Village	Rusagara
Parish	Rusagara
Sub-County	Nyamata
County	Eastern Province
District	Bugesera
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	6.5	Q-planned	12		Q-actual	10	
Supervisor		Michael Kazinda					
Date start :		08/08/2018	Time:	03:05	Top of screen 1	36.64	mbgl
Date end :		9/8/20418	Time:	03:05	Top of screen 2	34.64	mbgl
Casing inner diameter		99.00	mm		Available drawdown PID/SWL	30.42	m
Total depth of well:		40.00	m		datum level (dl)	0.36	magl
Depth of pump intake:		34.64	mbgl		reported water strikes: 1		mbgl
Type of pump:		SP-13-14			2		mbgl
SWL:		1.22	mbgl		3		mbgl
DWL:		22.94	mbgl		4		mbgl
Yield indicator:		20	liters		5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		1.44	7.12	10.11	
1	0:01	4.84		10.11	
2	0:02	5.04		10.11	
3	0:03	5.33		10.11	
4	0:04	5.36		10.11	
5	0:05	5.41		10.11	
6	0:06	5.47		10.11	
7	0:07	5.50		10.11	
8	0:08	5.52		10.11	
9	0:09	5.54		10.11	
10	0:10	5.57		10.11	
12	0:12	5.59		10.11	
14	0:14	5.62		10.11	
16	0:16	5.64		10.11	
18	0:18	5.66		10.11	
20	0:20	5.68		10.11	
25	0:25	5.71		10.11	
30	0:30	5.73	7.14	10.08	
35	0:35	5.75		10.08	
40	0:40	5.78		10.08	
45	0:45	5.79		10.08	
50	0:50	5.81		10.08	
55	0:55	5.83	7.18	10.03	
60	1:00	5.84		10.03	
70	1:10	5.87		10.03	
80	1:20	5.90		10.03	
90	1:30	5.93		10.03	
100	1:40	5.96		10.03	
120	2:00	5.99		10.03	
140	2:20	6.01		10.03	
160	2:40	6.04		10.03	
180	3:00	6.04		10.03	
210	3:30	6.05	7.16	10.06	
240	4:00	5.99		10.06	
270	4:30	9.61		10.06	
300	5:00	10.64	6.55	10.99	
360	6:00	11.19		10.99	
420	7:00	11.44		10.99	
480	8:00	11.64		10.99	
540	9:00	11.85		10.99	
600	10:00	12.08		10.99	
660	11:00	12.34		10.99	
720	12:00	12.71		10.99	
780	13:00	13.04		10.99	
840	14:00	13.52		10.99	
960	16:00	14.54		10.99	
1080	18:00	19.53	6.70	10.75	
1200	20:00	19.53		10.75	
1320	22:00	20.83		10.75	
1440	24:00	22.94		10.75	

RECOVERY TEST DATA SHEET

WE consult

Borehole Nr.	RWA-03-BUG
UTM X	180282
UTM Y	9762808
Location/Village	Rusagara
Parish	Rusagara
Sub-County	Nyamata
County	Eastern Province
District	Bugesera
Project Nr. :	201811
Client	Water for Growth - Rwanda

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Q-air	6.5	Q-planned	12.0		Q-actual	10.0	
Supervisor		Michael Kazinda					
Date start :		9/8/20418	Time:	03:05	Top of screen 1	36.64	mbgl
Date end :		9/8/20418	Time:		Top of screen 2	34.64	mbgl
Casing inner diameter		99		mm	Available drawdown PID/SWL		m
Total depth of well:		40.00		m	datum level (dl)	0.36	magl
Depth of pump intake:		34.64		mbgl	reported water strikes: 1		mbgl
Type of pump:		SP-13-14			2		mbgl
SWL:		1.22		mbgl	3		mbgl
DWL:		22.94		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
		22.94	21.72		
1441	1	7.44	6.22	71%	
1442	2	4.24	3.02	86%	
1443	3	3.44	2.22	90%	
1444	4	1.84	0.62	97%	
1445	5	1.74	0.52	98%	
1446	6	1.74	0.52	98%	
1447	7	1.64	0.42	98%	
1448	8	1.64	0.42	98%	
1449	9	1.63	0.41	98%	
1450	10	1.62	0.40	98%	
1452	12	1.60	0.38	98%	

STEP TEST
DATA SHEET

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Borehole Nr.	RWA-03-BUG
UTM X	180282
UTM Y	9762808
Location/Village	Rusagara
Parish	Rusagara
Sub-County	Nyamata
County	Eastern Province
District	Bugesera
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	07/08/2018	Time:	19:30	Top of screen 1	36.64	mbgl
Date end :	08/08/2018	Time:	00:50	Top of screen 2	34.64	mbgl
Total depth of well:	40.00	m		Available drawdown PID/SWL	30.42	m
Depth of pump intake:	34.64	mbgl		datum level (dl)	0.36	magl
Type of pump:	SP-13-14			reported water strikes: 1		mbgl
SWL:	1.22	mbgl		2		mbgl
DWL:	32.64	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**2**	Borehole nr. **RWA-03-BUG**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	mbgl	Seconds	m3/h	
0	1.24			
1	2.02	35.62	2.02	
2	2.34		2.02	
3	2.08		2.02	
4	1.94	35.62	2.02	
5	1.88		2.02	
6	1.86		2.02	
7	1.83		2.02	
8	1.84		2.02	
9	1.92		2.02	
10	1.92		2.02	
12	1.93	35.62	2.02	
14	1.93		2.02	
16	1.93		2.02	
18	1.93		2.02	
20	1.93		2.02	
25	1.94		2.02	
30	1.94		2.02	
35	1.94		2.02	
40	1.94	35.62	2.02	
45	1.95		2.02	
50	1.96		2.02	
55	1.96		2.02	
60	1.96		2.02	
70				
80				
90				

Step Nr.	**Step 2**	Yield (m3/h)	**4**	Borehole nr.	**RWA-03-BUG**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	1.96		2.02		
1	2.27	17.35	4.15		
2	2.62		4.15		
3	2.64	17.35	4.15		
4	2.65		4.15		
5	2.66		4.15		
6	2.66		4.15		
7	2.67		4.15		
8	2.67		4.15		
9	2.67		4.15		
10	2.68	17.35	4.15		
12	2.68		4.15		
14	2.68		4.15		
16	2.68		4.15		
18	2.69		4.15		
20	2.69		4.15		
25	2.69		4.15		
30	2.69		4.15		
35	2.70		4.15		
40	2.70		4.15		
45	2.70		4.15		
50	2.71		4.15		
55	2.71	17.34	4.15		
60	2.71		4.15		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**6**	Borehole nr.	**RWA-03-BUG**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	2.71		4.15		
1	2.94	11.39	6.32		
2	3.24		6.32		
3	3.27		6.32		
4	3.27		6.32		
5	3.28	11.39	6.32		
6	3.29		6.32		
7	3.29		6.32		
8	3.30		6.32		
9	3.30		6.32		
10	3.30		6.32		
12	3.31		6.32		
14	3.31		6.32		
16	3.31	11.39	6.32		
18	3.31		6.32		
20	3.32		6.32		
25	3.32		6.32		
30	3.32		6.32		
35	3.33	11.39	6.32		
40	3.33	8.53	6.32		
45	3.34		6.32		
50	3.34		6.32		
55	3.34		6.32		
60	3.35		6.32		
70					
80					
90					

Step Nr.	Step 4	Yield (m3/h)	8	Borehole nr.	RWA-03-BUG
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	3.35		6.32		
1	3.74	8.53	8.44		
2	3.84	8.53	8.44		
3	4.07		8.44		
4	4.09		8.44		
5	4.13		8.44		
6	4.14		8.44		
7	4.14		8.44		
8	4.14	8.53	8.44		
9	4.15		8.44		
10	4.15		8.44		
12	4.16		8.44		
14	4.16		8.44		
16	4.17		8.44		
18	4.17		8.44		
20	4.17		8.44		
25	4.18		8.44		
30	4.18		8.44		
35	4.19		8.44		
40	4.19		8.44		
45	4.19	8.53	8.44		
50	4.20		8.44		
55	4.20		8.44		
60	4.20		8.44		

Step Nr.	Step 5	Yield (m3/h)	10	Borehole nr.	RWA-03-BUG
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	4.20		8.44		
1	4.44	6.90	10.43		
2	4.51		10.43		
3	5.14		10.43		
4	5.24		10.43		
5	5.22		10.43		
6	5.23		10.43		
7	5.23		10.43		
8	5.23		10.43		
9	5.24		10.43		
10	5.24	6.88	10.47		
12	5.24		10.47		
14	5.24		10.47		
16	5.24		10.47		
18	5.25		10.47		
20	5.25		10.47		
25	5.26		10.47		
30	5.27		10.47		
35	5.36		10.47		
40	5.36		10.47		
45	5.37	6.90	10.43		
50	5.38		10.43		
55	5.39		10.43		
60	5.44		10.43		
70					
80					
90					

Step Nr.	**Step 6**	Yield (m3/h)	**15**	Borehole nr.	**RWA-03-BUG**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	5.44		10.43		
1	6.74		10.43		
2	7.44	4.70	15.32		
3	9.54		15.32		
4	12.54		15.32		
5	13.49		15.32		
6	17.44		15.32		
7	18.24		15.32		
8	20.10		15.32		
9	21.74		15.32		
10	23.49	4.70	15.32		
12	24.26		15.32		
14	26.10		15.32		
16	26.76		15.32		
18	28.24		15.32		
20	32.64		15.32	Water level near pump installation depth. Test stoped here	
25					
30					
35					
40					
45					
50					
55					
60					
70					
80					
90					

CONSTANT RATE TEST
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Borehole Nr.	RWA-04-KAY
UTM X	221123
UTM Y	9809462
Location/Village	Nyamirama
Parish	Murundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	3.5	Q-planned	5	Q-actual	4.6	
Supervisor		Michael Kazinda				
Date start :		11/08/2018	Time: 16:00	Top of screen 1		mbgl
Date end :		12/08/2018	Time: 16:00	Top of screen 2	39.83	mbgl
Casing inner diameter		99.00	mm	Available drawdown PID/SWL	34.95	m
Total depth of well:		50.00	m	datum level (dl)	0.17	magl
Depth of pump intake:		39.83	mbgl	reported water strikes: 1		mbgl
Type of pump:		SQ-5-70		2		mbgl
SWL:		1.88	mbgl	3		mbgl
DWL:		32.92	mbgl	4		mbgl
Yield indicator:		20	liters	5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		4.43	12.00	6.00	
1	0:01	18.25		6.00	
2	0:02	20.14	15.52	4.64	
3	0:03	20.83		4.64	
4	0:04	22.21		4.64	
5	0:05	24.48		4.64	
6	0:06	24.56		4.64	
7	0:07	24.82		4.64	
8	0:08	24.98		4.64	
9	0:09	25.08	15.52	4.64	
10	0:10	25.26		4.64	
12	0:12	25.96		4.64	
14	0:14	26.33		4.64	
16	0:16	26.97	15.58	4.62	
18	0:18	28.03		4.62	
20	0:20	28.98		4.62	
25	0:25	29.23		4.62	
30	0:30	29.62		4.62	
35	0:35	29.87		4.62	
40	0:40	30.37		4.62	
45	0:45	30.58		4.62	
50	0:50	30.84		4.62	
55	0:55	31.02	15.72	4.58	
60	1:00	31.19		4.58	
70	1:10	31.60		4.58	
80	1:20	31.79		4.58	
90	1:30	32.08		4.58	
100	1:40	32.25		4.58	
120	2:00	32.61		4.58	
140	2:20	32.75		4.58	
160	2:40	32.87		4.58	
180	3:00	32.78		4.58	
210	3:30	32.81		4.58	
240	4:00	32.82		4.58	
270	4:30	32.84		4.58	
300	5:00	32.86	15.72	4.58	
360	6:00	32.87		4.58	
420	7:00	32.87		4.58	
480	8:00	32.88		4.58	
540	9:00	32.88		4.58	
600	10:00	32.89		4.58	
720	12:00	32.89		4.58	
780	13:00	32.89		4.58	
840	14:00	32.89		4.58	
960	16:00	32.90		4.58	
1080	18:00	32.90		4.58	
1200	20:00	32.91	15.72	4.58	
1320	22:00	32.91		4.58	
1440	24:00	32.92		4.58	

RECOVERY TEST
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Borehole Nr.	RWA-04-KAY
UTM X	221123
UTM Y	9809462
Location/Village	Nyamirama
Parish	Murundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	3.5	Q-planned	5.0	Q-actual	4.6
Supervisor	Michael Kazinda				
Date start :	12/08/2018	Time: 16:00		Top of screen 1	mbgl
Date end :	12/08/2018	Time: 17:00		Top of screen 2	39.83 mbgl
Casing inner diameter	99	mm		Available drawdown PID/SWL	m
Total depth of well:	50.00	m		datum level (dl)	0.17 magl
Depth of pump intake:	39.83	mbgl		reported water strikes: 1	mbgl
Type of pump:	SQ-5-70			2	mbgl
SWL:	1.88	mbgl		3	mbgl
DWL:	32.92	mbgl		4	mbgl
Yield indicator:	20	liters		5	mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
1440		32.91	31.03		
1441	1	20.93	19.05	39%	
1442	2	18.84	16.96	45%	
1443	3	16.33	14.45	53%	
1444	4	15.93	14.05	55%	
1445	5	14.93	13.05	58%	
1446	6	13.93	12.05	61%	
1447	7	13.33	11.45	63%	
1448	8	12.75	10.87	65%	
1449	9	12.25	10.37	67%	
1450	10	11.83	9.95	68%	
1452	12	11.43	9.55	69%	
1454	14	10.71	8.83	72%	
1456	16	10.47	8.59	72%	
1458	18	10.03	8.15	74%	
1460	20	9.78	7.90	75%	
1465	25	9.23	7.35	76%	
1470	30	8.81	6.93	78%	
1475	35	8.45	6.57	79%	
1480	40	8.24	6.36	80%	
1485	45	8.01	6.13	80%	
1490	50	7.73	5.85	81%	
1495	55	7.43	5.55	82%	
1500	60	6.93	5.05	84%	

STEP TEST
DATA SHEET

Water, Environment & Geo Services Ltd

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Borehole Nr.	RWA-04-KAY
UTM X	221123
UTM Y	9809462
Location/Village	Nyamirama
Parish	Murundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	11/08/2018	Time:	08:40	Top of screen 1		mbgl
Date end :	11/08/2018	Time:	14:40	Top of screen 2	39.83	mbgl
Total depth of well:	50.00	m		Available drawdown PID/SWL	21.35	m
Depth of pump intake:	39.83	mbgl		datum level (dl)	0.17	magl
Type of pump:	SQ-5-70			reported water strikes: 1		mbgl
SWL:	1.88	mbgl		2		mbgl
DWL:	32.88	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**1**	Borehole nr.	**RWA-04-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	1.84				
1	6.33	81.26	0.89		
2	5.43		0.89		
3	5.28		0.89		
4	5.43	67.74	1.06		
5	5.53		1.06		
6	5.58		1.06		
7	5.63		1.06		
8	5.68		1.06		
9	5.73		1.06		
10	5.78		1.06		
12	5.83	69.28	1.04		
14	6.03		1.04		
16	6.13		1.04		
18	6.21		1.04		
20	6.23		1.04		
25	6.32		1.04		
30	6.39		1.04		
35	6.48		1.04		
40	6.54	69.27	1.04		
45	6.61		1.04		
50	6.67		1.04		
55	6.72		1.04		
60	6.77		1.04		
70					
80					
90					

Step Nr.	**Step 2**	Yield (m3/h)	**2**	Borehole nr.	**RWA-04-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	6.77		1.04		
1	7.03	40.27	1.79		
2	7.23		1.79		
3	7.63	37.91	1.90		
4	8.28	34.67	2.08		
5	9.33		2.08		
6	9.53		2.08		
7	9.93		2.08		
8	10.03		2.08		
9	10.13		2.08		
10	10.23	34.67	2.08		
12	10.38		2.08		
14	10.50		2.08		
16	10.59		2.08		
18	10.68		2.08		
20	10.78	34.67	2.08		
25	10.92		2.08		
30	11.04		2.08		
35	11.14		2.08		
40	11.22		2.08		
45	11.28		2.08		
50	11.35		2.08		
55	11.40		2.08		
60	11.46		2.08		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**3**	Borehole nr.	**RWA-04-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	11.46		2.08		
1	11.49	24.69	2.92		
2	11.68	24.69	2.92		
3	12.04		2.92		
4	12.21		2.92		
5	12.38	22.98	3.13		
6	13.53		3.13		
7	14.18		3.13		
8	14.48		3.13		
9	14.83		3.13		
10	14.98		3.13		
12	15.33		3.13		
14	15.43		3.13		
16	15.55	22.98	3.13		
18	15.62		3.13		
20	15.70		3.13		
25	15.93		3.13		
30	16.10		3.13		
35	16.21		3.13		
40	16.25	18.26	3.13		
45	16.34		3.13		
50	16.43		3.13		
55	16.48		3.13		
60	16.55		3.13		
70					
80					
90					

Step Nr.	Step 4	Yield (m3/h)	4	Borehole nr.	RWA-04-KAY
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	16.55		3.13		
1	17.25		3.13		
2	17.84	18.26	3.94		
3	18.49		3.94		
4	20.03		3.94		
5	20.83		3.94		
6	21.63		3.94		
7	22.38		3.94		
8	22.52	17.68	4.07		
9	22.83		4.07		
10	23.03		4.07		
12	23.33		4.07		
14	23.77	16.97	4.24		
16	22.65	17.99	4.00		
18	22.58		4.00		
20	22.41		4.00		
25	22.48		4.00		
30	22.61		4.00		
35	22.72		4.00		
40	22.86		4.00		
45	22.93		4.00		
50	23.03		4.00		
55	23.13	17.99	4.00		
60	23.23		4.00		

Step Nr.	Step 5	Yield (m3/h)	5	Borehole nr.	RWA-04-KAY
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	23.23		4.00		
1	23.78		4.00		
2	25.83	13.26	5.43		
3	26.23		5.43		
4	26.78		5.43		
5	27.64	13.60	5.29		
6	28.53		5.29		
7	28.93		5.29		
8	29.29		5.29		
9	29.58		5.29		
10	29.83	14.21	5.07		
12	30.43		5.07		
14	30.59		5.07		
16	30.73		5.07		
18	30.83		5.07		
20	30.98	14.21	5.07		
25	31.33		5.07		
30	31.83		5.07		
35	32.23		5.07		
40	32.35		5.07		
45	32.39	14.21	5.07		
50	32.40		5.07		
55	32.42		5.07		
60	32.44		5.07		

Step Nr.	**Step 6**	Yield (m3/h)	**5.7**	Borehole nr.	**RWA-04-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	32.44		5.07		
1	32.48	12.59	5.72		
2	32.53		5.72		
3	32.53		5.72		
4	32.53		5.72		
5	32.54		5.72		
6	32.54		5.72		
7	32.54		5.72		
8	32.54	12.59	5.72		
9	32.54		5.72		
10	32.55		5.72		
12	32.57		5.72		
14	32.73		5.72		
16	32.76		5.72		
18	32.77		5.72		
20	32.77		5.72		
25	32.77		5.72		
30	32.78		5.72		
35	32.81		5.72		
40	32.84		5.72		
45	32.85		5.72		
50	32.86	12.59	5.72		
55	32.87		5.72		
60	32.88		5.72		
70					
80					
90					

CONSTANT RATE TEST
DATA SHEET

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Borehole Nr.	RWA-05-KAY
UTM X	222152
UTM Y	9807888
Location/Village	Nyamugando
Parish	Omurundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	20	Q-planned	30	Q-actual	27	
Supervisor		Michael Kazinda				
Date start :	16/08/2018	Time:	01:10	Top of screen 1		mbgl
Date end :	17/08/2018	Time:	01:10	Top of screen 2	24.15	mbgl
Casing inner diameter	114.30	mm		Available drawdown PID/SWL	21.90	m
Total depth of well:	33.20	m		datum level (dl)	0.85	magl
Depth of pump intake:	24.15	mbgl		reported water strikes: 1		mbgl
Type of pump:	SP 13-14			2		mbgl
SWL:	-0.75	mbgl		3		mbgl
DWL:	7.05	mbgl		4		mbgl
Yield indicator:	20	liters		5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		0.35	2.65	27.17	
1	0:01	2.35		27.17	
2	0:02	2.75		27.17	
3	0:03	2.85	2.65	27.17	
4	0:04	3.05		27.17	
5	0:05	3.10		27.17	
6	0:06	3.15		27.17	
7	0:07	3.23		27.17	
8	0:08	3.29		27.17	
9	0:09	3.33		27.17	
10	0:10	3.35		27.17	
12	0:12	3.42		27.17	
14	0:14	3.51		27.17	
16	0:16	3.57		27.17	
18	0:18	3.61		27.17	
20	0:20	3.65		27.17	
25	0:25	3.75		27.17	
30	0:30	3.85		27.17	
35	0:35	3.95		27.17	
40	0:40	4.02		27.17	
45	0:45	4.09	2.65	27.17	
50	0:50	4.14		27.17	
55	0:55	4.19		27.17	
60	1:00	4.24		27.17	
70	1:10	4.33		27.17	
80	1:20	4.43		27.17	
90	1:30	4.52	2.65	27.17	
100	1:40	4.63		27.17	
120	2:00	4.72		27.17	
140	2:20	4.84		27.17	
160	2:40	4.92		27.17	
180	3:00	5.03		27.17	
210	3:30	5.12		27.17	
240	4:00	5.25		27.17	

Time elapsed		Water level	Time to Fill	Yield	Remarks
270	4:30	5.36		27.17	
300	5:00	5.45		27.17	
360	6:00	5.55		27.17	
420	7:00	5.65		27.17	
480	8:00	5.76		27.17	
540	9:00	5.90		27.17	
600	10:00	6.02		27.17	
720	12:00	6.21	2.65	27.17	
780	13:00	6.37		27.17	
840	14:00	6.45		27.17	
960	16:00	6.60		27.17	
1080	18:00	6.73		27.17	
1200	20:00	6.84		27.17	
1320	22:00	6.94		27.17	
1440	24:00	7.05		27.17	

RECOVERY TEST
DATA SHEET

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Borehole Nr.	RWA-05-KAY
UTM X	222152
UTM Y	9807888
Location/Village	Nyamugando
Parish	Omurundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	20	Q-planned	30.0	Q-actual	27.0	
Supervisor		Michael Kazinda				
Date start :		17/08/2018	Time: 01:10	Top of screen 1		mbgl
Date end :		17/08/2018	Time: 05:40	Top of screen 2	24.15	mbgl
Casing inner diameter		114	mm	Available drawdown PID/SWL		m
Total depth of well:		33.20	m	datum level (dl)	0.85	magl
Depth of pump intake:		24.15	mbgl	reported water strikes: 1		mbgl
Type of pump:		SP 13-14		2		mbgl
SWL:		-0.75	mbgl	3		mbgl
DWL:		7.05	mbgl	4		mbgl
Yield indicator:		20	liters	5		mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
1440		7.05	7.80		
1441	1.00	4.25	5.00	36%	
1442	2.00	4.13	4.88	37%	
1443	3.00	3.97	4.72	39%	
1444	4.00	3.85	4.60	41%	
1445	5.00	3.75	4.50	42%	
1446	6.00	3.66	4.41	43%	
1447	7.00	3.60	4.35	44%	
1448	8.00	3.53	4.28	45%	
1449	9.00	3.44	4.19	46%	
1450	10.00	3.36	4.11	47%	
1452	12.00	3.35	4.10	47%	
1454	14.00	3.30	4.05	48%	
1456	16.00	3.25	4.00	49%	
1458	18.00	3.20	3.95	49%	
1460	20.00	3.13	3.88	50%	
1465	25.00	3.00	3.75	52%	
1470	30.00	2.88	3.63	53%	
1475	35.00	2.77	3.52	55%	
1480	40.00	2.66	3.41	56%	
1485	45.00	2.57	3.32	57%	
1490	50.00	2.47	3.22	59%	
1495	55.00	2.45	3.20	59%	
1500	60.00	2.37	3.12	60%	
1510	70.00	2.25	3.00	62%	
1520	80.00	2.14	2.89	63%	
1530	90.00	2.04	2.79	64%	
1540	100.00	1.94	2.69	66%	
1560	120.00	1.78	2.53	68%	
1580	140.00	1.61	2.36	70%	
1600	160.00	1.45	2.20	72%	
1620	180.00	1.32	2.07	73%	
1650	210.00	0.93	1.68	78%	
1680	240.00	0.85	1.60	79%	
1710	270.00	0.79	1.54	80%	

STEP TEST
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Borehole Nr.	RWA-05-KAY
UTM X	222152
UTM Y	9807888
Location/Village	Nyamugando
Parish	Omurundi
Sub-County	Karambi
County	Eastern Province
District	Kayonza
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	15/08/2018	Time:	19:00	Top of screen 1		mbgl
Date end :	15/08/2018	Time:	12:00	Top of screen 2	24.15	mbgl
Total depth of well:	33.20	m		Available drawdown PID/SWL	21.90	m
Depth of pump intake:	24.15	mbgl		datum level (dl)	0.85	magl
Type of pump:	SP 13-14			reported water strikes: 1		mbgl
SWL:	-0.75	mbgl		2		mbgl
DWL:	4.45	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**10**	Borehole nr. **RWA-05-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	mbgl	Seconds	m3/h	
0	-0.55	31.30		
1	-0.18	14.30	5.03	
2	-0.12		5.03	
3	-0.09		5.03	
4	-0.07		5.03	
5	-0.05		5.03	
6	-0.04		5.03	
7	-0.02	14.30	5.03	
8			5.03	
9	0.02		5.03	
10	0.03		5.03	
12	0.05		5.03	
14	0.05		5.03	
16	0.06		5.03	
18	0.07		5.03	
20	0.08		5.03	
25	0.10	14.30	5.03	
30	0.12		5.03	
35	0.13		5.03	
40	0.14		5.03	
45	0.14		5.03	
50	0.16		5.03	
55	0.16	14.30	5.03	
60	0.18		5.03	
70				
80				
90				

Step Nr.	**Step 2**	Yield (m3/h)	**15**	Borehole nr.	**RWA-05-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	0.18		5.03		
1	0.95		5.03		
2	1.15	6.44	11.18		
3	1.22		11.18		
4	1.28		11.18		
5	1.33		11.18		
6	1.35		11.18		
7	1.35		11.18		
8	1.38		11.18		
9	1.40	7.02	10.26		
10	1.42		10.26		
12	1.45		10.26		
14	1.48		10.26		
16	1.50		10.26		
18	1.53	7.02	10.26		
20	1.55		10.26		
25	1.60		10.26		
30	1.66		10.26		
35	1.69		10.26		
40	1.73		10.26		
45	1.77		10.26		
50	1.80		10.26		
55	1.83	7.02	10.26		
60	1.87		10.26		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**20**	Borehole nr.	**RWA-05-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	1.87		10.26		
1	2.00		10.26		
2	2.45		10.26		
3	2.50	4.44	16.22		
4	2.54		16.22		
5	2.58		16.22		
6	2.60		16.22		
7	2.62		16.22		
8	2.65		16.22		
9	2.67		16.22		
10	2.70		16.22		
12	2.73		16.22		
14	2.75		16.22		
16	2.76	4.44	16.22		
18	2.79		16.22		
20	2.82		16.22		
25	2.85		16.22		
30	2.90		16.22		
35	2.95		16.22		
40	2.97	3.49	16.22		
45	3.01		16.22		
50	3.04		16.22		
55	3.08		16.22		
60	3.12		16.22		
70					
80					
90					

Step Nr.	**Step 4**	Yield (m3/h)	**25**	Borehole nr.	**RWA-05-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	3.12		16.22		
1	3.20		16.22		
2	3.24	3.49	20.63		
3	3.29		20.63		
4	3.32		20.63		
5	3.35		20.63		
6	3.37		20.63		
7	3.39		20.63		
8	3.40		20.63		
9	3.41		20.63		
10	3.43		20.63		
12	3.45		20.63		
14	3.46	3.54	20.34		
16	3.47		20.34		
18	3.49		20.34		
20	3.50		20.34		
25	3.53		20.34		
30	3.57		20.34		
35	3.61		20.34		
40	3.65		20.34		
45	3.68	3.54	20.34		
50	3.71		20.34		
55	3.75		20.34		
60	3.77	3.54	20.34		
70	4.15	26.67	2.70		
80	4.16	26.67			
90	4.17	26.67			

Step Nr.	**Step 5**	Yield (m3/h)		Borehole nr.	**RWA-05-KAY**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	3.77	3.54	20.34		
1	3.88		20.34		
2	3.97	2.70	26.67		
3	4.05		26.67		
4	4.07		26.67		
5	4.08		26.67		
6	4.09		26.67		
7	4.12		26.67		
8	4.13		26.67		
9	4.14		26.67		
10	4.15	2.70	26.67		
12	4.16		26.67		
14	4.17		26.67		
16	4.18		26.67		
18	4.19		26.67		
20	4.21	2.70	26.67		
25	4.24		26.67		
30	4.27		26.67		
35	4.30		26.67		
40	4.32		26.67		
45	4.36		26.67		
50	4.39		26.67		
55	4.42		26.67		
60	4.45	2.70	26.67		
70					
80					
90					

CONSTANT RATE TEST DATA SHEET

WE consult

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Borehole Nr.	RWA-06-KIR
UTM X	229589
UTM Y	9745870
Location/Village	Lwabutazi
Parish	Rurembo I
Sub-County	Gatore
County	Eastern Province
District	Kirehe
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	2.4	Q-planned	3		Q-actual	2.5	
Supervisor		Michael Kazinda					
Date start :		19/08/2018	Time:	23:00	Top of screen 1		mbgl
Date end :		20/08/2018	Time:	23:00	Top of screen 2	24.15	mbgl
Casing inner diameter		114.30		mm	Available drawdown PID/SWL	18.99	m
Total depth of well:		33.20		m	datum level (dl)	0.85	magl
Depth of pump intake:		24.15		mbgl	reported water strikes: 1		mbgl
Type of pump:		sq-5-70			2		mbgl
SWL:		2.16		mbgl	3		mbgl
DWL:		13.79		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		1.93	46.90	1.54	
1	0:01	6.80		1.54	
2	0:02	7.15	41.66	1.73	
3	0:03	7.70	31.65	2.27	
4	0:04	8.15		2.27	
5	0:05	9.23		2.27	
6	0:06	9.70		2.27	
7	0:07	10.05		2.27	
8	0:08	10.35		2.27	
9	0:09	10.55		2.27	
10	0:10	10.75		2.27	
12	0:12	11.02		2.27	
14	0:14	11.23		2.27	
16	0:16	11.35		2.27	
18	0:18	11.45		2.27	
20	0:20	11.55		2.27	
25	0:25	11.73		2.27	
30	0:30	11.84		2.27	
35	0:35	11.94		2.27	
40	0:40	12.02		2.27	
45	0:45	12.10		2.27	
50	0:50	12.15		2.27	
55	0:55	12.21		2.27	
60	1:00	12.24		2.27	
70	1:10	12.27		2.27	
80	1:20	12.29		2.27	
90	1:30	12.31		2.27	
100	1:40	12.33		2.27	
120	2:00	12.35		2.27	
140	2:20	12.37		2.27	
160	2:40	12.40		2.27	
180	3:00	12.42		2.27	
210	3:30	12.45		2.27	

Time elapsed		Water level	Time to Fill	Yield	Remarks
240	4:00	12.47		2.27	
270	4:30	12.49		2.27	
300	5:00	12.51		2.27	
360	6:00	12.52		2.27	
420	7:00	12.55	31.05	2.32	
480	8:00	13.51	31.27	2.30	
540	9:00	13.53		2.30	
600	10:00	14.03	30.93	2.33	
720	12:00	14.05		2.33	
780	13:00	14.05	30.90	2.33	
840	14:00	13.85		2.33	
960	16:00	13.83	31.05	2.32	
1080	18:00	13.81		2.32	
1200	20:00	13.78		2.32	
1320	22:00	13.78		2.32	
1440	24:00	13.79		2.32	

RECOVERY TEST
DATA SHEET

WE consult

Borehole Nr.	RWA-06-KIR
UTM X	229589
UTM Y	9745870
Location/Village	Lwabutazi
Parish	Rurembo I
Sub-County	Gatore
County	Eastern Province
District	Kirehe
Project Nr. :	201811
Client	Water for Growth - Rwanda

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Q-air	2.4	Q-planned	3.0	Q-actual	2.5	
Supervisor		Michael Kazinda				
Date start :	20/08/2018	Time: 23:00		Top of screen 1		mbgl
Date end :	20/08/2018	Time: 23:25		Top of screen 2	24.15	mbgl
Casing inner diameter	114	mm		Available drawdown PID/SWL		m
Total depth of well:	33.20	m		datum level (dl)	0.85	magl
Depth of pump intake:	24.15	mbgl		reported water strikes: 1		mbgl
Type of pump:	sq-5-70			2		mbgl
SWL:	2.16	mbgl		3		mbgl
DWL:	13.79	mbgl		4		mbgl
Yield indicator:	20	liters		5		mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
1440		13.79	11.63		
1441	1441	6.15	3.99	66%	
1442	1442	5.87	3.71	68%	
1443	1443	4.73	2.57	78%	
1444	1444	4.47	2.31	80%	
1445	1445	4.30	2.14	82%	
1446	1446	4.10	1.94	83%	
1447	1447	3.93	1.77	85%	
1448	1448	3.78	1.62	86%	
1449	1449	3.69	1.53	87%	
1450	1450	3.59	1.43	88%	
1452	1452	3.38	1.22	90%	
1454	1454	3.21	1.05	91%	
1456	1456	3.08	0.92	92%	
1458	1458	2.97	0.81	93%	
1460	1460	2.89	0.73	94%	
1465	1465	2.75	0.59	95%	

STEP TEST
DATA SHEET

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Borehole Nr.	RWA-06-KIR
UTM X	229589
UTM Y	9745870
Location/Village	Lwabutazi
Parish	Rurembo I
Sub-County	Gatore
County	Eastern Province
District	Kirehe
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	19/08/2018	Time:	16:00	Top of screen 1		mbgl
Date end :	19/08/2018	Time:	20:00	Top of screen 2	24.15	mbgl
Total depth of well:	33.20	m		Available drawdown PID/SWL	18.99	m
Depth of pump intake:	24.15	mbgl		datum level (dl)	0.85	magl
Type of pump:	sq-5-70			reported water strikes: 1		mbgl
SWL:	2.16	mbgl		2		mbgl
DWL:	18.15	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**0.7**	Borehole nr.	**RWA-06-KIR**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	2.00	96.76			
1	2.45				
2	5.95				
3	5.50				
4	5.35				
5	5.15				
6	5.15				
7	5.15				
8	5.12				
9	5.11				
10	5.10	96.76	0.74		
12	5.09		0.74		
14	5.08		0.74		
16	5.08		0.74		
18	5.07		0.74		
20	5.07		0.74		
25	5.05		0.74		
30	5.05		0.74		
35	5.06		0.74		
40	5.06		0.74		
45	5.06		0.74		
50	5.06		0.74		
55	5.06	96.76	0.74		
60	5.06		0.74		
70					
80					
90					

Step Nr.	**Step 2**	Yield (m3/h)	**1.44**	Borehole nr.	**RWA-06-KIR**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	5.06		0.74		
1	6.00		0.74		
2	6.95	55.34	1.30		
3	7.25	48.70	1.48		
4	7.50		1.48		
5	7.70		1.48		
6	7.85		1.48		
7	8.00		1.48		
8	8.05		1.48		
9	8.07		1.48		
10	8.10		1.48		
12	8.16		1.48		
14	8.17		1.48		
16	8.19		1.48		
18	8.20	48.70	1.48		
20	8.25		1.48		
25	8.27		1.48		
30	8.30		1.48		
35	8.32		1.48		
40	8.35		1.48		
45	8.36		1.48		
50	8.39		1.48		
55	8.40	48.70	1.48		
60	8.42		1.48		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**2.16**	Borehole nr.	**RWA-06-KIR**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	8.42		1.48		
1	9.65		1.48		
2	10.15	30.70	2.35		
3	10.45		2.35		
4	10.45	31.74	2.27		
5	10.95		2.27		
6	11.50		2.27		
7	11.65		2.27		
8	11.80		2.27		
9	11.97		2.27		
10	12.07		2.27		
12	12.25		2.27		
14	12.31		2.27		
16	12.39		2.27		
18	12.46	31.74	2.27		
20	12.49		2.27		
25	12.51		2.27		
30	12.52		2.27		
35	12.53		2.27		
40	12.53	24.68	2.27		
45	12.55		2.27		
50	12.57		2.27		
55	12.58		2.27		
60	12.60		2.27		
70					
80					
90					

Step Nr.	**Step 4**	Yield (m3/h)	**2.8**	Borehole nr.	**RWA-06-KIR**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	12.60		2.27		
1	12.95		2.27		
2	14.15	24.68	2.92		
3	14.81		2.92		
4	15.25		2.92		
5	15.35		2.92		
6	15.75		2.92		
7	15.75		2.92		
8	15.75		2.92		
9	15.75		2.92		
10	15.76		2.92		
12	16.35		2.92		
14	16.38	24.68	2.92		
16	16.40		2.92		
18	16.73		2.92		
20	17.05		2.92		
25	17.35		2.92		
30	17.55		2.92		
35	17.69		2.92		
40	17.79		2.92		
45	17.89	24.68	2.92		
50	18.03		2.92		
55	18.08		2.92		
60	18.15		2.92		
70					
80					
90					

CONSTANT RATE TEST
DATA SHEET

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Borehole Nr.	RWA-07-GAT
UTM X	221624
UTM Y	9820574
Location/Village	Akamahoro
Parish	Rwikiniro
Sub-County	Rwimbogo
County	Eastern Province
District	Gatsibo
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	4.3	Q-planned	8		Q-actual	7	
Supervisor		Michael Kazinda					
Date start :		26/08/2018	Time:	06:49	Top of screen 1		mbgl
Date end :		27/08/2018	Time:	06:49	Top of screen 2	49.6	mbgl
Casing inner diameter		99.06		mm	Available drawdown PID/SWL	44.18	m
Total depth of well:		60.00		m	datum level (dl)	0.4	magl
Depth of pump intake:		49.60		mbgl	reported water strikes: 1		mbgl
Type of pump:		SP-13-14			2		mbgl
SWL:		2.42		mbgl	3		mbgl
DWL:		35.60		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		3.14		m³/hr	
1	0:01	7.30	17.09	4.21	
2	0:02	10.15	12.34	5.83	
3	0:03	10.93	9.72	7.41	
4	0:04	12.14		7.41	
5	0:05	14.58		7.41	
6	0:06	15.22		7.41	
7	0:07	15.81		7.41	
8	0:08	16.35		7.41	
9	0:09	16.78		7.41	
10	0:10	17.08		7.41	
12	0:12	17.60		7.41	
14	0:14	18.01		7.41	
16	0:16	18.40		7.41	
18	0:18	18.68		7.41	
20	0:20	18.98		7.41	
25	0:25	19.58		7.41	
30	0:30	20.09	10.19	7.07	
35	0:35	20.52		7.07	
40	0:40	20.90		7.07	
45	0:45	21.21		7.07	
50	0:50	21.48		7.07	
55	0:55	21.76	10.22	7.05	
60	1:00	21.98		7.05	
70	1:10	22.40		7.05	
80	1:20	22.76		7.05	
90	1:30	23.45	10.22	7.05	
100	1:40	23.80		7.05	
120	2:00	24.40		7.05	
140	2:20	24.88		7.05	
160	2:40	25.17		7.05	
180	3:00	25.45		7.05	
210	3:30	28.00		7.05	

Time elapsed		Water level	Time to Fill	Yield	Remarks
240	4:00	28.80		7.05	
270	4:30	29.66		7.05	
300	5:00	30.38	10.21	7.05	
360	6:00	30.74		7.05	
420	7:00	31.10	10.09	7.14	
480	8:00	31.70		7.14	
540	9:00	32.02		7.14	
600	10:00	32.39		7.14	
720	12:00	32.96		7.14	
780	13:00	33.38		7.14	
840	14:00	33.65		7.14	
960	16:00	34.20		7.14	
1080	18:00	34.54		7.14	
1200	20:00	34.97		7.14	
1320	22:00	35.39		7.14	
1440	24:00	35.60		7.14	

RECOVERY TEST
DATA SHEET

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Borehole Nr.	RWA-07-GAT
UTM X	221624
UTM Y	9820574
Location/Village	Akamahoro
Parish	Rwikiniro
Sub-County	Rwimbogo
County	Eastern Province
District	Gatsibo
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	4.3	Q-planned	8.0	Q-actual	7.0		
Supervisor		Michael Kazinda					
Date start :		27/08/2018	Time:	06:49	Top of screen 1		mbgl
Date end :		27/08/2018	Time:	08:49	Top of screen 2	49.6	mbgl
Casing inner diameter		99	mm		Available drawdown PID/SWL		m
Total depth of well:		60.00	m		datum level (dl)	0.4	magl
Depth of pump intake:		49.60	mbgl		reported water strikes: 1		mbgl
Type of pump:		SP-13-14			2		mbgl
SWL:		2.42	mbgl		3		mbgl
DWL:		35.60	mbgl		4		mbgl
Yield indicator:		20	liters		5		mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
1440		35.60	33.18		
1441	1.00	27.60	25.18	24%	
1442	2.00	23.90	21.48	35%	
1443	3.00	20.40	17.98	46%	
1444	4.00	19.11	16.69	50%	
1445	5.00	17.80	15.38	54%	
1446	6.00	16.60	14.18	57%	
1447	7.00	15.65	13.23	60%	
1448	8.00	15.00	12.58	62%	
1449	9.00	14.50	12.08	64%	
1450	10.00	13.80	11.38	66%	
1452	12.00	13.20	10.78	68%	
1454	14.00	12.60	10.18	69%	
1456	16.00	12.03	9.61	71%	
1458	18.00	11.55	9.13	72%	
1460	20.00	11.30	8.88	73%	
1465	25.00	10.55	8.13	75%	
1470	30.00	10.10	7.68	77%	
1475	35.00	9.75	7.33	78%	
1480	40.00	9.20	6.78	80%	
1485	45.00	8.80	6.38	81%	
1490	50.00	8.55	6.13	82%	
1495	55.00	8.15	5.73	83%	
1500	60.00	8.00	5.58	83%	
1510	70.00	7.75	5.33	84%	
1520	80.00	7.30	4.88	85%	
1530	90.00	6.89	4.47	87%	
1540	100.00	6.70	4.28	87%	
1560	120.00	6.00	3.58	89%	

STEP TEST
DATA SHEET

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Borehole Nr.	RWA-07-GAT
UTM X	221624
UTM Y	9820574
Location/Village	Akamahoro
Parish	Rwikiniro
Sub-County	Rwimbogo
County	Eastern Province
District	Gatsibo
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	25/08/2018	Time: 19:58	Top of screen 1			mbgl
Date end :	26/08/2018	Time: 01:58	Top of screen 2	49.6		mbgl
Total depth of well:	60.00	m	Available drawdown PID/SWL	44.18		m
Depth of pump intake:	49.60	mbgl	datum level (dl)	0.40		magl
Type of pump:	SP-13-14		reported water strikes: 1			mbgl
SWL:	2.42	mbgl	2			mbgl
DWL:	36.30	mbgl	3			mbgl
Yield indicator:	20	liters	4			mbgl

Step Nr.	Step 1	Yield (m3/h)	1.3	Borehole nr.	RWA-07-GAT
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	2.54				
1	4.10	68.67	1.05		
2	4.20		1.05		
3	4.54		1.05		
4	4.25		1.05		
5	4.35		1.05		
6	4.45		1.05		
7	4.50		1.05		
8	4.55		1.05		
9	4.60	53.94	1.33		
10	4.65		1.33		
12	4.73		1.33		
14	4.75		1.33		
16	4.78		1.33		
18	4.81		1.33		
20	4.85		1.33		
25	4.90		1.33		
30	4.95		1.33		
35	5.01		1.33		
40	5.05	53.60	1.34		
45	5.10		1.34		
50	5.12		1.34		
55	5.14		1.34		
60	5.18		1.34		
70					
80					
90					

Step Nr.	**Step 2**	Yield (m3/h)	**2.6**	Borehole nr.	**RWA-07-GAT**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	5.18		1.34		
1	5.65		1.34		
2	5.90	34.48	2.09		
3	6.30		2.09		
4	6.45		2.09		
5	6.85		2.09		
6	6.87		2.09		
7	6.89		2.09		
8	6.95		2.09		
9	7.05		2.09		
10	7.28	26.12	2.76		
12	7.35		2.76		
14	7.40		2.76		
16	7.49		2.76		
18	7.55		2.76		
20	7.63		2.76		
25	7.75		2.76		
30	7.83		2.76		
35	7.90		2.76		
40	7.97		2.76		
45	8.03		2.76		
50	8.07		2.76		
55	8.03	26.12	2.76		
60	8.17		2.76		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**4**	Borehole nr.	**RWA-07-GAT**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	8.17		2.76		
1	9.06	17.37	4.15		
2	9.85		4.15		
3	10.10		4.15		
4	10.41		4.15		
5	10.60		4.15		
6	10.72		4.15		
7	10.83		4.15		
8	10.92	17.40	4.14		
9	11.01		4.14		
10	11.07		4.14		
12	11.20		4.14		
14	11.30		4.14		
16	11.38		4.14		
18	11.46		4.14		
20	11.54		4.14		
25	11.67		4.14		
30	11.78		4.14		
35	11.93	17.48	4.12		
40	12.05		4.12		
45	12.14		4.12		
50	12.20		4.12		
55	12.25		4.12		
60	12.30		4.12		
70					
80					
90					

Step Nr.	**Step 4**	Yield (m3/h)	**5**	Borehole nr.	**RWA-07-GAT**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	12.30		4.12		
1	14.30	13.40	5.37		
2	14.40		5.37		
3	14.50		5.37		
4	14.80		5.37		
5	14.85		5.37		
6	14.90		5.37		
7	15.08		5.37		
8	15.15	13.49	5.34		
9	15.25		5.34		
10	15.30		5.34		
12	15.47		5.34		
14	15.55		5.34		
16	15.60		5.34		
18	15.80		5.34		
20	15.90		5.34		
25	16.00		5.34		
30	16.10		5.34		
35	16.30		5.34		
40	16.50		5.34		
45	16.55	13.50	5.33		
50	16.64		5.33		
55	16.76		5.33		
60	16.80		5.33		
70					
80					
90					

Step Nr.	**Step 5**	Yield (m3/h)	**7**	Borehole nr.	**RWA-07-GAT**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	16.80		5.33		
1	17.81		5.33		
2	18.30	10.08	7.14		
3	18.90		7.14		
4	19.38		7.14		
5	19.90		7.14		
6	20.20		7.14		
7	20.35		7.14		
8	20.50		7.14		
9	19.75		7.14		
10	21.00		7.14		
12	21.20		7.14		
14	21.50	10.17	7.08		
16	21.70		7.08		
18	21.90		7.08		
20	22.00		7.08		
25	22.55		7.08		
30	22.85		7.08		
35	23.05		7.08		
40	23.45		7.08		
45	23.65		7.08		
50	23.85	10.23	7.04		
55	24.12		7.04		
60	24.25		7.04		
70					
80	25.12	10.29			
90	25.62	10.29			

Step Nr.	**Step 6**	Yield (m3/h)	**10**	Borehole nr.	**RWA-07-GAT**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	24.25		7.04		
1	24.70	9.00	8.00		
2	25.12		8.00		
3	25.62		8.00		
4	26.15	9.00	8.00		
5	26.67		8.00		
6	26.76		8.00		
7	26.89		8.00		
8	27.00		8.00		
9	27.80	7.00	10.29		
10	28.60		10.29		
12	29.41		10.29		
14	29.73		10.29		
16	30.25	7.00	10.29		
18	30.82		10.29		
20	32.05		10.29		
25	33.00		10.29		
30	34.15		10.29		
35	34.50		10.29		
40	34.80		10.29		
45	35.28		10.29		
50	35.80		10.29		
55	36.00		10.29		
60	36.30	7.00	10.29		
70					
80					
90					

CONSTANT RATE TEST DATA SHEET

WE consult

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Borehole Nr.	RWA-08-NYA
UTM X	206331
UTM Y	9863158
Location/Village	Kituro
Parish	Kabare II
Sub-County	Rwempasha
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	2.5	Q-planned	6		Q-actual	5	
Supervisor		Michael Kazinda					
Date start :		31/08/2018	Time:	05:50	Top of screen 1		mbgl
Date end :		01/09/2018	Time:	05:50	Top of screen 2	51.15	mbgl
Casing inner diameter		99.06		mm	Available drawdown PID/SWL	25.17	m
Total depth of well:		60.00		m	datum level (dl)	0.85	magl
Depth of pump intake:		51.15		mbgl	reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		21.33		mbgl	3		mbgl
DWL:		47.35		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		23.35		m³/hr	
1	0:01	28.47	13.00	5.54	
2	0:02	29.52		5.54	
3	0:03	30.15	14.00	5.14	
4	0:04	30.75		5.14	
5	0:05	31.20		5.14	
6	0:06	31.55		5.14	
7	0:07	31.82		5.14	
8	0:08	32.10		5.14	
9	0:09	32.34		5.14	
10	0:10	32.55		5.14	
12	0:12	32.95		5.14	
14	0:14	33.24	14.00	5.14	
16	0:16	33.49		5.14	
18	0:18	33.72		5.14	
20	0:20	33.92		5.14	
25	0:25	34.34		5.14	
30	0:30	34.67	14.00	5.14	
35	0:35	34.93		5.14	
40	0:40	35.15		5.14	
45	0:45	35.40		5.14	
50	0:50	35.63		5.14	
55	0:55	35.82		5.14	
60	1:00	36.03		5.14	
70	1:10	36.39		5.14	
80	1:20	36.69		5.14	
90	1:30	37.03		5.14	
100	1:40	37.36		5.14	
120	2:00	37.84		5.14	
140	2:20	38.36		5.14	
160	2:40	38.85		5.14	
180	3:00	39.31	14.40	5.00	
210	3:30	39.61		5.00	

Time elapsed		Water level	Time to Fill	Yield	Remarks
240	4:00	39.95		5.00	
270	4:30	40.41		5.00	
300	5:00	40.91		5.00	
360	6:00	41.46		5.00	
420	7:00	42.11		5.00	
480	8:00	42.95		5.00	
540	9:00	43.35		5.00	
600	10:00	44.35		5.00	
720	12:00	45.16		5.00	
780	13:00	45.63		5.00	
840	14:00	45.89		5.00	
960	16:00	46.53		5.00	
1080	18:00	47.25	15.84	4.55	
1200	20:00	47.33	16.00	4.50	
1320	22:00	47.33		4.50	
1440	24:00	47.35		4.50	

RECOVERY TEST
DATA SHEET

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Borehole Nr.	RWA-08-NYA
UTM X	206331
UTM Y	9863158
Location/Village	Kituro
Parish	Kabare II
Sub-County	Rwempasha
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	2.5	Q-planned	6.0		Q-actual	5.0	
Supervisor		Michael Kazinda					
Date start :		01/09/2018	Time:	05:50	Top of screen 1		mbgl
Date end :		20/08/2018	Time:	12:50	Top of screen 2	51.15	mbgl
Casing inner diameter		99		mm	Available drawdown PID/SWL		m
Total depth of well:		60.00		m	datum level (dl)	0.85	magl
Depth of pump intake:		51.15		mbgl	reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		21.33		mbgl	3		mbgl
DWL:		47.35		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		Water level	drawdown	recovery	Remarks
min.	min rec	mbgl	m	%	
1440		47.35	26.02		
1441	1.00	44.65	23.32	10%	
1442	2.00	43.97	22.64	13%	
1443	3.00	43.46	22.13	15%	
1444	4.00	42.85	21.52	17%	
1445	5.00	41.65	20.32	22%	
1446	6.00	41.28	19.95	23%	
1447	7.00	41.10	19.77	24%	
1448	8.00	40.95	19.62	25%	
1449	9.00	40.75	19.42	25%	
1450	10.00	40.65	19.32	26%	
1452	12.00	40.35	19.02	27%	
1454	14.00	40.15	18.82	28%	
1456	16.00	40.01	18.68	28%	
1458	18.00	39.75	18.42	29%	
1460	20.00	39.60	18.27	30%	
1465	25.00	39.20	17.87	31%	
1470	30.00	38.95	17.62	32%	
1475	35.00	38.70	17.37	33%	
1480	40.00	38.45	17.12	34%	
1485	45.00	38.24	16.91	35%	
1490	50.00	38.10	16.77	36%	
1495	55.00	37.85	16.52	37%	
1500	60.00	37.70	16.37	37%	
1510	70.00	37.35	16.02	38%	
1520	80.00	37.05	15.72	40%	
1530	90.00	36.75	15.42	41%	
1540	100.00	36.49	15.16	42%	
1560	120.00	36.03	14.70	44%	
1580	140.00	35.49	14.16	46%	
1600	160.00	35.13	13.80	47%	
1620	180.00	34.75	13.42	48%	
1650	210.00	34.15	12.82	51%	
1680	240.00	33.75	12.42	52%	
1710	270.00	33.28	11.95	54%	
1740	300.00	32.92	11.59	55%	
1800	360.00	32.90	11.57	56%	
1860	420.00	32.85	11.52	56%	

STEP TEST
DATA SHEET

Borehole Nr.	RWA-08-NYA
UTM X	206331
UTM Y	9863158
Location/Village	Kituro
Parish	Kabare II
Sub-County	Rwempasha
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Water, Environment & Geo Services Ltd

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Supervisor	Michael Kazinda					
Date start :	29/08/2018	Time:	15:29	Top of screen 1		mbgl
Date end :	29/08/2018	Time:	21:29	Top of screen 2	51.15	mbgl
Total depth of well:	60.00	m		Available drawdown PID/SWL	26.82	m
Depth of pump intake:	51.15	mbgl		datum level (dl)	0.85	magl
Type of pump:	SQ-5-70			reported water strikes: 1		mbgl
SWL:	21.33	mbgl		2		mbgl
DWL:	22.88	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**0.75**	Borehole nr. **RWA-08-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	mbgl	Seconds	m3/h	
0	21.53			
1	22.95	90.74	0.79	
2	22.85		0.79	
3	22.70		0.79	
4	22.53		0.79	
5	22.54		0.79	
6	22.56		0.79	
7	22.58		0.79	
8	22.59		0.79	
9	22.60	90.74	0.79	
10	22.61		0.79	
12	22.62		0.79	
14	22.63		0.79	
16	22.66		0.79	
18	22.67	90.74	0.79	
20	22.68		0.79	
25	22.72		0.79	
30	22.75		0.79	
35	22.78		0.79	
40	22.80		0.79	
45	22.82		0.79	
50	22.84	90.82	0.79	
55	22.87		0.79	
60	22.88		0.79	
70				
80				
90				

Step Nr.	**Step 2**	Yield (m3/h)	**1.5**	Borehole nr.	**RWA-08-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	22.88		0.79		
1	23.02		0.79		
2	23.13	27.48	2.62		
3	23.58		2.62		
4	23.66		2.62		
5	23.75		2.62		
6	23.79	27.48	2.62		
7	23.84		2.62		
8	23.88		2.62		
9	23.91		2.62		
10	23.95		2.62		
12	24.01		2.62		
14	24.06	27.48	2.62		
16	24.11		2.62		
18	24.14		2.62		
20	24.17		2.62		
25	24.25		2.62		
30	24.31		2.62		
35	24.37		2.62		
40	24.42		2.62		
45	24.46	27.50	2.62		
50	24.51		2.62		
55	24.55		2.62		
60	24.60		2.62		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**2.5**	Borehole nr.	**RWA-08-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	24.60		2.62		
1	24.65	28.62	2.52		
2	24.99		2.52		
3	25.35		2.52		
4	25.75		2.52		
5	25.85		2.52		
6	25.90		2.52		
7	25.98		2.52		
8	26.03	28.65	2.51		
9	26.08		2.51		
10	26.14		2.51		
12	26.22		2.51		
14	26.28		2.51		
16	26.40		2.51		
18	26.34		2.51		
20	26.45		2.51		
25	26.56		2.51		
30	26.66		2.51		
35	26.74	28.68	2.51		
40	26.82		2.51		
45	26.90		2.51		
50	26.97		2.51		
55	27.04		2.51		
60	27.11		2.51		
70					
80					
90					

Step Nr.	Step 4	Yield (m3/h)	3.2	Borehole nr.	RWA-08-NYA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	27.11		2.51		
1	27.11	21.37	3.37		
2	27.23		3.37		
3	27.49		3.37		
4	27.80		3.37		
5	28.01		3.37		
6	28.23		3.37		
7	28.27		3.37		
8	28.32		3.37		
9	28.38		3.37		
10	28.45	21.37	3.37		
12	28.49		3.37		
14	28.65		3.37		
16	28.72		3.37		
18	28.75		3.37		
20	28.96		3.37		
25	28.96		3.37		
30	29.06		3.37		
35	29.16		3.37		
40	29.26		3.37		
45	29.34	21.37	3.37		
50	29.43		3.37		
55	29.50		3.37		
60	29.56		3.37		
70	31.02	4.12			
80	31.10	4.12			
90	31.19	4.12	17.47		

Step Nr.	Step 5	Yield (m3/h)	4	Borehole nr.	RWA-08-NYA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	31.19	4.12	17.47		
1	31.27	4.12			
2	31.32	4.12			
3	31.38	4.12			
4	31.52	4.12			
5	31.64	4.12			
6	31.75	4.12			
7	31.85	4.12			
8	31.95	4.12			
9	32.05	4.12	17.47		
10	32.14	4.12			
12	32.23	4.12			
14	32.63	6.20	11.61		
16	33.15	6.20			
18	33.85	6.20			
20	34.25	6.20	11.61		
25	34.60	6.20			
30	34.73	6.20			
35	35.02	6.20			
40	34.73	6.20			
45	35.02	6.20			
50	35.14	6.20			
55	35.35	6.20	11.61		
60	35.70	6.20			
70	35.95	6.20			
80	36.15	6.20			
90	36.35	6.20			

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Borehole Nr.	- RWA-09-NYA
UTM X	215629
UTM Y	9855364
Location/Village	Kirebe Diary
Parish	Kirebe
Sub-County	Rwimiyaga
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	3.6	Q-planned	6		Q-actual	5.7		
Supervisor		Michael Kazinda						
Date start :		02/09/2018	Time:	19:04	Top of screen 1	51.15		mbgl
Date end :		03/09/2018	Time:	19:04	Top of screen 2	49.15		mbgl
Casing inner diameter		127.00		mm	Available drawdown PID/SWL	28.58		m
Total depth of well:		60.00		m	datum level (dl)	0.85		magl
Depth of pump intake:		49.15		mbgl	reported water strikes: 1			mbgl
Type of pump:		SQ-5-70			2			mbgl
SWL:		17.57		mbgl	3			mbgl
DWL:		34.17		mbgl	4			mbgl
Yield indicator:		20		liters	5			mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		17.97		m³/hr	
1	0:01	23.49	12.60	5.71	
2	0:02	25.65		5.71	
3	0:03	26.65		5.71	
4	0:04	27.45		5.71	
5	0:05	27.95		5.71	
6	0:06	28.25		5.71	
7	0:07	28.50		5.71	
8	0:08	28.70		5.71	
9	0:09	28.85		5.71	
10	0:10	28.95		5.71	
12	0:12	29.16		5.71	
14	0:14	29.33		5.71	
16	0:16	29.41		5.71	
18	0:18	29.52		5.71	
20	0:20	29.60		5.71	
25	0:25	29.73	12.59	5.72	
30	0:30	29.82		5.72	
35	0:35	29.95		5.72	
40	0:40	30.05		5.72	
45	0:45	30.12		5.72	
50	0:50	30.23		5.72	
55	0:55	30.39	12.47	5.77	
60	1:00	30.52		5.77	
70	1:10	30.65		5.77	
80	1:20	30.70		5.77	
90	1:30	30.80		5.77	
100	1:40	30.88		5.77	
120	2:00	30.98		5.77	
140	2:20	31.07	12.49	5.76	
160	2:40	31.15		5.76	
180	3:00	31.21		5.76	
210	3:30	31.31		5.76	

Time elapsed		Water level	Time to Fill	Yield	Remarks
240	4:00	31.43		5.76	
270	4:30	31.51		5.76	
300	5:00	31.57		5.76	
360	6:00	31.68		5.76	
420	7:00	31.87	12.49	5.76	
480	8:00	31.95		5.76	
540	9:00	32.02		5.76	
600	10:00	32.09		5.76	
720	12:00	32.22		5.76	
780	13:00	32.30		5.76	
840	14:00	32.38		5.76	
960	16:00	32.51		5.76	
1080	18:00	32.61		5.76	
1200	20:00	32.71		5.76	
1320	22:00	32.81	12.00	6.00	
1440	24:00	34.17		6.00	

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Borehole Nr.	- RWA-09-NYA
UTM X	215629
UTM Y	9855364
Location/Village	Kirebe Diary
Parish	Kirebe
Sub-County	Rwimiyaga
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	3.6	Q-planned	6.0		Q-actual	5.7	
Supervisor		Michael Kazinda					
Date start :		03/09/2018	Time:	19:04	Top of screen 1	51.15	mbgl
Date end :		03/09/2018	Time:	19:54	Top of screen 2	49.15	mbgl
Casing inner diameter		127	mm		Available drawdown PID/SWL		m
Total depth of well:		60.00	m		datum level (dl)	0.85	magl
Depth of pump intake:		49.15	mbgl		reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		17.57	mbgl		3		mbgl
DWL:		34.17	mbgl		4		mbgl
Yield indicator:		20	liters		5		mbgl

Time elapsed		**Water level**	**drawdown**	**recovery**	**Remarks**
min.	min rec	mbgl	m	%	
1440		34.17	16.60		
1441	1.00	27.15	9.58	42%	
1442	2.00	24.55	6.98	58%	
1443	3.00	23.65	6.08	63%	
1444	4.00	23.15	5.58	66%	
1445	5.00	22.65	5.08	69%	
1446	6.00	22.05	4.48	73%	
1447	7.00	21.75	4.18	75%	
1448	8.00	21.30	3.73	78%	
1449	9.00	21.25	3.68	78%	
1450	10.00	21.10	3.53	79%	
1452	12.00	20.95	3.38	80%	
1454	14.00	20.85	3.28	80%	
1456	16.00	20.75	3.18	81%	
1458	18.00	20.65	3.08	81%	
1460	20.00	20.49	2.92	82%	
1465	25.00	20.40	2.83	83%	
1470	30.00	20.34	2.77	83%	
1475	35.00	20.29	2.72	84%	
1480	40.00	20.23	2.66	84%	
1485	45.00	20.16	2.59	84%	
1490	50.00	20.09	2.52	85%	

STEP TEST
DATA SHEET

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Borehole Nr.	- RWA-09-NYA
UTM X	215629
UTM Y	9855364
Location/Village	Kirebe Diary
Parish	Kirebe
Sub-County	Rwimiyaga
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	2/9/20418	Time: 11:57	Top of screen 1		51.15	mbgl
Date end :	02/09/2018	Time: 12:57	Top of screen 2		49.15	mbgl
Total depth of well:	60.00	m	Available drawdown PID/SWL		15.39	m
Depth of pump intake:	49.15	mbgl	datum level (dl)		0.85	magl
Type of pump:	SQ-5-70		reported water strikes:	1		mbgl
SWL:	17.57	mbgl		2		mbgl
DWL:	32.96	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**1.1**	Borehole nr. **- RWA-09-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	mbgl	Seconds	m3/h	
0	17.57			
1	18.55	77.72	0.93	
2	19.05		0.93	
3	18.95		0.93	
4	19.05	64.62	1.11	
5	19.05		1.11	
6	19.05		1.11	
7	19.05		1.11	
8	19.05		1.11	
9	19.03	64.21	1.12	
10	19.02		1.12	
12	19.03		1.12	
14	19.02		1.12	
16	19.03		1.12	
18	19.04		1.12	
20	19.05		1.12	
25	19.05		1.12	
30	19.06		1.12	
35	19.07		1.12	
40	19.09		1.12	
45	19.10		1.12	
50	19.11	64.21	1.12	
55	19.12		1.12	
60	19.13		1.12	
70				
80				
90				

Step Nr.	**Step 2**	Yield (m3/h)	**2.2**	Borehole nr.	**- RWA-09-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	19.13		1.12		
1	20.00		1.12		
2	20.60	35.84	2.01		
3	20.77		2.01		
4	20.95		2.01		
5	21.03		2.01		
6	21.09	31.12	2.31		
7	21.15		2.31		
8	21.20		2.31		
9	21.22		2.31		
10	21.25		2.31		
12	21.30		2.31		
14	21.32	31.11	2.31		
16	21.35		2.31		
18	21.38		2.31		
20	21.40		2.31		
25	21.44		2.31		
30	21.49		2.31		
35	21.51		2.31		
40	21.53		2.31		
45	21.55	31.12	2.31		
50	21.58		2.31		
55	21.60		2.31		
60	21.61		2.31		
70					
80					
90					

Step Nr.	**Step 3**	Yield (m3/h)	**3.3**	Borehole nr.	**- RWA-09-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	21.61		2.31		
1	22.15	20.00	3.60		
2	22.75		3.60		
3	23.07		3.60		
4	23.23		3.60		
5	23.40		3.60		
6	23.45		3.60		
7	23.48		3.60		
8	23.53	20.00	3.60		
9	23.57		3.60		
10	23.60		3.60		
12	23.65		3.60		
14	23.68		3.60		
16	23.72		3.60		
18	23.75		3.60		
20	23.78		3.60		
25	23.83		3.60		
30	23.87		3.60		
35	23.91	20.00	3.60		
40	23.96		3.60		
45	23.97	15.44	3.60		
50	24.00		3.60		
55	24.04		3.60		
60	24.06		3.60		
70					
80					
90					

Step Nr.	Step 4	Yield (m3/h)	4.4	Borehole nr.	- RWA-09-NYA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	24.06		3.60		
1	24.50		3.60		
2	24.57		3.60		
3	24.85	15.44	4.66		
4	25.01		4.66		
5	25.12		4.66		
6	25.19		4.66		
7	25.25		4.66		
8	26.91		4.66		
9	26.15		4.66		
10	26.65	16.30	4.42		
12	27.06		4.42		
14	27.15		4.42		
16	27.25		4.42		
18	27.29		4.42		
20	27.39		4.42		
25	27.47		4.42		
30	27.54		4.42		
35	27.55	16.30	4.42		
40	27.55		4.42		
45	27.56		4.42		
50	27.65		4.42		
55	27.78		4.42		
60	27.85		4.42		
70					
80					
90					

Step Nr.	Step 5	Yield (m3/h)	5.5	Borehole nr.	- RWA-09-NYA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	27.85		4.42		
1	28.57		4.42		
2	28.70	13.09	5.50		
3	28.77		5.50		
4	28.86		5.50		
5	28.96		5.50		
6	29.03		5.50		
7	29.09		5.50		
8	29.16		5.50		
9	29.29		5.50		
10	29.37		5.50		
12	29.36		5.50		
14	29.59	13.09	5.50		
16	29.65		5.50		
18	29.81		5.50		
20	29.87		5.50		
25	29.95		5.50		
30	30.09	13.20	5.45		
35	30.11		5.45		
40	30.14		5.45		
45	30.17		5.45		
50	30.19		5.45		
55	30.21		5.45		
60	30.23		5.45		
70					
80					
90					

Step Nr.	**Step 6**	Yield (m3/h)	**6.3**	Borehole nr.	**- RWA-09-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	30.23		5.45		
1	30.80	11.19	6.43		
2	31.33		6.43		
3	31.74		6.43		
4	31.85		6.43		
5	31.98		6.43		
6	32.08		6.43		
7	32.15		6.43		
8	32.22		6.43		
9	32.28	11.19	6.43		
10	32.32		6.43		
12	32.38		6.43		
14	32.44		6.43		
16	32.48		6.43		
18	32.53	11.27	6.39		
20	32.56		6.39		
25	32.65		6.39		
30	32.69		6.39		
35	32.75		6.39		
40	32.80		6.39		
45	32.85		6.39		
50	32.89		6.39		
55	32.94		6.39		
60	32.96		6.39		
70					
80					
90					

CONSTANT RATE TEST
DATA SHEET

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WE consult

Borehole Nr.	RWA-10-NYA
UTM X	212340
UTM Y	9846923
Location/Village	Kamate
Parish	Kamate
Sub-County	Karangazi
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	8	Q-planned	10	Q-actual	8
Supervisor	Michael Kazinda				
Date start :	04/09/2018	Time: 20:30	Top of screen 1		mbgl
Date end :	05/09/2018	Time: 20:30	Top of screen 2	34.49	mbgl
Casing inner diameter	114.30	mm	Available drawdown PID/SWL	26.15	m
Total depth of well:	45.45	m	datum level (dl)	0.51	magl
Depth of pump intake:	34.49	mbgl	reported water strikes: 1		mbgl
Type of pump:	SQ-5-70		2		mbgl
SWL:	5.34	mbgl	3		mbgl
DWL:	6.72	mbgl	4		mbgl
Yield indicator:	20	liters	5		mbgl

Time elapsed		**Water level**	**Time to Fill**	**Yield**	**Remarks**
min.	hour	mbgl	Seconds	m3/h	
0		5.43		m³/hr	
1	0:01	6.14	8.61	8.36	
2	0:02	6.22		8.36	
3	0:03	6.23		8.36	
4	0:04	6.26		8.36	
5	0:05	6.29		8.36	
6	0:06	6.30		8.36	
7	0:07	6.31		8.36	
8	0:08	6.32		8.36	
9	0:09	6.33	8.73	8.25	
10	0:10	6.34		8.25	
12	0:12	6.37		8.25	
14	0:14	6.39		8.25	
16	0:16	6.40		8.25	
18	0:18	6.41		8.25	
20	0:20	6.42		8.25	
25	0:25	6.44		8.25	
30	0:30	6.46		8.25	
35	0:35	6.47		8.25	
40	0:40	6.48		8.25	
45	0:45	6.50		8.25	
50	0:50	6.51		8.25	
55	0:55	6.52		8.25	
60	1:00	6.54		8.25	
70	1:10	6.55		8.25	
80	1:20	6.55		8.25	
90	1:30	6.56	8.73	8.25	
100	1:40	6.57		8.25	
120	2:00	6.58		8.25	
140	2:20	6.58		8.25	
160	2:40	6.59		8.25	
180	3:00	6.61		8.25	
210	3:30	6.62		8.25	

Time elapsed		Water level	Time to Fill	Yield	Remarks
240	4:00	6.63		8.25	
270	4:30	6.63		8.25	
300	5:00	6.64		8.25	
360	6:00	6.65		8.25	
420	7:00	6.67	8.92	8.07	
480	8:00	6.67		8.07	
540	9:00	6.68		8.07	
600	10:00	6.69		8.07	
720	12:00	6.70		8.07	
780	13:00	6.71		8.07	
840	14:00	6.70		8.07	
960	16:00	6.70		8.07	
1080	18:00	6.70		8.07	
1200	20:00	6.70	8.86	8.13	
1320	22:00	6.71		8.13	
1440	24:00	6.72		8.13	

RECOVERY TEST
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Borehole Nr.	RWA-10-NYA
UTM X	212340
UTM Y	9846923
Location/Village	Kamate
Parish	Kamate
Sub-County	Karangazi
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Q-air	8	Q-planned	10.0		Q-actual	8.0	
Supervisor		Michael Kazinda					
Date start :		05/09/2018	Time:	20:30	Top of screen 1		mbgl
Date end :		05/09/2018	Time:	20:55	Top of screen 2	34.49	mbgl
Casing inner diameter		114		mm	Available drawdown PID/SWL		m
Total depth of well:		45.45		m	datum level (dl)	0.51	magl
Depth of pump intake:		34.49		mbgl	reported water strikes: 1		mbgl
Type of pump:		SQ-5-70			2		mbgl
SWL:		5.34		mbgl	3		mbgl
DWL:		6.72		mbgl	4		mbgl
Yield indicator:		20		liters	5		mbgl

Time elapsed		Water level	drawdown	recovery	Remarks
min.	min rec	mbgl	m	%	
1440		6.72	1.38		
1441	1441	5.89	0.55	60%	
1442	1442	5.91	0.57	59%	
1443	1443	5.90	0.56	59%	
1444	1444	5.88	0.54	61%	
1445	1445	5.86	0.52	62%	
1446	1446	5.85	0.51	63%	
1447	1447	5.83	0.49	64%	
1448	1448	5.81	0.47	66%	
1449	1449	5.80	0.46	67%	
1450	1450	5.79	0.45	67%	
1452	1452	5.78	0.44	68%	
1454	1454	5.77	0.43	69%	
1456	1456	5.75	0.41	70%	
1458	1458	5.73	0.39	72%	
1460	1460	5.72	0.38	72%	
1465	1465	5.70	0.36	74%	
1470	1470	5.68	0.34	75%	
1475	1475	5.66	0.32	77%	
1480	1480	5.65	0.31	78%	
1485	1485	5.64	0.30	78%	
1490	1490	5.63	0.29	79%	
1495	1495	5.62	0.28	80%	
1500	1500	5.60	0.26	81%	
1510	1510	5.58	0.24	83%	
1520	1520	5.57	0.23	83%	
1530	1530	5.55	0.21	85%	
1540	1540	5.53	0.19	86%	
1560	1560	5.53	0.19	86%	
1580	1580	5.52	0.18	87%	

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Borehole Nr.	RWA-10-NYA
UTM X	212340
UTM Y	9846923
Location/Village	Kamate
Parish	Kamate
Sub-County	Karangazi
County	Eastern Province
District	Nyagatare
Project Nr. :	201811
Client	Water for Growth - Rwanda

Supervisor	Michael Kazinda					
Date start :	04/09/2018	Time:	15:24	Top of screen 1		mbgl
Date end :	04/09/2018	Time:	19:24	Top of screen 2	34.49	mbgl
Total depth of well:	45.45	m		Available drawdown PID/SWL	1.20	m
Depth of pump intake:	34.49	mbgl		datum level (dl)	0.51	magl
Type of pump:	SQ-5-70			reported water strikes: 1		mbgl
SWL:	5.34	mbgl		2		mbgl
DWL:	6.54	mbgl		3		mbgl
Yield indicator:	20	liters		4		mbgl

Step Nr.	**Step 1**	Yield (m3/h)	**2**	Borehole nr.	**RWA-10-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	5.31	56.46			
1	5.44	38.10	1.89		
2	5.39		1.89		
3	5.40		1.89		
4	5.44		1.89		
5	5.49	34.01	2.12		
6	5.47		2.12		
7	5.48		2.12		
8	5.49		2.12		
9	5.49		2.12		
10	5.49		2.12		
12	5.49		2.12		
14	5.49		2.12		
16	5.49		2.12		
18	5.49		2.12		
20	5.50		2.12		
25	5.50	34.01	2.12		
30	5.51		2.12		
35	5.52		2.12		
40	5.52		2.12		
45	5.52		2.12		
50	5.52		2.12		
55	5.53	34.01	2.12		
60	5.53		2.12		
70					
80					
90					

Step Nr.	Step 2	Yield (m3/h)	4	Borehole nr.	RWA-10-NYA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	5.53		2.12		
1	5.57		2.12		
2	5.64	25.00	2.88		
3	5.69	20.07	3.59		
4	5.71		3.59		
5	5.72	17.56	4.10		
6	5.72		4.10		
7	5.73		4.10		
8	5.73		4.10		
9	5.73		4.10		
10	5.74		4.10		
12	5.74		4.10		
14	5.75		4.10		
16	5.75		4.10		
18	5.76	17.56	4.10		
20	5.76		4.10		
25	5.77		4.10		
30	5.77		4.10		
35	5.78		4.10		
40	5.78		4.10		
45	5.79		4.10		
50	5.79		4.10		
55	5.80	17.56	4.10		
60	5.80		4.10		
70					
80					
90					

Step Nr.	Step 3	Yield (m3/h)	6	Borehole nr.	RWA-10-NYA
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	5.80		4.10		
1	5.91	12.31	5.85		
2	6.04		5.85		
3	6.06		5.85		
4	6.07		5.85		
5	6.09		5.85		
6	6.09		5.85		
7	6.10		5.85		
8	6.11	11.58	6.22		
9	6.11		6.22		
10	6.11		6.22		
12	6.12		6.22		
14	6.13		6.22		
16	6.13		6.22		
18	6.14		6.22		
20	6.14		6.22		
25	6.15		6.22		
30	6.16	11.58	6.22		
35	6.17		6.22		
40	6.18	8.94	6.22		
45	6.18		6.22		
50	6.19		6.22		
55	6.19		6.22		
60	6.20		6.22		
70					
80					
90					

Step Nr.	**Step 4**	Yield (m3/h)	**8**	Borehole nr.	**RWA-10-NYA**
Time	**Water level**	**Time to Fill**	**Yield**	**Remarks**	
min.	mbgl	Seconds	m3/h		
0	6.20		6.22		
1	6.35		6.22		
2	6.35	8.94	8.05		
3	6.39		8.05		
4	6.42		8.05		
5	6.42		8.05		
6	6.43		8.05		
7	6.43		8.05		
8	6.44		8.05		
9	6.45		8.05		
10	6.46		8.05		
12	6.46		8.05		
14	6.47	8.94	8.05		
16	6.47		8.05		
18	6.47		8.05		
20	6.48		8.05		
25	6.48		8.05		
30	6.49		8.05		
35	6.50		8.05		
40	6.50		8.05		
45	6.51	8.94	8.05		
50	6.51		8.05		
55	6.52		8.05		
60	6.54	8.94	8.05		
70					
80					
90					

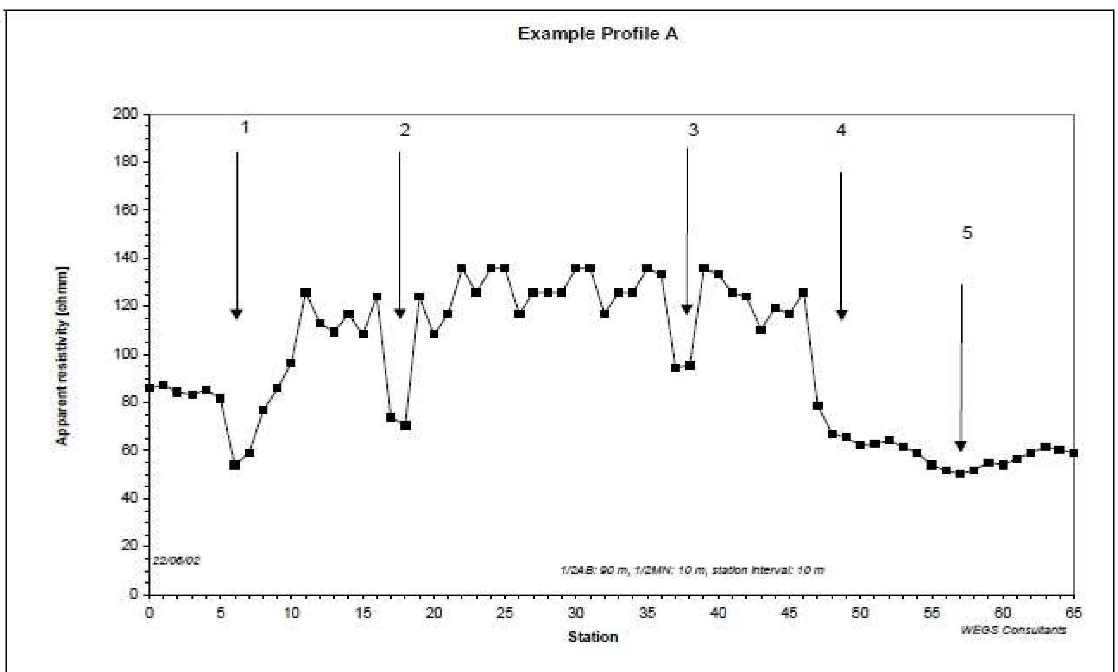
Annex 4. Hydrogeological study guidelines and checks

Hydrogeological study guidelines and checks

Phase	Topic		Required information to be included in the report	Comments
DESKSTUDY	Location village	1	Adminsitrative,	Please note that the desk stuyd is already the start of the reporting. Most information is inlcuded in the final report. After the fieldwork there is only the interpretation and recommendations. The more weget to know during bthe desk study the better will be the survey and the final results
		2	Location in District / Country map	
		3	Coordinates	
	Preferred sites	4	Coordinates	
	Topography	5	General	Absolute height in amsl. Is it relatively high or low in the area
		6	Topographic profile N-S Google Earth 2-5 km length	Elevation of the preferred site bottom valley 1
		7	Topographic profile E-W Google Earth 2-5 km length	Elevation of the preferred site bottom valley 2
		8	Topographic map	Steep slopes? Roads?
		9	DEM map	
		10	Hillshade map	
	Geological map	11	Geology preferred site	What formation? Good or bad? Better nearby?
		12	Geology surroundings	
		13	Faults fractures	Any
		14	Geological Report Uganda	
	Source / Borehole data	15	Water Source location map	Watsup/borehole database data
		16	Groundwatre mapping maps	
		17	Water quality	
		18	Successrate	
		19	DTB	
		20	Borehole yield map	TGS / MWE / WE
		21	Borehole characteristics table per admin unit in excel	Include neighboring units
		22	Borehole characteristics per geological unit in excel	Include neighboring units
		23	Static Water Level expected depth? SWL not too deep?	
		24	Calibration BH nearby for geophysical measurements	
	Geophysical data nearby	25	Any earlier surveys done near the site? Results? dry and successful important, check anomaly and VES and compare later with results	
	Lineament analysis	26	Aerial Photos 1:39,000 and 1:60,000 from EBB, show more than Google Earth, digitize lineaments in GIS	Be aware that the linemanets that you dientify are not always very accurate when you zoom into the area where you want to carry out the survey. Feel free to move the linemant line slightly when you zoom in if you think it is necessary. Make your profiles not to shiort bets is at leats 150 m before and 150 m after the linemant. But alos know that the loneger the line the more overview you get.
		27	DEM Contours	
		28	Topomap	
		29	Rivers	
		30	Google Earth	
		31	Hillshade	
		32	Fractures faults geological map	
	Target sites for geophysics	33	In sediments no 1D profiling, VES only or ERT. High resistivities are target.	Make sure you plan the survey already in the office. Mark the starting and end coordinates for the profiles. Make sure you use Google Earth to identify tracks / roads / non vegtated lines that will allow you to cross the expecetd lineament as perpendicular as possible.
		34	For handpump borehole in flat areas 2 profiles perpendicular. Otherwsie target lineament or valleys if less than 1000 m from preferred site	
		35	For production boreholes, target lineaments and valleys only. Cross in different places	
RECON	Reconnaissance survey	36	Verify the sites in field on location accessibility	
		37	Check results earlier drilling programmes,	
		38	Check general potential and accessibility, verify expectations from desk study, check whether community is aware of the drilling programme with community	
FIELDWORK	Fieldwork	39	Profiles as per locations indicated in desk study:	Go ti field use GPS and make sure you have the right stat
		40	Mark every station with a small peg	
		41	Write down the locations of any feature the profile is crossing like trees, house fence, latrine,etc. If necessary mark when AB MN electrodes are crossing something (when you expecet conductor in underground, high volatage line, bridge etc.). Paint station numbers on trees (in accuracy of meters: Station 21.5 is 215 meter from start and 5 m from 21)	
		42	On anomaly take coordinates	
		43	Mark the promising anomalies with a large peg	
			1D option	
		44	Run profile perpendicular to the anticipated valley / structure / lineament	
		45	Run parallel profile paralllel to original if possible	
		46	Check anomalies and correlate to determine the orientation between the anomalies	
		47	Compare the orientation of the anomalies with expected lineaments	
		48	Run VES through stations of anomalies on both profiles	
		49	Compare anomaly and VES with other VES and anomalies in similar areas where drilling results are positive	
			ERT option	
		50	Run ERT profile perpendicular to the anticipated valley / structure / lineament	
		51	Run parallel 1D or ERT profile if possible	
		52	Check anomalies and correlate to determine the orientation between the anomalies	
		53	Compare the orientation of the anomalies with expected lineaments	
		54	Run VES through stations of anomalies on both profiles	
		55	Compare anomaly and VES with other VES and anomalies in similar areas where drilling results are positive	
REPORT	Interpretation	56	Interprete the VES using model based on existing borehole data	
		57	If no data use realistic models and depths (not DTB of 200m for example)	
	Prioritisation of drill sites	58	Use scoring table, example below	Do not recommend sites where a drilling rig cannot reach. Use borehole data characteristics to come up with realistic recommended drilling depths! In case of no data one uses common sense or geophysical data but the latter are not conclusive on depths. Drilling deeper than the maximum water strikes in the borehole data for the region is done more at luck than on knowledge

Criteria % weight	Explanation	Specific criteria		Score	Max
Topography -20%	The topography of a location is determining for the groundwater potential. The potential depends on the location on a slope; the highest potential is the bottom of a valley and the lowest is at the top of a high hill.	Ridge / hill top		0	
		Upper slope		5	
		Flat area / head of valley		10	
		Saddle / lower slope		15	
		valley / foot lower slope		20	20
Lineament 15%	Lineaments often have a high groundwater potential. The presence and quality of a lineament is acquired from analyses of aerial photos, topographical maps, or field observation.	Lineament present	Very clear	20	20
		No lineament present	Clear	10	
			Vague	5	
			No lineament	0	
Anomaly -30%	Experience shows that the anomaly is the most reliable indicator for high potential areas. Because a ½ AB distance of 90 m is used, the anomalies become more pronounced and deeply weathered zones or cracks are more precisely indicated .The potential is amongst others based on the general shape, resistivity and width of the anomaly.	Contrast (shoulder/ lowest anomaly value)	< 1.5 or > 4	0	
			2-4	10	10
		Width (shoulder to shoulder)	< 19 m and > 80 m	0	
			20 – 60	5	5
		Shape of anomaly and trend of profile	Minor anomaly in sloping trend	2	
			Major anomaly in horizontal trend	7	7
		Confirmation of anomaly (shape and value)	None	0	
			little	3	
			Shape and value	8	8
VES 10%	The VES is usually carried out on an anomaly and indicates the resistance of different layers. The aspects of importance are general shape, resistivity at depth and width of trough. The VES interpretations are the most reliable when the geology is well known.	VES dip	> 200 Ωm	0	
			10 - 100 Ωm	7	7
		Depth to bedrock	45 º is < 27m or > 120	0	
			45 º is 40m - 83m	8	8
Similarity 15%	Confirmation profiles and VES near existing high yielding boreholes, and survey results of earlier projects, have resulted in types of VES and anomaly. If the actual VEs or anomaly shows good similarity a higher score is attributed	Anomaly	Low-high similarity	10	10
		VES	Low-high similarity	5	5
General information 10%	This category allows you to make your own judgements based on general information. If the successrates are high then a site closer to the VPS can gte more points, if there are signs in the field (site near springs) one can give extra points	General	no dry boreholes drilled before	3	
			dry boreholes before	0	7
		Other	other features	3	
			distance to VPS	3	8
100%					100

Please note that this scoring table is just an example and can be adapated based on the characteristics of the area you are operating in. The purpose of the table is to systematically evaluate various potential sites in the area.



Anomaly	Significance
1	promising anomaly - asymmetrical
2	the most promising anomaly, a deep trough far below the trend, symmetrical
3	a less promising anomaly, a trough but only slightly below the general trend
4	a large contrast between two formations
5	a general low usually related to the topography, general no real prospects

Figure 20 Types of anomalies on a resistivity profile

Annex 5. JICA 2014 Geophysical data

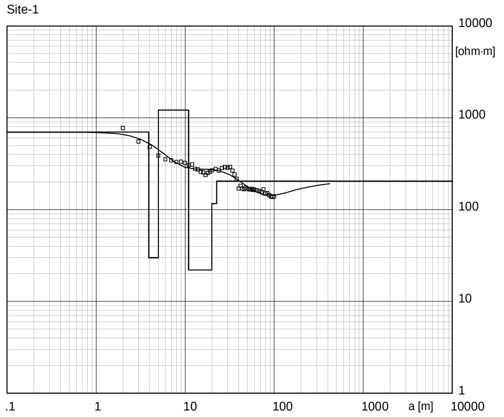
D7. Geophysical Survey Data

7.1 ρ- a Curves

Location 1 **Name:** Rwinkwanvu

Electrical sounding Wenner - Site-1.WS3

Site-1



Location X = 030 36' 26.3 " Y = 01 56' 39.7 01 56'39.7 Z = Azim = 1342

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
697	3.9	
30	1.1	3.9
1209	5.9	5
22	9	11
116	2.7	20
204		23

VES was carried out at Rwinkwanvu. Interpreted layers: Top soil, lateritic formation, clayey sand, sandy quartz gravel, saturated clay, weathered/ fractured rock & Hard rock

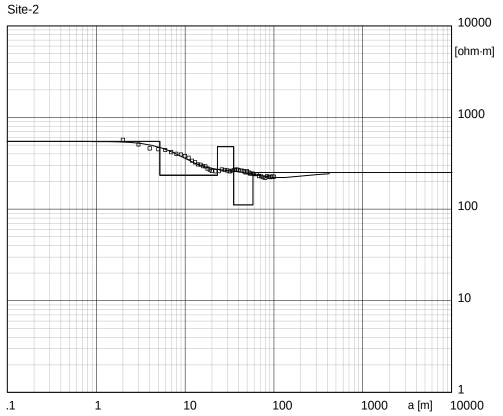
W-GeoSoft / WinSev 6.1

Comments: VES indicates 23m of sediments; site has low to medium potential.

Location 2 **Name:** Nkondo

Electrical sounding Wenner - Site-2.WS3

Site-2



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
547	5.2		156
234	18	5.2	150.8
481	12	23	133
111	23	35	121
250		58	98

VES was carried out at Nkondo. Interpreted layers are: Top soil, clay, weathjered formation and Hard rock

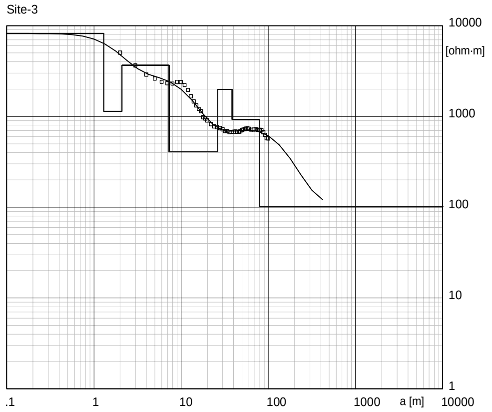
W-GeoSoft / WinSev 6.1

Comments: Thick sediments of mostly sands and gravel; site shows medium to high potential.

Location 3 **Name:** Matinza

Electrical sounding Wenner - Site-3.WS3

Site-3



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
8209	1.3		154
1142	.8	1.3	152.7
3663	5.2	2.1	151.9
408	19	7.3	146.7
1985	12	26	128
928	41	38	116
102		79	75

VES was carried out at Matinza. Interpreted layers are: Top soil, clay, weathjered formation and Hard rock

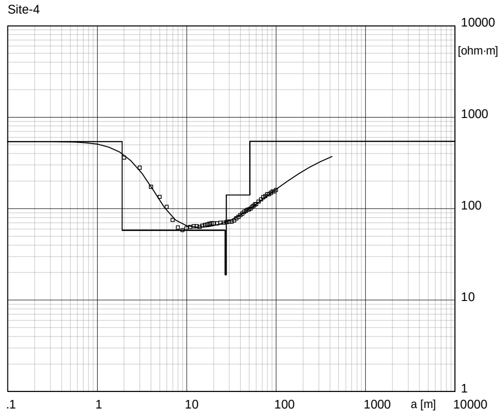
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick sediments at very high resistivities; site shows medium to low potential. . However, detailed investigations involving aerial photo interpretation, geo-electric profiling, etc. recommended to identify areas of pronounced fracture zones and/ or thick sediments/ overburden.

Location 4 **Name:** Kigarama

Electrical sounding Wenner - Site-4.WS3

Site-4



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
541	1.9		153
58	25	1.9	151.1
19	.93	27	126
141	23	28	125
543		51	102

VES was carried out at Kigarama. Interpreted layers are: Top soil, clayey sand, weathered fractured rock and Hard rock

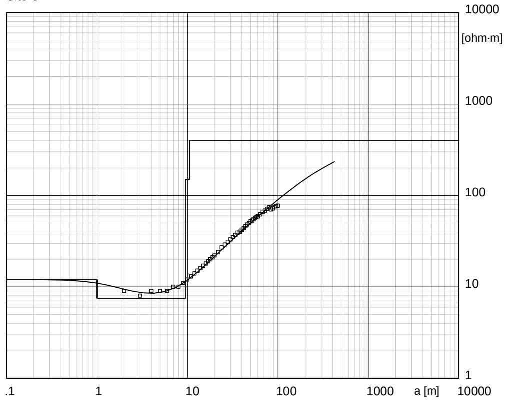
W-GeoSoft / WinSev 6.1

Comments: The site has medium to poor potential; site has medium to high potential.

Location 5 Name: Kageyo

Electrical sounding Wenner - Site-5.WS3

Site-5



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
12	1	
7.5	8.5	1
150	1	9.5
400		10

VES was carried out at Kageyo. Interpreted layers are: Clayey top soil, clay, weathered formation and beddrock

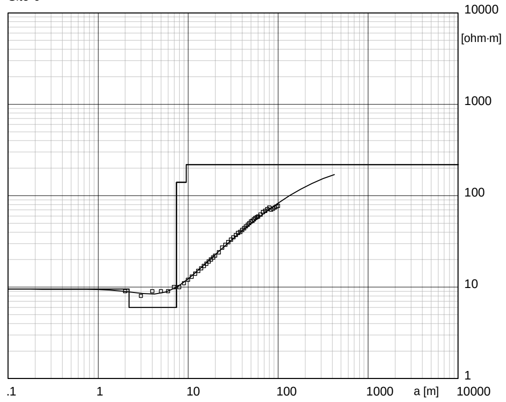
W-GeoSoft / WinSev 6.1

Comments: Thin sediments (overburden) on a schist; site has very poor potential. . However, detailed investigations involving aerial photo interpretation, geo-electric profiling, etc. recommended to identify areas of pronounced fracture zones and/ or thick sediments/ overburden.

Location 6 Name: Nyamiyaga

Electrical sounding Wenner - Site-6.WS3

Site-6



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
9.5	2.2	
6	5.2	2.2
140	2.1	7.4
219		9.5

VES was carried out at Nyamiyaga. Interpreted layers are: Clayey top soil, clay, and weathered formation and hardrock

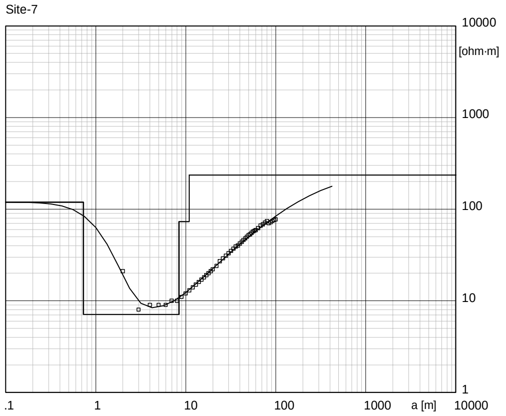
W-GeoSoft / WinSev 6.1

Comments: Thin sediments (overburden) on a schist; site has very poor potential. . However, detailed investigations involving aerial photo interpretation, geo-electric profiling, etc. recommended to identify areas of pronounced fracture zones and/ or thick sediments/ overburden.

Location 7 Name: Nyamiyaga

Electrical sounding Wenner - Site-7.WS3

Site-7



Location X = 030 38' 10.6 Y = 01 47' 36.7 Z = 1305 Azim = 30-210

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
119	.73		1305
7.1	7.7	.73	1304.3
73	2.5	8.4	1296.6
235		11	1294

VES was carried out at Nyamiyaga. Interpreted layers are: Top soil, clay, and coarse sandstone

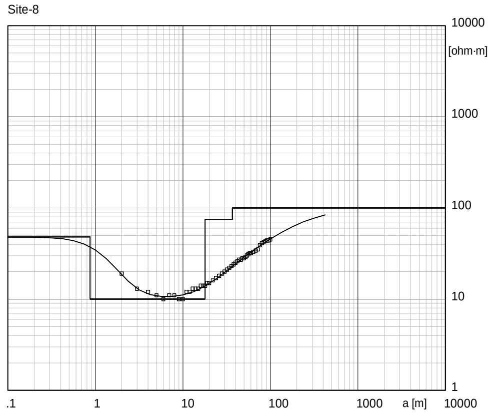
W-GeoSoft / WinSev 6.1

Comments: VES indicates poor potential. However, detailed investigations involving aerial photo interpretation, geo-electric profiling, etc. recommended to identify areas of pronounced fracture zones and/ or thick sediments/ overburden.

Location 8 Name: Nyamiyaga

Electrical sounding Wenner - Site-8.WS3

Site-8



Location X = 030 36' 37.4 Y = 01 42' 14.7 Z = 1308 Azim = 20-200

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
48	.87		1308
10	17	.87	1307.1
75	19	18	1290
100		37	1271

VES was carried out at Nyamiyaga. Interpreted layers are: top soil, clay, and fine sand

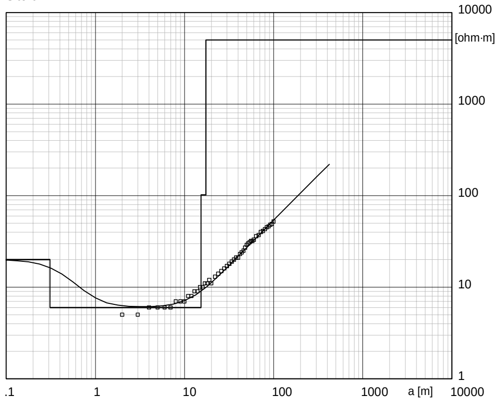
W-GeoSoft / WinSev 6.1

Comments: VES indicates medium to high potential of especially shallow well.

Location 9 Name: Mucucu

Electrical sounding Wenner - Site-9.WS3

Site-9



Location X = 030 36' 37.4 Y = 01 42' 14.7 Z = 1308 Azim = 20-200

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
20	.31		1308
6	15	.31	1307.7
102	2	15	1293
5000		17	1291

VES was carried out at Mucucu. Interpreted layers are: clayey top soil, clay, weathered formation and hardrock.

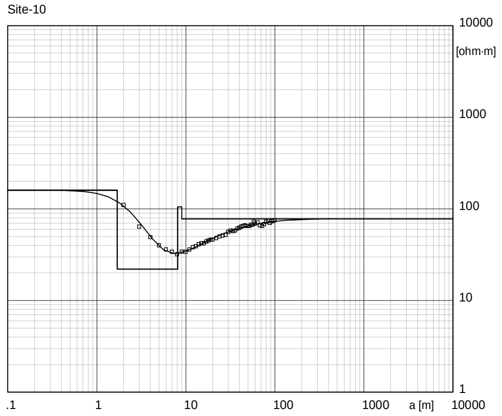
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of 17m; site has low to medium potential; detailed investigations recommended for better

Location 10 Name: Gakoma

Electrical sounding Wenner - Site-10.WS3

Site-10



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
160	1.7		139
22	6.4	1.7	137.3
105	.88	8.1	130.9
78		9	130

VES was carried out at Gakoma. Interpreted layers are: sandy top soil, clayey sand, coarse sand and fine sand

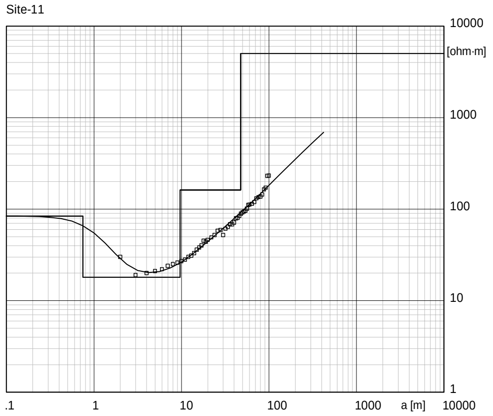
W-GeoSoft / WinSev 6.1

Comments: VES indicates sediments of medium to high potential.

Location 11 Name: Kakoma

Electrical sounding Wenner - Site-11.WS3

Site-11



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
84	.75		138
18	8.9	.75	137.2
162	38	9.6	128.4
5000		48	90

VES made at Kakoma. Interpreted layers: top soil, clay, weathered/fractured formation and hardrock.

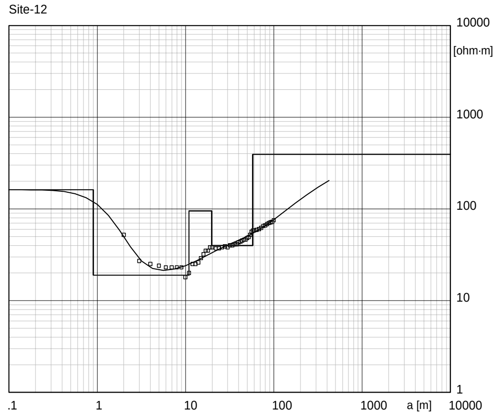
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thick overburden overlying partly fractured / weathered granite; site has medium to high potential.

Location 12 Name: Gikoobwa

Electrical sounding Wenner - Site-12.WS3

Site-12



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
162	.9		138
19	10	.9	137.1
95	8.9	11	127
40	38	20	118
393		58	80

VES taken at Gikoobwa. Interpreted layers are: top soli, clay, sand, saturated sand and weathered schist.

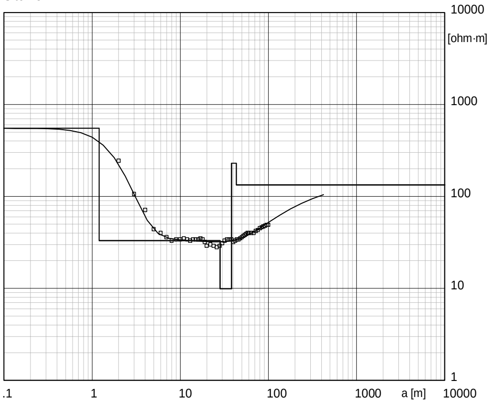
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick sediments resting on schist; site has medium to high potential.

Location 13	**Name:**

Electrical sounding Wenner - Site-13.WS3

Site-13



Location X = 030 34' 16.5 Y = 01 34' 23.2 Z = Azim = 1304

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
550	1.2	
33	27	1.2
9.9	10	28
230	5	38
133		43

VES was carried out at . Interpreted layers are: top soil, sandy clay, clay and bedrock

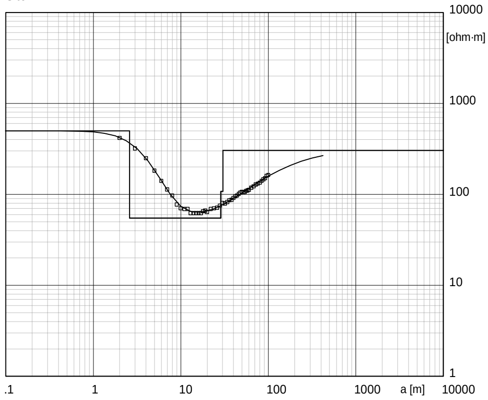
W-GeoSoft / WinSev 6.1

Comments: VES indicated relatively thick sediments probably overlying schist; site has medium to high potential.

Location 14	**Name:** Nsenene

Electrical sounding Wenner - Site-14.WS3

Site-14



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
499	2.6		132
55	26	2.6	129.4
108	1.6	29	103
305		31	101

VES was carried out at Nsenene. Interpreted layers are: sandy top soil, clay, weathered formation and fractured rock

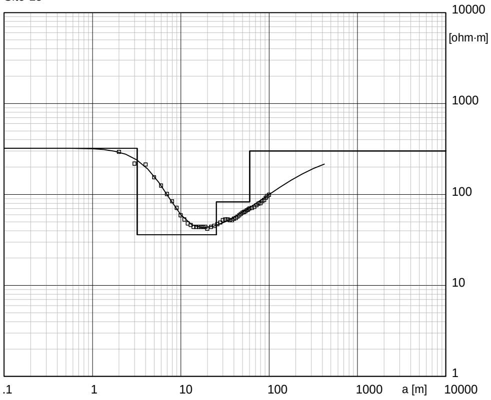
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden; site has low to medium potential.

Location 15	**Name:** Micucu

Electrical sounding Wenner - Site-15.WS3

Site-15



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
322	3.2		132
36	22	3.2	128.8
83	35	25	107
300		60	72

VES was carried out at Micucu. Interpreted layers are: sandy top soil, sandy clay, sand and weathered schist

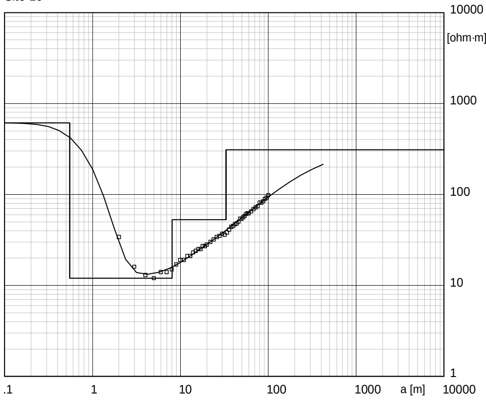
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thick overburden; site has medium to high potential.

Location 16	**Name:** Mucucu

Electrical sounding Wenner - Site-16.WS3

Site-16



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
614	.55		138
12	7.5	.55	137.4
53	25	8	130
311		33	105

Interpreted layers: top soil, clay, clayey sand and schist

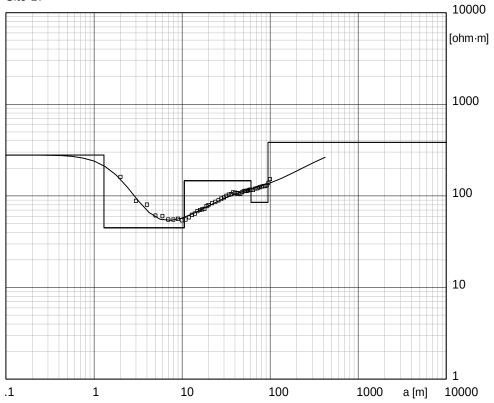
W-GeoSoft / WinSev 6.1

Comments: VES indicates a shallow overburden; site has low to medium potential.

Location 17 Name: Munini

Electrical sounding Wenner - Site-17.WS3

Site-17



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
279	1.3		1362
45	9.3	1.3	1360.7
146	50	11	1351
85	34	61	1301
383		95	1267

VES was carried out at Munini. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

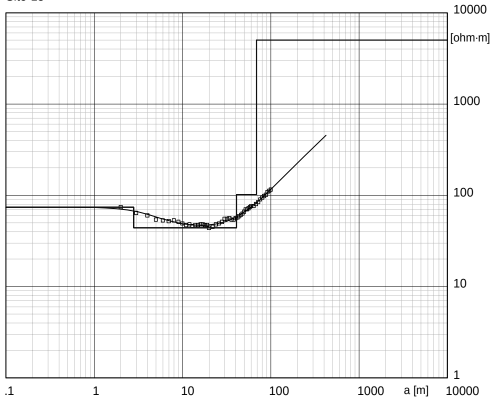
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick sediments; site has medium to high potential.

Location 18 Name: Military training ground

Electrical sounding Wenner - Site-18.WS3

Site-18



Location X = 030 32' 14.7 Y = 01 34' 03.7 Z = Azim = 1320

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
74	2.8	
44	38	2.8
102	28	41
5000		69

VES was carried out at Military training ground. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock (granite)

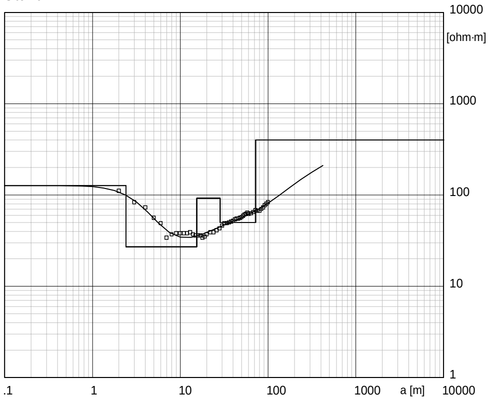
W-GeoSoft / WinSev 6.1

Comments: VES indicates a relatively thick overburden; site shows medium to high potential.

Location 19 Name: Nyamwiza

Electrical sounding Wenner - Site-19.WS3

Site-19



Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
127	2.4		135
27	13	2.4	132.6
92	13	15	120
50	44	28	107
400		72	63

VES was carried out at Nyamwiza. Interpreted layers are: top soil, clayey , sand, weathered formation and hard rock

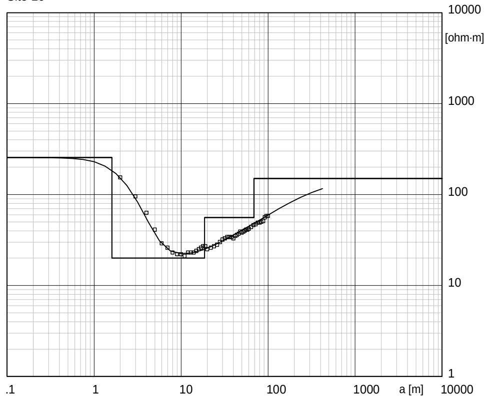
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 20 Name: Munini

Electrical sounding Wenner - Site-20.WS3

Site-20



Location X = 030 36' 19.9 Y = 01 30' 36.8 Z = Azim = 1320

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
255	1.6	
20	17	1.6
56	50	19
150		69

VES was carried out at Munini. Interpreted layers are: top soil, clay, saturated sand and gravel

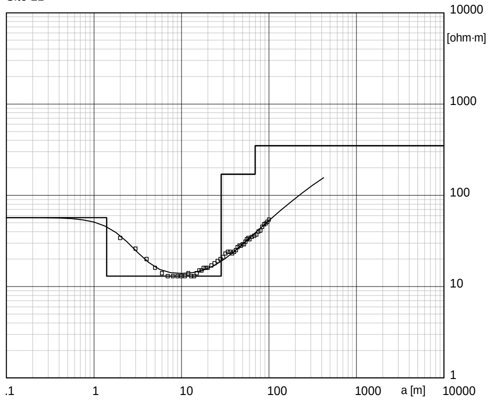
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 21	**Name:** Kabeza

Electrical sounding Wenner - Site-21.WS3

Site-21



Location X = 030 30' 51.3 Y = 01 37' 36.3 Z = Azim = 1322

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
57	1.4	
13	27	1.4
170	41	28
350		69

VES was carried out at Kabeza. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

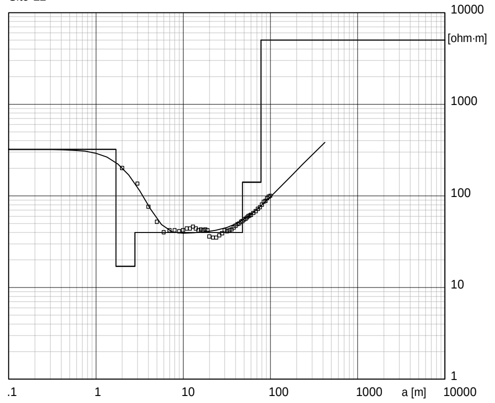
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 22	**Name:** Kabeza

Electrical sounding Wenner - Site-22.WS3

Site-22



Location X = 030 30' 51.3 Y = 01 37' 36.3 Z = Azim = 1322

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
321	1.7	
17	1.1	1.7
40	45	2.8
141	30	48
5000		78

VES was carried out at Munini. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

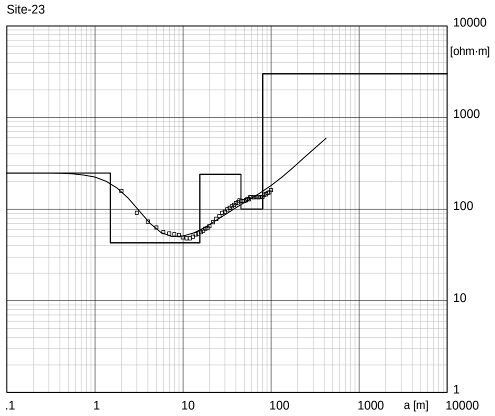
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 23	**Name:** Ngumeri I

Electrical sounding Wenner - Site-23.WS3

Site-23



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
248	1.5		138
43	14	1.5	136.5
240	30	16	122
100	35	46	92
3000		81	57

VES taken at Ngumeri I. Interpreted layers are: top soil, clayey sand, gravel, saturated sand and sandstone (hard rock)

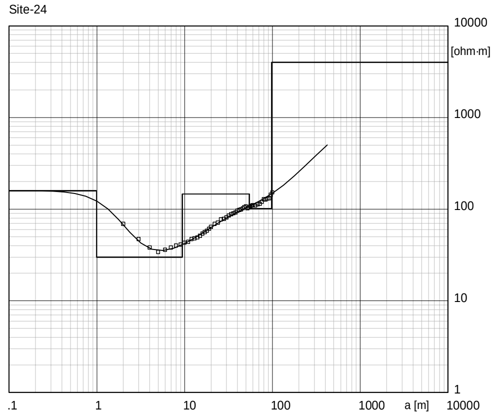
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 24	**Name:** Akamina

Electrical sounding Wenner - Site-24.WS3

Site-24



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
159	.99		138
30	8.4	.99	137
146	45	9.4	128.6
101	44	54	84
4000		98	40

VES taken at Akamina. Interpreted layers are: topsoil, sandy gravel, weathered/fractured rock and hard rock.

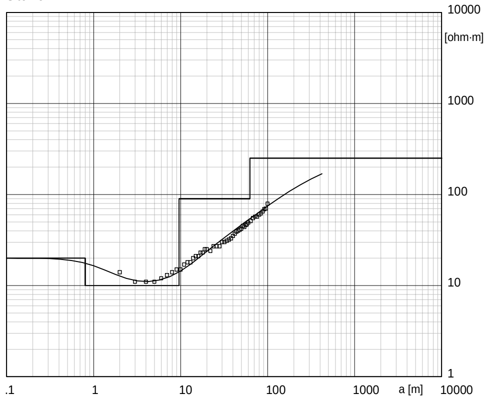
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly sediments; site has medium to high potential.

Location 25 Name: Gafunzo

Electrical sounding Wenner - Site-25.WS3

Site-25



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
20	.8	
10	8.8	.8
90	53	9.6
250		63

VES was carried out at Gafunzo. Interpreted layers are: clayey top soil, clay, sand and weathered schist

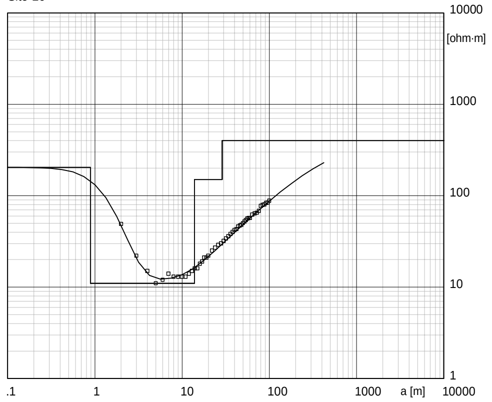
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 26 Name:

Electrical sounding Wenner - Site-26.WS3

Site-26



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
204	.89	
11	13	.89
150	15	14
400		29

Interpreted layers are: top soil, clay, weathered formation and hard rock (probably schist)

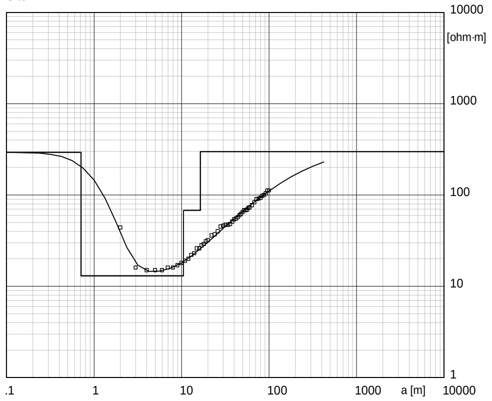
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low to medium potential.

Location 27 Name: Kayange

Electrical sounding Wenner - Site-27.WS3

Site-27



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
293	.71	
13	9.8	.71
68	5.9	11
298		17

VES was carried out at Kayange. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

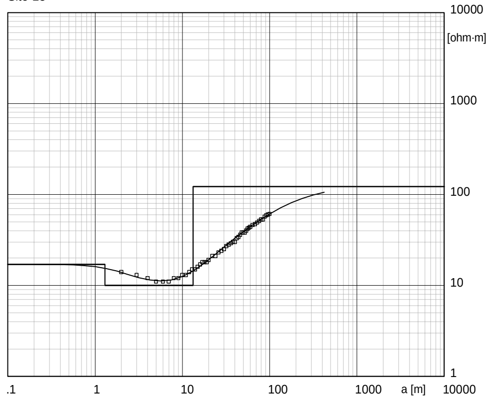
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low to medium potential.

Location 28 Name: Kayange

Electrical sounding Wenner - Site-28.WS3

Site-28



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
17	1.3	
10	12	1.3
122		13

VES was carried out at Munini. Interpreted layers are: clayey top soil, clay, sandy gravel and weathered schist

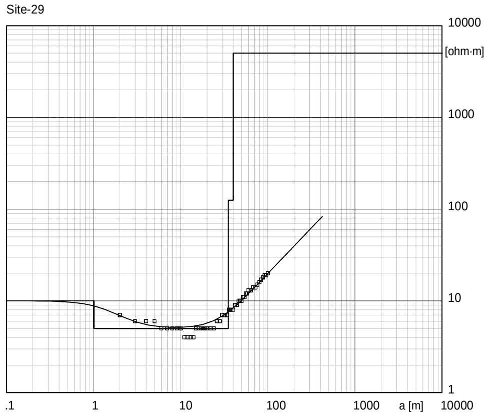
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low to medium potential.

Location 29 | Name: Kayanje I

Electrical sounding Wenner - Site-29.WS3

Site-29



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity	**Thickness**	**Depth**
[ohm·m]	[m]	[m]
10	1	
5	34	1
125	5	35
5000		40

VES was carried out at Kayanje I. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

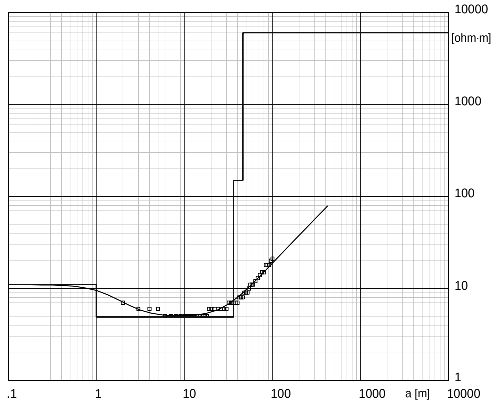
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clays; site has low to medium potential.

Location 30 | Name: Kayanje II

Electrical sounding Wenner - Site-30.WS3

Site-30



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity	**Thickness**	**Depth**
[ohm·m]	[m]	[m]
11	.99	
4.9	35	.99
150	10	36
6000		46

VES was carried out at Kayanje II. Interpreted layers are: top soil, clay, weathered formation and hard rock

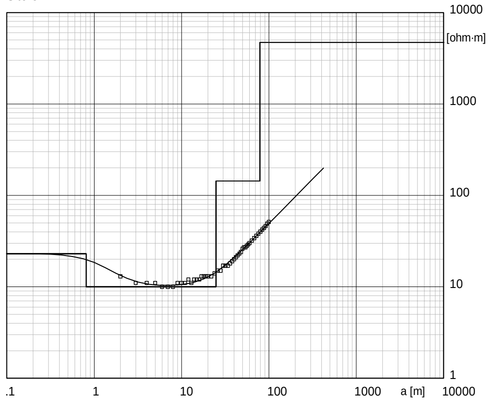
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thick overburden; site has medium to high potential.

Location 31 | Name: Kayanje III

Electrical sounding Wenner - Site-31.WS3

Site-31



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity	**Thickness**	**Depth**
[ohm·m]	[m]	[m]
23	.81	
10	24	.81
144	54	25
4700		79

VES was carried out at Kayanje III. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

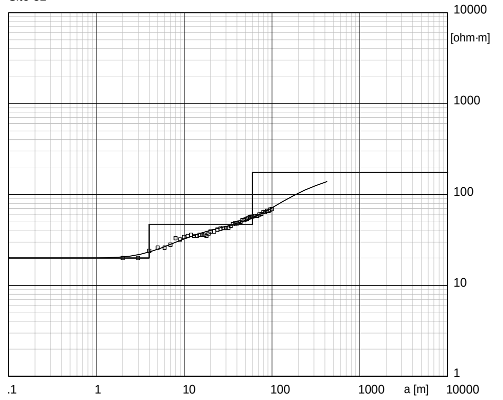
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 32 | Name: Akagera

Electrical sounding Wenner - Site-32.WS3

Site-32



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	**Thickness**	**Depth**	**Altitude**
[ohm·m]	[m]	[m]	[m]
20	4		1362
47	56	4	1358
176		60	1302

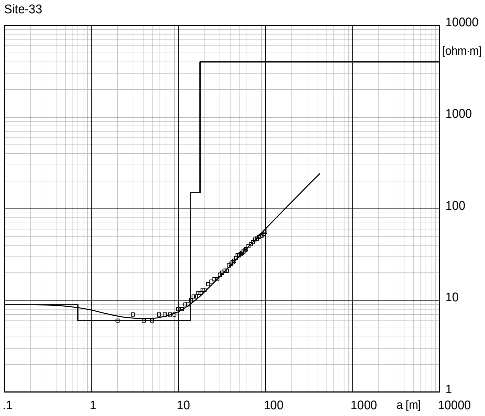
VES was carried out at Akagera. Interpreted layers are: clay top soil, clayey sand and weathered schist

W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly sandy clays; site has low to medium potential.

Location 33 Name: Kyembogo

Electrical sounding Wenner - Site-33.WS3



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
9	.7		1362
6	13	.7	1361.3
150	4	14	1348
4000		18	1344

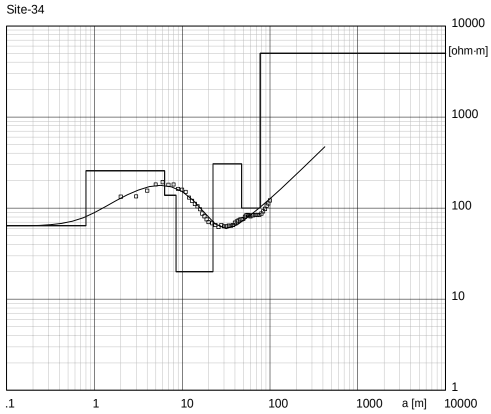
VES was carried out at Kyembogo. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of mostly clay; site has low to medium potential.

Location 34 Name: Kyembogo II

Electrical sounding Wenner - Site-34.WS3



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
64	.8		1362
257	5.5	.8	1361.2
138	2.2	6.3	1355.7
20	14	8.5	1353.5
307	25	22	1340
100	30	47	1315
5000		77	1285

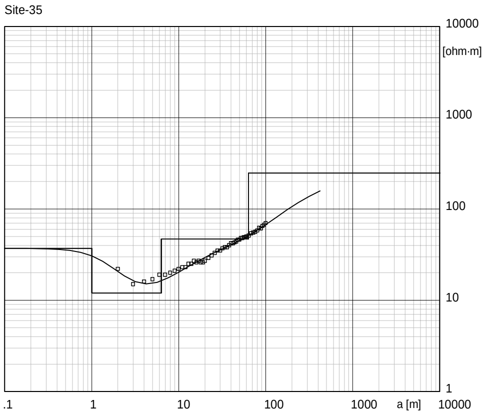
VES was carried out at Kyembogo II. Interpreted layers are: top soil, gravel, coarse sand, clay, gravel, weathered formation and hard rock

W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly sediments; site has medium to high potential.

Location 35 Name: Gikungu

Electrical sounding Wenner - Site-35.WS3



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
37	1		1362
12	5.3	1	1361
47	57	6.3	1355.7
247		63	1299

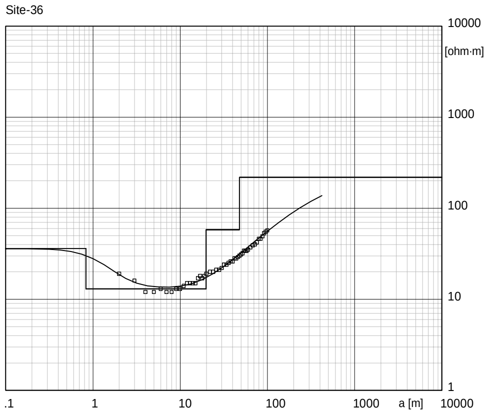
VES was carried out at Gikungu. Interpreted layers are: clayey top soil, clay, clayey sand and sandstone

W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clays and clayey sands; site has low potential.

Location 36 Name: Mushorerwa

Electrical sounding Wenner - Site-36.WS3



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
36	.83		1362
13	19	.83	1361.2
58	28	20	1342
219		48	1314

VES was carried out at Mushorerwa. Interpreted layers are: top soil, clay, sand and hard rock(sandstone)

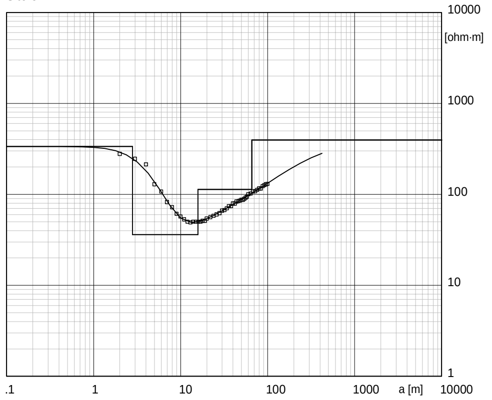
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clay and fine sand; site has low to medium potential.

Location 37	**Name:** Kinombe

Electrical sounding Wenner - Site-37.WS3

Site-37



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
336	2.8		1362
36	13	2.8	1359.2
113	50	16	1346
395		66	1296

VES was carried out at Kinombe. Interpreted layers are: top soil, sandy clay, coarse sand and hard rock

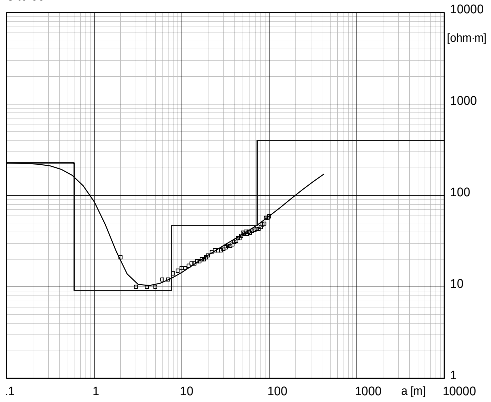
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 38	**Name:** Nyamenge

Electrical sounding Wenner - Site-38.WS3

Site-38



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
227	.59		1362
9.1	7	.59	1361.4
47	65	7.6	1354.4
400		73	1289

VES was carried out at Nyamenge. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

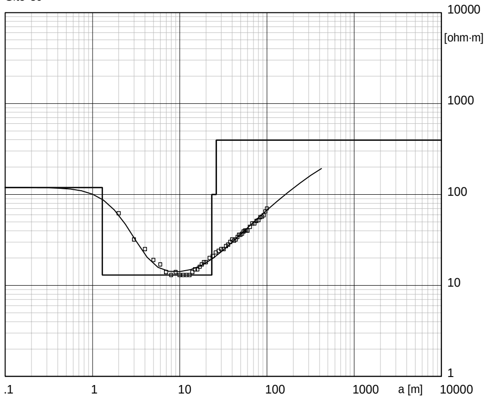
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clay and clayey sands; site has low to medium potential.

Location 39	**Name:** Omukakindo

Electrical sounding Wenner - Site-39.WS3

Site-39



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
119	1.3		1362
13	22	1.3	1360.7
100	3	23	1339
395		26	1336

VES was carried out at Omukakindo. Interpreted layers are: top soil, clay, sand and hard rock(schist)

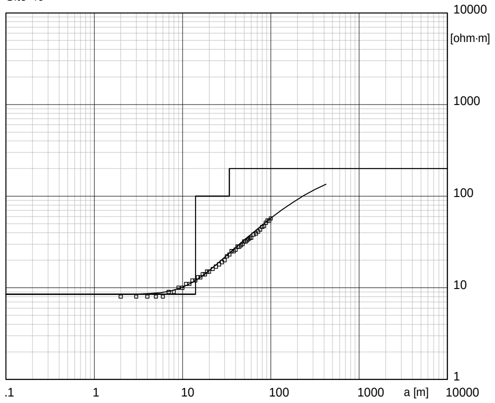
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of mostly clay; site has low to medium potential.

Location 40	**Name:** Gakindo

Electrical sounding Wenner - Site-40.WS3

Site-40



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
8.5	14		1362
100	20	14	1348
200		34	1328

VES was carried out at Gakindo. Interpreted layers are: clay top soil, sand and weathered schist

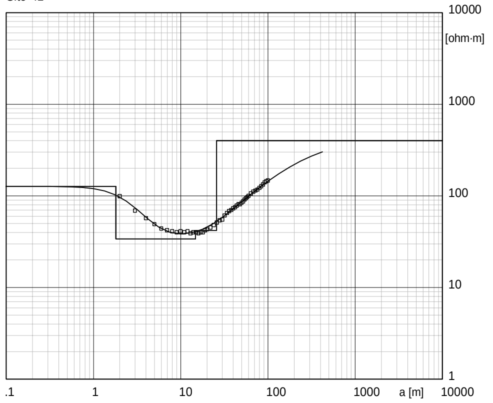
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of sediments overlying a schist; site has low to medium potential.

Location 41 **Name:** Kijojo

Electrical sounding Wenner - Site-41.WS3

Site-41



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
127	1.8		1362
34	13	1.8	1360.2
42	11	15	1347
400		26	1336

VES was carried out at Kijojo. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

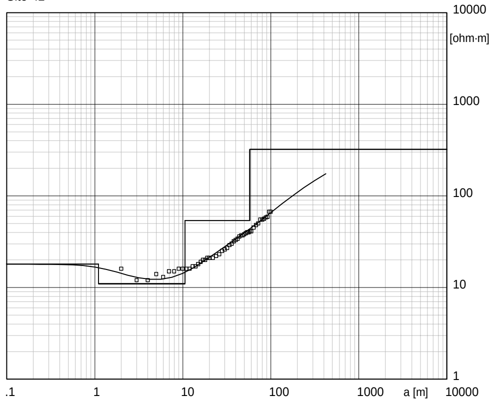
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of mostly clay and sandy clay; site has low to medium potential.

Location 42 **Name:** Gasinga

Electrical sounding Wenner - Site-42.WS3

Site-42



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
18	1.1		1362
11	9.5	1.1	1360.9
54	47	11	1351
321		58	1304

VES was carried out at Gasinga. Interpreted layers are: top soil, clayey sand, weathered formation and bedrock

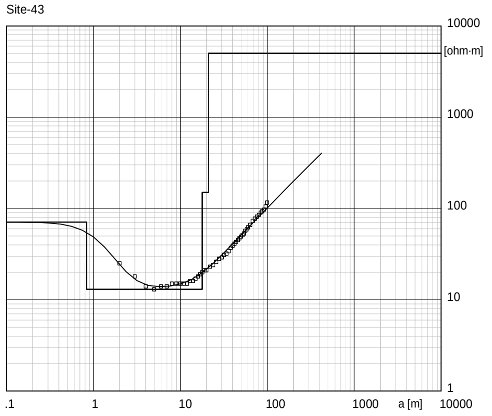
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 43 **Name:** Gasinga

Electrical sounding Wenner - Site-43.WS3

Site-43



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
71	.83		1362
13	17	.83	1361.2
150	3.1	18	1344
5000		21	1341

VES was carried out at Gasinga. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

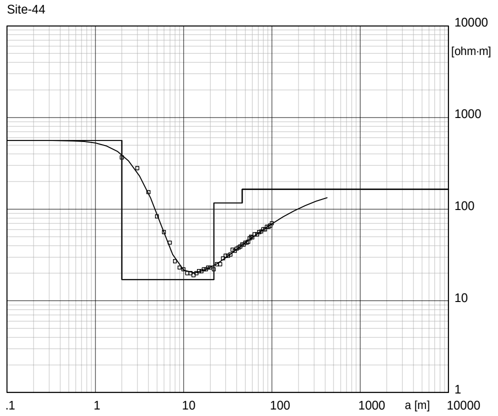
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of mostly clays; site has low to medium potential.

Location 44 **Name:** Gasinga

Electrical sounding Wenner - Site-44.WS3

Site-44



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
563	2		1362
17	20	2	1360
117	24	22	1340
165		46	1316

VES was carried out at Gasinga. Interpreted layers are: dry top soil, clay, sand and weathered schist

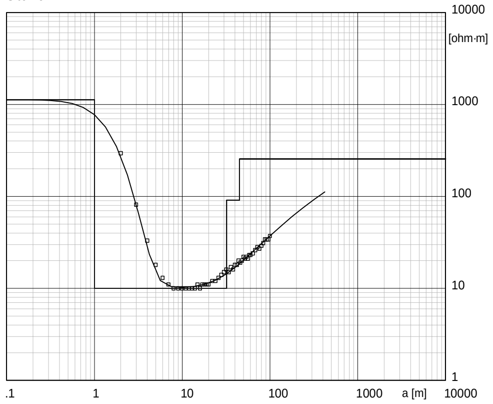
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thick overburden of sediments; site has medium to high potential.

Location 45 Name: Katagira

Electrical sounding Wenner - Site-45.WS3

Site-45



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1126	1		1362
10	31	1	1361
91	13	32	1330
256		45	1317

VES was carried out at Katagira. Interpreted layers are: dry sandy top soil, clay, weathered sand and weathered schist

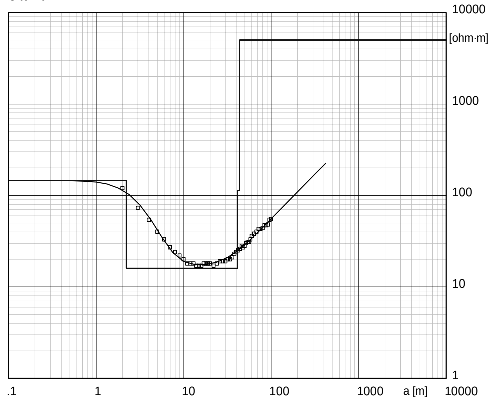
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 46 Name: Kabare

Electrical sounding Wenner - Site-46.WS3

Site-46



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
146	2.2		1362
16	39	2.2	1359.8
113	2.2	41	1321
5000		43	1319

VES was carried out at Kabaare. Interpreted layers are: top soil, clay, weathered formation and hard rock

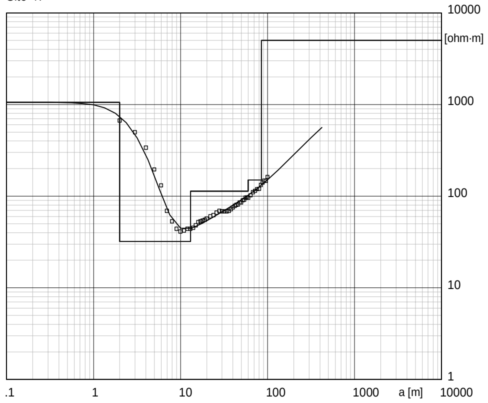
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clay; site has low to medium potential.

Location 47 Name: Nshekye

Electrical sounding Wenner - Site-47.WS3

Site-47



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1058	2		1362
32	11	2	1360
113	47	13	1349
150	25	60	1302
5000		85	1277

VES was carried out at Nshekye. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

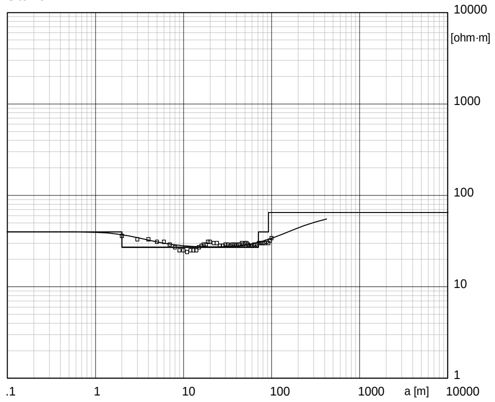
W-GeoSoft / WinSev 6.1

Comments: VES indicates very thick overburden; site has medium to high potential.

Location 48 Name: Nyegyeza

Electrical sounding Wenner - Site-48.WS3

Site-48



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
40	2		1362
27	69	2	1360
40	21	71	1291
65		92	1270

VES was carried out at Nyegyeza. Interpreted layers are: clayey top soil, clay, sandy clay and sand

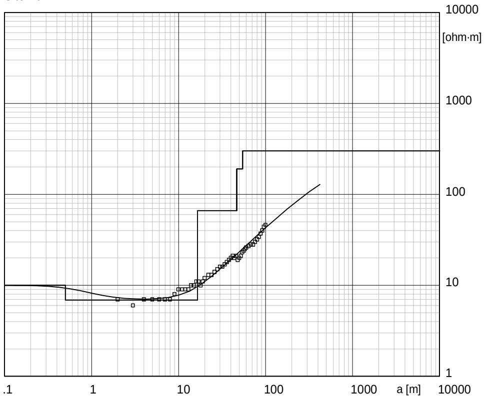
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments of mostly clays, sandy clays and fine sand; site has low to medium

Location 49	Name: Nyagatare town

Electrical sounding Wenner - Site-49.WS3

Site-49



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
10	.5		1362
6.9	16	.5	1361.5
66	30	16	1346
190	8	46	1316
300		54	1308

VES was carried out at Nyagatare town. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

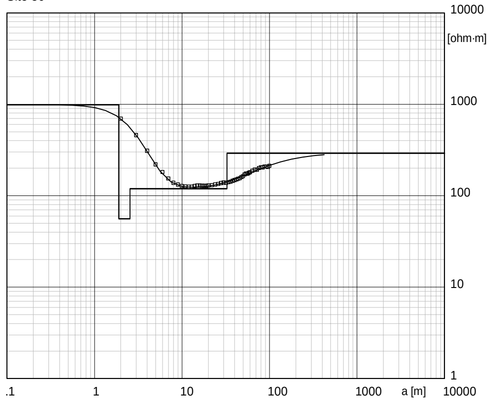
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 50	Name: Mirama

Electrical sounding Wenner - Site-50.WS3

Site-50



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
986	1.9		1362
56	.65	1.9	1360.1
119	30	2.6	1359.4
292		33	1329

VES was carried out at Mirama II. Interpreted layers are: top soil, clayey sand, coarse sand with gravel and weathered schist (bedrock)

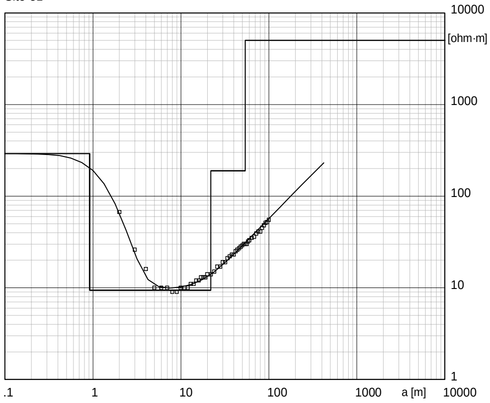
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 51	Name: Beinenshaka

Electrical sounding Wenner - Site-51.WS3

Site-51



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
291	.92		1362
9.4	21	.92	1361.1
189	32	22	1340
5000		54	1308

VES was carried out at Cyonyo. Interpreted layers are: top soil, clay, weathered/ fravtured formation and hard rock

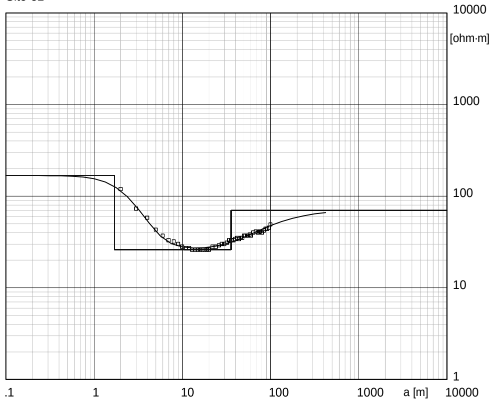
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 52	Name: Cyonyo

Electrical sounding Wenner - Site-52.WS3

Site-52



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
168	1.7		1362
26	34	1.7	1360.3
70		36	1326

VES was carried out at Cyonyo. Interpreted layers are: top soil, sandy clay, sand

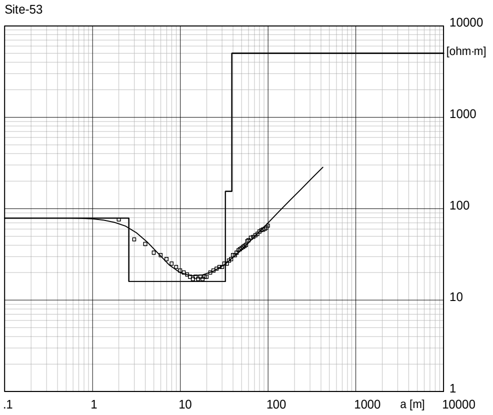
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 53 Name: Kiboga II

Electrical sounding Wenner - Site-53.WS3

Site-53



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
79	2.6		1362
16	30	2.6	1359.4
155	6	33	1329
5000		39	1323

VES was carried out at Kiboga II Interpreted layers are: top soil, clay, weathered/ fractured formation and hard rock

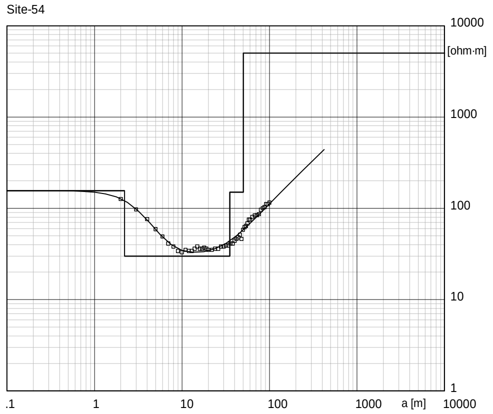
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clays; site has low to medium potential.

Location 54 Name: Nkongi

Electrical sounding Wenner - Site-54.WS3

Site-54



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
156	2.2		1362
30	33	2.2	1359.8
150	15	35	1327
5000		50	1312

VES was carried out at Nkongi. Interpreted layers are: top soil, sandy clay, weathered/ fractured formation and hard rock

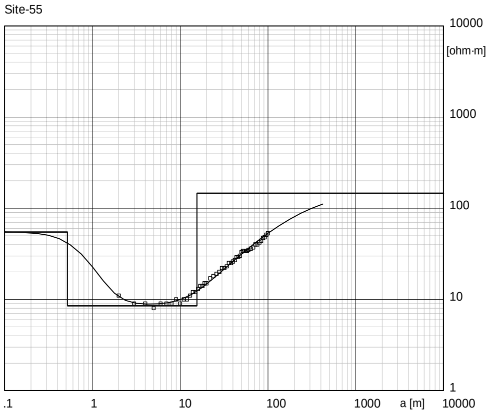
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 55 Name: Sangano

Electrical sounding Wenner - Site-55.WS3

Site-55



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
55	.52		1362
8.5	15	.52	1361.5
146		16	1346

VES was carried out at Sangano. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

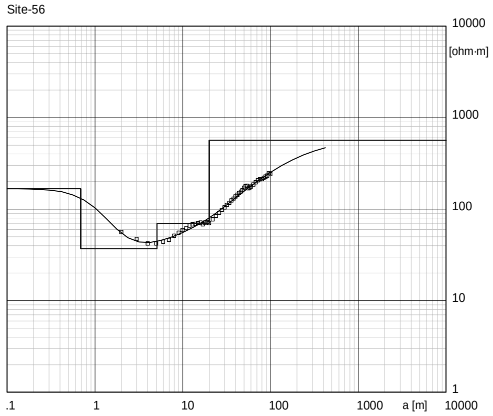
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low potential.

Location 56 Name: Nyamworoma

Electrical sounding Wenner - Site-56.WS3

Site-56



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
167	.69		1362
37	4.4	.69	1361.3
70	15	5.1	1356.9
564		20	1342

VES was carried out at Nyamworoma. Interpreted layers are: top soil,sandy clay, weathered formation and hard rock

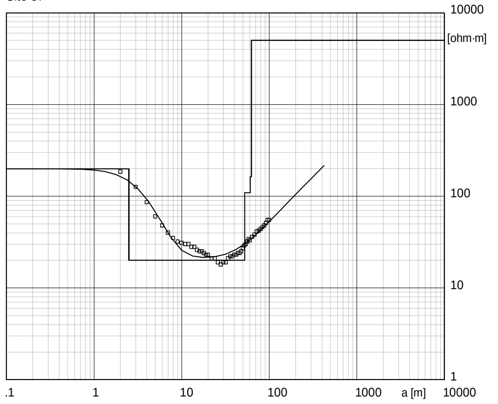
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden; site has low to medium potential.

Location 57 Name: Huliro

Electrical sounding Wenner - Site-57.WS3

Site-57



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
199	2.5		1362
20	50	2.5	1359.5
109	8	52	1310
163	2	60	1302
5000		62	1300

VES was carried out at Huliro. Interpreted layers are: top soil, clay, coarse sand, weathered formation and hard rock

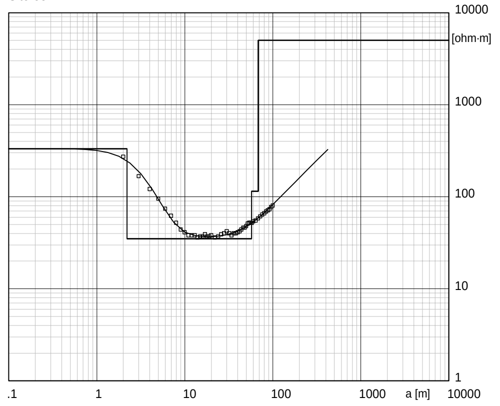
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly sediments; site has medium to high potential.

Location 58 Name: Kiyovu

Electrical sounding Wenner - Site-58.WS3

Site-58



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
333	2.2		1362
35	55	2.2	1359.8
115	11	57	1305
5000		68	1294

VES was carried out at Kiyovu. Interpreted layers are: top soil, sandy clay, weathered formation and hard rock

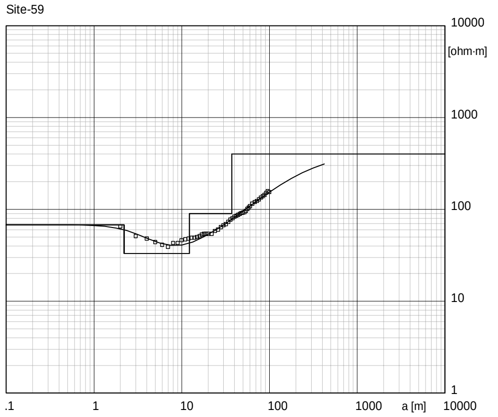
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments but mostly clays; site has medium to high potential.

Location 59 Name: Isangano

Electrical sounding Wenner - Site-59.WS3

Site-59



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
68	2.2		1362
33	10	2.2	1359.8
90	25	12	1350
400		37	1325

VES was carried out at Isangano. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

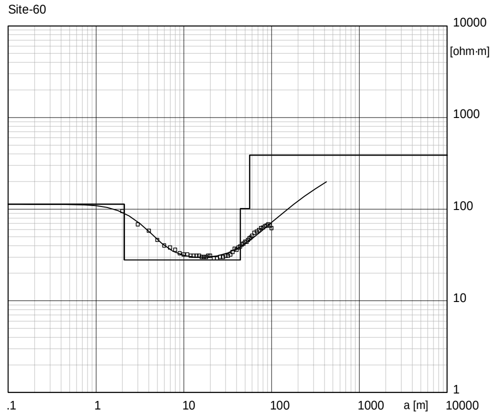
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thick overburden of sediments, mostly clays and fine sand; site has low to medium potential.

Location 60 Name: Shenga

Electrical sounding Wenner - Site-60.WS3

Site-60



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
113	2.1		1362
28	42	2.1	1359.9
101	12	44	1318
388		56	1306

VES was carried out at Shenga. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

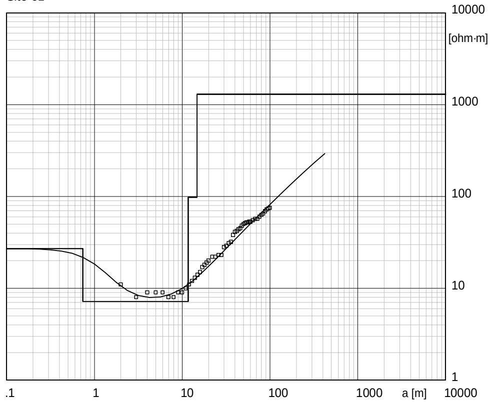
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 61	Name: Karukwanzi

Electrical sounding Wenner - Site-61.WS3

Site-61



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
27	.74		1362
7.2	11	.74	1361.3
98	3	12	1350
1300		15	1347

VES was carried out at Karukwanzi. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

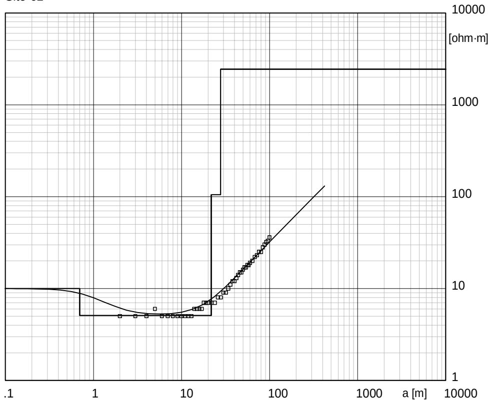
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of mostly clay; site has low to medium potential.

Location 62	Name: Nyakajenje

Electrical sounding Wenner - Site-62.WS3

Site-62



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
10	.7		1362
5.1	21	.7	1361.3
105	6	22	1340
2443		28	1334

VES was carried out at Nyakajenje. Interpreted layers are: clay top soil, clay, weathered formation and hard rock

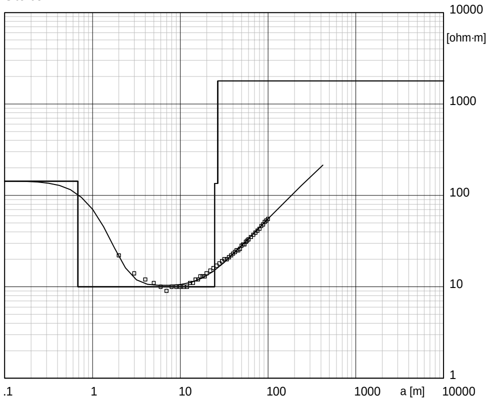
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of mostly clay; site has low to medium potential.

Location 63	Name: Urugano

Electrical sounding Wenner - Site-63.WS3

Site-63



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
143	.68		1362
10	24	.68	1361.3
135	2	25	1337
1781		27	1335

VES was carried out at Urugano. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

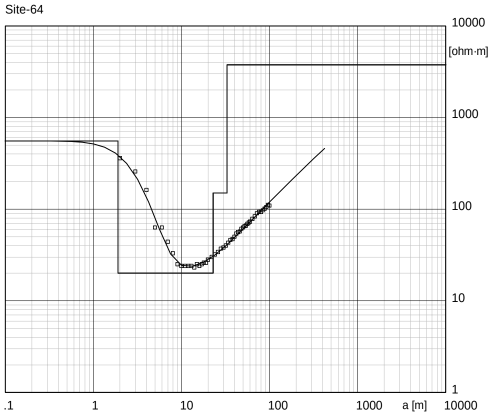
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of mostly clay; site has low to medium potential.

Location 64	Name: Kirebe

Electrical sounding Wenner - Site-64.WS3

Site-64



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
555	1.9	
20	21	1.9
150	10	23
3750		33

VES was carried out at Kirebe. Interpreted layers are: top soil, clay, weathered formation and hard rock

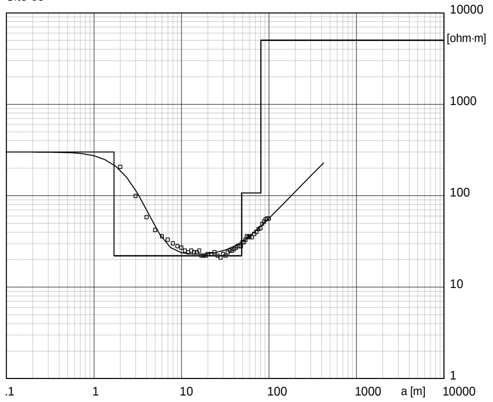
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly clay; site has low to medium potential.

Location 65	**Name:** Kirebe

Electrical sounding Wenner - Site-65.WS3

Site-65



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
300	1.7	
22	47	1.7
107	32	49
5000		81

VES was carried out at Kirebe. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

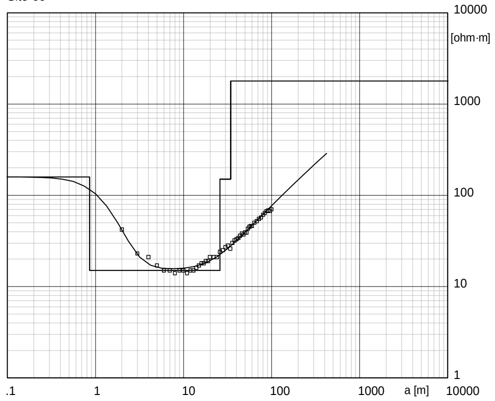
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 66	**Name:** Kirebe

Electrical sounding Wenner - Site-66.WS3

Site-66



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
159	.86	
15	25	.86
150	8.5	26
1781		34

VES was carried out at Kirebe. Interpreted layers are: top soil, clayey sand, weathered formation and hard rock

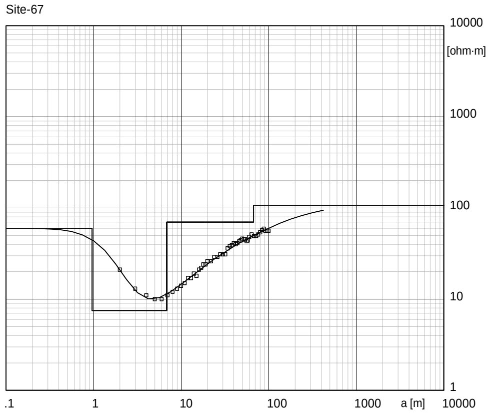
W-GeoSoft / WinSev 6.1

Comments: VES indicates relatively thin overburden of mainly clay; site has low to medium potential.

Location 67	**Name:** Bugaragara

Electrical sounding Wenner - Site-67.WS3

Site-67



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
60	.96	
7.5	5.9	.96
70	60	6.9
107		67

VES was carried out at Bugaragara. Interpreted layers are: top soil, clay, sand and weathered bed rock

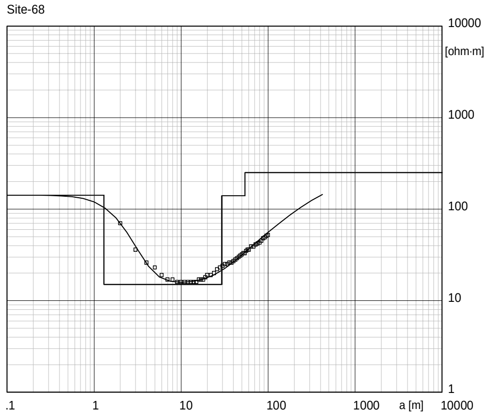
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden; site has medium to high potential.

Location 68	**Name:** Muzehe

Electrical sounding Wenner - Site-68.WS3

Site-68



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
142	1.3	
15	28	1.3
140	25	29
250		54

VES was carried out at Muzehe. Interpreted layers are: top soil, clay, weathered/ fractured formation and schist

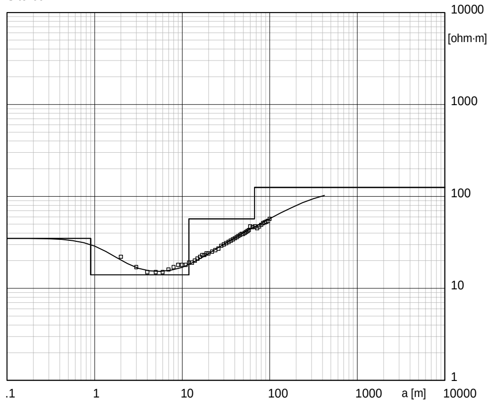
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mainly clay; site has low to medium potential.

Location 69 **Name:** Buhongora

Electrical sounding Wenner - Site-69.WS3

Site-69



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
35	.9	
14	11	.9
57	55	12
125		67

VES was carried out at Buhongoro. Interpreted layers are: top soil, clay, fine sand, and weathered formation (probably schist)

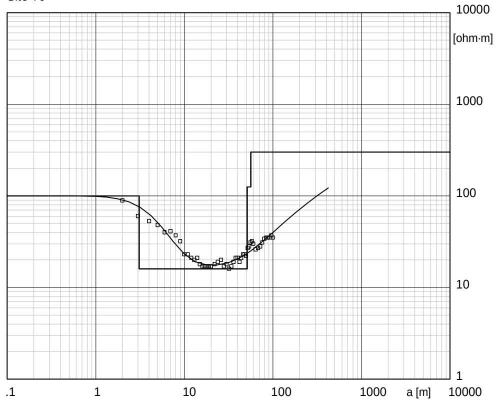
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mostly fine sand; site has medium to high potential.

Location 70 **Name:** Buhongora II

Electrical sounding Wenner - Site-70.WS3

Site-70



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
100	3.1	
16	48	3.1
125	5	51
300		56

VES was carried out at Buhongora II. Interpreted layers are: top soil, clay, weathered formation and bedrock (probably schist)

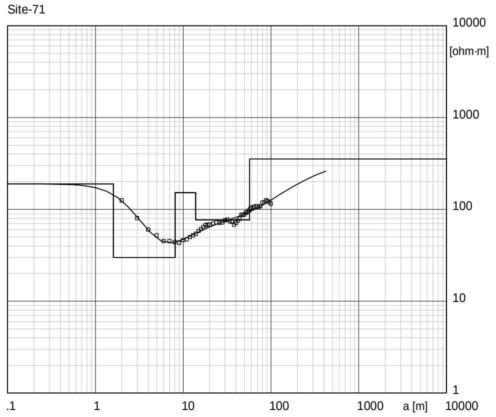
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mainly clays; site has low to medium potential.

Location 71 **Name:** Karangazi

Electrical sounding Wenner - Site-71.WS3

Site-71



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
189	1.6	
30	6.5	1.6
152	5.8	8.1
77	43	14
353		57

VES was carried out at Karangazi. Interpreted layers are: top soil, sandy clay, gravel, weathered formation and hard rock

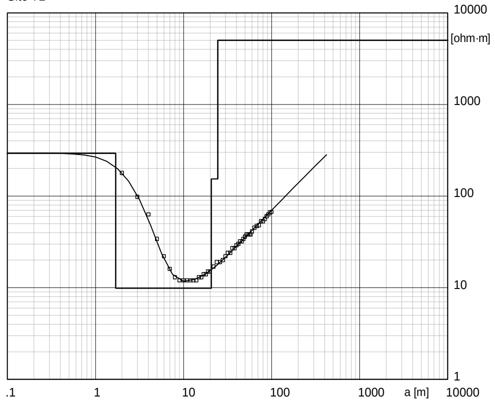
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of mainly sediments; site has medium to high potential.

Location 72 **Name:** Kahi

Electrical sounding Wenner - Site-72.WS3

Site-72



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
294	1.7	
9.9	19	1.7
154	3.8	21
5000		25

VES was carried out at Kahi. Interpreted layers are: top soil, clay, weathered formation and hard rock

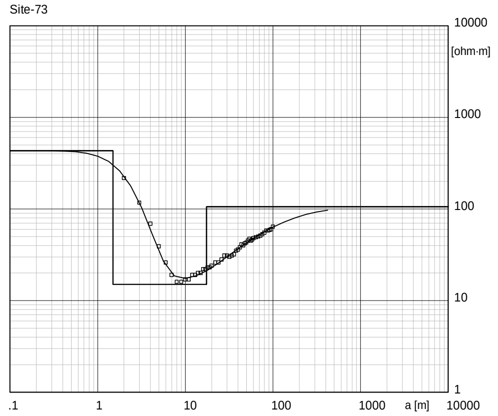
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has low to medium potential.

Location 73	**Name:** Rebero

Electrical sounding Wenner - Site-73.WS3

Site-73



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
433	1.5	
15	16	1.5
106		18

VES was carried out at Rebero. Interpreted layers are: top soil, clay, and sand

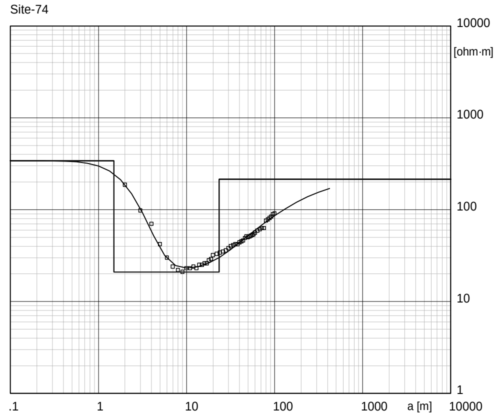
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of sediments; site has low to medium potential.

Location 74	**Name:** Byimana

Electrical sounding Wenner - Site-74.WS3

Site-74



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = Azim = 1307

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]
341	1.5	
21	22	1.5
215		24

VES was carried out at Byimana. Interpreted layers are: top soil, clay, and coarse sand

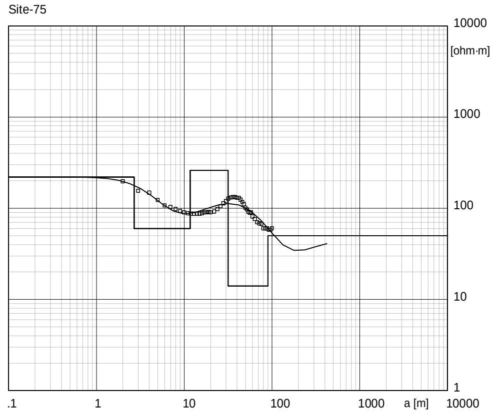
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of mainly clay; site has low potential.

Location 75	**Name:** Gisubizo

Electrical sounding Wenner - Site-75.WS3

Site-75



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
220	2.7		1362
60	9	2.7	1359.3
260	20	12	1350
14	58	32	1330
50		90	1272

VES was carried out at Gisubizo. Interpreted layers are: top soil, sand, gravel,clay, sand

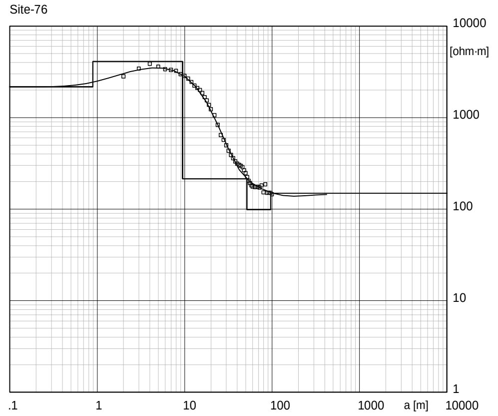
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 76	**Name:**

Electrical sounding Wenner - Site-76.WS3

Site-76



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
2165	.89		1362
4102	8.6	.89	1361.1
214	42	9.5	1352.5
99	45	52	1310
149		97	1265

VES was carried out at. Interpreted layers are: lateritic top soil, laterite (gravel), coarse sand, saturated sand and gravel.

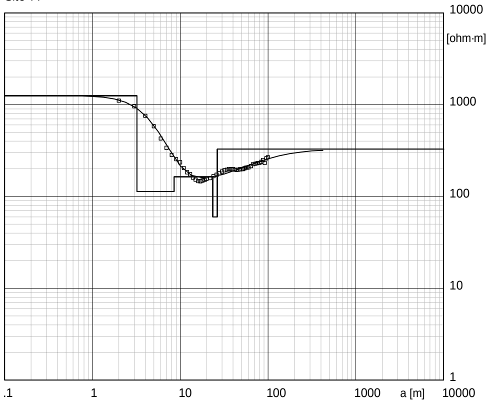
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has high potential.

Location 77 Name: Kibondo

Electrical sounding Wenner - Site-77.WS3

Site-77



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1248	3.2		1362
113	5.3	3.2	1358.8
164	15	8.5	1353.5
60	2.9	24	1338
328		27	1335

VES was carried out at Kibondo. Interpreted layers are: dry top soil, sand, coarse sand, saturated sand and bed rock (schist)

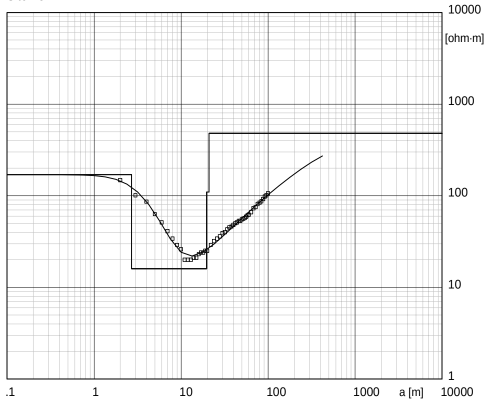
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low to medium potential.

Location 78 Name: Gisanze

Electrical sounding Wenner - Site-78.WS3

Site-78



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
170	2.7		1362
16	17	2.7	1359.3
110	1.2	20	1342
481		21	1341

VES was carried out at Gisanze. Interpreted layers are: top soil, clay, weathered formation and bedrock (probably schist)

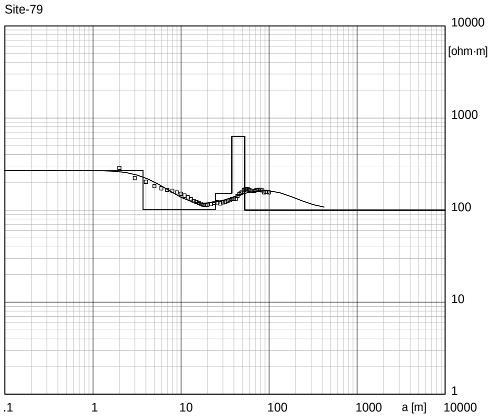
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of mainly clay; site has low potential.

Location 79 Name: Iribagiza

Electrical sounding Wenner - Site-79.WS3

Site-79



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
271	3.7		1362
102	21	3.7	1358.3
152	13	25	1337
631	15	38	1324
100		53	1309

VES was carried out at Iribagiza. Interpreted layers are: top soil, fine sand, gravel, conglomerates and coarse sand

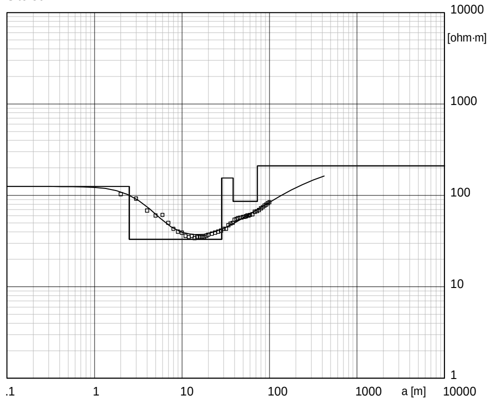
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 80 Name: Rusaave

Electrical sounding Wenner - Site-80.WS3

Site-80



Location X = 030 30' 08.9 Y = 01 35' 30.8 Z = 1362 Azim = 320-140

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
125	2.5		1362
33	26	2.5	1359.5
155	10	28	1334
86	34	38	1324
210		72	1290

VES was carried out at Rusaave. Interpreted layers are: top soil, clay, sand, saturated sand and bedrock (partly weathered schist)

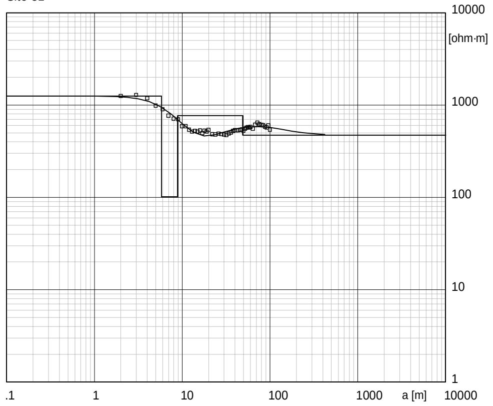
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments; site has medium to high potential.

Location 81	**Name:** Mugatare

Electrical sounding Wenner - Site-81.WS3

Site-81



Model

Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
1253	5.8	
101	3.1	5.8
767	40	8.9
471		49

VES carried out at Mugatare. Interpreted layers are: gravel, sand, gravel and bedrock (schist)

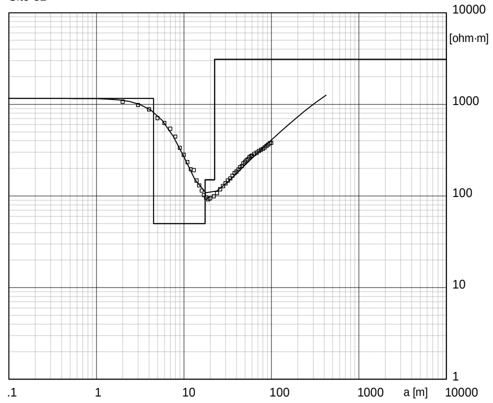
W-GeoSoft / WinSev 6.1

Comments: VES indicates thick overburden of sediments but of high resistivities; site has low potential.

Location 82	**Name:** Bukora

Electrical sounding Wenner - Site-82.WS3

Site-82



Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1158	4.5		2
50	13	4.5	-2.5
150	5	18	-16
3100		23	-21

VES carried out at Bukora. Interpreted layers are: laterite (duricrust), fine sand, weathered formation and bedrock (granite)

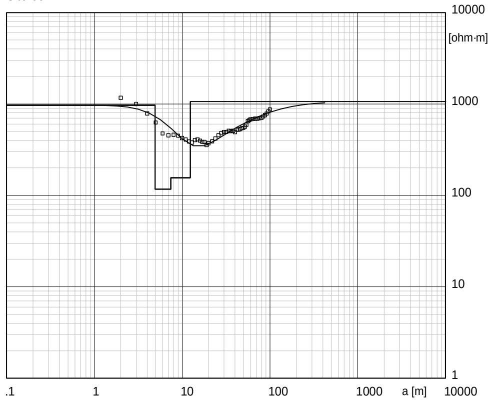
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low to medium potential.

Location 83	**Name:** Bukora

Electrical sounding Wenner - Site-83.WS3

Site-83



Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
969	4.9		2
117	2.5	4.9	-2.9
156	5	7.4	-5.4
1066		12	-10

VES carried out at Bukora. Interpreted layers are: lateritic top soil, sand, weathered formation and bedrock

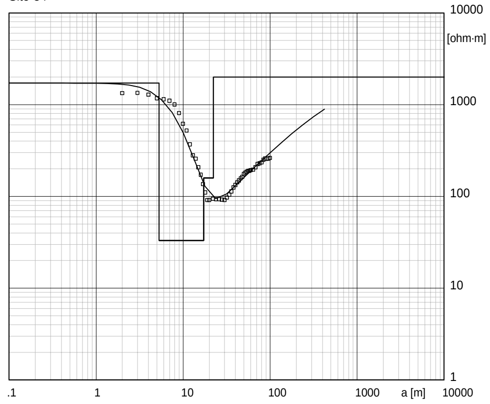
W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden; site has low potential.

Location 84	**Name:** Mwoga

Electrical sounding Wenner - Site-84.WS3

Site-84



Location X = 030 48' 49.5 Y = 02 17'39.2 Z = 1301 Azim = 20-200

Model

Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
1716	5.3		1301
33	12	5.3	1295.7
159	5	17	1284
2000		22	1279

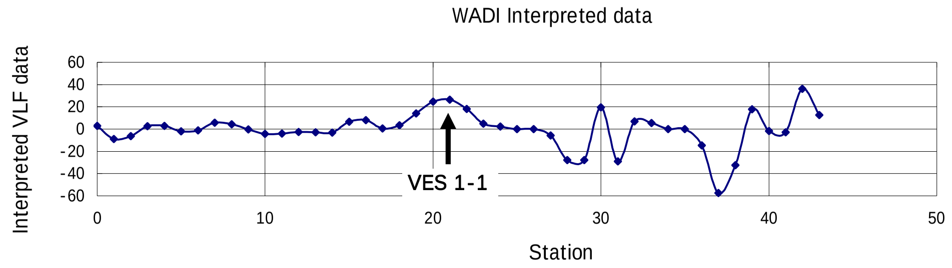
VES carried out at Mwoga. Interpreted layers are: laterite, sandy clay, weathered formation and hard rock.

W-GeoSoft / WinSev 6.1

Comments: VES indicates thin overburden of sediments; site has low to medium potential.

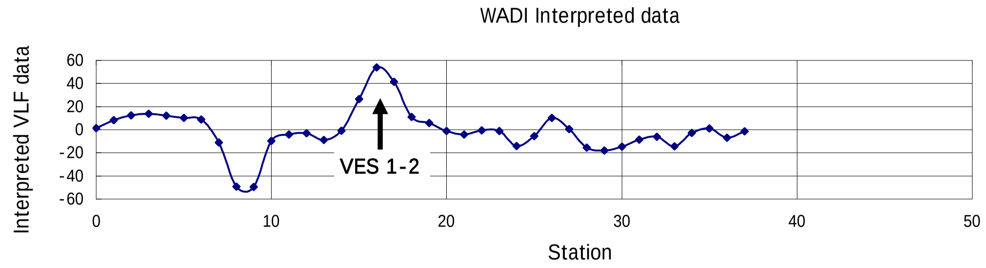
7.2 Interpreted Data

Location:	1-1	Date:	08/06/2009	
Village:	Rukundo	Profiles:	Latitude	Longitude
Sector:	Rwimyaga	Start profile:	S 01 16' 53,9"	E 30 26'39,9"
District:	Nyagatare	End profile:	S 01 17' 05.8"	E 30 26'27.5"



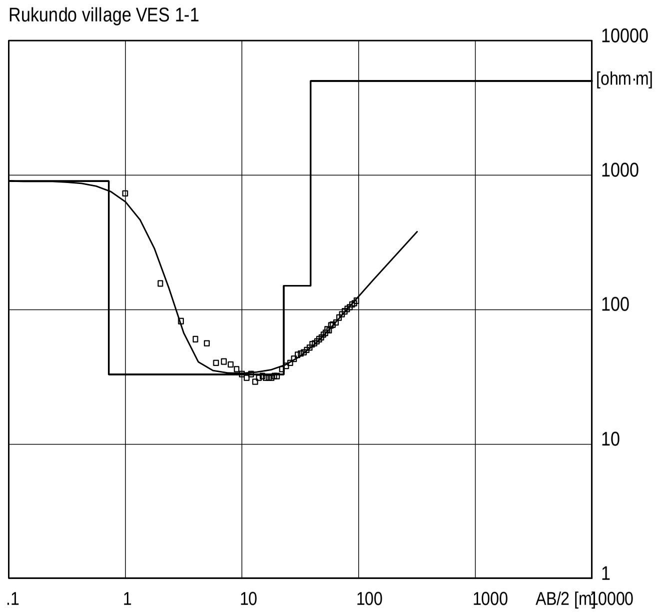
Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:50	Remarks	10m	Profile:50	Remarks
0	2.9		26	0.0	
1	-8.9		27	-5.8	
2	-6.2		28	-27.9	
3	2.7		29	-27.9	
4	2.8		30	19.4	
5	-1.9		31	-28.9	
6	-1.1		32	6.9	
7	5.8		33	5.5	
8	4.2		34	0.1	
9	-0.4		35	0.0	
10	-4.4		36	-14.5	crosses at station 12 of profile43
11	-4.1		37	-57.4	
12	-2.5		38	-32.4	
13	-3.0		39	17.8	
14	-3.3		40	-1.8	
15	6.5		41	-2.8	
16	8.0		42	36.2	
17	0.5		43	12.6	
18	3.5		44		
19	14.0		45		
20	24.8		46		
21	26.4		47		
22	18.2		48		
23	5.0		49		
24	2.2		50		
25	0.0		51		

Location:	1-2	Date:	08/06/2009	
Village:	Rukundo	Profiles:	Latitude	Longitude
Sector:	Rwimyaga	Start profile:	S 01 16' 59.0"	E 30 26'24,9"
District:	Nyagatare	End profile:	S 01 17' 38.1"	E 30 25'57.2"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:51	Remarks	10m	Profile:51	Remarks
0	1.5		26	10.3	
1	8.2		27	0.5	
2	12.5		28	-15.4	
3	13.9		29	-17.9	
4	12.3		30	-14.7	
5	10.1		31	-8.5	
6	8.8		32	-6.1	
7	-11.0		33	-14.4	
8	-49.3		34	-2.7	
9	-49.5		35	1.2	
10	-9.8		36	-6.9	
11	-4.1		37	-1.5	
12	-3.1		38		
13	-8.8		39		
14	-0.7		40		
15	26.6		41		
16	53.8		42		
17	41.6		43		
18	11.0		44		
19	5.8		45		
20	-1.2		46		
21	-4.1		47		
22	-0.5		48		
23	-1.2	crosses at station 25 of profile50	49		
24	-14.1		50		
25	-5.5		51		

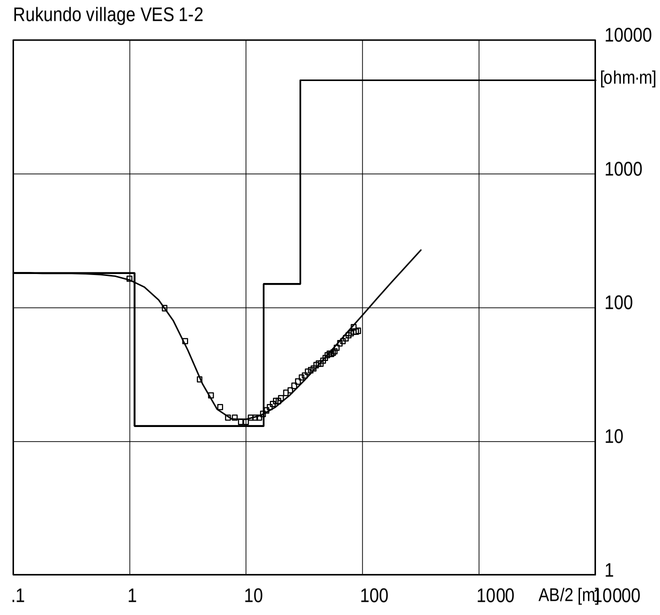
Location	1-1	**Name:**	Rukondo



Model Resistivity	**Thickness**	**Depth**	**Altitude**
[ohm·m]	[m]	[m]	[m]
902	.72		116
33	22	.72	115.3
150	16	23	93
5000		39	77

Comments: The VES was carried out at station 21 of profile 50.
Interpreted layers are: top soil,
clay, weathered formation and hard rock

Location	1-2	**Name:**	Rukondo

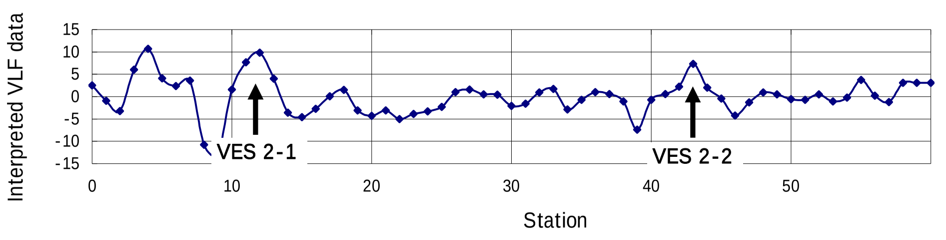


Location X = 30 26' 28.7 Y = 1 17' 00.9 Z = Azim = 1331

Model Resistivity	**Thickness**	**Depth**
[ohm·m]	[m]	[m]
181	1.1	
13	13	1.1
150	15	14
5000		29

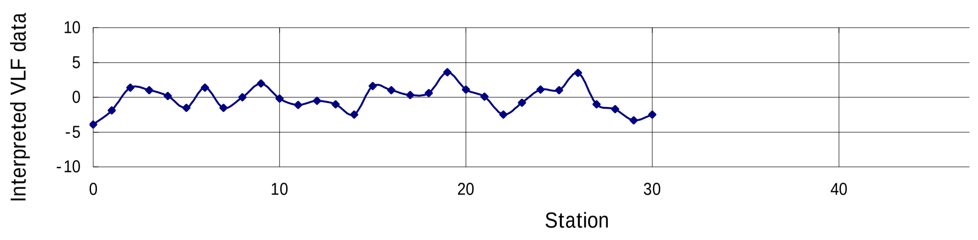
Comments: The VES was carried out at station 16 of profile 51.
Interpreted layers are: top soil,
clay, weathered formation and hard rock

Location:	2-1	Date:	08/06/2009	
Village:	Rukundo	Profiles:	Latitude	Longitude
Sector:	Rwimyaga	Start profile:	S 01 16'03.7"	E 30 26'12.3"
District:	Nyagatare	End profile:	S 01 15' 44.4"	E 30 26'07.2"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:48	Remarks	10m	Profile:48	Remarks
0	2.5		31	-1.6	
1	-0.9		32	0.9	
2	-3.2		33	1.7	
3	6.0		34	-2.9	
4	10.7		35	-0.7	
5	4.1		36	1.0	
6	2.4		37	0.6	
7	3.6		38	-1.1	
8	-10.8		39	-7.4	
9	-12.9		40	-0.7	
10	1.6		41	0.6	
11	7.7		42	2.2	
12	9.8		43	7.3	
13	4.0		44	2.0	
14	-3.6		45	-0.4	center of valley
15	-4.6		46	-4.2	
16	-2.7		47	-1.3	
17	0.1		48	0.9	
18	1.5		49	0.5	
19	-3.1		50	-0.6	
20	-4.3		51	-0.7	
21	-3.1		52	0.5	
22	-5.0		53	-1.1	
23	-3.9		54	-0.2	
24	-3.3		55	3.7	
25	-2.3		56	0.2	
26	1.0		57	-1.2	
27	1.6		58	3.1	
28	0.5		59	3.1	
29	0.4		60	3.1	
30	-2.1		61		

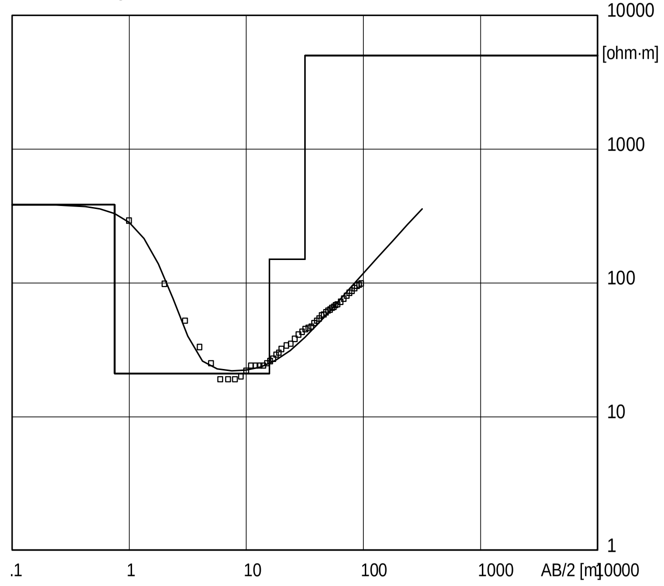
Location:	2-2	Date:	08/06/2009	
Village:	Rukundo	Profiles:	Latitude	Longitude
Sector:	Rwimyaga	Start profile:	S 01 15'51.8"	E 30 26'08.9"
District:	Nyagatare	End profile:	S 01 15' 51.8"	E 30 25'59.9"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:49	Remarks	10m	Profile:49	Remarks
0	-3.9		26	3.5	
1	-1.9		27	-1.0	
2	1.4		28	-1.7	
3	1.0		29	-3.3	
4	0.2		30	-2.5	
5	-1.5		31		
6	1.4		32		
7	-1.5		33		
8	0.0		34		
9	2.0		35		
10	-0.2		36		
11	-1.1		37		
12	-0.5		38		
13	-1.0		39		
14	-2.5		40		
15	1.6		41		
16	1.0		42		
17	0.3		43		
18	0.6		44		
19	3.6		45		
20	1.1		46		
21	0.1		47		
22	-2.5		48		
23	-0.8		49		
24	1.1		50		
25	1.0		51		

Location 2-1 **Name:** Rukondo

Rukundo village VES 2-1



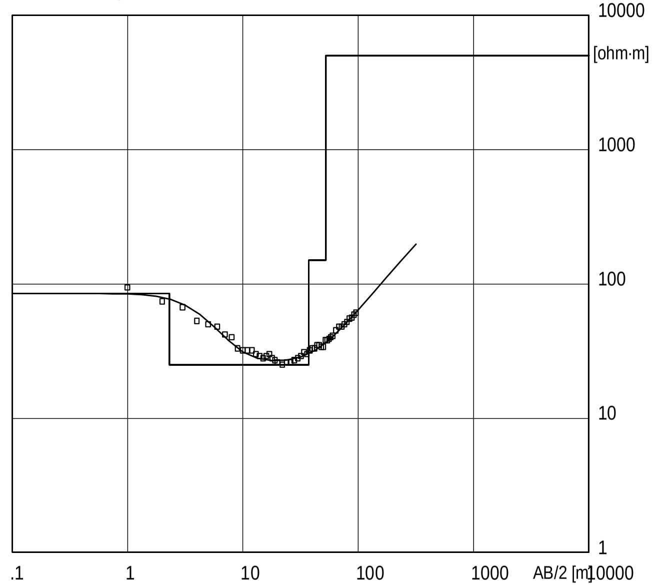
Location X = 30 26' 11.4 Y = 1 15' 59.8 Z = Azim = 1351

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
384	.75	
21	15	.75
150	16	16
5000		32

Comments: The VES was carried out at station 12 0f profile 48. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location 2-2 **Name:** Rukondo

Rukundo village VES 2-2

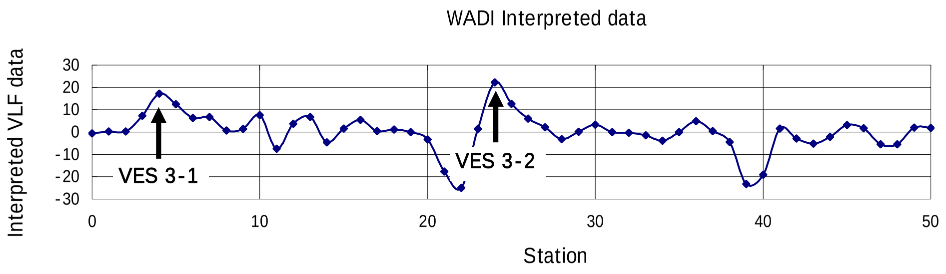


Location X = 30 26' 08.9 Y = 1 15' 50.2 Z = Azim = 1337

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
85	2.3	
25	35	2.3
150	15	37
5000		52

Comments: VES was carried out at station 43 of profile 48. Interpreted layers are: top soil, clay, weathered formation and hard rock

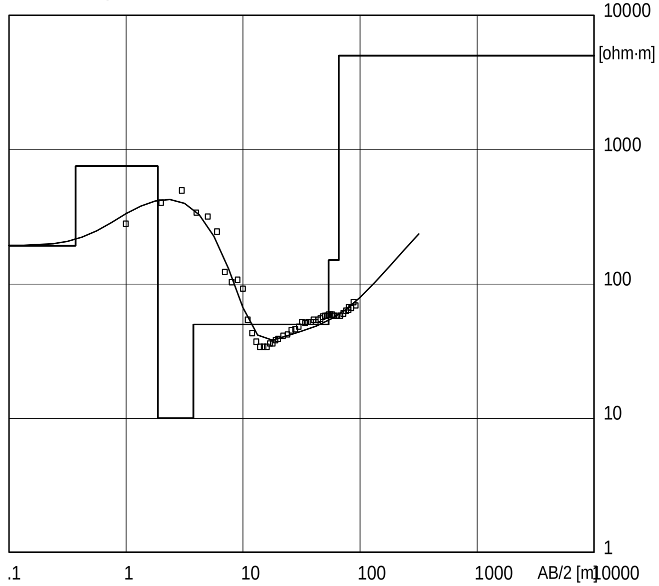
Location:	3-1	Date:	08/07/2009	
Village:	Rukiri 1	Profiles:	Latitude	Longitude
Sector:	Rwimyaga	Start profile:	S 01 14'33.7"	E 30 25'58.0"
District:	Nyagatare	End profile:	S 01 14' 32.5"	E 30 25'42.4"



Station interval 10m	Interpreted WADI Value(kHz) Profile:52	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:52	Remarks
0	-0.6		27	2.2	
1	0.3		28	-3.1	
2	0.3		29	0.2	
3	7.3		30	3.3	
4	17.2		31	0.0	
5	12.5		32	-0.3	
6	6.3		33	-1.4	
7	6.8		34	-3.9	
8	0.7		35	0.0	
9	1.4		36	4.9	
10	7.6		37	0.4	
11	-7.4		38	-4.5	
12	3.7		39	-23.3	
13	6.7		40	-19.1	
14	-4.6		41	1.6	
15	1.6		42	-2.9	
16	5.5		43	-5.1	
17	0.4		44	-2.1	
18	1.1		45	3.2	
19	0.0		46	1.7	
20	-3.3		47	-5.4	
21	-17.6		48	-5.5	
22	-25.0		49	2.0	
23	1.4		50	1.8	
24	22.2		51	2.1	
25	12.6		52	-4.3	
26	6.0		53	-4.3	

Location 3-1 **Name:** Rukiri

Rukiri 1 village VES 3-1



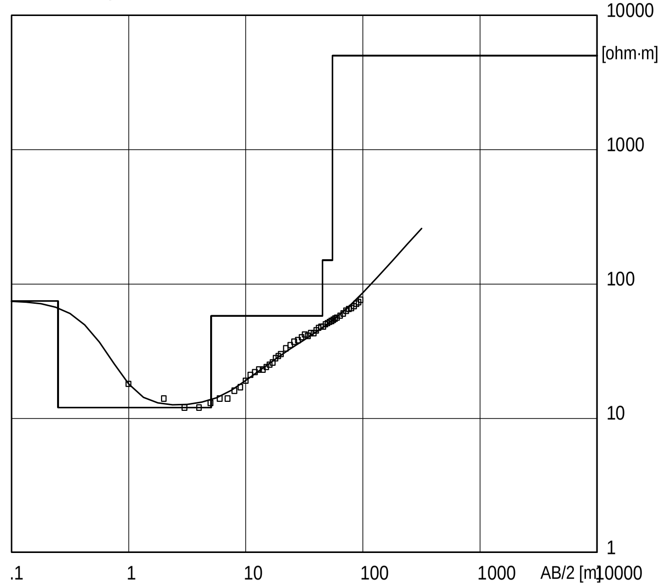
Location X = 30 25' 57.3 Y = 1 14' 38.0 Z = Azim = 1344

Model Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
193	.37	
755	1.5	.37
10	1.9	1.9
50	50	3.8
150	12	54
5000		66

Comments: VES`was carried out at station 4 of profile 52. Interpreted layers are: top soil, quartzite,lateritic clay, sandy clay, weathered formation and hard rock

Location 3-2 **Name:** Rukiri

Rukiri 1 village VES 3-2

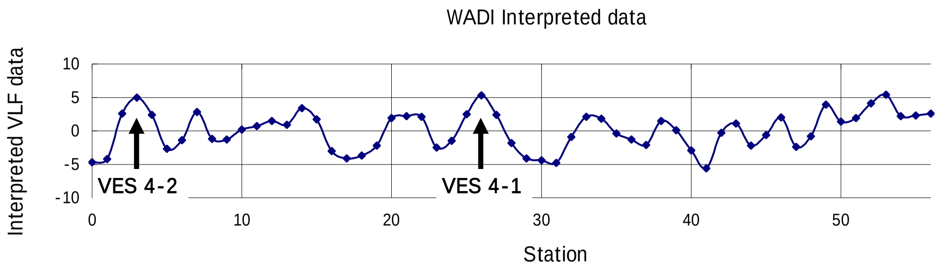


Location X = 30 25' 51.2 Y = 1 14' 35.6 Z = Azim = 1347

Model Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
75	.25	
12	4.8	.25
58	40	5
150	10	45
5000		55

Comments: VES was carried out at station 24 0f profile 52. Interpreted layers are: top soil, clay, clayey sand, weathered formation and hard rock

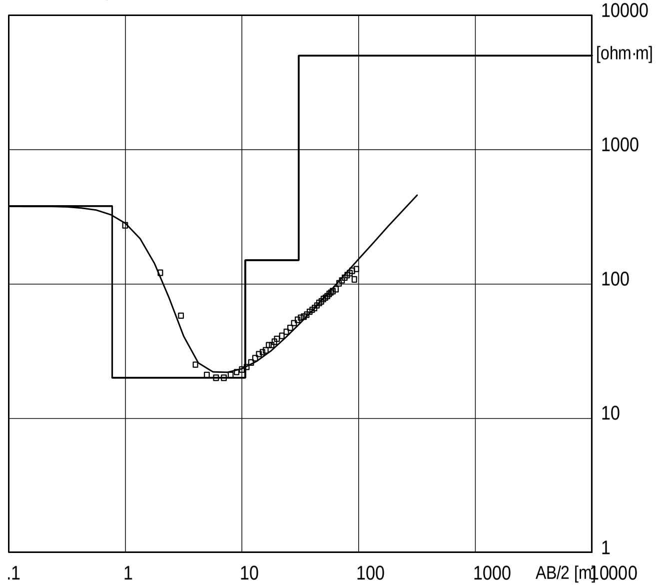
Location:	4-1	Date:	08/07/2009	
Village:	Gikoma	Profiles:	Latitude	Longitude
Sector:	Rwimyaga	Start profile:	S 01 12'26.1"	E 30 26'25.2"
District:	Nyagatare	End profile:	S 01 12' 40.6"	E 30 26'36.4"



Station interval 10m	Interpreted WADI Value(kHz) Profile:53	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:53	Remarks
0	-4.7		29	-4.1	
1	-4.2		30	-4.4	
2	2.6		31	-4.8	
3	5.0		32	-0.9	
4	2.4		33	2.1	
5	-2.7		34	1.8	
6	-1.4		35	-0.4	
7	2.8		36	-1.3	
8	-1.2		37	-2.1	
9	-1.3		38	1.5	
10	0.2		39	0.1	
11	0.7		40	-2.9	
12	1.5		41	-5.6	
13	0.9		42	-0.3	
14	3.4		43	1.1	
15	1.7		44	-2.2	
16	-3.0		45	-0.6	
17	-4.1		46	2.0	
18	-3.7		47	-2.4	
19	-2.2		48	-0.8	
20	1.9		49	3.9	
21	2.2		50	1.4	
22	2.1		51	1.9	
23	-2.5		52	4.1	
24	-1.5		53	5.4	
25	2.5		54	2.2	
26	5.3		55	2.3	
27	2.4		56	2.6	
28	-1.8		57		

Location 4-1 **Name:** Gikoma

Gikoma village VES 4-1



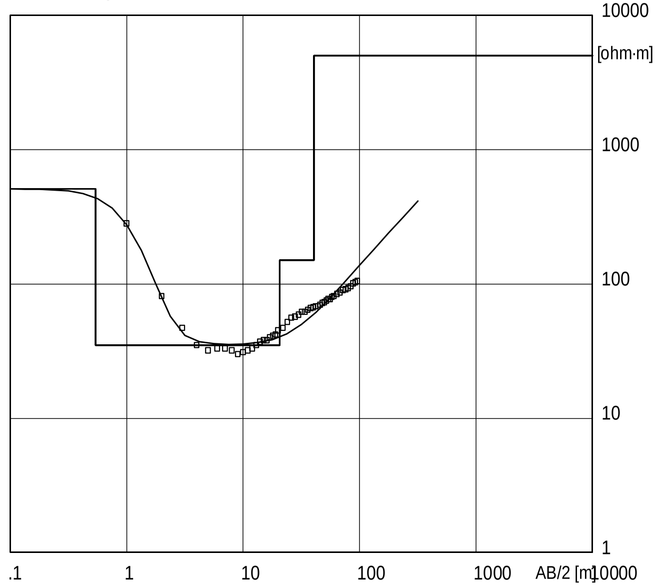
Location X = 30 26' 30.5 Y = 1 12' 33.1 Z = 1335 Azim = 140/320

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
379	.77		1335
20	9.9	.77	1334.2
150	20	11	1324
5000		31	1304

Comments: The VES was carried out at station 26 0f profile 53. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location 4-2 **Name:** Gikoma

Gikoma village VES 4-2

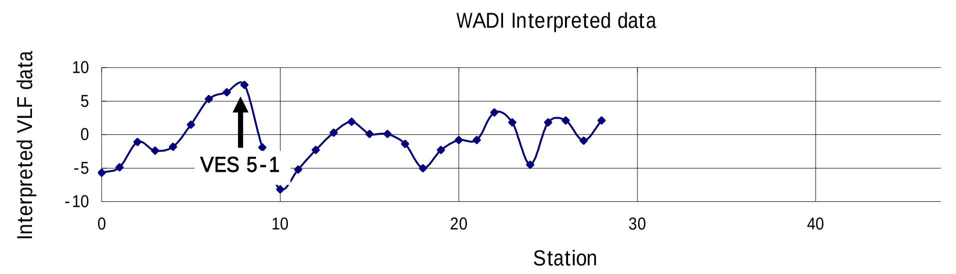


Location X = 30 26' 25.7 Y = 1 12' 26.9 Z = Azim = 1337

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
510	.54	
35	20	.54
150	20	21
5000		41

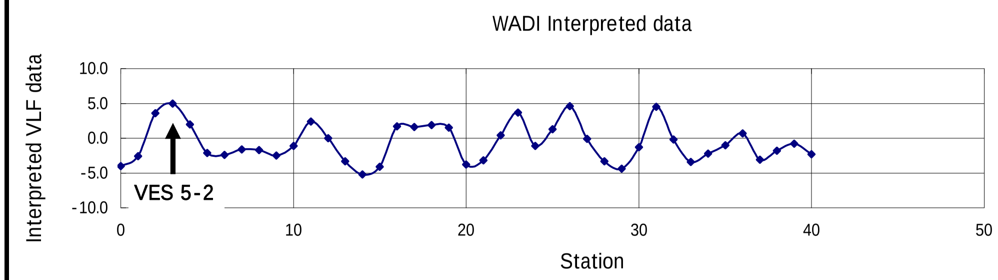
Comments: The VES was carried out at station 3 0f profile 53.Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	5-1	Date:	08/05/2009	
Village:	Kamate	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 21'24.4"	E 30 25'05.4"
District:	Nyagatare	End profile:	S 01 21' 16.4"	E 30 24'56.9"



Station interval 10m	Interpreted WADI Value(kHz) Profile:46	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:46	Remarks
0	-5.7		26	2.1	
1	-4.9		27	-0.9	
2	-1.1		28	2.1	Floods in rainy season
3	-2.4		29		
4	-1.8		30		
5	1.5		31		
6	5.3		32		
7	6.3		33		
8	7.4		34		
9	-1.9		35		
10	-8.2		36		
11	-5.2		37		
12	-2.3		38		
13	0.3		39		
14	1.9		40		
15	0.1		41		
16	0.1		42		
17	-1.4		43		
18	-5.0		44		
19	-2.3		45		
20	-0.8		46		
21	-0.8		47		
22	3.3		48		
23	1.8		49		
24	-4.5		50		
25	1.8		51		

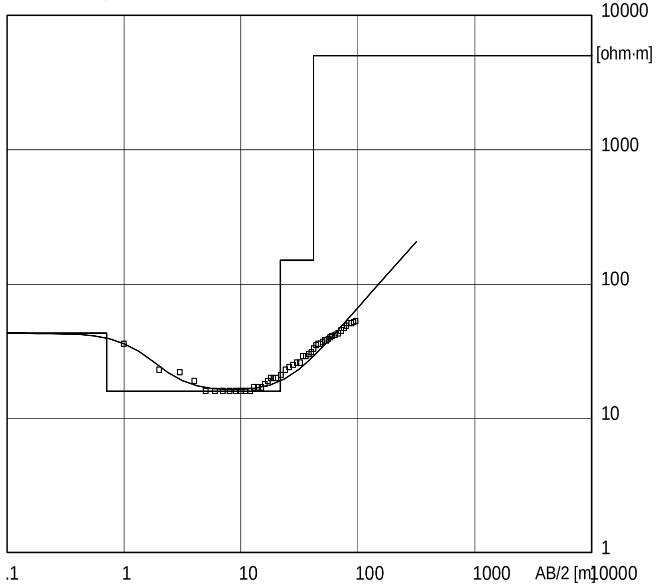
Location:	5-2	Date:	08/05/2009	
Village:	Kamate	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 21'27.3"	E 30 25'05.3"
District:	Nyagatare	End profile:	S 01 21' 14.4"	E 30 25'12.4"



Station interval 10m	Interpreted WADI Value(kHz) Profile:47	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:47	Remarks
0	-4.0		26	4.6	
1	-2.6		27	-0.1	
2	3.6		28	-3.3	
3	5.0		29	-4.4	
4	2.0		30	-1.3	
5	-2.1		31	4.5	
6	-2.4		32	-0.2	
7	-1.6		33	-3.4	
8	-1.7		34	-2.2	
9	-2.5		35	-1.0	
10	-1.1		36	0.7	
11	2.4	valley dam 30m away	37	-3.1	
12	0.0		38	-1.8	
13	-3.3		39	-0.8	
14	-5.2		40	-2.3	
15	-4.1		41		
16	1.7		42		
17	1.6		43		
18	1.9		44		
19	1.5		45		
20	-3.8		46		
21	-3.2		47		
22	0.4		48		
23	3.7		49		
24	-1.1		50		
25	1.3		51		

Location 5-1 **Name:** Kamato

Kamate village VES 5-1



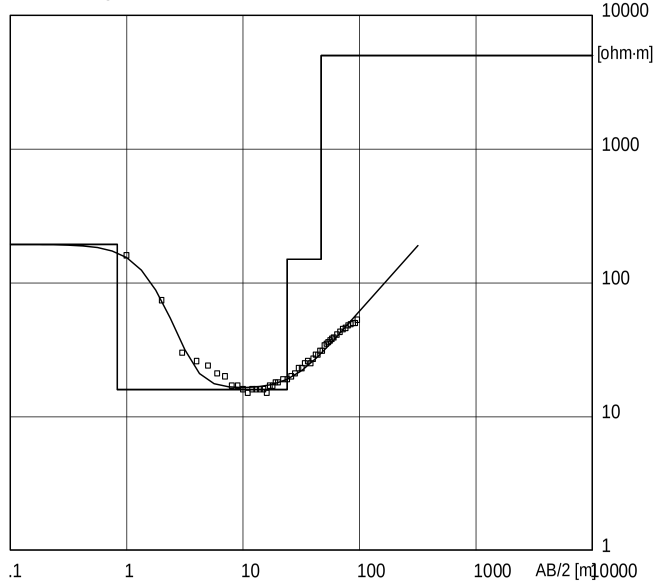
Location X = 30 25' 03.3 Y = 1 21' 22.2 Z = Azim = 1342

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
43	.71	
16	21	.71
150	20	22
5000		42

Comments: The VES was carried out on station 8 0f profile 46. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location 5-2 **Name:** Kamato

Kamate village VES 5-2

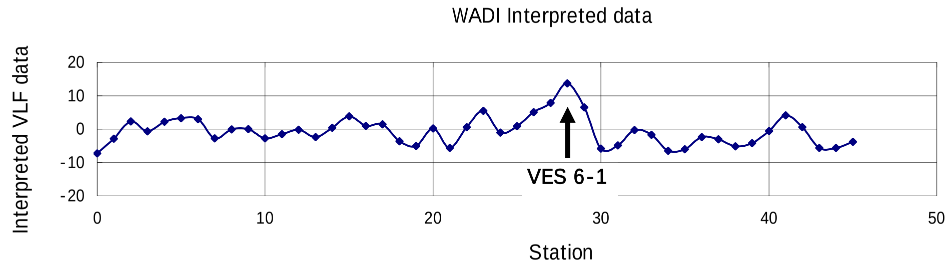


Location X = 30 25' 06.4 Y = 1 21' 26.3 Z = Azim = 1350

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
194	.83	
16	23	.83
150	23	24
5000		47

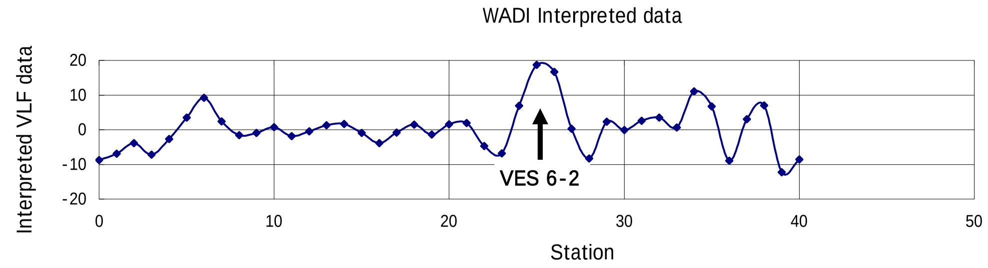
Comments: The VES was carried out at station 3 of profile 47. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	6-1	Date:	08/04/2009	
Village:	Nyamirama	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 27'01.0"	E 30 27'18.2"
District:	Nyagatare	End profile:	S 01 26' 47.9"	E 30 27'22.7"



Station interval 10m	Interpreted WADI Value(kHz) Profile:42	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:42	Remarks
0	-7.3		26	5.1	
1	-2.9		27	7.8	
2	2.3		28	13.7	
3	-0.7		29	6.5	
4	2.2		30	-5.8	
5	3.3		31	-4.9	
6	3.0		32	-0.3	
7	-2.8		33	-1.7	
8	-0.1		34	-6.5	
9	0.0		35	-6.0	
10	-2.8		36	-2.4	crosses at station 12 of profile43
11	-1.5		37	-3.1	
12	-0.2		38	-5.2	
13	-2.4		39	-4.2	
14	0.4		40	-0.6	
15	3.8		41	4.1	
16	1.0		42	0.6	
17	1.4		43	-5.6	
18	-3.6		44	-5.6	
19	-5.1		45	-3.8	
20	0.2		46		
21	-5.6		47		
22	0.6		48		
23	5.5		49		
24	-1.1		50		
25	0.9		51		

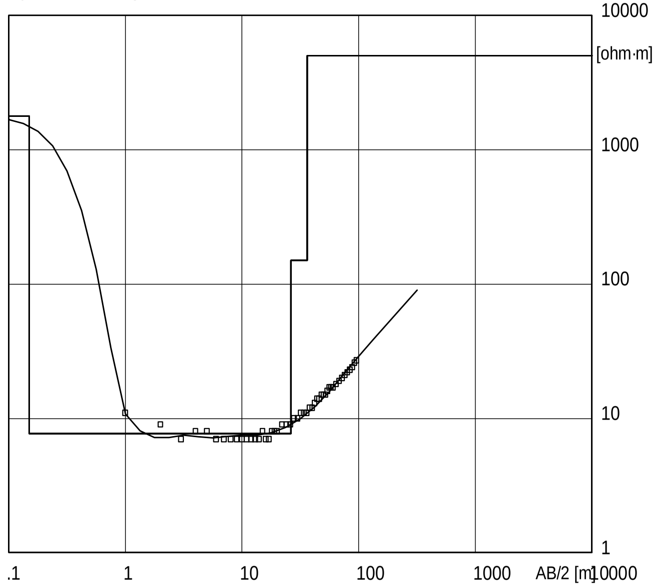
Location:	6-2	Date:	08/04/2009	
Village:	Nyamirama	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 26'53.1"	E 30 27'25.6"
District:	Nyagatare	End profile:	S 01 26' 46.9"	E 30 27'12.7"



Station interval 10m	Interpreted WADI Value(kHz) Profile:43	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:43	Remarks
0	-8.8		26	16.7	
1	-6.9		27	0.3	
2	-3.9		28	-8.3	
3	-7.2		29	2.3	
4	-2.7		30	-0.1	
5	3.5		31	2.6	
6	9.2		32	3.5	
7	2.4		33	0.6	
8	-1.6		34	11.1	
9	-0.9		35	6.7	
10	0.7		36	-8.9	
11	-1.8		37	3.0	
12	-0.5	crosses at station 36 of profile42	38	7.0	
13	1.3		39	-12.3	
14	1.7		40	-8.6	valley dam 50m away
15	-0.9		41		
16	-3.9		42		
17	-0.8		43		
18	1.5		44		
19	-1.4		45		
20	1.6		46		
21	1.9		47		
22	-4.7		48		
23	-6.8		49		
24	6.9		50		
25	18.7		51		

Location 6-1 **Name:** Nyamirama

Nyamirama village VES 6-1



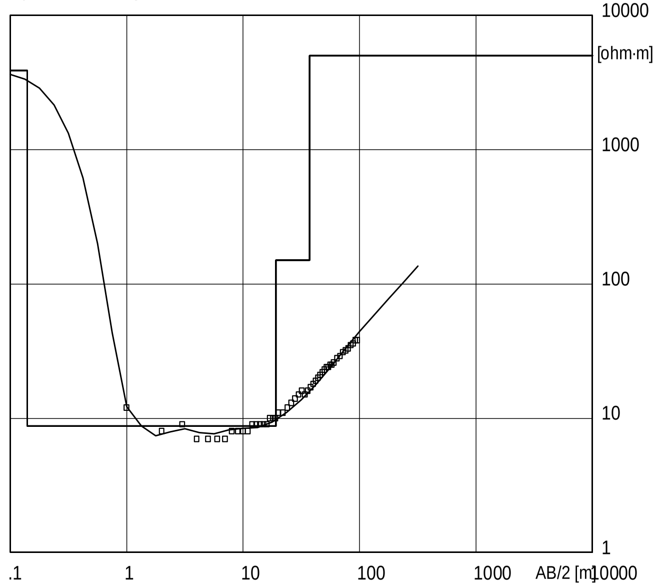
Location X = 030 27' 20.8 Y = 1 26' 53.3 Z = Azim = 1332

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
1781	.15	
7.7	26	.15
150	10	26
5000		36

Comments: The VES was carried out at station 28 of profile 42.
Interpreted layers are: top soil,
sandy stone, clay, weathered formation and hard rock

Location 6-2 **Name:** Nyamirama

Nyamirama village VES 6-2

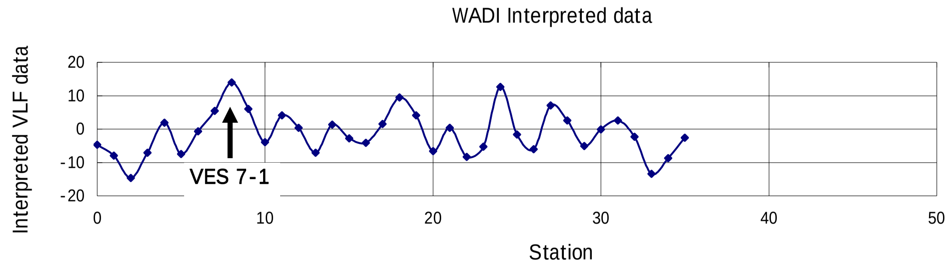


Location X = 030 27' 17.1 Y = 1 26' 49.2 Z = Azim = 1348

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
3897	.14	
8.8	19	.14
150	18	19
5000		37

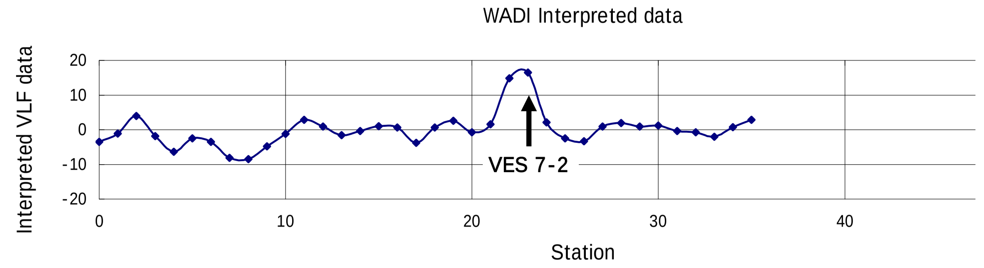
Comments: The VES was carried out at station 25 of profile 43.
Interpreted layers are: top soil,
sandy stone, clay, weathered formation and hard rock

Location:	7-1	Date:	08/04/2009	
Village:	Kayange	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 26'10.7"	E 30 30'16.0"
District:	Nyagatare	End profile:	S 01 26' 19.7"	E 30 30'05.4"



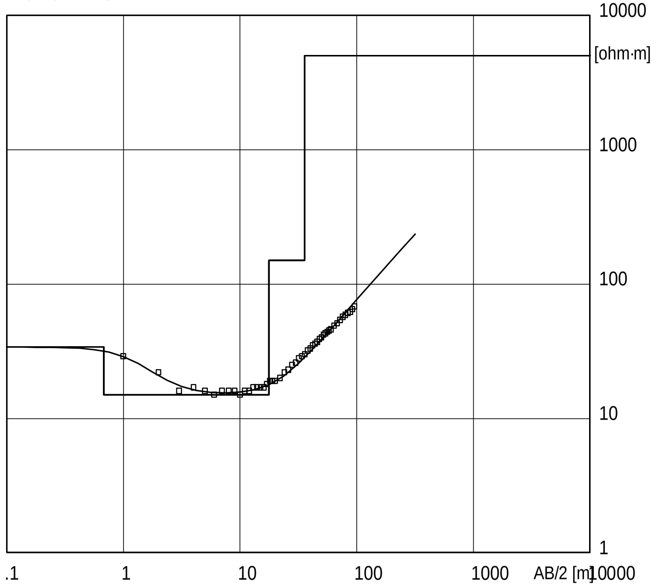
Station interval 10m	Interpreted WADI Value(kHz) Profile:44	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:44	Remarks
0	-4.7		26	-6.0	
1	-7.9		27	7.1	
2	-14.6		28	2.6	
3	-7.1		29	-5.1	
4	1.9		30	-0.1	
5	-7.5		31	2.6	Floods in rainy season
6	-0.7		32	-2.3	
7	5.5		33	-13.4	
8	14.0		34	-8.7	
9	6.0		35	-2.6	
10	-3.9		36		
11	4.1		37		
12	0.4		38		
13	-7.1		39		
14	1.3		40		
15	-2.8		41		
16	-4.1		42		
17	1.5		43		
18	9.5		44		
19	4.1		45		
20	-6.6		46		
21	0.4		47		
22	-8.3		48		
23	-5.3		49		
24	12.6		50		
25	-1.6		51		

Location:	7-2	Date:	08/05/2009	
Village:	Kayange	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 26'08.8"	E 30 30'10.5"
District:	Nyagatare	End profile:	S 01 26' 12.9"	E 30 29'59.8"



Station interval 10m	Interpreted WADI Value(kHz) Profile:45	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:45	Remarks
0	-3.5		26	-3.3	
1	-1.1		27	0.9	
2	4.0		28	1.9	
3	-1.8		29	0.9	
4	-6.4		30	1.2	
5	-2.5		31	-0.4	
6	-3.5		32	-0.7	
7	-8.1		33	-2.0	
8	-8.5		34	0.7	
9	-4.8		35	2.9	
10	-1.2		36		
11	2.9		37		
12	0.9	crosses at station 36 of profile42	38		
13	-1.6		39		
14	-0.4		40		
15	1.0		41		
16	0.6		42		
17	-3.8		43		
18	0.6		44		
19	2.6		45		
20	-0.7		46		
21	1.6		47		
22	14.8		48		
23	16.5		49		
24	2.1		50		
25	-2.5		51		

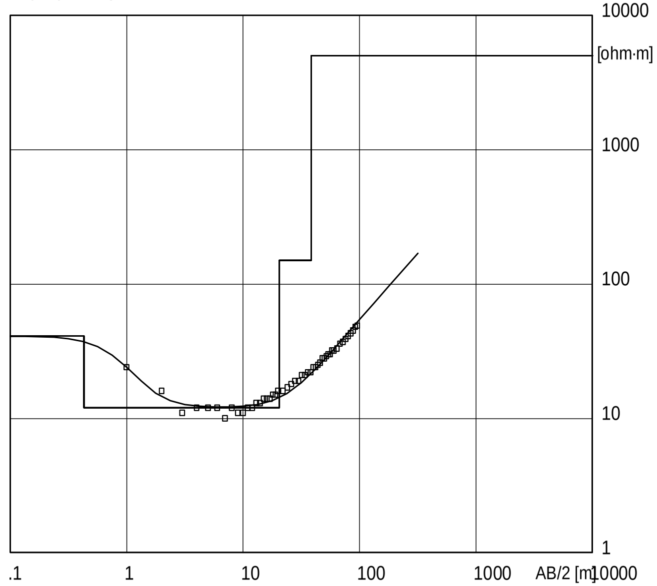
Location	7-1	Name:	Kayanje



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
34	.68		126
15	17	.68	125.3
150	18	18	108
5000		36	90

Comments: The VES was carried out at station 8 of profile 44. Interpreted layers are: top soil, clay, weathered formation and hard rock

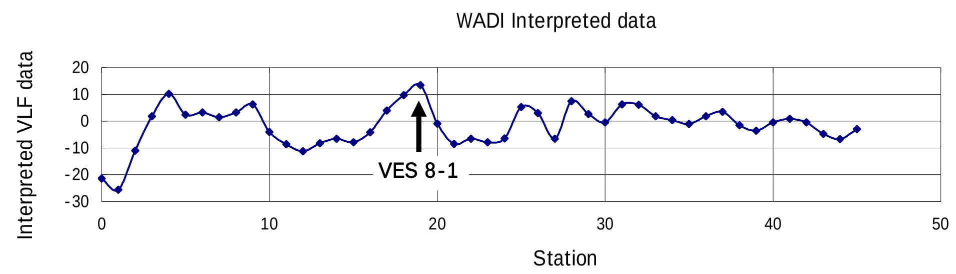
Location	7-2	Name:	Kayanje



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
41	.43		126
12	20	.43	125.6
150	18	20	106
5000		38	88

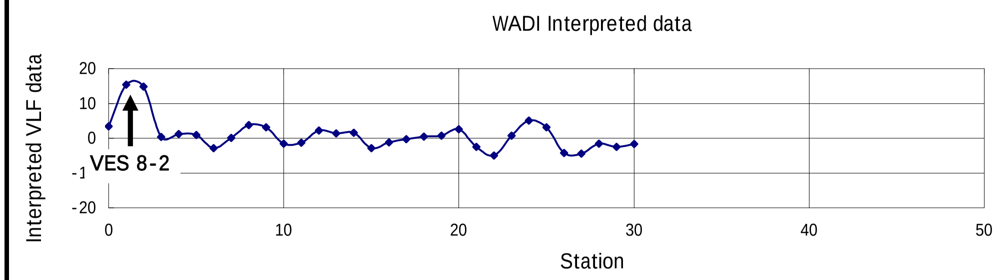
Comments: The VEs was carried out at station 23 of profile 45. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	8-1	Date:	08/04/2009	
Village:	Ndama	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 25'29.7"	E 30 25'50.8"
District:	Nyagatare	End profile:	S 01 25' 30.1"	E 30 25'35.0"



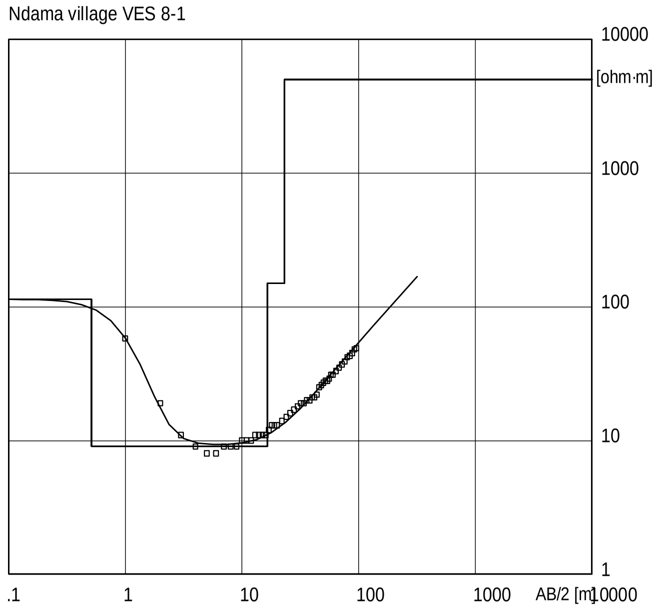
Station interval 10m	Interpreted WADI Value(kHz) Profile:40	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:40	Remarks
0	-21.4		26	3.0	crosses at station 9 of profile41
1	-25.6		27	-6.5	
2	-11.0		28	7.4	
3	1.8		29	2.7	
4	10.2		30	-0.4	
5	2.4		31	6.2	
6	3.3		32	6.1	
7	1.5		33	1.8	
8	3.3		34	0.4	
9	6.3		35	-1.0	
10	-4.1		36	1.8	
11	-8.6		37	3.5	
12	-11.2		38	-1.5	
13	-8.2		39	-3.6	
14	-6.5		40	-0.4	
15	-7.9		41	0.9	
16	-4.2		42	-0.5	
17	4.0		43	-4.8	
18	9.7		44	-6.7	
19	13.4		45	-3.0	
20	-0.9		46		
21	-8.5		47		
22	-6.5		48		
23	-7.9		49		
24	-6.4		50		
25	5.3		51		

Location:	8-2	Date:	08/04/2009	
Village:	Ndama	Profiles:	Latitude	Longitude
Sector:	Karangazi	Start profile:	S 01 25'33.4"	E 30 25'40.6"
District:	Nyagatare	End profile:	S 01 25' 22.9"	E 30 25'41.6"



Station interval 10m	Interpreted WADI Value(kHz) Profile:41	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:41	Remarks
0	3.4		26	-4.2	
1	15.4		27	-4.4	
2	14.8		28	-1.6	
3	0.4		29	-2.5	
4	1.2		30	-1.7	
5	0.9		31		
6	-2.9		32		
7	0.1		33		
8	3.8		34		
9	3.1	crosses at station 26 of profile40	35		
10	-1.6		36		
11	-1.3		37		
12	2.2		38		
13	1.4		39		
14	1.6		40		
15	-2.9		41		
16	-1.2		42		
17	-0.3		43		
18	0.5		44		
19	0.7		45		
20	2.6		46		
21	-2.5		47		
22	-5.0		48		
23	0.7		49		
24	5.1		50		
25	3.1		51		

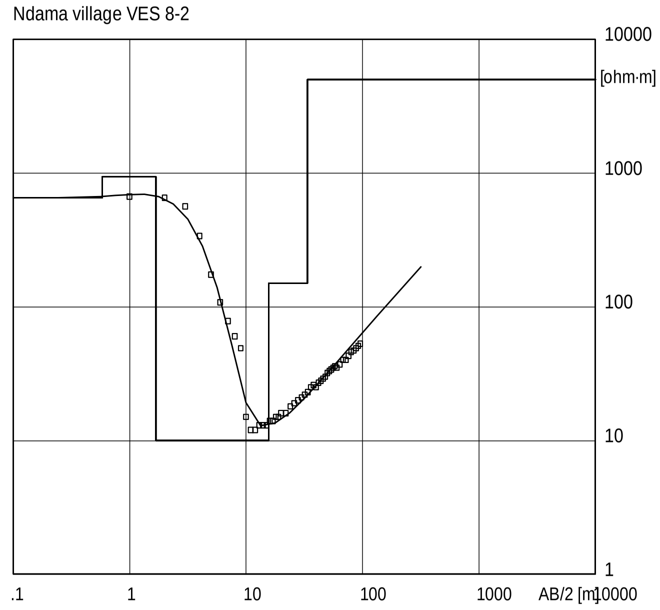
Location	8-1	Name:	Ndama



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
114	.51		125
9.1	16	.51	124.5
150	6.5	17	108
5000		24	101

Comments: The VES was carried out at station 19 of profile 40. Interpreted layers are: top soil, clay , weathered formation and hard rock

Location	8-2	Name:	Ndama

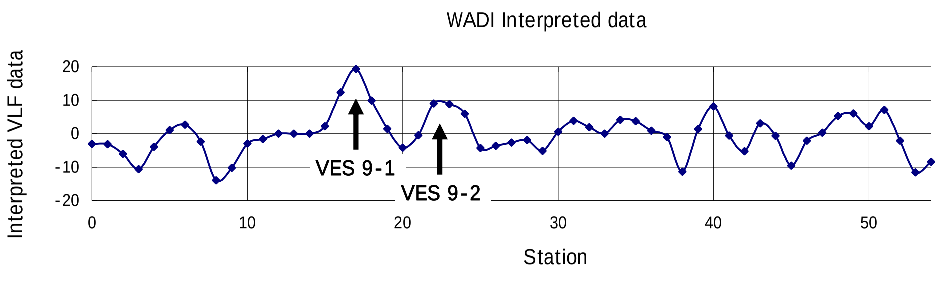


Location X = 30 25' 39.9 Y = 1 25' 32.4 Z = Azim = 1368

Model Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
655	.58	
941	1.1	.58
10	14	1.7
150	18	16
5000		34

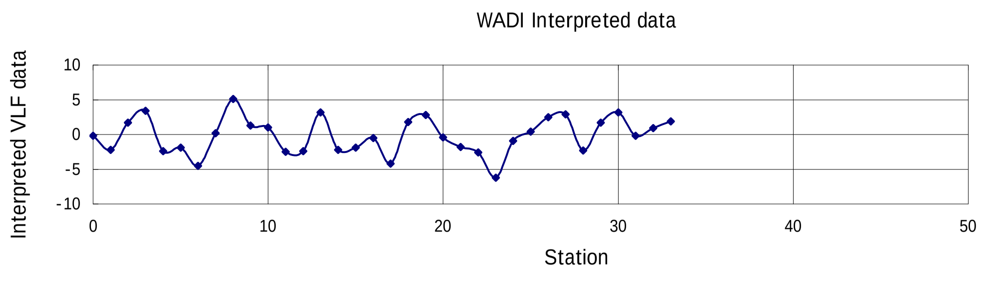
Comments: VES carried out on station 1 of profile 41. Interpreted layers are: top soil, lateritic clay, clay , weathered formation and hard rock

Location:	9-1	Date:	08/03/2009	
Village:	Ruhura	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 33'43.9"	E 30 23'52.6"
District:	Gatsibo	End profile:	S 01 33' 27.2"	E 30 23'58.1"



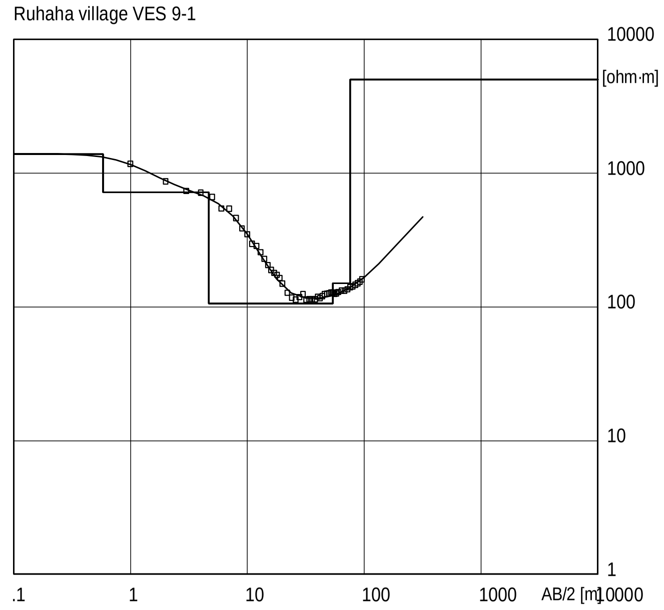
Station interval 10m	Interpreted WADI Value(kHz) Profile:38	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:38	Remarks
0	-3.1		28	-1.9	
1	-3.2		29	-5.2	
2	-6.0		30	0.6	
3	-10.6		31	3.8	
4	-3.9		32	1.9	
5	1.1		33	0.0	
6	2.7		34	4.1	
7	-2.4		35	3.7	
8	-14.0		36	0.9	
9	-10.2		37	-1.1	
10	-3.0		38	-11.4	
11	-1.6		39	1.3	
12	0.0		40	8.1	
13	0.0		41	-0.6	
14	0.0		42	-5.3	
15	2.2		43	3.1	
16	12.3		44	-0.7	
17	19.3		45	-9.6	
18	9.9		46	-2.1	
19	1.4		47	0.3	
20	-4.2		48	5.3	
21	-0.5		49	6.0	
22	9.0		50	2.2	
23	8.8		51	7.1	
24	5.9		52	-2.1	
25	-4.3		53	-11.6	
26	-3.6		54	-8.4	
27	-2.7		55		

Location:	9-2	Date:	08/03/2009	
Village:	Ruhura	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 33'39.5"	E 30 23'51.9"
District:	Gatsibo	End profile:	S 01 33' 35.3"	E 30 24'03.2"



Station interval 10m	Interpreted WADI Value(kHz) Profile:39	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:39	Remarks
0	-0.2		26	2.5	
1	-2.2		27	2.9	
2	1.7		28	-2.3	
3	3.4		29	1.7	
4	-2.4		30	3.2	
5	-1.9		31	-0.2	
6	-4.5		32	0.9	
7	0.2		33	1.9	
8	5.1		34		
9	1.3		35		
10	1.0		36		
11	-2.5		37		
12	-2.4		38		
13	3.2		39		
14	-2.2		40		
15	-1.9		41		
16	-0.5		42		
17	-4.2		43		
18	1.8		44		
19	2.8		45		
20	-0.4		46		
21	-1.8		47		
22	-2.6		48		
23	-6.2		49		
24	-0.9		50		
25	0.4		51		

Location 9-1 **Name:** Ruhuha

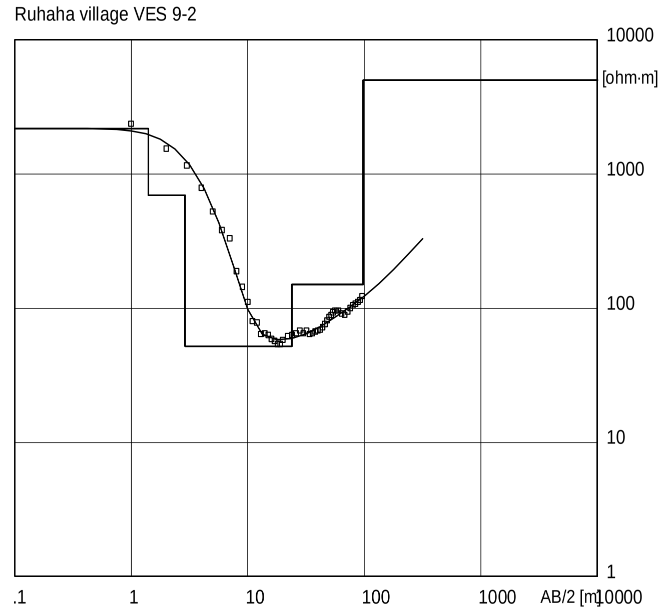


Location X = 30 23' 55.2 Y = 1 33' 38.0 Z = Azim = 1448

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
1392	.58	
720	4.1	.58
106	49	4.7
150	22	54
5000		76

Comments: The VES was carried out at station 17 of profile 38. Interpreted layers are: top soil, lateritic clay, clay , weathered formation and hard rock

Location 9-2 **Name:** Ruhuha

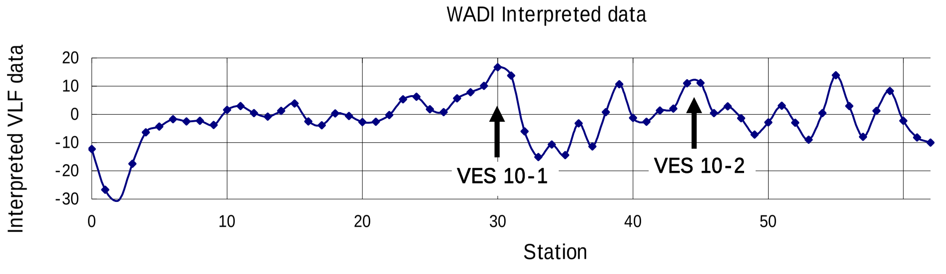


Location X = 30 23' 56.1 Y = 1 33' 36.1 Z = Azim = 1446

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
2186	1.4	
694	1.5	1.4
52	21	2.9
150	74	24
5000		98

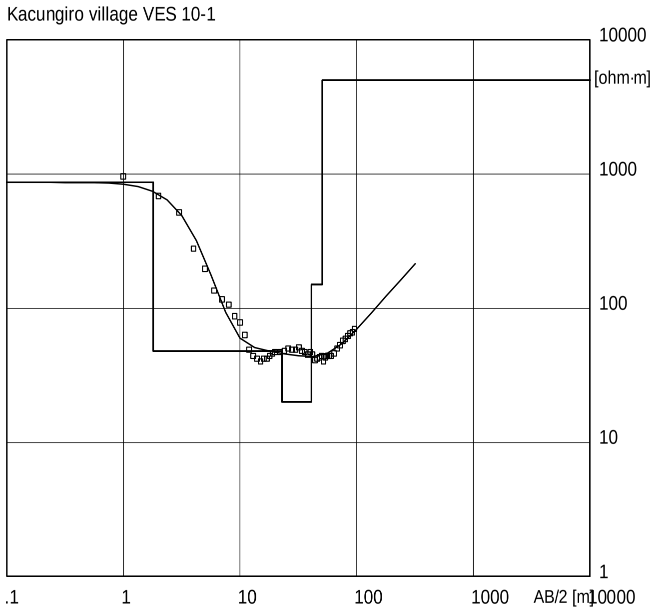
Comments: The VES was carried out on station 22 of profile 38. Interpreted layers are: top soil, lateritic clay, clay , weathered formation and hard rock

Location:	10-1	Date:	08/03/2009	
Village:	Kacungiro	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 30'03.4"	E 30 24'16.0"
District:	Gatsibo	End profile:	S 01 30' 02.7"	E 30 23'55.4"



Station interval 10m	Interpreted WADI Value(kHz) Profile:37	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:37	Remarks
0	-12.3		32	-6.0	
1	-26.7		33	-15.1	
2	-30.3		34	-10.7	
3	-17.5		35	-14.4	
4	-6.4		36	-3.2	
5	-4.3		37	-11.4	
6	-1.7		38	0.8	
7	-2.5		39	10.7	
8	-2.3		40	-1.2	
9	-3.7		41	-2.6	
10	1.6		42	1.4	
11	2.9		43	2.1	
12	0.4		44	11.0	
13	-0.8		45	11.1	
14	1.3		46	0.5	
15	3.9		47	2.8	
16	-2.5		48	-1.4	
17	-3.9		49	-7.2	
18	0.3		50	-2.8	
19	-0.6		51	3.1	
20	-2.7		52	-2.9	
21	-2.6		53	-9.0	
22	-0.2		54	0.4	
23	5.3		55	13.9	
24	6.2		56	2.9	
25	1.8		57	-7.9	
26	0.8		58	1.3	
27	5.7		59	8.3	
28	7.8		60	-2.3	
29	10.1		61	-8.2	
30	16.7		62	-10.0	
31	13.7		63		

Location	10-1	**Name:**	Kacungiro

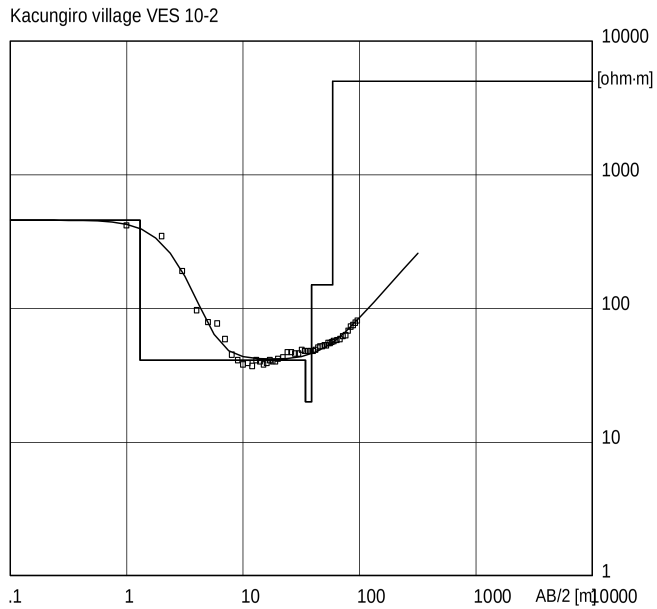


Location X = 30 24' 05.1 Y = 1 30' 02.2 Z = Azim = 1401

Model Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
866	1.8	
48	21	1.8
20	18	23
150	10	41
5000		51

Comments: The VES was carried out at station 30 of profile 37.
Interpreted layers are: top soil,
sandy clay, clay, weathered formation and hard rock

Location	10-2	**Name:**	Kacungiro

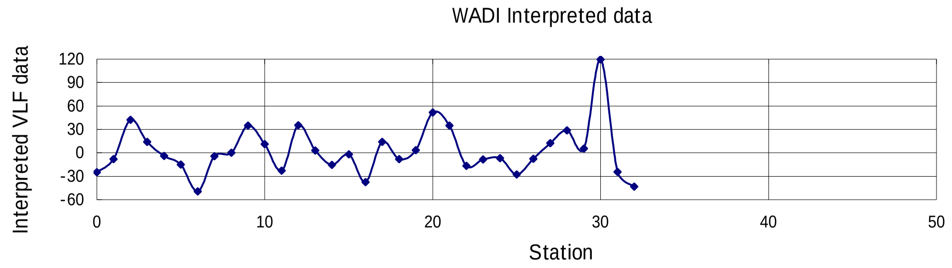


Location X = 30 24' 00.6 Y = 1 30' 02.6 Z = Azim = 1380

Model Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
458	1.3	
41	33	1.3
20	4.3	34
150	20	38
5000		58

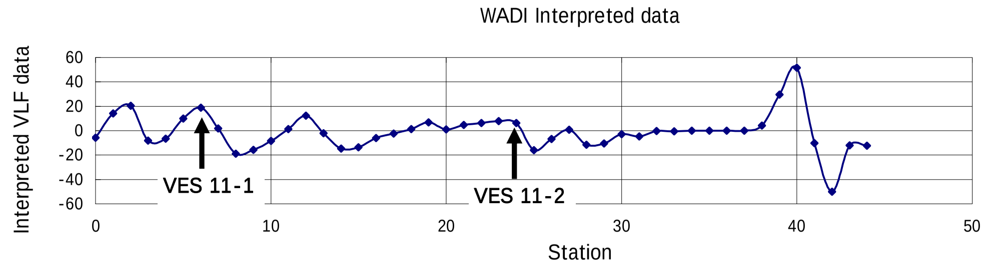
Comments: The VES was carried out at station 45 of profile 37.
Interpreted layers are: top soil,
sandy clay, clay, weathered formation and hard rock

Location:	11-1	Date:	07/30/2009	
Village:	Kabeza	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 38'37.0"	E 30 30'11.5"
District:	Gatsibo	End profile:	S 01 38' 45.7"	E 30 29'16.1"



Station interval 10m	Interpreted WADI Value(kHz) Profile:27	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:27	Remarks
0	-24.7		26	-7.7	
1	-8.0		27	12.5	
2	42.2		28	28.9	
3	13.9		29	5.3	
4	-3.9		30	119.4	
5	-15.0		31	-24.4	
6	-49.5		32	-43.4	
7	-4.2		33		
8	0.2		34		
9	34.9		35		
10	11.3		36		
11	-22.7		37		
12	35.2		38		
13	3.2		39		
14	-15.5		40		
15	-2.1	crosses at station 19	41		
16	-37.6	of profile 28	42		
17	14.1		43		
18	-7.9		44		
19	3.4		45		
20	51.7		46		
21	35.0		47		
22	-16.6		48		
23	-8.4		49		
24	-6.7		50		
25	-27.8		51		

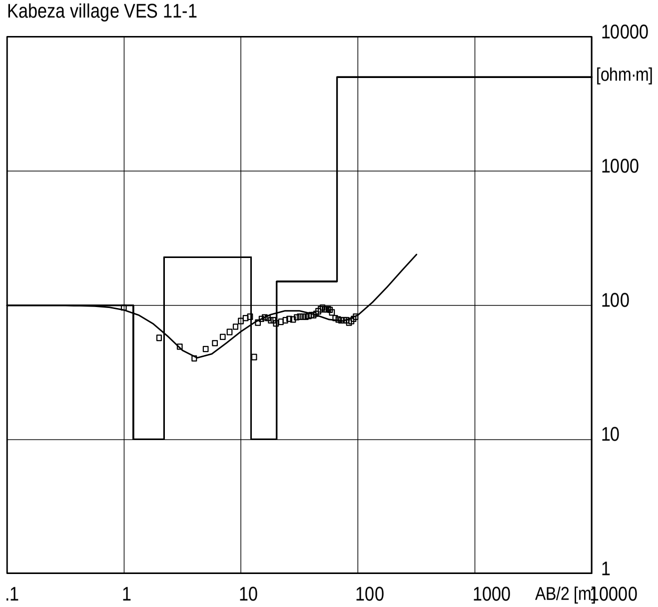
Location:	11-2	Date:	07/30/2009	
Village:	Kabeza	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 38'47.4"	E 30 30'13.4"
District:	Gatsibo	End profile:	S 01 38' 33.7"	E 30 30'14.6"



Station interval 10m	Interpreted WADI Value(kHz) Profile:28	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:28	Remarks
0	-5.7		26	-6.8	
1	14.2		27	0.9	
2	20.4		28	-11.4	
3	-8.2		29	-10.6	
4	-6.6		30	-2.8	
5	10.0		31	-4.6	
6	18.9		32	-0.2	
7	1.8		33	-0.5	
8	-18.8		34	0.0	
9	-15.7		35	0.0	
10	-8.5		36	0.0	
11	1.3		37	0.0	
12	12.4		38	4.1	
13	-2.2		39	29.7	
14	-14.7		40	51.5	
15	-13.7		41	-10.2	
16	-6.0		42	-50.0	
17	-2.4		43	-12.1	
18	1.2		44	-12.2	
19	6.8	crosses at station 15	45		
20	1.1	of profile 27	46		
21	4.6		47		
22	6.3		48		
23	7.9		49		
24	6.3		50		
25	-16.1		51		

Location 11-1 **Name:** Kabeza

Kabeza village VES 11-1

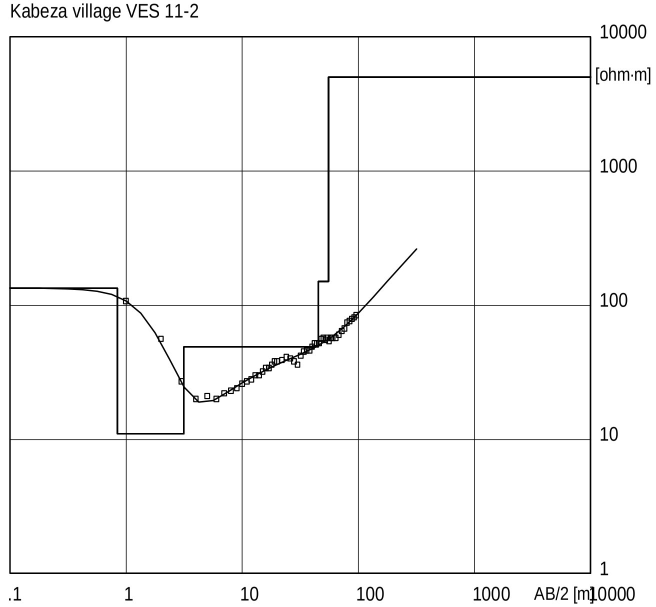


Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
100	1.2		138
10	1	1.2	136.8
228	10	2.2	135.8
10	8	12	126
150	46	20	118
5000		66	72

Comments: The VES was carried out at station 6 of profile 28. Interpreted layers are: top soil, clay, sandclay, clay, weathered formation and hard rock

Location 11-2 **Name:** Kabeza

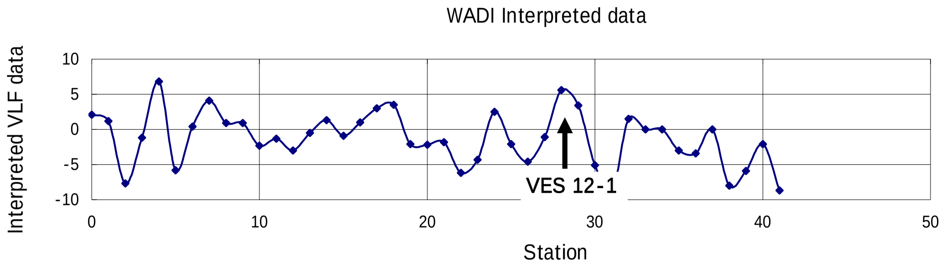
Kabeza village VES 11-2



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
134	.84		138
11	2.3	.84	137.2
49	42	3.1	134.9
150	10	45	93
5000		55	83

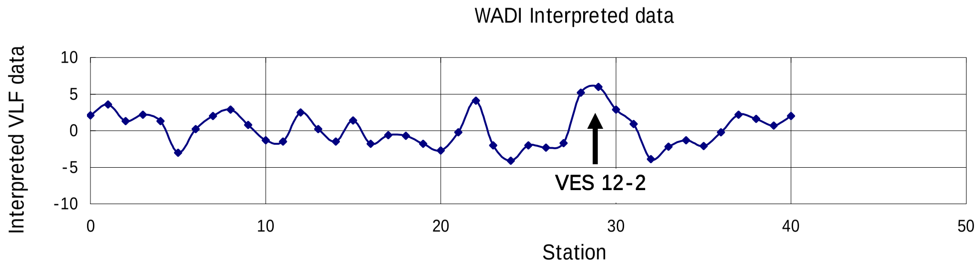
Comments: The VES was carried out at station 23 of profile 28. Interpreted layers are: top soil, clay, sandclay, weathered formation and hard rock

Location:	12-1	Date:	07/30/2009	
Village:	Munini	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 39'36.7"	E 30 30'02.9"
District:	Gatsibo	End profile:	S 01 39' 33.6"	E 30 29'50.1"



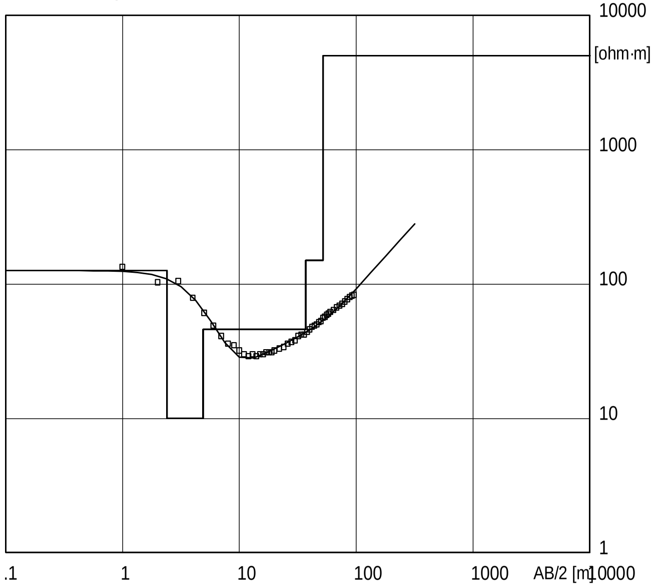
Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:25	Remarks	10m	Profile:25	Remarks
0	2.1	main road and upper slope	26	-4.6	
1	1.2		27	-1.1	
2	-7.7		28	5.6	
3	-1.2		29	3.4	
4	6.8		30	-5.1	
5	-5.8		31	-8.9	
6	0.4		32	1.5	
7	4.1		33	0.0	
8	0.9		34	0.0	
9	0.9		35	-3.0	
10	-2.3		36	-3.4	
11	-1.3		37	0.0	
12	-3.0		38	-8.0	swampy area
13	-0.5		39	-5.9	
14	1.3		40	-2.1	
15	-0.9		41	-8.7	
16	1.0		42		
17	3.0		43		
18	3.5		44		
19	-2.1		45		
20	-2.2		46		
21	-1.8		47		
22	-6.2		48		
23	-4.3		49		
24	2.5	crosses at station 9 of profile 26	50		
25	-2.1		51		

Location:	12-2	Date:	07/30/2009	
Village:	Munini	Profiles:	Latitude	Longitude
Sector:	Rwinbogo	Start profile:	S 01 39'34.4"	E 30 29'55.4"
District:	Gatsibo	End profile:	S 01 39' 41.2"	E 30 29'45.6"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:26	Remarks	10m	Profile:26	Remarks
0	2.1		26	-2.3	
1	3.6		27	-1.7	
2	1.3		28	5.2	
3	2.2		29	6.0	
4	1.3		30	2.9	
5	-3.0		31	0.9	
6	0.2		32	-3.9	
7	2.0		33	-2.2	
8	2.9		34	-1.3	
9	0.8		35	-2.1	
10	-1.3	crosses at station 25 of profile 25	36	-0.2	
11	-1.5		37	2.2	
12	2.5		38	1.6	
13	0.2		39	0.7	
14	-1.5		40	2.0	
15	1.4		41		
16	-1.8		42		
17	-0.6		43		
18	-0.7		44		
19	-1.8		45		
20	-2.7		46		
21	-0.2		47		
22	4.1		48		
23	-2.0		49		
24	-4.1		50		
25	-2.0		51		

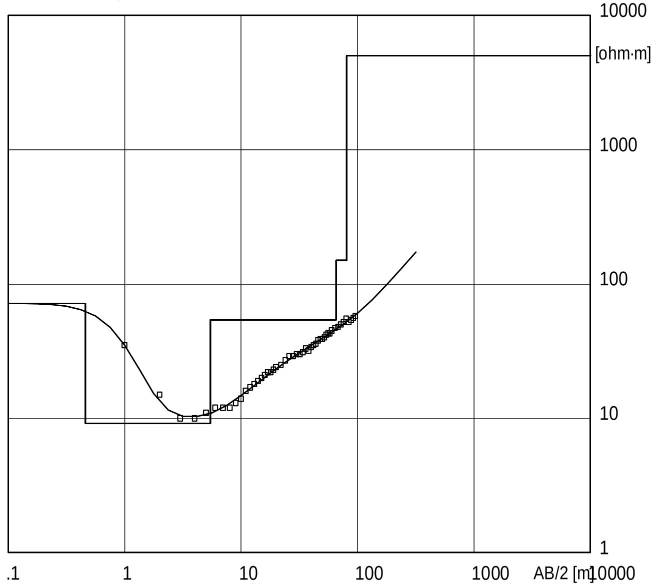
Location	12-1	Name:	Marembo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
126	2.4		139
10	2.5	2.4	136.6
46	32	4.9	134.1
150	15	37	102
5000		52	87

Comments: The VES was carried out at station 28 of profile 25.
Interpreted layers are: top soil,
clay, sandclay, weathered formation and hard rock

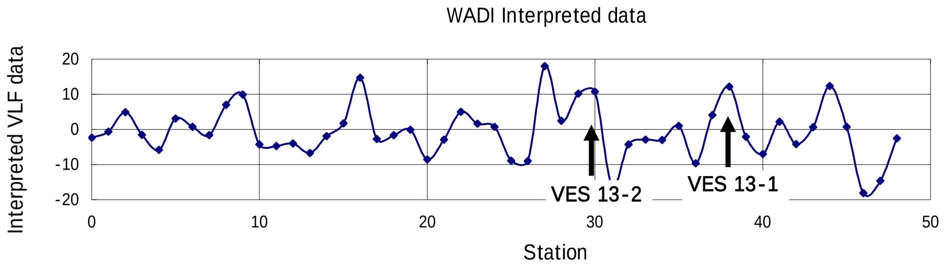
Location	12-2	Name:	Marembo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
72	.46		139
9.2	5	.46	138.5
54	60	5.5	133.5
150	15	66	73
5000		81	58

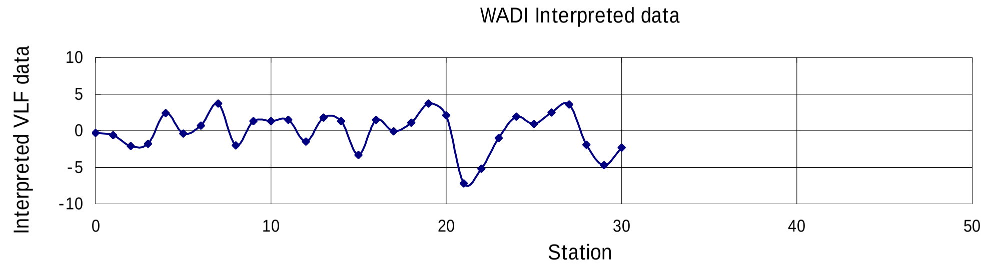
Comments: The VES was carried out at station 29 of profile 26.
Interpreted layers are: top soil,
clay, sandclay, weathered formation and hard rock

Location:	13-1	Date:	08/01/2009	
Village:	Ruhuha	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 33'25.1"	E 30 22'24.5"
District:	Gatsibo	End profile:	S 01 33' 40.2"	E 30 22'17.8"



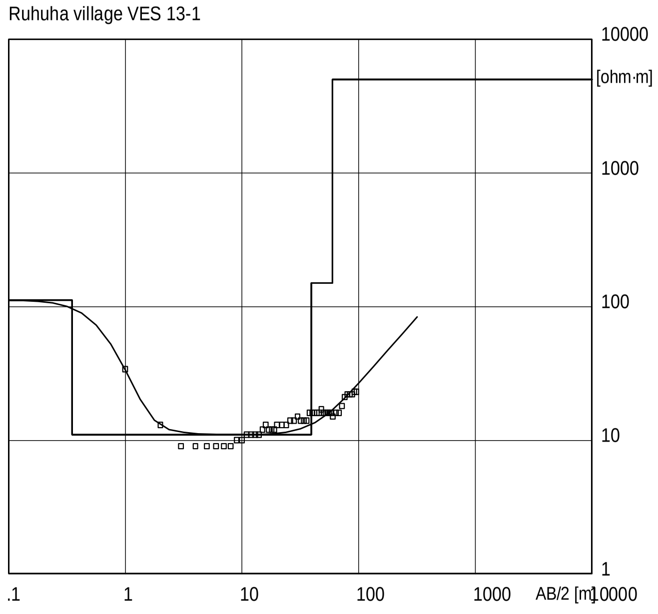
Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:32	Remarks	10m	Profile:32	Remarks
0	-2.4		26	-9.0	
1	-0.6		27	18.0	
2	4.9		28	2.5	
3	-1.5		29	10.2	
4	-5.8		30	10.7	crosses at station 14 of profile 33
5	3.1		31	-15.9	
6	0.7		32	-4.3	
7	-1.6		33	-2.9	
8	7.0		34	-3.0	
9	9.9		35	1.0	
10	-4.3		36	-9.6	
11	-4.7		37	4.1	
12	-4.0		38	12.2	
13	-6.7		39	-2.1	
14	-1.9		40	-7.0	
15	1.7		41	2.2	
16	14.7		42	-4.2	
17	-2.7		43	0.6	
18	-1.6		44	12.4	
19	-0.1		45	0.7	
20	-8.5		46	-18.1	
21	-2.9		47	-14.6	
22	5.0		48	-2.5	
23	1.6		49		
24	0.7		50		
25	-8.9		51		

Location:	13-2	Date:	08/01/2009	
Village:	Ruhuha	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 33'32.2"	E 30 22'16.7"
District:	Gatsibo	End profile:	S 01 33' 37.6"	E 30 22'24.8"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:33	Remarks	10m	Profile:33	Remarks
0	-0.3		26	2.5	
1	-0.6		27	3.6	
2	-2.1		28	-1.9	
3	-1.8		29	-4.7	
4	2.4		30	-2.3	
5	-0.4		31		
6	0.7		32		
7	3.7		33		
8	-2.0		34		
9	1.3		35		
10	1.3		36		
11	1.5		37		
12	-1.5		38		
13	1.8		39		
14	1.3	crosses at station 29 of profile 32	40		
15	-3.3		41		
16	1.5		42		
17	-0.1		43		
18	1.1		44		
19	3.7		45		
20	2.1		46		
21	-7.2		47		
22	-5.2		48		
23	-1.0		49		
24	1.9		50		
25	0.9		51		

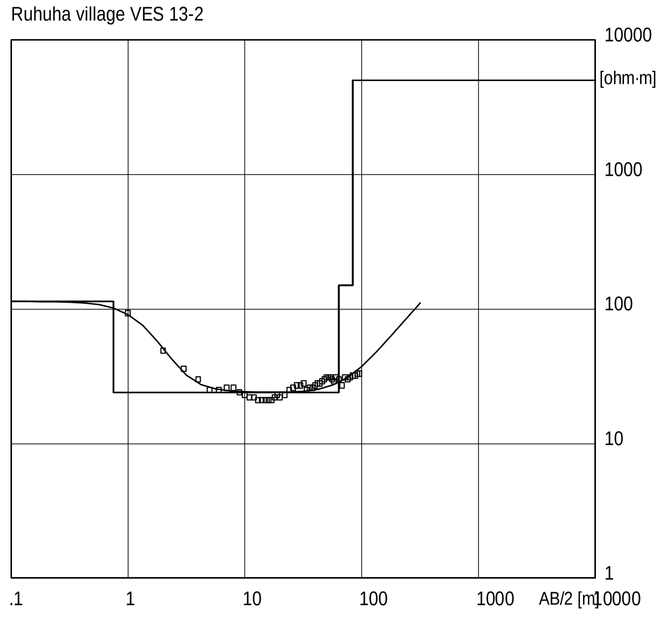
Location	13-1	Name:	Ruhuha



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
112	.35		133
11	39	.35	132.6
150	20	39	94
5000		59	74

Comments: The VES was carried out at station 38 of profile 32.
Interpreted layers are: top soil,
clay, weathered formation and hard rock

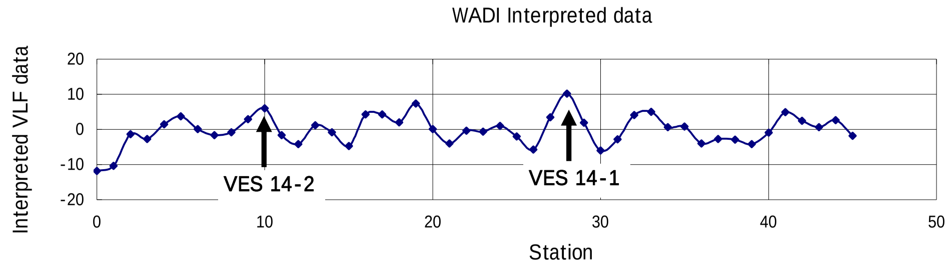
Location	13-2	Name:	Ruhuha



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
114	.75		133
24	63	.75	132.2
150	20	64	69
5000		84	49

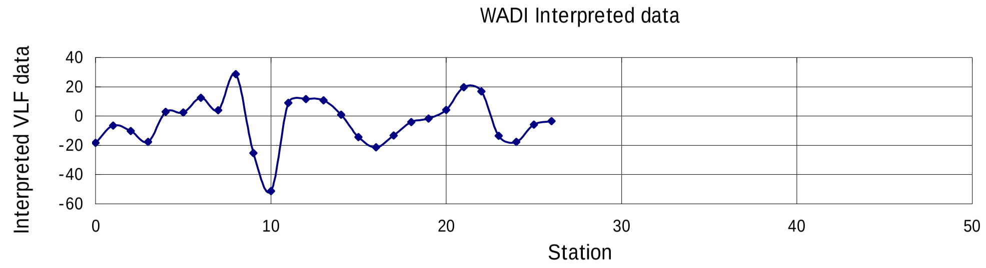
Comments: The VES was carried out at station 30 of profile 32.
Interpreted layers are: top soil,
clay, weathered formation and hard rock

Location:	14-1	Date:	07/31/2009	
Village:	Isimbwa	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 34'49.4"	E 30 21'57.0"
District:	Gatsibo	End profile:	S 01 34' 37.5"	E 30 22'03.8"



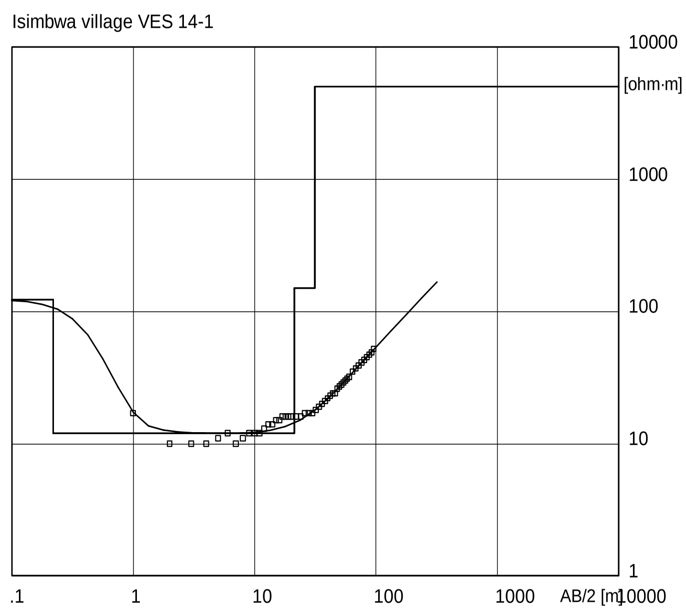
Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:30	Remarks	10m	Profile:30	Remarks
0	-11.8		26	-5.7	
1	-10.4		27	3.5	crosses at station 5 of profile 31
2	-1.4		28	10.2	
3	-2.7		29	1.9	
4	1.5		30	-6.0	
5	3.7		31	-2.8	
6	0.1		32	4.1	
7	-1.6		33	5.0	
8	-0.8		34	0.6	
9	2.9		35	0.8	
10	6.0		36	-4.0	
11	-1.6		37	-2.7	
12	-4.2		38	-2.9	
13	1.2		39	-4.2	
14	-0.8		40	-0.9	
15	-4.7		41	4.9	
16	4.3		42	2.5	
17	4.3		43	0.6	
18	2.0		44	2.6	
19	7.4		45	-1.8	
20	0.1		46		
21	-4.0		47		
22	-0.4		48		
23	-0.6		49		
24	1.0		50		
25	-2.0		51		

Location:	14-2	Date:	07/31/2009	
Village:	Isimbwa	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 34'40.3"	E 30 22'00.5"
District:	Gatsibo	End profile:	S 01 34' 47.8"	E 30 22'05.1"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:31	Remarks	10m	Profile:31	Remarks
0	-18.2		26	-3.5	
1	-6.6		27		
2	-10.2		28		
3	-17.6		29		
4	2.8		30		
5	2.4	crosses at station 27 of profile 30	31		
6	12.4		32		
7	3.9		33		
8	28.7		34		
9	-25.3		35		
10	-51.2		36		
11	9.0		37		
12	11.7		38		
13	10.7		39		
14	1.0		40		
15	-14.3		41		
16	-21.3		42		
17	-13.2		43		
18	-4.1		44		
19	-1.7		45		
20	4.3		46		
21	19.7		47		
22	16.8		48		
23	-13.6		49		
24	-17.7		50		
25	-5.9		51		

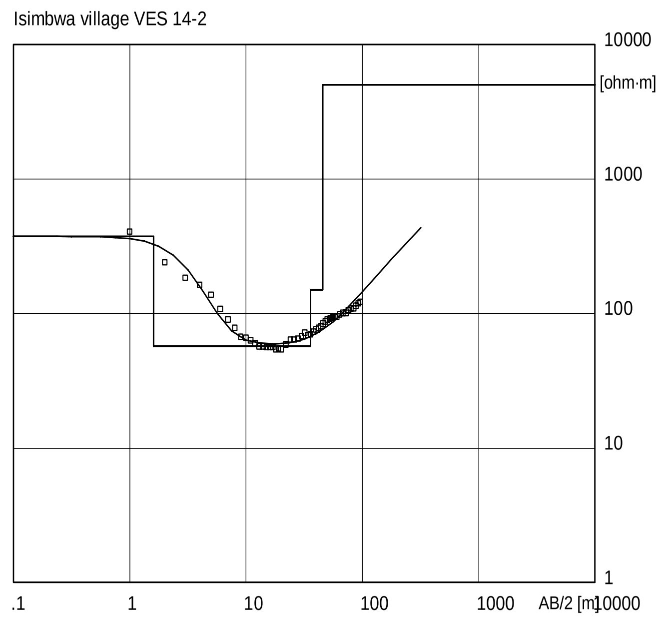
Location	14-1	Name:	Isimbwa



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
123	.22		134
12	21	.22	133.8
150	10	21	113
5000		31	103

Comments: The VES was carried out at station 28 of profile 30.
Interpreted layers are: top soil,
clay, weathered formation and hard rock

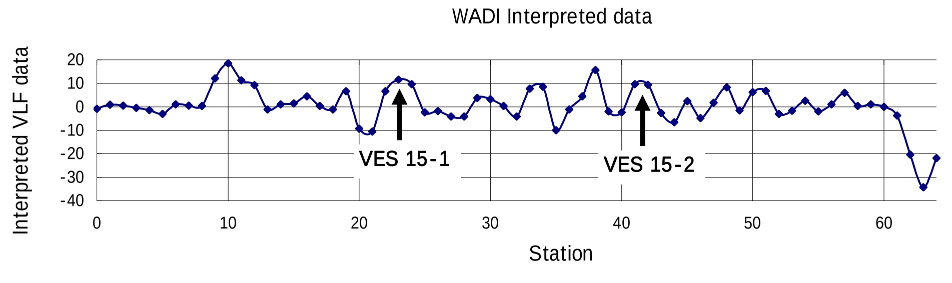
Location	14-2	Name:	Isimbwa



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
374	1.6		134
57	34	1.6	132.4
150	10	36	98
5000		46	88

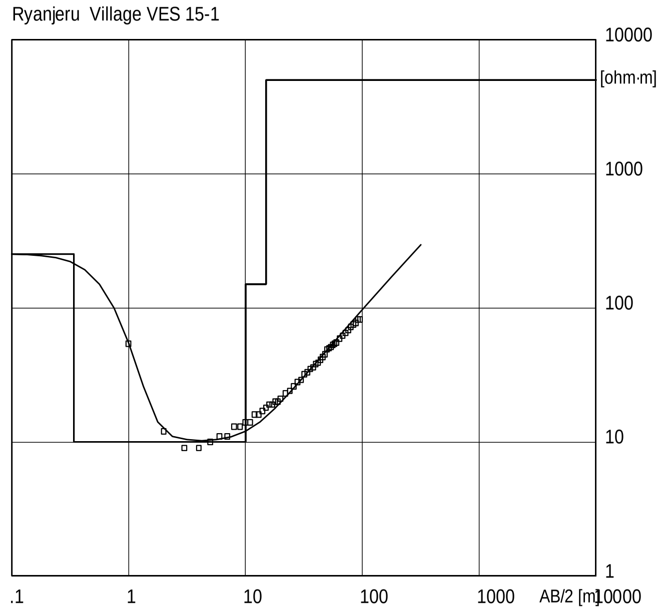
Comments: The VES was carried out at station 10 of profile 30.
Interpreted layers are: top soil,
sandy clay, weathered formation and hard rock

Location:	15-1	Date:	07/31/2009	
Village:	Ryanjeru	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 36'36.4"	E 30 21'16.1"
District:	Gatsibo	End profile:	S 01 36' 20.6"	E 30 21'03.0"



Station interval 10m	Interpreted WADI Value(kHz) Profile:29	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:29	Remarks
0	-0.8		33	7.7	
1	0.9		34	8.6	
2	0.5		35	-10.0	
3	-0.4		36	-1.1	
4	-1.4		37	4.5	
5	-3.0		38	15.7	
6	1.1		39	-2.0	
7	0.5		40	-2.4	
8	0.4		41	9.7	
9	12.1		42	9.4	
10	18.5		43	-2.7	
11	11.3		44	-6.6	
12	9.2		45	2.4	
13	-1.1		46	-4.8	
14	1.1		47	1.7	
15	1.5		48	8.3	
16	4.5		49	-1.5	
17	0.4		50	6.2	
18	-1.2		51	6.8	
19	6.7		52	-3.0	
20	-9.3		53	-1.7	
21	-10.5		54	2.5	
22	6.6		55	-2.0	
23	11.5		56	1.0	
24	9.7		57	6.0	
25	-2.3		58	0.4	
26	-1.8		59	1.1	
27	-4.1		60	0.0	
28	-4.1		61	-3.7	
29	3.8		62	-20.3	
30	3.2		63	-34.3	
31	0.4		64	-21.8	
32	-4.2		65		

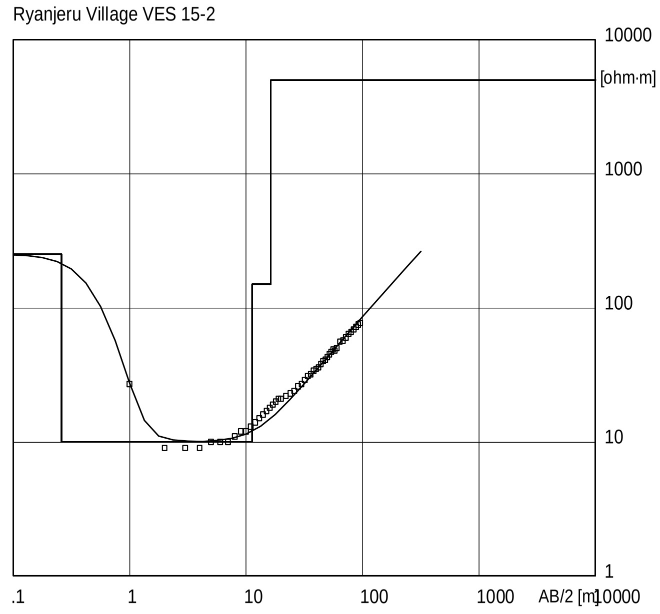
Location 15-1 **Name:** Ryanjeru



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
253	.34		136
10	9.7	.34	135.7
150	5	10	126
5000		15	121

Comments: The VES was carried out at station 23 of profile 29. Interpreted layers are: top soil, clay, weathered formation and hard rock

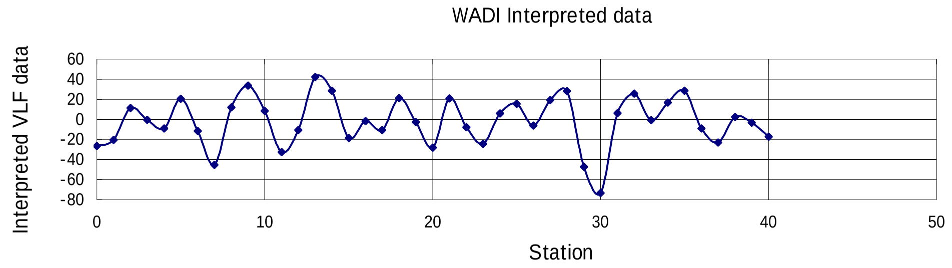
Location 15-2 **Name:** Ryanjeru



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
252	.26		136
10	11	.26	135.7
150	5	11	125
5000		16	120

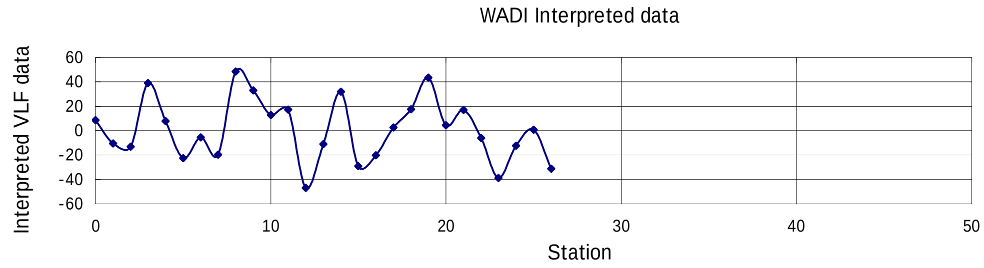
Comments: The VES was carried out at station 41 of profile 29. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	16-1	Date:	08/01/2009	
Village:	Rutenderi	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 34'13.8"	E 30 19'34.6"
District:	Gatsibo	End profile:	S 01 34' 26.7"	E 30 19'31.8"



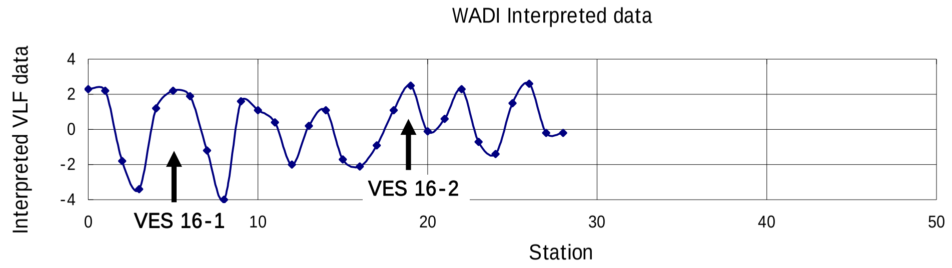
Station interval 10m	Interpreted WADI Value(kHz) Profile:34	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:34	Remarks
0	-26.7		26	-6.2	
1	-20.4		27	19.4	
2	11.3		28	28.1	
3	-0.4		29	-47.2	
4	-9.2		30	-73.2	
5	20.6		31	6.1	
6	-11.7		32	25.7	
7	-45.3		33	-0.9	
8	12.0		34	16.6	
9	33.5		35	28.4	
10	8.5		36	-9.0	
11	-32.6		37	-23.1	
12	-10.7		38	2.4	
13	42.1		39	-3.2	
14	28.6		40	-17.4	
15	-18.5		41		
16	-1.8		42		
17	-10.5		43		
18	21.3		44		
19	-2.6		45		
20	-28.1		46		
21	20.8		47		
22	-7.8		48		
23	-24.3		49		
24	5.9		50		
25	15.5		51		

Location:	16-2	Date:	08/01/2009	
Village:	Rutenderi	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 34'29.2"	E 30 19'27.2"
District:	Gatsibo	End profile:	S 01 34' 38.1"	E 30 19'30.4"



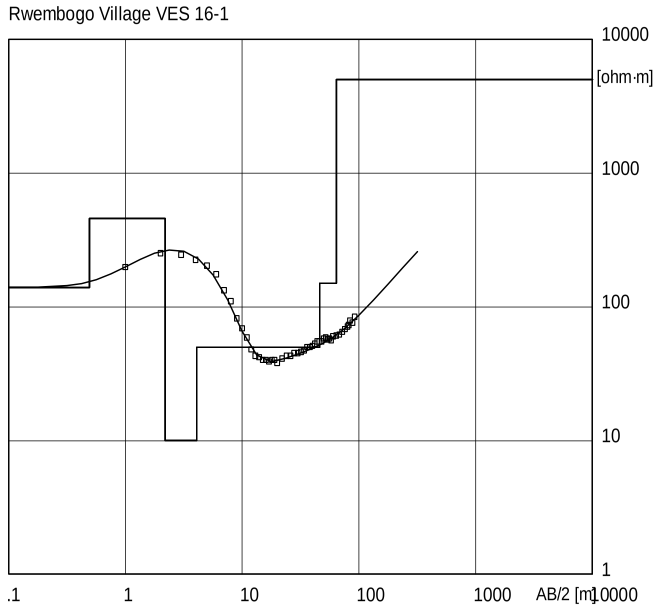
Station interval 10m	Interpreted WADI Value(kHz) Profile:35	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:35	Remarks
0	8.6		26	-31.1	
1	-10.6		27		
2	-13.2		28		
3	39.1		29		
4	7.8		30		
5	-22.6		31		
6	-5.6		32		
7	-19.6		33		
8	48.5		34		
9	33.0		35		
10	12.8		36		
11	17.3		37		
12	-47.0		38		
13	-11.0		39		
14	31.9		40		
15	-29.0		41		
16	-20.1		42		
17	2.6		43		
18	17.5		44		
19	43.5		45		
20	4.5		46		
21	16.9		47		
22	-5.9		48		
23	-38.8		49		
24	-12.2		50		
25	0.8		51		

Location:	16-3	Date:	08/01/2009	
Village:	Rutenderi	Profiles:	Latitude	Longitude
Sector:	Kabarole	Start profile:	S 01 34'13.8"	E 30 19'34.6"
District:	Gatsibo	End profile:	S 01 34' 26.7"	E 30 19'31.8"



Station interval 10m	Interpreted WADI Value(kHz) Profile:34	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:34	Remarks
0	2.3		26	2.6	
1	2.2		27	-0.2	
2	-1.8		28	-0.2	
3	-3.4		29		
4	1.2		30		
5	2.2		31		
6	1.9		32		
7	-1.2		33		
8	-4.0		34		
9	1.6		35		
10	1.1		36		
11	0.4		37		
12	-2.0		38		
13	0.2		39		
14	1.1		40		
15	-1.7		41		
16	-2.1		42		
17	-0.9		43		
18	1.1		44		
19	2.5		45		
20	-0.1		46		
21	0.6		47		
22	2.3		48		
23	-0.7		49		
24	-1.4		50		
25	1.5		51		

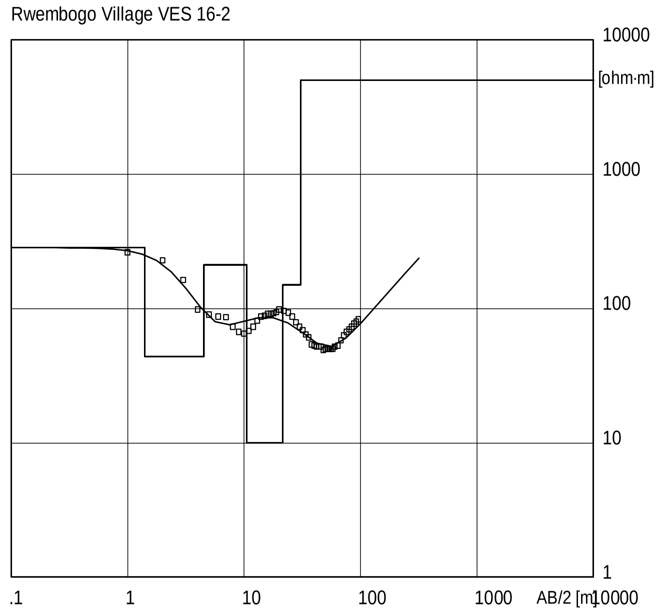
Location 16-1 **Name:** Rutenderi



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
140	.49		134
459	1.7	.49	133.5
10	1.9	2.2	131.8
50	42	4.1	129.9
150	18	46	88
5000		64	70

Comments: VES was carried at station 5 of profile 36. Interpreted layers are: top soil, sandy gravel, clay, sandy clay, weathered formation and hard rock

Location 16-2 **Name:** Rutenderi

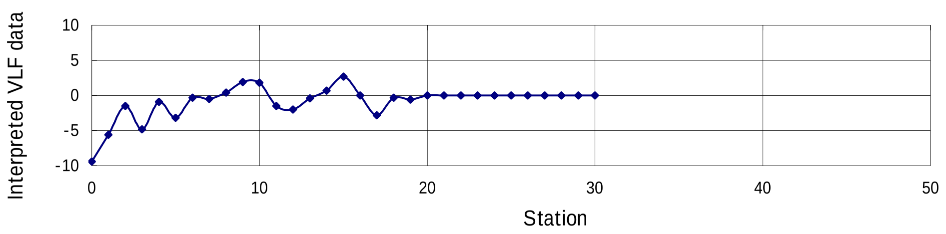


Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
284	1.4		134
44	3.1	1.4	132.6
212	6	4.5	129.5
10	11	10	124
150	9	21	113
5000		30	104

Comments: VES was carried out at station 19 of profile 36. Interpreted layers are: top soil, clay, sandyclay, clay, weathered formation and hard rock

Location:	17-1	Date:	07/29/2009	
Village:	Kinyana	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 40'19.9"	E 30 29'46.1"
District:	Kayonza	End profile:	S 01 40' 21.8"	E 30 29'36.1"

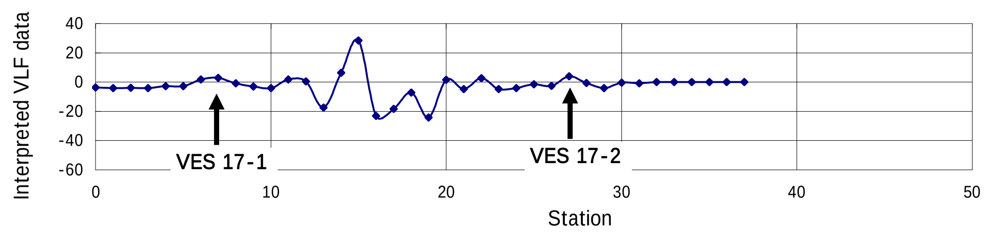
WADI Interpreted data



Station interval 10m	Interpreted WADI Value(kHz) Profile:21	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:21	Remarks
0	-9.4		26	0.0	
1	-5.6		27	0.0	
2	-1.5		28	0.0	
3	-4.8		29	0.0	
4	-0.9		30	0.0	
5	-3.2		31		
6	-0.3		32		
7	-0.5		33		
8	0.4		34		
9	1.9		35		
10	1.8		36		
11	-1.5		37		
12	-2.0		38		
13	-0.4		39		
14	0.7		40		
15	2.7	Antihill	41		
16	0.0		42		
17	-2.8		43		
18	-0.3		44		
19	-0.6		45		
20	0.0		46		
21	0.0		47		
22	0.0		48		
23	0.0		49		
24	0.0		50		
25	0.0		51		

Location:	17-2	Date:	07/29/2009	
Village:	Kinyana	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 40'19.9"	E 30 29'44.8"
District:	Kayonza	End profile:	S 01 40' 11.2"	E 30 29'39.0"

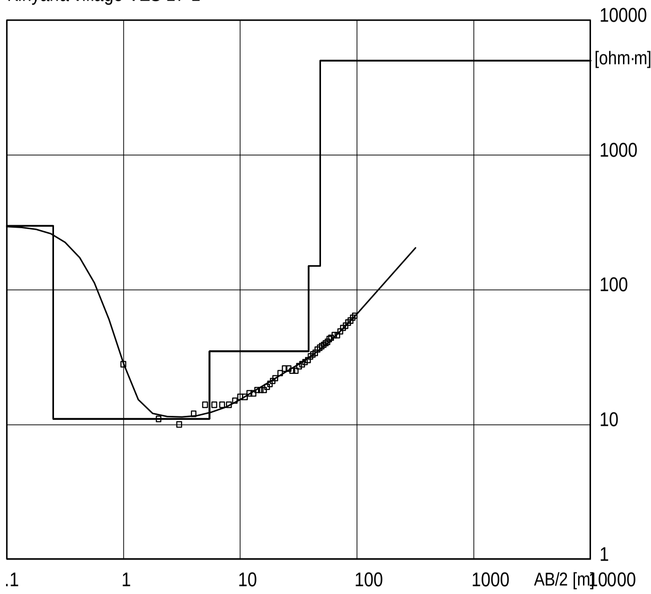
WADI Interpreted data



Station interval 10m	Interpreted WADI Value(kHz) Profile:22	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:22	Remarks
0	-3.6		26	-2.6	
1	-4.2		27	3.9	
2	-3.8		28	-0.6	
3	-4.2		29	-4.2	
4	-2.9		30	-0.4	
5	-2.8		31	-0.9	
6	1.8		32	0.0	
7	2.8		33	0.0	
8	-0.8		34	0.0	
9	-3.1		35	0.0	
10	-4.0		36	0.0	
11	1.8		37	0.0	
12	0.5		38		
13	-17.4		39		
14	6.3		40		
15	28.5		41		
16	-23.1		42		
17	-18.3		43		
18	-7.2		44		
19	-24.3		45		
20	1.5		46		
21	-4.8		47		
22	2.7		48		
23	-4.7		49		
24	-4.0		50		
25	-1.4		51		

Location	17-1	**Name:**	Kinyana

Kinyana village VES 17-1

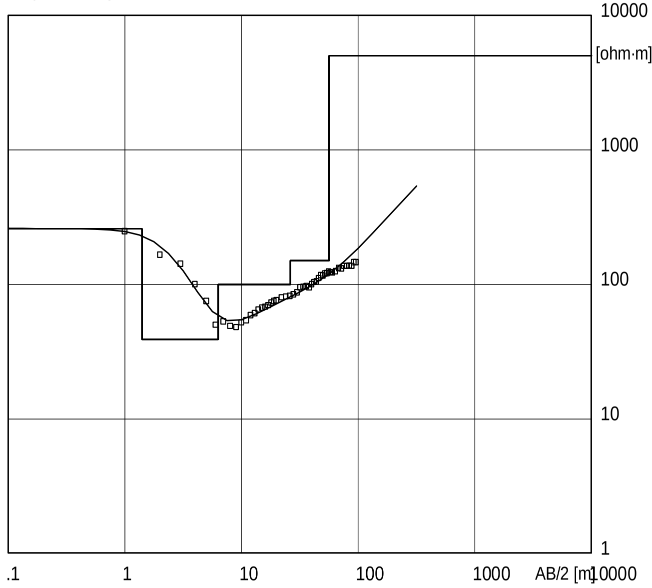


Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
299	.25		140
11	5.2	.25	139.8
35	33	5.4	134.6
150	10	38	102
5000		48	92

Comments: The VES was carried out at station 27 of profile 22 .
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

Location	17-2	**Name:**	Kinyana

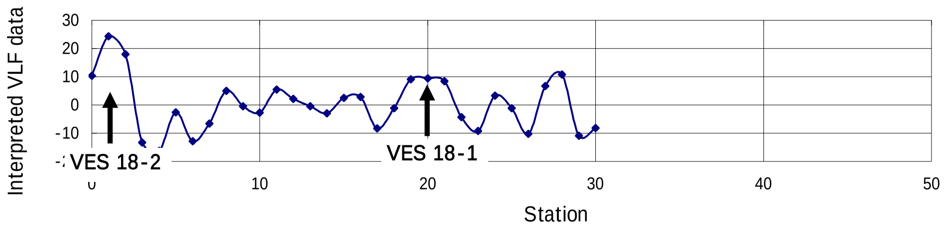
Kinyana village VES 17-2



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
260	1.4		140
39	4.9	1.4	138.6
100	20	6.3	133.7
150	30	26	114
5000		56	84

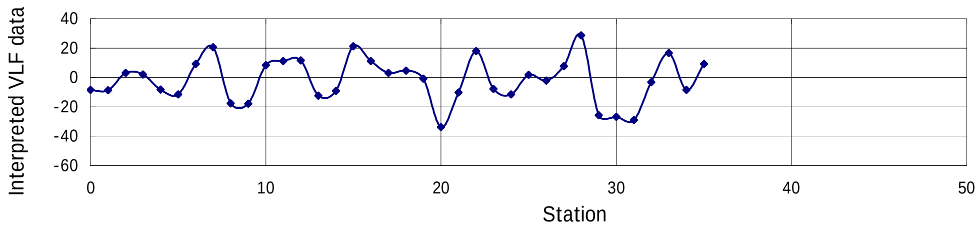
Comments: The VES was carried out on station 7 of profile 22.
Interpreted layers are: top soil,
clay, sandt clay, weathered formation and hard rock

Location:	18-1	Date:	07/29/2009	
Village:	Munini	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 40'01.8"	E 30 30'08.9"
District:	Kayonza	End profile:	S 01 39' 57.6"	E 30 29'58.0"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:23	Remarks	10m	Profile:23	Remarks
0	10.3		26	-10.2	
1	24.3		27	6.7	
2	18.0		28	10.8	
3	-13.3		29	-10.9	
4	-16.3		30	-8.2	
5	-2.6		31		
6	-12.8		32		
7	-6.6		33		
8	5.0		34		
9	-0.5		35		
10	-2.7		36		
11	5.4		37		
12	2.2		38		
13	-0.5		39		
14	-2.9		40		
15	2.5		41		
16	2.8		42		
17	-8.3		43		
18	-1.1		44		
19	9.1		45		
20	9.4		46		
21	8.4		47		
22	-4.3		48		
23	-9.2		49		
24	3.3		50		
25	-1.1		51		

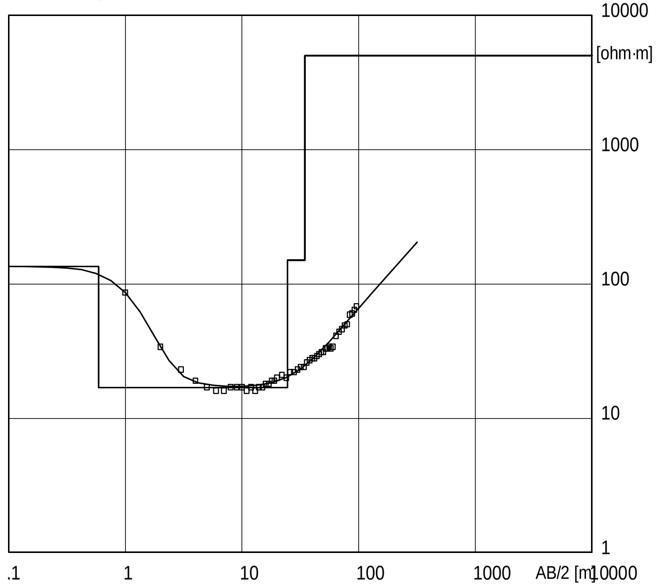
Location:	18-2	Date:	07/29/2009	
Village:	Munini	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 39'58.6"	E 30 29'57.5"
District:	Kayonza	End profile:	S 01 39' 54.6"	E 30 29'46.4"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:24	Remarks	10m	Profile:24	Remarks
0	-8.5		26	-2.1	
1	-8.6		27	7.7	
2	3.0		28	28.7	
3	1.9		29	-25.8	
4	-8.3		30	-26.9	
5	-11.5		31	-28.9	
6	9.3		32	-3.3	
7	20.5		33	16.6	
8	-17.6		34	-8.5	
9	-17.8		35	9.3	
10	8.4		36		
11	11.2	parallel to not functioning borehole 50m away	37		
12	11.6		38		
13	-12.4		39		
14	-9.1		40		
15	21.3		41		
16	11.2		42		
17	3.0		43		
18	4.7		44		
19	-0.9		45		
20	-33.9		46		
21	-10.3		47		
22	17.9		48		
23	-7.9		49		
24	-11.6		50		
25	1.7		51		

Location 18-1 **Name:** Munini

Munini village VES 18-1

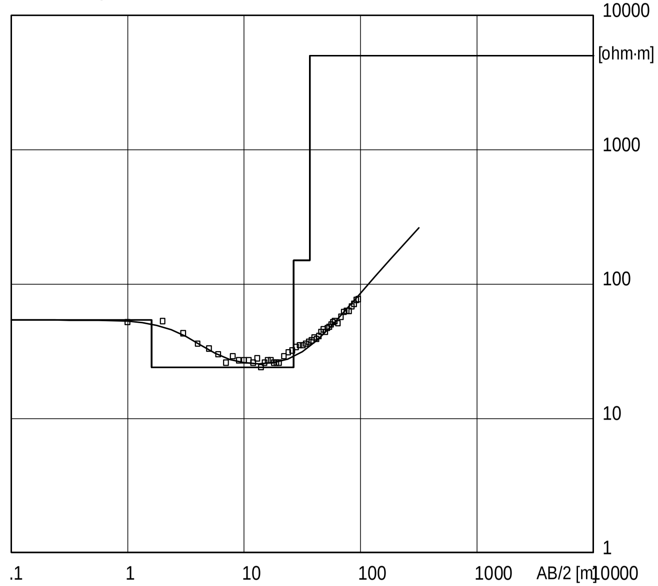


Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
135	.59		139
17	24	.59	138.4
150	10	25	114
5000		35	104

Comments: The VES was carried out at station 20 of profile 23 . Interpreted layers are: top soil, clay, weathered formation and hard rock

Location 18-2 **Name:** Munini

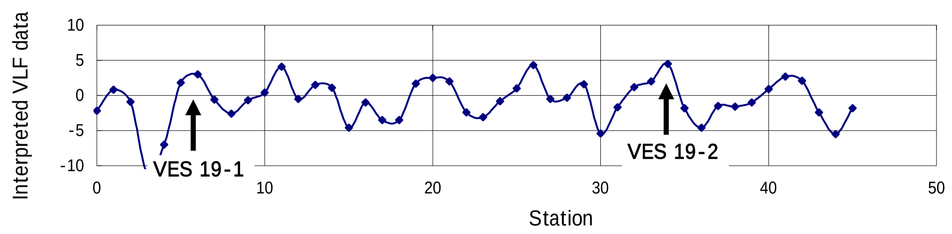
Munini village VES 18-2



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
54	1.6		140
24	25	1.6	138.4
150	10	27	113
5000		37	103

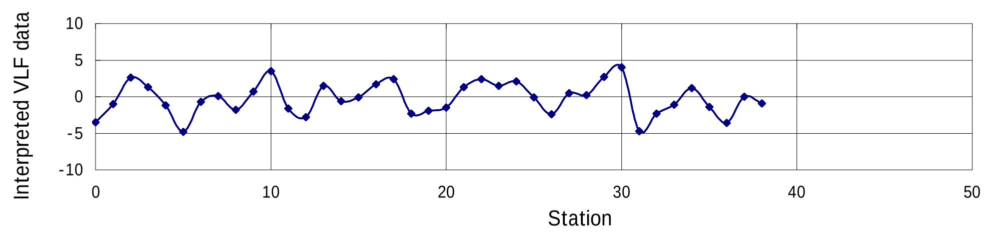
Comments: The VES was carried out at station 1 of profile 23 . Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	19-1	Date:	07/28/2009	
Village:	Karambi	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 42'16.9"	E 30 29'33.7"
District:	Kayonza	End profile:	S 01 41' 56.0"	E 30 29'34.6"



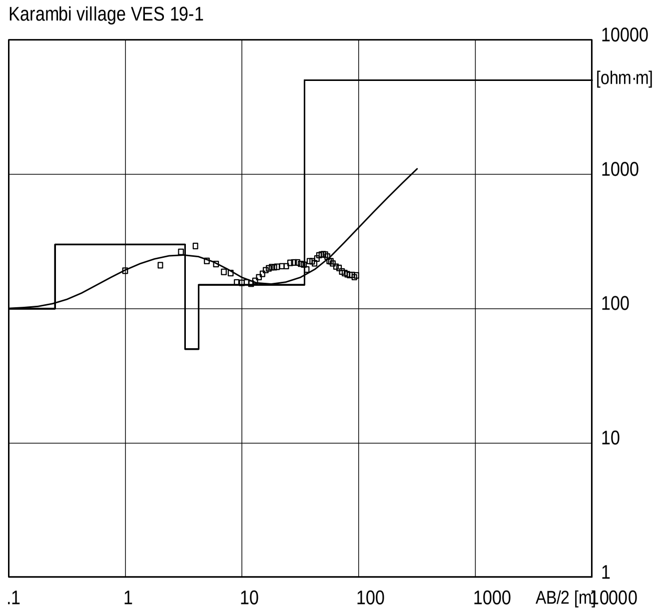
Station interval 10m	Interpreted WADI Value(kHz) Profile:18	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:18	Remarks
0	-2.2		26	4.3	
1	0.8		27	-0.5	
2	-0.9		28	-0.3	
3	-11.0		29	1.6	
4	-7.0		30	-5.4	
5	1.8		31	-1.7	
6	3.0		32	1.2	
7	-0.6		33	2.0	
8	-2.6		34	4.5	
9	-0.7		35	-1.8	
10	0.4		36	-4.6	
11	4.1		37	-1.5	
12	-0.5		38	-1.6	
13	1.5		39	-1.0	
14	1.1	Parallel to existin well	40	0.9	
15	-4.6		41	2.7	Perpendicular to station 2 of profile 19
16	-1.0		42	2.1	
17	-3.5		43	-2.4	
18	-3.5	wet surface	44	-5.5	
19	1.7		45	-1.8	
20	2.5		46		
21	2.0		47		
22	-2.4		48		
23	-3.1		49		
24	-0.8		50		
25	1.0		51		

Location:	19-2	Date:	07/28/2009	
Village:	Karambi	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 41'56.2"	E 30 29'35.7"
District:	Kayonza	End profile:	S 01 42' 00.6"	E 30 29'24.9"



Station interval 10m	Interpreted WADI Value(kHz) Profile:19	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:19	Remarks
0	-3.5		26	-2.4	
1	-1.0		27	0.5	
2	2.6	Perpendicular to station 41 of profile 18	28	0.2	
3	1.3		29	2.7	
4	-1.2		30	4.0	
5	-4.8		31	-4.7	
6	-0.7		32	-2.3	
7	0.1		33	-1.1	
8	-1.8		34	1.2	
9	0.7		35	-1.4	
10	3.5		36	-3.6	
11	-1.6		37	0.0	
12	-2.8		38	-0.9	
13	1.5		39		
14	-0.6		40		
15	-0.1		41		
16	1.7		42		
17	2.4		43		
18	-2.3		44		
19	-1.9		45		
20	-1.5		46		
21	1.3		47		
22	2.4		48		
23	1.5		49		
24	2.1		50		
25	-0.1		51		

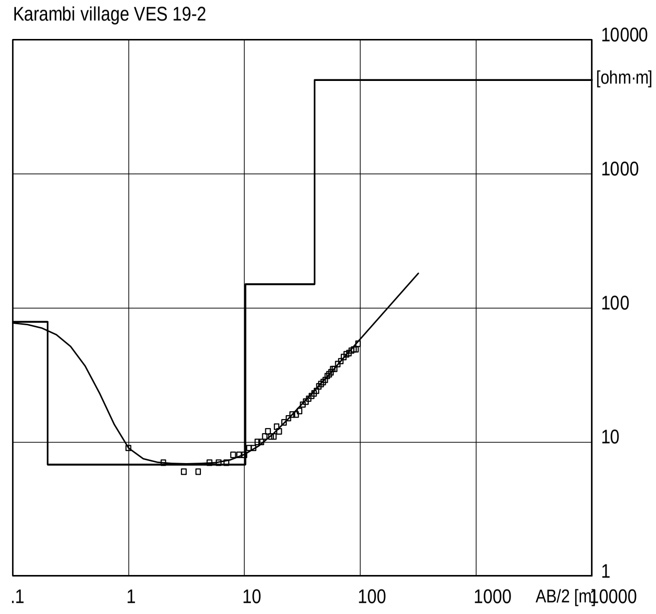
Location	19-1	**Name:**	Karambi



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
100	.25		142
300	3	.25	141.8
50	1	3.2	138.8
150	30	4.2	137.8
5000		34	108

Comments: The VES was carried out at station 6 of profile 18 .
Interpreted layers are: top soil,
gravel, sandy clay, weathered formation and hard rock

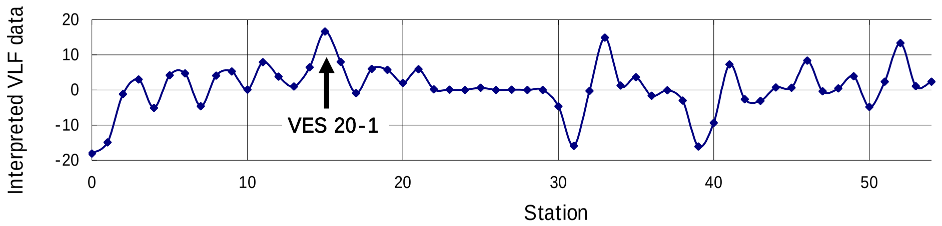
Location	19-2	**Name:**	Karambi



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
79	.2		141
6.8	10	.2	140.8
150	30	10	131
5000		40	101

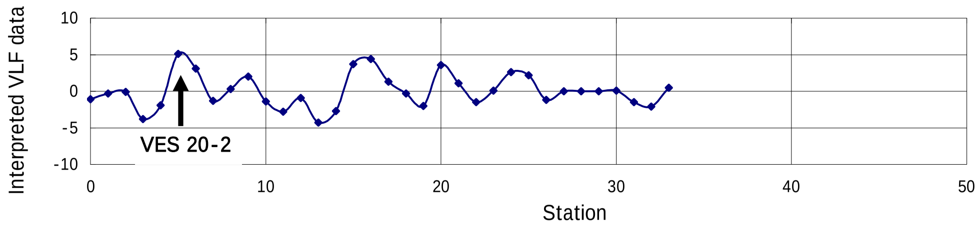
Comments: The VES was carried out at station 34 of profile 18 .
Interpreted layers are: top soil,
clay, weathered formation and hard rock

Location:	20-1	Date:	07/28/2009	
Village:	Rwamanyonyi	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 44'05.3"	E 30 32'26.6"
District:	Kayonza	End profile:	S 01 44' 15.3"	E 30 32'10.8"



Station interval 10m	Interpreted WADI Value(kHz) Profile:16	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:16	Remarks
0	-18.1	main road to Buhabwa	28	0.0	
1	-14.9		29	0.0	
2	-1.2		30	-4.6	
3	3.0		31	-15.9	
4	-5.1		32	-0.3	
5	4.2		33	14.9	stream crossing
6	4.7		34	1.3	
7	-4.6		35	3.6	
8	4.1		36	-1.6	
9	5.3		37	-0.1	
10	0.1		38	-3.0	
11	7.9		39	-16.1	
12	3.8		40	-9.4	
13	1.0		41	7.3	
14	6.5		42	-2.6	
15	16.6		43	-3.1	
16	8.0		44	0.7	
17	-0.9		45	0.6	
18	6.0		46	8.4	
19	5.7		47	-0.4	
20	2.0		48	0.5	
21	5.9		49	3.9	
22	0.2		50	-4.8	
23	0.1		51	2.4	
24	0.0		52	13.4	
25	0.6		53	1.1	
26	0.0	crosses station 13 of profile 17	54	2.4	
27	0.1		55		

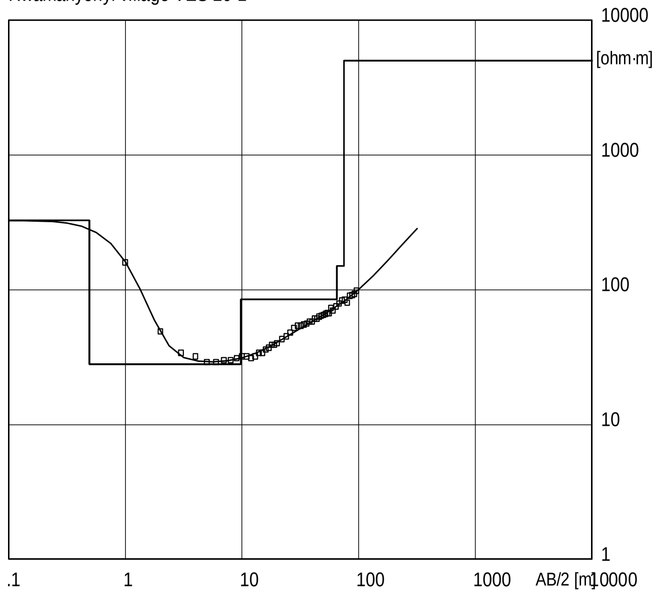
Location:	20-2	Date:	07/28/2009	
Village:	Rwamanyonyi	Profiles:	Latitude	Longitude
Sector:	Murundi	Start profile:	S 01 44'14.8"	E 30 32'19.0"
District:	Kayonza	End profile:	S 01 44' 04.8"	E 30 32'16.2"



Station interval 10m	Interpreted WADI Value(kHz) Profile:17	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:17	Remarks
0	-1.1		26	-1.2	
1	-0.3		27	0.0	
2	-0.1		28	0.0	
3	-3.8		29	0.0	
4	-1.9		30	0.1	
5	5.1		31	-1.5	
6	3.1		32	-2.1	
7	-1.3		33	0.5	
8	0.3		34		
9	2.0	centre of road	35		
10	-1.4		36		
11	-2.8		37		
12	-0.9		38		
13	-4.3	crosses station 27 of profile 16	39		
14	-2.7		40		
15	3.7		41		
16	4.4		42		
17	1.3		43		
18	-0.3		44		
19	-2.0		45		
20	3.6		46		
21	1.1		47		
22	-1.5		48		
23	0.1		49		
24	2.6		50		
25	2.2		51		

Location	20-1	Name:	Rwamanyonyi

Rwamanyonyi village VES 20-1

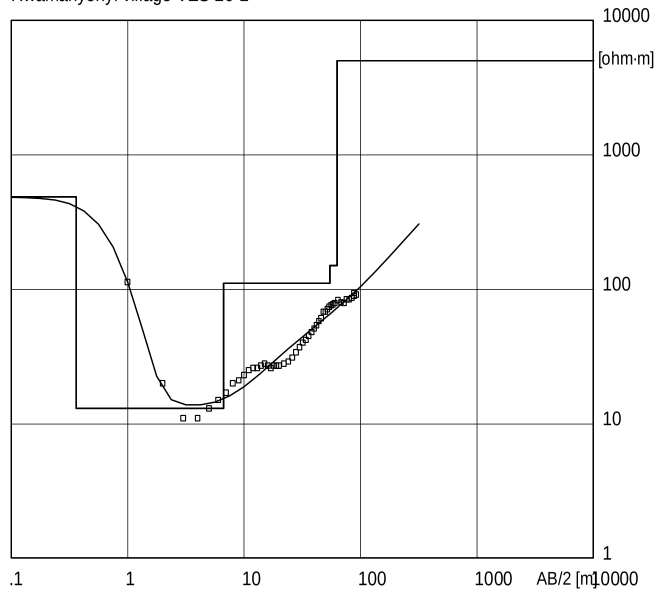


Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
327	.49		144
28	9.3	.49	143.5
85	55	9.8	134.2
150	10	65	79
5000		75	69

Comments: The VES was carried out at station 15 of profile 16 .
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

Location	20-2	Name:	Rwamanyonyi

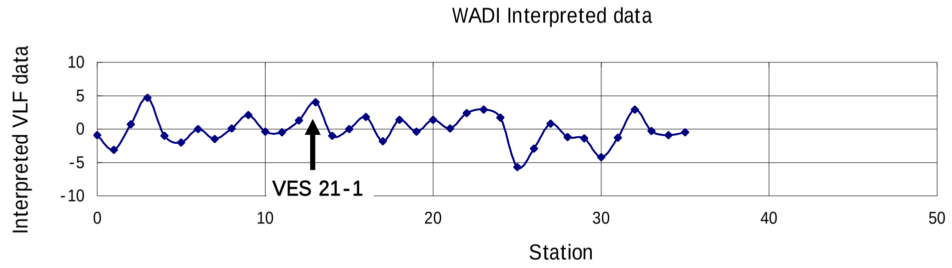
Rwamanyonyi village VES 20-2



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
487	.36		144
13	6.3	.36	143.6
111	48	6.7	137.3
150	8	55	89
5000		63	81

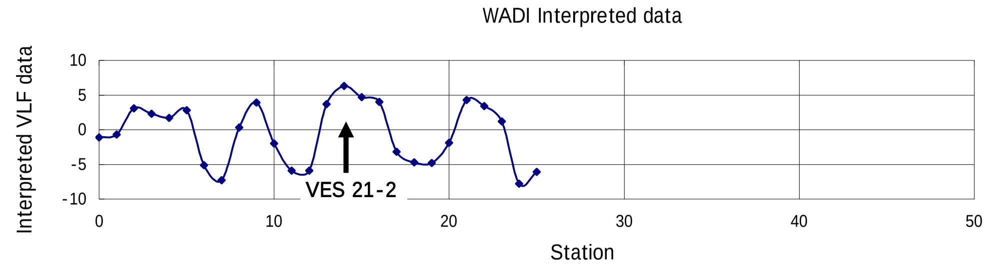
Comments: The VES was carried out at station 5 of profile 17 .
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

Location:	21-1	Date:	07/23/2009	
Village:	Kageyo	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 50'38.2"	E 30 39'35.5"
District:	Kayonza	End profile:	S 01 50' 36.7"	E 30 39'48.0"



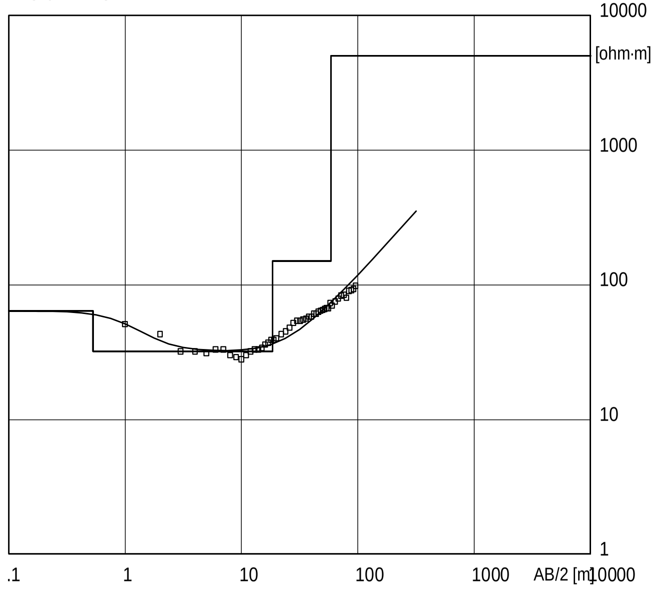
Station interval 10m	Interpreted WADI Value(kHz) Profile:2	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:2	Remarks
0	-0.9		26	-2.9	
1	-3.1		27	0.8	
2	0.7	Parallel to a borehole not functioning	28	-1.2	
3	4.7		29	-1.4	
4	-1.0		30	-4.2	
5	-2.0		31	-1.3	
6	0.0		32	2.9	
7	-1.5		33	-0.3	
8	0.1		34	-0.9	
9	2.1		35	-0.5	
10	-0.4		36		
11	-0.5		37		
12	1.3		38		
13	4.0		39		
14	-1.0		40		
15	0.0		41		
16	1.8		42		
17	-1.8		43		
18	1.4		44		
19	-0.4		45		
20	1.4		46		
21	0.1		47		
22	2.4		48		
23	2.9		49		
24	1.7		50		
25	-5.7		51		

Location:	21-2	Date:	07/23/2009	
Village:	Kageyo	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 50'36.4"	E 30 39'34.3"
District:	Kayonza	End profile:	S 01 50' 32.3"	E 30 39'26.9"



Station interval 10m	Interpreted WADI Value(kHz) Profile:3	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:3	Remarks
0	-1.1	road edge	26		
1	-0.7		27		
2	3.1		28		
3	2.3		29		
4	1.7		30		
5	2.8		31		
6	-5.1		32		
7	-7.3		33		
8	0.3		34		
9	3.9		35		
10	-2.0		36		
11	-5.9		37		
12	-5.9		38		
13	3.7		39		
14	6.3		40		
15	4.7		41		
16	4.0		42		
17	-3.2		43		
18	-4.7		44		
19	-4.8		45		
20	-1.9		46		
21	4.3		47		
22	3.4		48		
23	1.2		49		
24	-7.8		50		
25	-6.1		51		

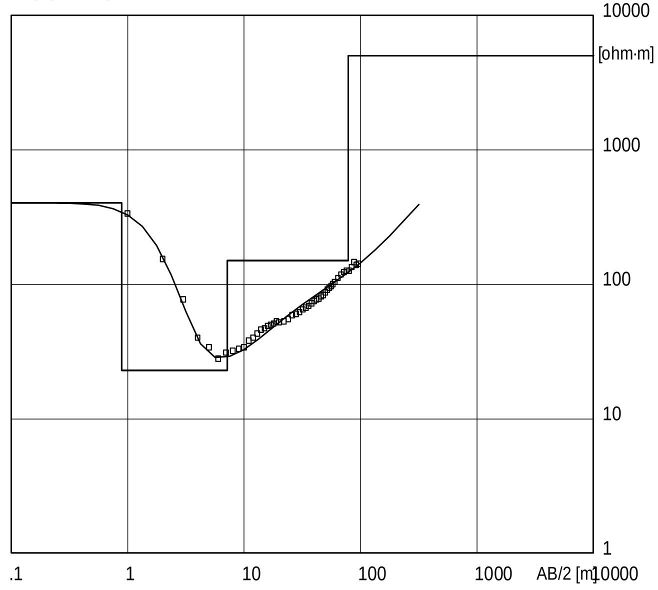
Location 21-1 **Name:** Kageyo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
64	.53		150
32	18	.53	149.5
150	40	19	131
5000		59	91

Comments: The VES was carried out at station 13 of profile 16 . Interpreted layers are: top soil, clay, weathered formation and hard rock

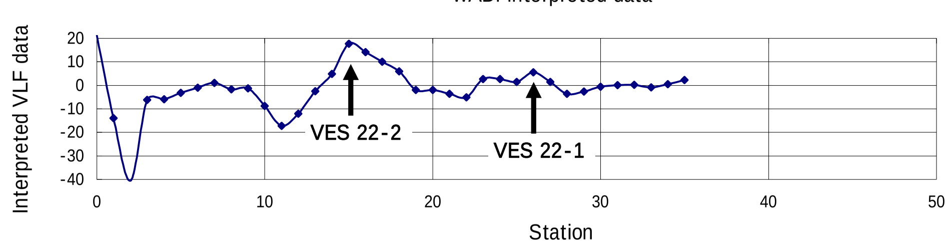
Location 21-2 **Name:** Kageyo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
404	.89		150
23	6.3	.89	149.1
150	71	7.2	142.8
5000		78	72

Comments: The VES was carried out on station 14 of profile 3 . Interpreted layers are: top soil, clay, weathered formation and hard rock

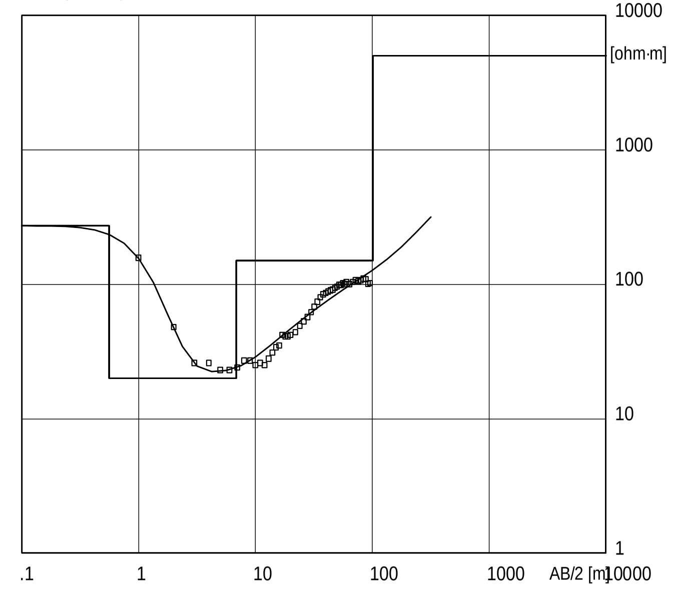
Location:	22-1	Date:	07/23/2009	
Village:	Ndago	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 53'35.7"	E 30 37'03.7"
District:	Kayonza	End profile:	S 01 53' 40.6"	E 30 37'53.7"



Station interval 10m	Interpreted WADI Value(kHz)		Station interval 10m	Interpreted WADI Value(kHz)	
	Profile:1	Remarks		Profile:1	Remarks
0	21.2	middle slope	26	5.6	
1	-14.0		27	1.4	
2	-40.5		28	-3.6	
3	-6.2		29	-2.6	
4	-5.9		30	-0.6	
5	-3.2		31	0.1	
6	-1.0		32	0.2	
7	1.0		33	-0.8	
8	-1.7		34	0.5	in accessible
9	-1.3		35	2.3	
10	-8.8		36		
11	-17.2		37		
12	-12.1		38		
13	-2.5	centre of valley	39		
14	4.8		40		
15	17.7		41		
16	14.1		42		
17	10.1		43		
18	6.0		44		
19	-2.0		45		
20	-1.9		46		
21	-3.6		47		
22	-5.1		48		
23	2.7		49		
24	2.7		50		
25	1.4		51		

Location 22-1 Name: Ndago

Ndango village VES 22-1

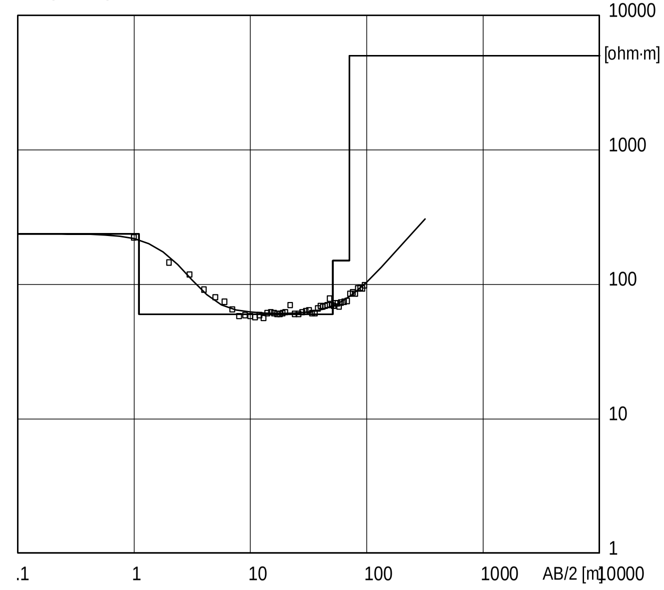


Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
273	.56		153
20	6.3	.56	152.4
150	94	6.9	146.1
5000		101	52

Comments: The VES was carried out at station 26 of profile 1 .
Interpreted layers are: top soil,
clay, weathered formation and hard rock

Location 22-2 Name: Ndago

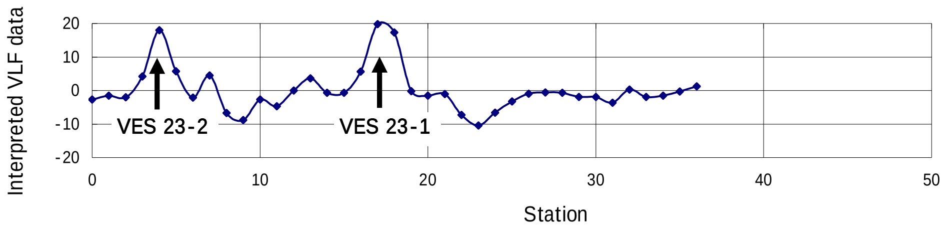
Ndago village VES 22-2



Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
237	1.1		153
60	50	1.1	151.9
150	20	51	102
5000		71	82

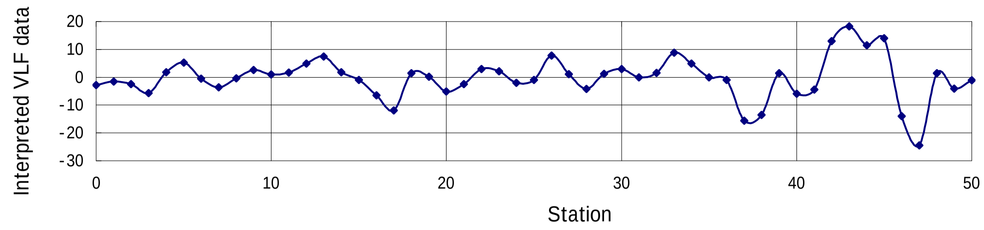
Comments: The VES was carried out at station 15 of profile 1 .
Interpreted layers are: top soil,
sandy clay, weathered formation and hard rock

Location:	23-1	Date:	07/24/2009	
Village:	Kageyo	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 49'45.7"	E 30 38'41.1"
District:	Kayonza	End profile:	S 01 49' 42.7"	E 30 38'29.7"



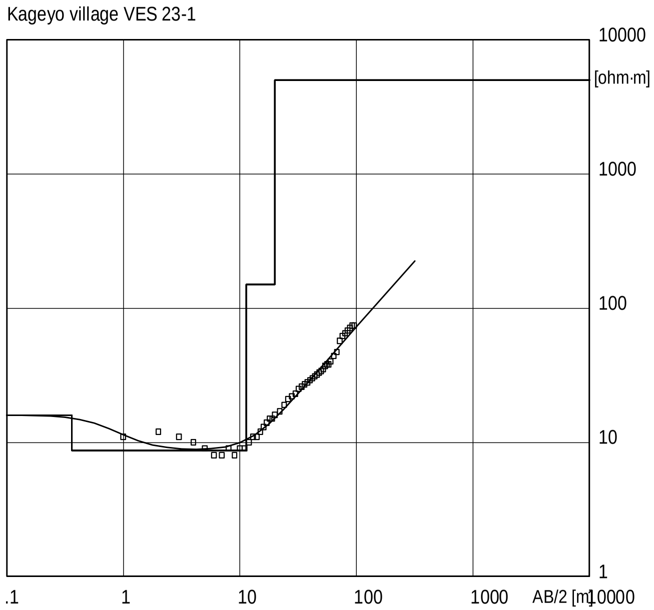
Station interval 10m	Interpreted WADI Value(kHz) Profile:6	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:6	Remarks
0	-2.7		26	-1.0	
1	-1.5		27	-0.6	
2	-2.0		28	-0.7	
3	4.2		29	-1.9	
4	18.0		30	-1.9	
5	5.7		31	-3.6	
6	-2.1		32	0.3	
7	4.5		33	-1.9	
8	-6.7		34	-1.5	
9	-8.8		35	-0.3	
10	-2.7		36	1.2	swampy area
11	-4.7		37		
12	0.0		38		
13	3.6		39		
14	-0.7		40		
15	-0.7		41		
16	5.6		42		
17	19.8		43		
18	17.3		44		
19	-0.2		45		
20	-1.5		46		
21	-1.1		47		
22	-7.3		48		
23	-10.4		49		
24	-6.6		50		
25	-3.3		51		

Location:	23-2	Date:	07/24/2009	
Village:	Kageyo	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 49'49.2"	E 30 38'37.4"
District:	Kayonza	End profile:	S 01 49' 31.7"	E 30 38'40.6"



Station interval 10m	Interpreted WADI Value(kHz) Profile:7	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:7	Remarks
0	-2.8		26	7.8	
1	-1.6		27	1.1	
2	-2.5		28	-4.2	
3	-5.7		29	1.2	
4	1.8		30	2.9	
5	5.2		31	0.0	
6	-0.5		32	1.6	
7	-3.6		33	8.8	
8	-0.4		34	4.9	
9	2.6		35	-0.1	
10	1.0		36	-1.0	
11	1.7		37	-15.6	
12	4.9		38	-13.5	
13	7.4		39	1.5	
14	1.8		40	-5.9	
15	-1.0		41	-4.4	
16	-6.5		42	13.0	
17	-11.9		43	18.3	
18	1.4		44	11.5	
19	0.2		45	14.0	
20	-5.1		46	-14.0	
21	-2.5		47	-24.5	
22	2.9		48	1.4	
23	2.1		49	-4.1	
24	-2.0		50	-1.1	
25	-1.0		51		

Location 23-1	Name: Kageyo

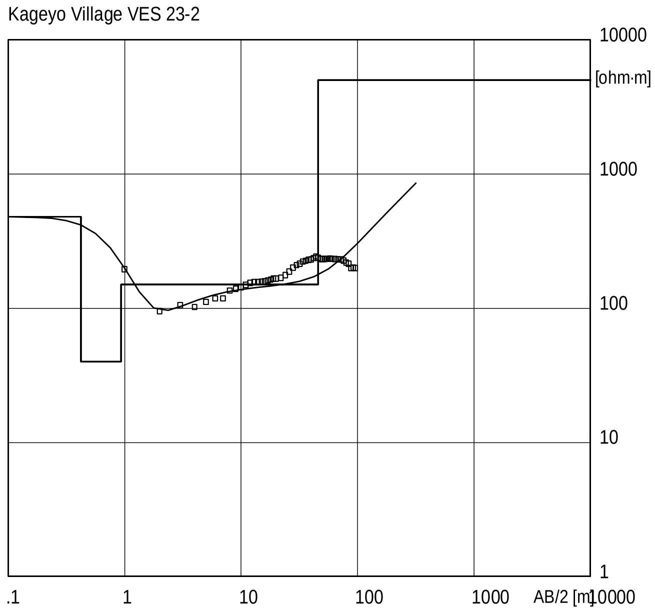


Location X = 30 38' 36.0 Y = 1 49' 43.7 Z = 1318 Azim = 200/20

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
16	.36		1318
8.7	11	.36	1317.6
150	8.6	11	1307
5000		20	1298

Comments: The VES was carried out at station 17 of profile 6 . Interpreted layers are: top soil, clay, weathered formation and hard rock

Location 23-2	Name: Kageyo

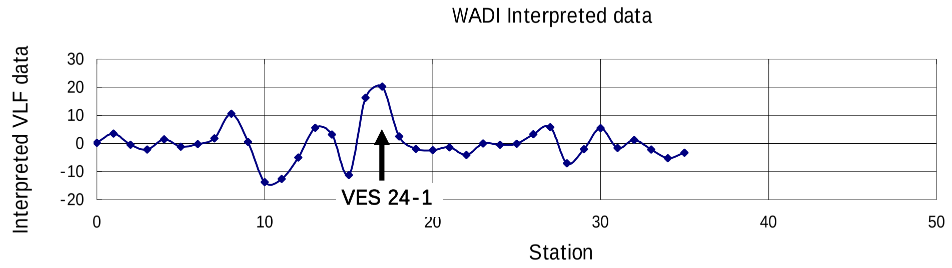


Location X = 030 38' 41.2 Y = 1 49' 45.3 Z = 1323 Azim = 40/220

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]	Altitude [m]
481	.42		1323
40	.51	.42	1322.6
150	45	.93	1322.1
5000		46	1277

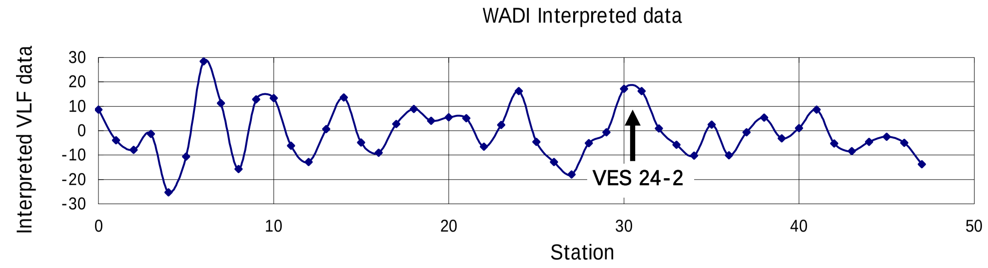
Comments: VES was carried at station 5 of profile 6. Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	24-1	Date:	07/24/2009	
Village:	Kageyo	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 50'19.2"	E 30 40'09.5"
District:	Kayonza	End profile:	S 01 50' 30.1"	E 30 40'09.1"



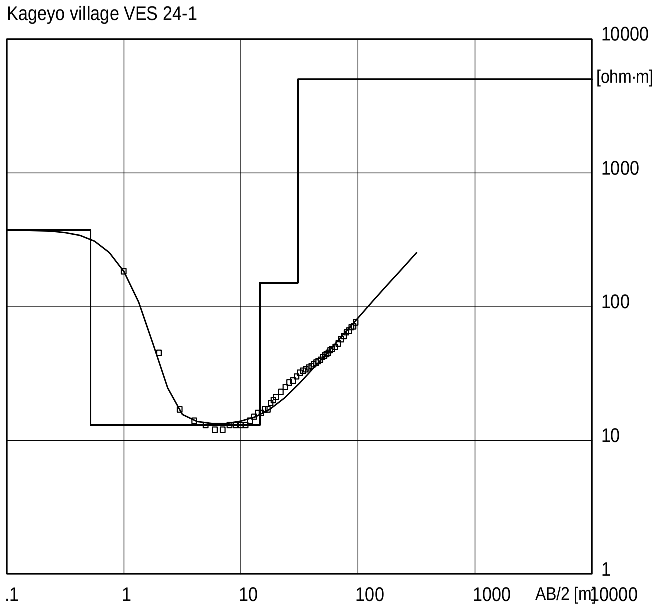
Station interval 10m	Interpreted WADI Value(kHz) Profile:4	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:4	Remarks
0	0.2		26	3.3	
1	3.5		27	5.8	
2	-0.5		28	-7.0	
3	-2.2		29	-2.1	
4	1.5		30	5.5	
5	-1.1		31	-1.6	
6	-0.2	start o valley	32	1.2	
7	1.8		33	-2.2	upper slope
8	10.6		34	-5.2	
9	0.6		35	-3.3	
10	-13.7		36		
11	-12.6		37		
12	-5.0		38		
13	5.6		39		
14	3.2		40		
15	-11.3		41		
16	16.2	centre of valley	42		
17	20.2		43		
18	2.5		44		
19	-1.9		45		
20	-2.4		46		
21	-1.4		47		
22	-4.1		48		
23	0.0		49		
24	-0.4		50		
25	-0.1		51		

Location:	24-2	Date:	07/24/2009	
Village:	Kageyo	Profiles:	Latitude	Longitude
Sector:	Mwiri	Start profile:	S 01 50'21.6"	E 30 40'14.2"
District:	Kayonza	End profile:	S 01 50' 27.2"	E 30 39'59.9"



Station interval 10m	Interpreted WADI Value(kHz) Profile:5	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:5	Remarks
0	8.7	upper slope	26	-12.9	
1	-3.9		27	-17.9	
2	-7.8		28	-5.1	
3	-1.3		29	-0.6	
4	-25.3		30	17.2	
5	-10.6		31	16.2	
6	28.4		32	0.9	
7	11.3		33	-5.8	
8	-15.7		34	-10.2	
9	12.8		35	2.5	
10	13.3		36	-10.1	
11	-6.1		37	-0.7	
12	-12.9		38	5.4	
13	0.7	centre of vally	39	-3.1	
14	13.6		40	1.0	
15	-4.9		41	8.7	
16	-9.0		42	-5.2	
17	2.8		43	-8.4	
18	8.9		44	-4.6	
19	4.0		45	-2.5	lower slope
20	5.5		46	-5.0	
21	5.1		47	-13.7	
22	-6.6		48		
23	2.3		49		
24	16.2		50		
25	-4.6		51		

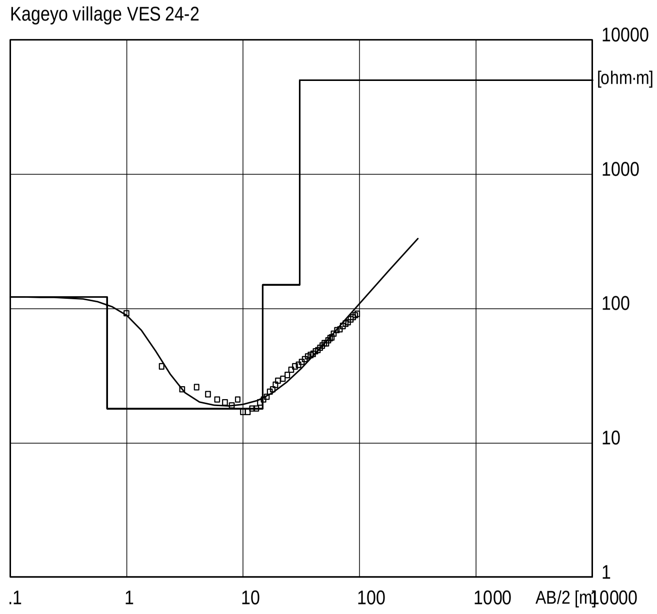
Location 24-1 **Name:** Kageyo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
374	.52		150
13	14	.52	149.5
150	16	15	135
5000		31	119

Comments: The VES was carried out on station 17 of profile 4 . Interpreted layers are: top soil, clay, weathered formation and hard rock

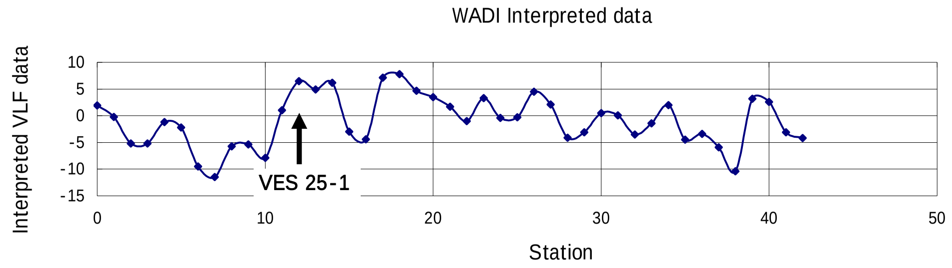
Location 24-2 **Name:** Kageyo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
122	.68		150
18	14	.68	149.3
150	16	15	135
5000		31	119

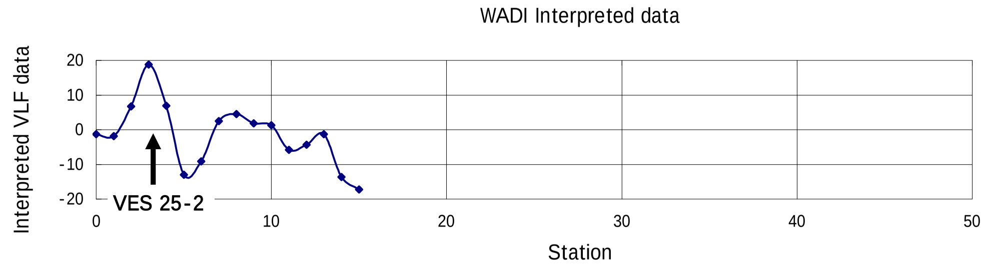
Comments: The VES was carried out at station 30 of profile 5 . Interpreted layers are: top soil, clay, weathered formation and hard rock

Location:	25-1	Date:	07/25/2009	
Village:	Nyamirambo	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 49'26.6"	E 30 34'11.3"
District:	Kayonza	End profile:	S 01 49' 39.8"	E 30 34'08.4"



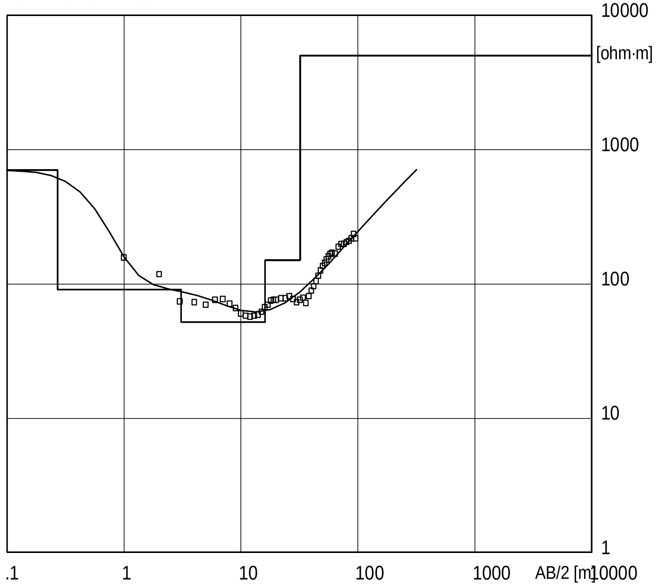
Station interval 10m	Interpreted WADI Value(kHz) Profile:8	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:8	Remarks
0	1.9	Lower slope	26	4.5	
1	-0.2		27	2.1	
2	-5.2		28	-4.1	
3	-5.2		29	-3.1	
4	-1.2		30	0.5	
5	-2.2		31	0.1	
6	-9.5		32	-3.5	Protected spring
7	-11.5		33	-1.4	
8	-5.7		34	2.0	
9	-5.4		35	-4.5	
10	-7.9		36	-3.4	Start of wetland
11	1.0		37	-5.9	
12	6.5		38	-10.4	
13	4.9		39	3.2	
14	6.2		40	2.6	
15	-3.0		41	-3.1	
16	-4.4		42	-4.2	
17	7.1		43		
18	7.8	Parpendicular to station 3 of profile 9	44		
19	4.7		45		
20	3.5		46		
21	1.7		47		
22	-1.0		48		
23	3.3		49		
24	-0.4		50		
25	-0.3		51		

Location:	25-2	Date:	07/25/2009	
Village:	Nyamirambo	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 49'32.5"	E 30 34'07.8"
District:	Kayonza	End profile:	S 01 49' 32.1"	E 30 34'14.6"



Station interval 10m	Interpreted WADI Value(kHz) Profile:9	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:9	Remarks
0	-1.3		26		
1	-1.8		27		
2	6.7		28		
3	18.8		29		
4	6.9		30		
5	-13.0		31		
6	-9.1		32		
7	2.5		33		
8	4.5		34		
9	1.8		35		
10	1.3		36		
11	-5.8		37		
12	-4.3		38		
13	-1.3		39		
14	-13.6		40		
15	-17.2		41		
16			42		
17			43		
18			44		
19			45		
20			46		
21			47		
22			48		
23			49		
24			50		
25			51		

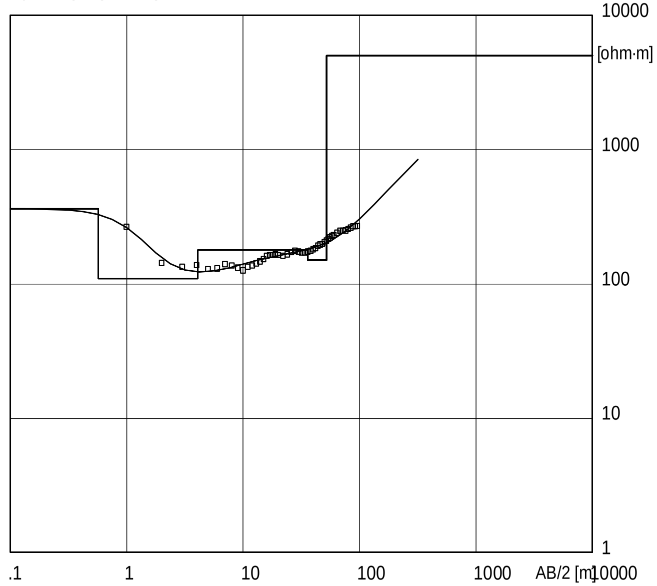
Location 25-1 **Name:** Nyamirambo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
706	.27		149
91	2.8	.27	148.7
52	13	3.1	145.9
150	16	16	133
5000		32	117

Comments: The VES was carried out at station 12 of profile 8 . Interpreted layers are: top soil, sandy clay, clay, weathered formation and hard rock

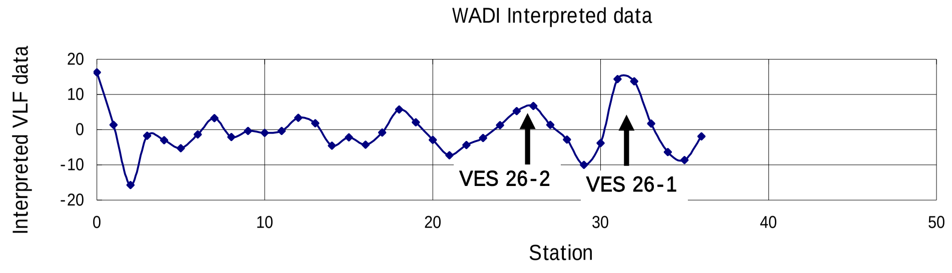
Location 25-2 **Name:** Nyamirambo



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
362	.57		149
110	3.5	.57	148.4
179	32	4.1	144.9
150	16	36	113
5000		52	97

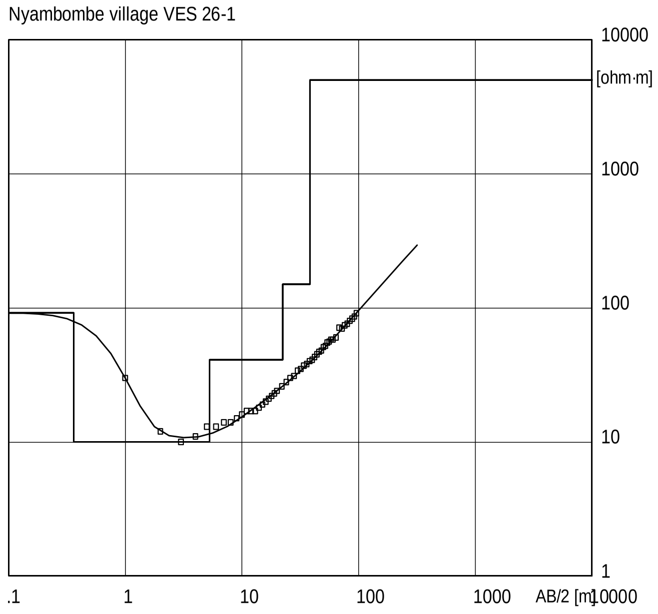
Comments: The VES was carried out at station 3 of profile 9. Interpreted layers are: top soil, sandy gravel, sany clay, weathered formation and hard rock

Location:	26-1	Date:	07/25/2009	
Village:	Nyabombe	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 49'35.3"	E 30 33'20.1"
District:	Kayonza	End profile:	S 01 49' 46.7"	E 30 33'25.1"



Station interval 10m	Interpreted WADI Value(kHz) Profile:10	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:10	Remarks
0	16.3	Parpendicular to station of 40 of profile 11	26	6.7	
1	1.4		27	1.4	
2	-15.7		28	-2.8	
3	-1.7		29	-10.0	
4	-3.0		30	-3.8	
5	-5.3		31	14.4	Parallel to a gravity scheme source
6	-1.4		32	13.7	
7	3.3		33	1.7	
8	-2.1		34	-6.4	
9	-0.4		35	-8.6	
10	-0.9		36	-1.9	Flooding zone
11	-0.4		37		
12	3.4		38		
13	1.8		39		
14	-4.5		40		
15	-2.2		41		
16	-4.3		42		
17	-0.8		43		
18	5.7		44		
19	2.1		45		
20	-2.9		46		
21	-7.3	unprotected spring	47		
22	-4.4		48		
23	-2.4		49		
24	1.3		50		
25	5.3		51		

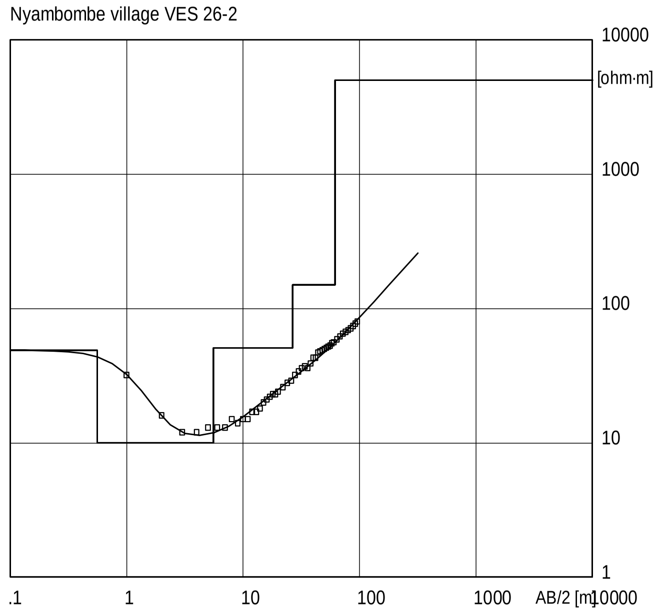
Location	26-1	**Name:**	Nyabombe



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
92	.36		149
10	4.9	.36	148.6
41	17	5.3	143.7
150	16	22	127
5000		38	111

Comments: The VES was carried out at station 31 of profile 10.
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

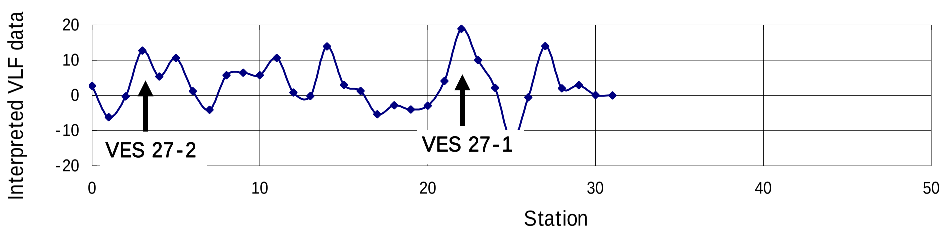
Location	26-2	**Name:**	Nyabombe



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
49	.56		149
10	5	.56	148.4
51	21	5.6	143.4
150	35	27	122
5000		62	87

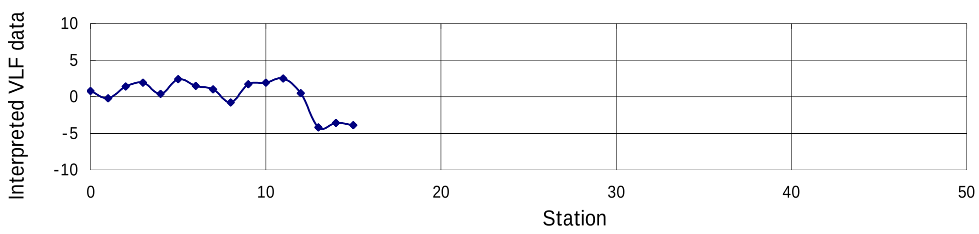
Comments: The VES was carried out at station 26 of profile 10.
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

Location:	27-1	Date:	07/27/2009	
Village:	Juru	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 48'54.9"	E 30 32'15.6"
District:	Kayonza	End profile:	S 01 48' 52.1"	E 30 32'05.8"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:14	Remarks	10m	Profile:14	Remarks
0	2.7	upper slope	26	-0.5	
1	-6.2		27	14.0	inaccessible swamp
2	-0.3		28	2.0	
3	12.7		29	2.9	
4	5.4		30	0.1	
5	10.6		31	0.0	
6	1.2		32		
7	-4.1		33		
8	5.7		34		
9	6.5		35		
10	5.7		36		
11	10.6		37		
12	0.8		38		
13	-0.2		39		
14	13.9		40		
15	3.0		41		
16	1.3		42		
17	-5.4		43		
18	-2.8		44		
19	-4.0		45		
20	-2.9		46		
21	4.1		47		
22	18.9		48		
23	10.0		49		
24	2.2		50		
25	-12.8		51		

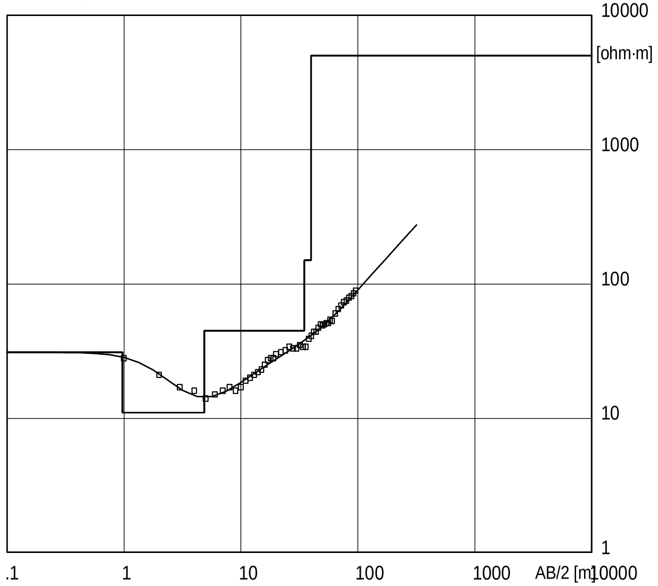
Location:	27-2	Date:	07/27/2009	
Village:	Juru	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 48'58.4"	E 30 32'12.0"
District:	Kayonza	End profile:	S 01 49' 01.0"	E 30 32'06.8"



Station interval	Interpreted WADI Value(kHz)		Station interval	Interpreted WADI Value(kHz)	
10m	Profile:15	Remarks	10m	Profile:15	Remarks
0	0.8		26		
1	-0.2		27		
2	1.4		28		
3	1.9		29		
4	0.4		30		
5	2.4		31		
6	1.5		32		
7	1.0		33		
8	-0.8		34		
9	1.7		35		
10	1.9		36		
11	2.5		37		
12	0.5		38		
13	-4.2		39		
14	-3.6		40		
15	-3.9		41		
16			42		
17			43		
18			44		
19			45		
20			46		
21			47		
22			48		
23			49		
24			50		
25			51		

Location 27-1 Name: Juru

Juru village VES 27-1



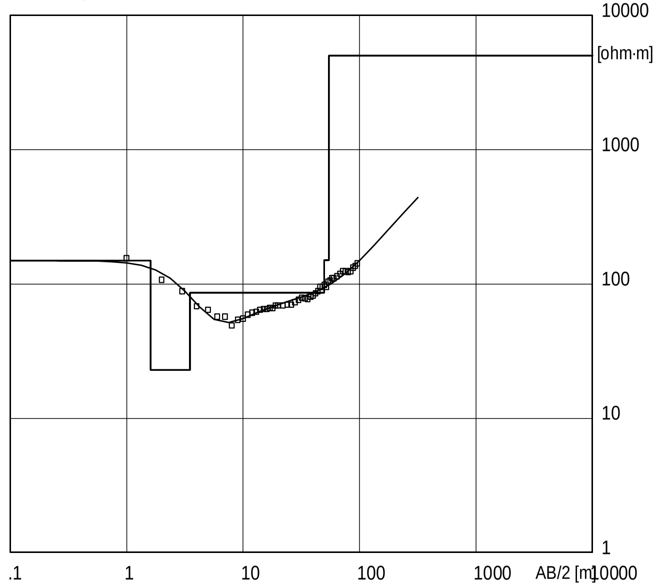
Location X = 30 32' 08.7 Y = 1 48' 52.8 Z = Azim = 1416

Model Resistivity	Thickness	Depth
[ohm·m]	[m]	[m]
31	.97	
11	3.9	.97
45	30	4.9
150	5	35
5000		40

Comments: The VES was carried out at station 22 of profile 14. Interpreted layers are: top soil, clay, sandy clay, weathered formation and hard rock

Location 27-2 Name: Juru

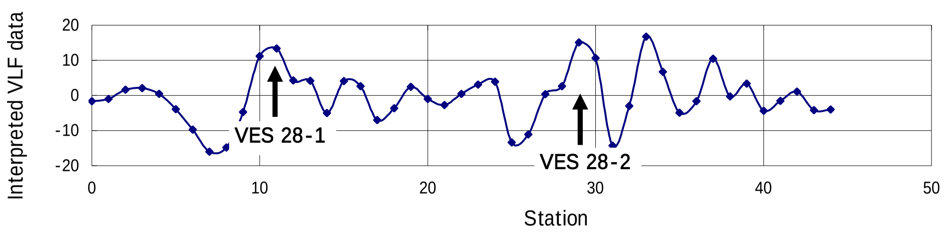
Juru village VES 27-2



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
149	1.6		148
23	1.9	1.6	146.4
86	46	3.5	144.5
150	5	50	98
5000		55	93

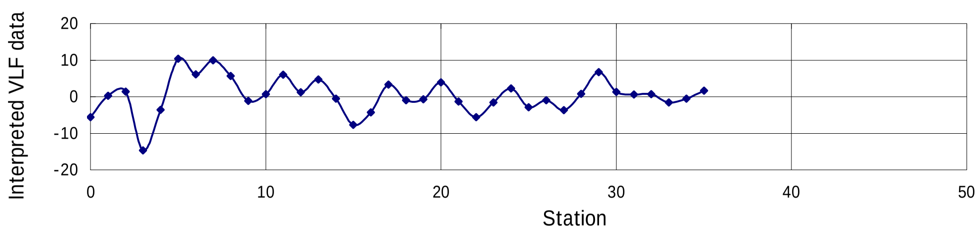
Comments: The VES was carried out on station 3 of profile 14. Interpreted layers are: top soil, clay, sandy clay, weathered formation and hard rock

Location:	28-1	Date:	07/27/2009	
Village:	Juru	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 48'32.4"	E 30 32'12.0"
District:	Kayonza	End profile:	S 01 48' 28.4"	E 30 31'56.4"



Station interval 10m	Interpreted WADI Value(kHz) Profile:12	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:12	Remarks
0	-1.6		26	-11.1	
1	-1.0		27	0.4	
2	1.6		28	2.6	
3	2.1		29	15.1	
4	0.5		30	10.6	
5	-3.9		31	-14.3	
6	-9.7		32	-3.0	
7	-16.0		33	16.7	Flooding zone
8	-14.8		34	6.7	
9	-4.7		35	-4.9	
10	11.2		36	-1.6	
11	13.4		37	10.5	
12	4.3		38	-0.3	
13	4.2		39	3.4	
14	-5.0		40	-4.4	
15	4.1		41	-1.5	
16	2.6		42	1.1	
17	-7.0		43	-4.2	
18	-3.6		44	-4.0	
19	2.5		45		
20	-1.0		46		
21	-2.7		47		
22	0.5		48		
23	3.1		49		
24	3.9		50		
25	-13.4		51		

Location:	28-2	Date:	07/27/2009	
Village:	Juru	Profiles:	Latitude	Longitude
Sector:	Gahini	Start profile:	S 01 48'34.1"	E 30 32'14.4"
District:	Kayonza	End profile:	S 01 48' 37.8"	E 30 32'03.5"



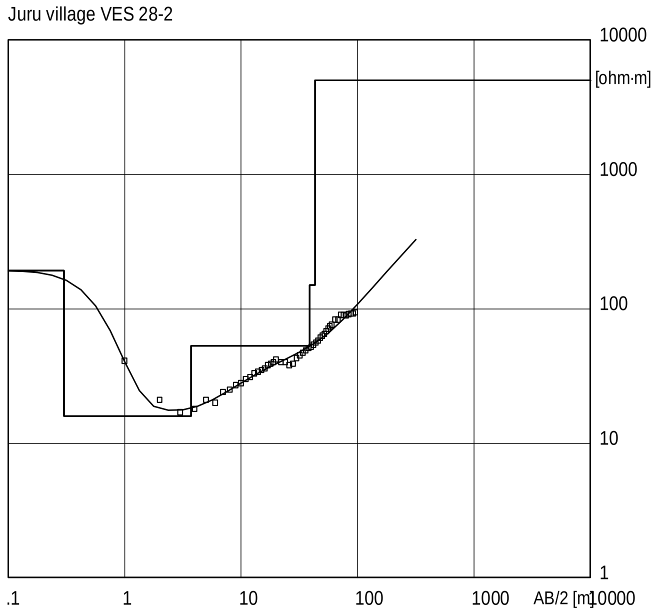
Station interval 10m	Interpreted WADI Value(kHz) Profile:13	Remarks	Station interval 10m	Interpreted WADI Value(kHz) Profile:13	Remarks
0	-5.6		26	-1.0	
1	0.3		27	-3.7	
2	1.4		28	0.8	
3	-14.7		29	6.7	
4	-3.6		30	1.3	
5	10.4		31	0.6	
6	6.1		32	0.7	
7	10.0		33	-1.6	
8	5.7		34	-0.5	
9	-1.1		35	1.7	
10	0.7		36		
11	6.0		37		
12	1.2		38		
13	4.7		39		
14	-0.5		40		
15	-7.7		41		
16	-4.3		42		
17	3.3		43		
18	-1.0		44		
19	-0.7		45		
20	3.9		46		
21	-1.3		47		
22	-5.6		48		
23	-1.6		49		
24	2.3		50		
25	-2.9		51		

Location 28-1 **Name:** Juru

Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
189	2		148
20	3.3	2	146
111	75	5.3	142.7
150	5	80	68
5000		85	63

Comments: The VES was carried out at station 11 of profile 12.
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

Location 28-2 **Name:** Juru



Model Resistivity	Thickness	Depth	Altitude
[ohm·m]	[m]	[m]	[m]
193	.3		148
16	3.4	.3	147.7
53	35	3.7	144.3
150	4.4	39	109
5000		43	105

Comments: The VES was carried out at station 29 of profile 12.
Interpreted layers are: top soil,
clay, sandy clay, weathered formation and hard rock

Annex 6. Drilling supervision guidelines and forms

Rural Water Supply Network

Field Note No 2012-2

Dotun Adekile

2012

Supervising Water Well Drilling

A Guide for Supervisors

Summary

Good supervision of water well drilling is essential for the provision of long-lasting water wells. This guidance note assists geologists and engineers in charge of the supervision of borehole construction as well as project managers. It can be used to prepare for training, and as a manual.

This guide details the responsibilities of the drilling supervisor at the different stages of borehole construction. It explains the actions to be carried out at each stage that will ensure that the driller delivers the borehole as specified in the contract.

The supervisor is expected to display great professionalism in carrying out his or her duties. A good knowledge of geology, hydrogeology and borehole construction is essential. Although the supervisor represents the client, he or she is expected to act with honesty, impartiality and fairness in any dispute over the contract. Young drilling supervisors need to be supported by more experienced personnel.

The publication part of a series by RWSN on Cost Effective Boreholes alongside:

- Code of Practice for Cost Effective Boreholes (Danert et al, 2010)
- Sustainable Groundwater Development: use, protect and enhance (Furey, 2012)
- Siting of Drilled Water Wells: A Guide for Project Managers (Carter et al, 2011)
- Costing and Pricing: A Guide for Water Well Drilling Enterprises (Danert et al, 2010)
- Procurement and Contract Management of Drilled Well Construction: A Guide for Supervisors and Project Managers (Adekile, 2012)

It is assumed that readers will have access to the other documents, all of which are available on the RWSN website http://www-rural-water-supply.net.

Contents

Introduction

There is currently a big push to meet the Millennium Development Goals target for drinking water. Soon the world may be talking about universal access. Whilst this is positive, it is important that quality is not compromised in the drive to serve more people. A poorly constructed borehole can fail after one year, resulting in wasted investment and disappointed users. If drilling and construction are not adequately supervised by trained professionals, corners may be cut, quality will be compromised and services will fail. Governments, NGOs and agencies have a responsibility to ensure that quality is not compromised by a lack of drilling supervision.

Groundwater sources, namely wells and boreholes, are often the first choice of water source for supplying rural areas. It is estimated that 1.25 billion people directly use boreholes for their drinking water (WHO/UNICEF 2012). If one assumes that 40% of the sources for drinking water through piped supplies are from boreholes, then 2.9 billion people (42% of the world's population) depend on drilled water wells. Groundwater sources are found in most places and are relatively easy and cheap to install. They are also not as prone to pollution as other sources of water.

It is crucial that boreholes are delivered in a cost effective manner. Cost effectiveness means getting the long-term best value for money invested, i.e. boreholes continue to function through the lifespan of 20 to 50 years. In some African countries, as many as 60% of groundwater sources are not working. Poor borehole construction contributes to this alarming figure. One of the best ways to tackle this problem is to improve the quality and professionalism of water well drilling including supervision.

Box 1: Why is good supervision important?

Abuja, Nigeria: The expected drilling depth was 35m. The Supervisor was late to site. When he arrived the driller was already at 60m depth, claiming little water was encountered at 35m and he had to continue. It was obvious he was only doing it to earn more metres, but it could not be proven. The clause in the contract that drilling should not commence without the Supervisor on site could be invoked but as a one-off case, the Driller's claim was accepted. Conclusion: the Supervisor should not keep the driller waiting.

Lagos, Nigeria: A telescopic design was specified. A large-diameter hole was drilled, cased and grouted in, and then drilling through the grout was performed with a smaller diameter *bit*. The grouting failed, and an eruption of sand and water occurred. Two truck-loads of sand were carted away from the site. The Driller said he was not used to the method specified and he would have used another method to achieve the design. A senior hydrogeologist in the Ministry of Water Resources was asked to arbitrate. He blamed the Supervisor for not using a pre-contract meeting to establish the ability of the Driller to execute the design. He blamed the Driller for not proposing a method within his competence. Conclusion: establish a common understanding with the Driller, in writing, before drilling starts.

In 2010, the Rural Water Supply Network (RWSN) published the Code of Practice for Cost Effective Boreholes based on international best practices. The Code of Practice focuses on nine principles (Box 2). These enable international organisations, private enterprises and NGOs to evaluate their approach to borehole delivery in accordance with good international practices. To strengthen the *Code of Practice* and support practitioners in the practical application of the principles, RWSN is publishing detailed guidance documents to cover all the principles.

This guidance note is part of the series and focuses on Supervision, which falls within Principle 6, which recommends that "*Supervision should be undertaken by government personnel or by the private sector; additional expertise can be brought in to cover capacity gaps with a view to build up long-term expertise*". RWSN identified that there is a capacity gap in water well drilling supervision. Hence this guide is aimed at inexperienced drilling Supervisors e.g. fresh geology and engineering graduates, general technicians and project managers. By applying this guidance, the reader should be able to reduce overall drilling costs, improve the quality of the finished borehole, and create a useful set of written records that will help rural water supply service managers operate and maintain that water source for many years.

To get the most from this guide, the reader should have a good knowledge of groundwater occurrence and drilling practices, and use the guide in conjunction with the other *Code of Practice* publications (listed in the summary on page 2). Note also the glossary of technical terms (page 17), *italicised* in the text.

Box 2: Nine principles of Cost Effective Boreholes

1	**Professional Drilling Enterprises and Consultants** - Construction of drilled water wells and supervision is undertaken by professional and competent organisations which adhere to national standards and are regulated by the public sector.
2	**Siting** - Appropriate siting practices are utilised and competently and scientifically carried out.
3	**Construction Method** - The construction method chosen for the borehole is the most economical, considering the design and available techniques in-country. Drilling technology needs to match the borehole design.
4	**Procurement** - Procurement procedures ensure that contracts are awarded to experienced and qualified consultants and drilling contractors.
5	**Design and Construction** - The borehole design is cost effective, designed to last for a lifespan of 20 to 50 years, and based on the minimum specification to provide a borehole which is fit for its intended purpose.
6	**Contract Management, Supervision and Payment** - Adequate arrangements are in place to ensure proper contract management, supervision and timely payment of the drilling contractor.
7	**Data and Information** – High-quality hydrogeological and borehole construction data for each well are collected in a standard format and submitted to the relevant government authority.
8	**Database and Record Keeping** - Storage of hydrogeological data is undertaken by a central Government institution with records updated and information made freely available and used in preparing subsequent drilling *specifications*.
9	**Monitoring** - Regular visits to water users with completed boreholes are made to monitor functionality in the medium as well as long-term, with the findings published.

Principles of Drilling Supervision

Aims, Roles and Responsibilities

The aim of supervising borehole drilling is to ensure that boreholes are produced as designed and all the data collected during the drilling are accurately recorded and reported to the relevant agencies. Good supervision is essential for a high quality borehole, even if a competent drilling contractor (henceforth referred to as the 'Driller') is employed. Without good supervision, the quality of the work may be compromised. An experienced Driller can easily hoodwink an inexperienced Supervisor. Supervisors thus need to be trained and given the chance to acquire the knowledge that will enable them carry out their duties.

Box 3: Drilling Roles and Responsibilities

The **Community** members are the end users of the water supply. They must be included in the process of siting and design so that the finished water point can meet their needs. There are cases where the Community is involved in supervision, but they should not be responsible for technical or contractual details unless their capacity has been built extensively.
The **Client** is the organisation or community that is contracting out the borehole construction. Their responsibility is to fulfil regulatory requirements and ensure that they have well trained Supervisors present on site for the full duration of drilling operations.
Note that even if **district local government** is not the client, it is still important for them to be involved in the process. District local government should attend the pre-mobilisation meeting as well as the end of construction supervision.
The **Funding Organisation** pays for the borehole. It may be the Client, or another organisation such as an international development partner or NGO. The funding organisation should not impose conditions that create perverse incentives or undermine the long-term sustainability of the finished borehole (e.g. by insisting that the cheapest bid is accepted regardless of quality). It should work within national or local government systems.
The **Regulator** issues permits or licences for drilling or abstraction. Legal requirements should be established by the Client early on to avoid delays.
The **Project Manager** is usually responsible for a wider project. The drilling will be just one component within a project plan comprising community training/mobilisation, pump technology choice, water point design and construction, and establishing or strengthening a rural water supply service.
The **Supervisor** is sometimes called the 'Rig Inspector'. Supervision is usually done either by the Client's staff or by a consultant. The Supervisor may be a hydrogeologist, an engineer, or a technician. Although the Driller and the Supervisor work together to deliver the product, their roles are different. The Supervisor's responsibility is to ensure that the Driller adheres to the *technical specification*, makes all the required measurements, keeps all records accurately and ensures that health and safety procedures are adhered to.
The **Driller, or Contractor**, is the organisation that physically does the drilling. Sometimes, this will be an independent private sector company. In other cases, it will be an in-house team working for a government agency or NGO. The Driller's responsibility is to drill the borehole as specified. Each Driller should have a designated 'Record Taker' who should remain on site at all times, with the duty to collate all the measurements and complete all the forms.

Levels of Supervision

There are three levels of drilling supervision:

1. **Full-time supervision:** a Supervisor stays with the drilling team throughout the drilling process, from the inspection to *demobilisation*. On large drilling programmes with multiple rigs, several Supervisors are deployed, and they stay in the Drillers' camp and go out with them each morning. While this supervision level is ideal, the resources needed are not always available.

2. **Part-time milestone supervision:** one Supervisor is in charge of several drilling rigs and may only witness crucial stages (milestones) of the drilling. The stages that must be carried out in the presence of the Supervisor need to be specified in the contract document and the consequences of not abiding by them stated. However, the Supervisor is expected to be promptly on site and should not cause undue delays. The milestones are:
   - *mobilisation*
   - check siting/site selection
   - termination of drilling
   - lining of the borehole
   - borehole development
   - pumping test
   - *demobilisation*
   - platform construction and pump installation (may be delegated, depending on contract).

The 'Record Keeper', one of the Driller team (Box 3) plays a very important role. He/she is designated to collating the measurements and preparing the forms at all stages of the process set out in the milestones above. This role should be specified in the contract documents.

Figure 1: Some kit – depth meter, electronic dipper, tape, EC and PH meters, Global Positioning System (GPS)

3. **End of contract supervision** is not actually supervision but a site inspection when the Supervisor goes through the records and inspects the functionality of the borehole on completion. Where this is the planned level, the supervising role of the community members is particularly important (Section 2.3). As in the case of part-time supervision, the role of the 'Record Taker' is also very important.

In all cases, the Supervisor requires a minimum level of equipment (Box 4) and needs to issue site instructions (Box 5).

Box 4: Supervisor Equipment

Vehicle: Ideally, the Supervisor should be independent. However, this may not be possible, in which case the Driller provides transport to and from the site.

Down-the-hole camera: useful for preventing arguments about casing lengths. In one example, a Supervisor carried out a camera survey of several boreholes on a project. The Driller had hurriedly drilled the boreholes not allowing any supervision. Several of the holes were found to be open holes whilst it was specified that they be lined. He had to re-drill them. Cameras are getting cheaper. Every project should have one.

Other: Boots; hard-hat; clipboard; notebook; duplicate book; digital camera; *global positioning system (GPS)* device; mobile phone; calliper; spirit level (for checking verticality of drill mast and pedestal as well as slope of run-off drains); dip meter; measuring tape; simple calibrated V-plate for measuring borehole yield, magnifying glass; stop watch; pH stick meters and calibrants; iron-checker disc and reagents; bottle of hydrochloric acid if limestone is predicted and a first aid kit.

Box 5: Site Instructions

The technical specification for the borehole should include the procedure for site instructions and the consequences for not abiding by them. Site instructions issued to the Driller by the Supervisor should be in writing in duplicate using carbon paper. The Driller should sign on the original and the duplicate instructions. The original is handed over to the Driller, and the Supervisor keeps the duplicate.

Community Involvement

Whichever level of supervision is adopted it is essential that community members are involved in the entire drilling process. This should foster the spirit of ownership and understanding of post-construction operation and maintenance. The need for this is even greater when either part-time supervision or end-of-project inspection is used.

Prior to the Driller's mobilisation or at the initial stages of the borehole construction, selected community members (school teachers, health workers, water users' association members) are taken through the drilling process and are taught how to:

- take the required measurements and record observations;
- keep daily records such as start and end times of drilling and any breaks, and the reasons for them;

- determine depth of drilling by counting the number of drill pipes lowered down;
- record depth and time of the first *water strike* and other strikes when drilling with air;
- count and record the length and number of casings and screens installed;
- count the number of bags of cement used;
- observe the installation of gravel and the sanitary seal, test pumping and whether borehole chlorination is undertaken.

From the information provided by the community supervision, the Supervisor can build an accurate account of the drilling progress which he/she can cross-check with the driller's daily log.

What can realistically be expected of the community will depend on their level of literacy and numeracy, too. It should also be clear that community involvement can never replace an experienced supervisor.

Borehole Construction Workflow and Steps

Figure 2 shows the borehole construction workflow and the responsibilities of the Driller and Supervisor at each step. This document is structured according to these steps. For each stage, a checklist for the Supervisor has been prepared (Annex B).

Figure 2: Borehole Construction Workflow

Steps in borehole construction	Driller's responsibilities	Supervisor's responsibilities
1. Inspection	Assemble equipment & personnel for inspection.	Inspect equipment and interview personnel.
2. Siting	Hydrogeological survey; geophysical survey; submit report.	Check equipment; provide guidance on siting borehole; approve siting report.
3. Pre-Mobilisation Meeting	Raise specific questions regarding the contract requirements.	Together with the client, thoroughly discuss the design, materials and procedures for each step of the contract.
4. Mobilisation	Submit program of work; submit samples of materials; move equipment to site.	Liaise with the community; approve drilling equipment & material; guide driller to site.
5. Drilling	Position and operate the rig; collect samples; report.	Monitor drilling; advise depth to stop drilling; log the borehole.
6. On-site Design Modifications	Install casing and screen; gravel pack; sanitary seal; report.	Instruct screening and casing depths; ensure gravel pack and sanitary seal properly placed.
7. Borehole development and site completion	Develop the hole; undertake test pumping; collect water sample; disinfect the hole.	Ensure water is clean; proper disinfection; supervise pumping test; ensure samples are taken and platform installed.
8. Demobilisation	Remove all equipment and rubbish from site; report.	Ensure the site is restored to its former state.
9. Complete documentation and handover	Submit all records. Hand over.	Hand over borehole to community. Report.

Step 1: Inspection

Aim: To verify the capabilities of the Driller BEFORE a contract is signed.

A pre-qualification inspection of equipment and personnel may be carried out as a pre-requisite for eligibility to tender, or as part of the tender process. This may be undertaken by the client, or a Supervisor may be engaged for this. It is essential to agree a date with the prospective Drillers. Minimum requirements vary from country to country, but Table 1 provides a list of essential equipment and personnel the Driller should have for a contract package of 10 boreholes from Nigeria. Supervision Checklist 1 (Annex B) shows the main aspects for inspection.

Where the Driller is required to carry out the geophysical survey for the siting of the boreholes, his capability for such surveys has to be determined. If the Driller proposes to employ a consultant to carry out the siting, the availability of the consultant should be confirmed and the equipment inspected and tested. The Driller's personnel or consultant should be a qualified hydrogeologist or geophysicist. Depending on the specification for the siting, the Driller should have a resistivity and electromagnetic meter, a *global positioning system (GPS)* and appropriate software for data interpretation. The sources of remote sensing tools, maps and existing borehole data should be confirmed.

When the Driller has been selected and the contract awarded, prior to mobilisation, the Driller should be asked to confirm the availability of the approved items of equipment

Table 1: Example of basic equipment and personnel required for a project of 10 boreholes

Type of Equipment	Personnel
1 drilling rig	1 drilling manager
1 *compressor*	1 hydrogeologist
1 mud pump	1 rig operator
1 water tanker	1 driver
1 support truck	1 mechanic
Adequate lengths of drill pipes to drill the deepest hole	3 rig assistants
Drill bits of the right diameter	
Casing, gravel and filter pack, drilling mud	

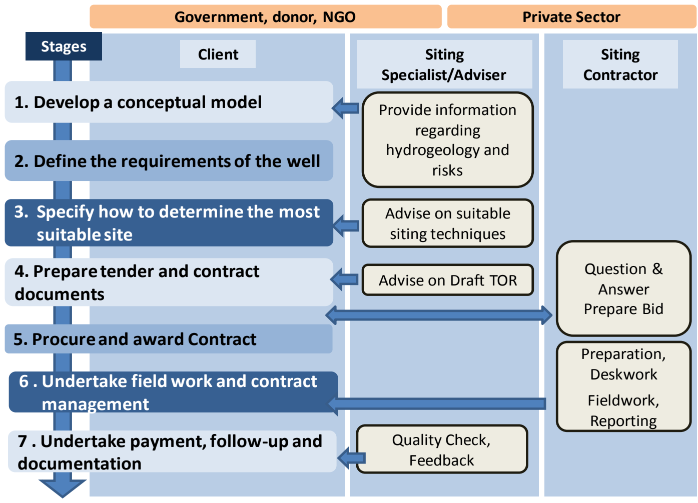
Step 2: Borehole siting

Aim: To ensure that the borehole is drilled in the right place so that it has water that is accessible to users and protected from pollution.

The Supervisor should refer to RWSN Publication 2010-5 *Siting of Drilled Water Wells: A Guide for Project Managers*, which provides details of the procedure for borehole siting. Checklist 2 (Annex B) highlights the areas that will require particular attention from the Supervisor.

Site Survey: A survey of the community or project area should have been carried out before the commencement of the project and the estimated drilling depth in the *Bill of Quantities* based on the depth indicated by the siting survey. The potential borehole sites should be marked and shown to the Community. Some communities have areas of cultural and religious values or sacred ground which should be avoided. The Drillers are responsible for siting the borehole if the contract does not pay for dry wells, the so-called "no water no pay" approach, in which case they should follow steps 1 to 3 in *Siting of Drilled Water Wells* (Figure 3).

Figure 3: Work Flow for Water Well Siting



Water Source Protection: When the Supervisor, Community representatives and landowners walk over the project area identifying suitable borehole sites, the areas of potential pollutants such as pit latrines, burial grounds, refuse dumps, fuel and lubricant depots should be identified. Main roads, animal kraals, power-lines also need to be considered, as well as the vulnerability of existing water sources such as private wells (see Carter et al, 2010). Table 2 gives some guidelines on the minimum distance of a borehole from existing structures. Such guidelines should exist for each country, and perhaps even for specific ground conditions. However, it should be remembered that where *aquifer* risk is low, i.e. the surface is impermeable and the *aquifer* confined, distances from potential pollution sources to the borehole can be less. If the best site identified is near a pollution source, such as a latrine, then look at options for moving it away from the proposed borehole.

Geophysical Surveys: Where the geophysical survey is carried out by the Driller, the Supervisor should witness the geophysical measurements and make sure that the equipment is working and the readings taken are accurate so that it is not just, as described by one water user: "*a ceremony of laying the cables*".

Sites identified for drilling are marked with painted wooden pegs or piles of stones and shown to the Community representatives. Three such sites should be identified in each community and numbered in the order of priority. The Driller should submit a report with the GPS coordinates of the sites and a community map identifying the sites.

Once the Supervisor is satisfied that the Driller has diligently carried out the survey to find the best sites, he/she approves the report and gives permission to start drilling.

Box 6: What happens if a suitable site for a borehole cannot be found?

A perfect site would have favourable hydrogeology, no nearby pollution threats, available land, and good access for the Drillers and water users. However, this often does not happen, and if no acceptable site can be found, then other sources of water will have to be sought by the Project Manager with the Community.

Table 2: Borehole distance from existing structures (adapted from FGN/NWRI, 2010)

Existing structures	Minimum distance (m) from borehole
Water supply boreholes	50
Hand-dug well	20
Other existing water wells	10
Septic tank/soak away	20
Streams, canals, irrigation ditches	20
Buildings	3
Approved solid waste dump and burial ground	1,000
Coastline	not normally within 1,000 meters

Step 3: Pre-Mobilisation Meeting

Aim: To ensure that the Driller and Supervisor are fully aware of their exact roles and responsibilities and contract details.

Once the contract has been signed, and prior to mobilisation, a meeting between the Client, Driller and Supervisor is essential. At the meeting, all three parties go over the design, materials and procedures for each step in the contract. Roles and responsibilities need to be clarified in detail. This provides an opportunity for any ambiguity to be resolved and the contract amended as necessary.

However, many Drillers do not read the contract, but simply add their prices into the *Bill of Quantities*. The pre-mobilisation meeting ensures that everything set out in the contract is clarified verbally, thus preventing conflicts while on site. Without this, there is always a danger that the wrong equipment or inferior materials will be taken to site, and the Supervisor compromised due to time-pressure.

Step 4: Mobilisation

Aim: To take the drilling project from contract signing to deployment of the drilling crew on site

Checklist 3 (Annex B) sets out the main aspects of this step, starting with liaison and ending up on site. Mobilisation includes the following activities:

1. **Contract:** All borehole projects and supervision are based on a contract agreement. Once the contract has been signed, and pre-mobilisation meeting held (Step 3), the mobilisation phase starts. Procurement and contract management aspects are covered in Adekile (2012).
2. **Programme of works:** The Supervisor should discuss the *technical specifications* and drilling procedure with the Driller, and discuss and agree the target depths. Then the Supervisor should ask the Driller to submit a programme of works. An example is shown in Table 3.

Table 3: Example of Program of Completing Drilling Works for a 5-borehole package

Description	Weeks									
	1	2	3	4	5	6	7	8	9	10
Mobilisation	■									
Borehole siting	■	■								
Drilling, lining & development										
Communities 1 & 2			■							
Communities 3 & 4				■						
Community 5					■					
Pumping test & water quality analysis					■	■				
Pad construction							■	■		
Pump installation									■	■
Demobilisation										■

3. **Community liaison:** It is essential that, before the Driller arrives on site, the Supervisor or Project Manager has had several discussions with the Community about the project and details of the drilling process and their expected obligations and contributions with the main contact persons or Community representatives. The Driller's representative should meet with the Community and agree a start date.
4. **Equipment check:** The equipment that is to be used by the Driller should be checked to make sure that it is all in working condition, and the same as, or equivalent to, what was examined in the inspection step.
5. **Materials check:** In some contracts, the suppliers, manufacturers, or sources of the material to be used, such as *drilling fluid*, *casing* and *screens*, are specified. The Driller should submit samples of the materials for the Supervisor's approval. The slot size and wall thickness should be checked, for example.

Figure 4: PVC screen (left 0.75mm slot, right 1mm slot)

6. **Data collection forms:** The format of drilling data collection to meet the contract requirements should be agreed on. Templates are provided in Annex E of the Code of Practice for Cost Effective Boreholes (Danert et al, 2010). The final version for copying will be agreed on site between the Driller and Supervisor, and signed by both parties once all the stages of the contract are completed.

7. **Project filing system**: Most of the data could be stored electronically, but hard copies are required for field use. A file (in duplicate) should be opened for every community and all records and data for the community stored in the file. Checklists for all stages of borehole construction (Annex B) are printed inside the flap of the folder and ticked as construction progresses. The original is kept in the office and the duplicate in the *Drill Camp* or site office.

8. ***Drill camp* layout:** On large projects where a *Drill Camp* is set up, the Driller should submit a drawing of the camp layout for approval. The main consideration in approving the plan is safety and sanitation: inflammable items should be kept away from likely sources of heat and fire; potential contaminants from water-supply sources and cooking areas; and PVC casing and screens are protected from direct sunlight, which makes them brittle. Where the project covers a large area, *Satellite Fly Camps* may be needed in the more remote parts to reduce the travelling time to a cluster of borehole sites. The same criteria as for the approval of the *Drill Camp* plan apply.

Once all the above have been completed and approved, the Driller and the Supervisor are ready to move to site.

Step 5: Drilling

Aim: To ensure a high-quality borehole is drilled in a way that is safe and well-documented.

Checklist 4 (Annex B) should be used once the Driller has reached the project site. The following aspects are critical:

1. **Safety:** Drilling is a very hazardous activity. Safety of the workers on site is absolutely vital. Responsibilities for ensuring safety should be clearly set out in the contract. The Supervisor must be constantly vigilant to prevent accidents, and to minimise injuries should accidents occur. The Supervisor should look after his or her own safety and be aware of risks to the Driller's crew and the public. A drilling operation is a novelty, and it quickly attracts a crowd, particularly children. Spectators should be kept behind a clearly defined barrier where they cannot be struck by falling objects, such as a drill pipe, or a hose breaking loose from a *compressor* or mud pump - which could be fatal. A community representative can be asked to support the process of policing the barrier tape. The Supervisor should have at least basic first aid training and medical aid kit.

Figure 5: Poor Safety – No Hard Hat – No Clearly Defined Barrier

2. **Rig position:** It is essential that the rig is horizontal and the mast vertical, otherwise a bent hole may result. Verticality of the drill pipe should be checked with a spirit level. The rig should be jacked on a robust wooden block so that verticality remains throughout. The rig should be positioned exactly over the pegged site. This is particularly important when the siting is undertaken by a consultant employed by the Client rather than the Driller. If the borehole is dry, there can be no argument that the borehole was not drilled on the specified location.

   The Driller should ensure that the weight on the drill string is adequate to maintain a straight hole. The use of a heavy drill collar is recommended on at least the first three metres of length behind the hammer. The first drill rod could have welded wings, adding weight as well as scraping to get a circular, straight bore. Also, the Driller should not drill with too much pull-down on the rods.

3. **Monitoring drilling depth:** The Supervisor needs to know the depth of the *drill bit* at all times to ensure that proper data logging is being done, to know the depth at which to tell the Driller to stop and to compare the drilled depth with the depth recommended in the contract. An unscrupulous Driller can try to rip off the Client either by drilling excessively deep, or by pretending that the borehole has been drilled deeper than it actually has. Box 7 describes measuring methods. The Record Taker (Box 3) should be taking notes at all times, in conjunction with the drilling depth.

Box 7: Measuring Drilling Depth (Adapted from Ball 2001)

The drilling depth can be monitored by measuring the length of the drill pipe and multiplying the number of full pipes that have gone down into the hole.

Chalk or grease can be used to mark the drill pipe: with the drilling rig set up with the first length of drill pipe and *bit* fitted, the *drill bit* is lowered to the ground. The drill pipe is marked "0" at the *rotary table* that centralises the drill-pipe, and then chalk marks are made at 1m intervals up the drill-pipe, numbering the marks from 0 upwards. Measured chalk marks are then made on subsequent drill pipes to be added. This procedure allows anyone on the drill team to know at a glance the exact depth of the *drill bit* from the ground surface. Note that if the hammer is changed to a longer one after drilling has commenced, the pipes will need to be remarked.

Figure (above) Drill-rod marking so that samples, penetration rates and air-lift yield can be accurately recorded

4. **Penetration rate:** This is the time taken to drill a particular interval. A fast penetration rate can indicate an *aquifer*, although this is not always the case. Less porous strata, such as fresh granites, are often slower to drill through.

5. **Drilling fluids & air-lift yield:** *Drilling fluids* are used to remove cuttings from the borehole and to stop the hole collapsing during drilling. The type of fluid should match the drilling method:

   - Down-the-hole-hammer: compressed air; water and air; or foam;
   - Rotary drilling: drilling mud (water + additive). Be aware that bentonite clay is commonly used but is outlawed in some countries because it can do permanent damage to the *aquifer*. Biodegradable polymers should be used;
   - Percussion drilling: fluids generally not used;
   - Manual drilling (percussion, auger, sludging, jetting): water.

   Monitoring the *drilling fluid* colour and *viscosity* is the responsibility of the Driller. *Viscosity* is checked by measuring the flow rate of the *drilling fluid* through a Marsh Funnel. The Supervisor should ensure the Driller has a Marsh Funnel and it is properly used. In the case of air-percussion drilling, the air-lift yield should be measured using a V-plate or pipe/container. All observations and measurements are recorded every metre, using the marks on the drill pipe as a guide.

6. **Drill cutting samples:** To collect the samples, the Driller stops drilling, flushes all cuttings in the hole to the surface, resumes drilling, and then collects the cuttings. In air drilling, the samples are caught in a bucket placed in the stream of air jetting from the borehole. In mud drilling the samples are collected by inserting a spade into a small collection pit as the cuttings flow to the main pit. It is the Driller's responsibility to ensure that the mud pump is of such rating and condition that it can lift the cuttings out of the hole. If the hole is not properly flushed, cuttings may become mixed up and not lifted out so that during lining, the casings do not get to the required depth.

Figure 6: Samples are laid out and logged for 1m depth intervals

The drill samples should be bagged in strong transparent bags, labelled with indelible ink, and stored in a position that they will not be contaminated by site conditions or drilling operations. The label should contain the borehole number and location, sample number and depth. The sample could be collected and stored in a sample box. A photograph of the samples should be taken as a permanent record. In mud drilling, the samples would have mixed with the *drilling fluid*. The samples should be washed before bagging, but care should be taken in washing soft rock material, such as clays, as they could disintegrate in water.

The depth interval of collecting samples might have been stated in the *Technical Specification*, but drilling conditions may require that this is reviewed. It might have been specified that samples should be taken at every metre interval. However, in a deep borehole where the formation does not change rapidly, the interval could be increased to three metres. Equally, where there is rapid change in *lithology*, the Supervisor may change the interval to half a metre.

Box 8: Describing sedimentary rock samples

Description is based on identifying and describing:

- the colour
- the texture
- the grain size and shape
- the material
- the rock type

For example, samples from a sedimentary borehole could be described as:

0 – 2 m	dark grey hard CLAY
2 – 4 m	grey brown coarse angular grained loose SAND
4 – 6 m	white medium to coarse partially compacted SANDSTONE
6 – 10 m	white coarse partially compacted SANDSTONE
10 – 23 m	white compacted SANDSTONE

7. **Strata Log:** Drill samples should be described and a strata log prepared by the Supervisor. Different methods are required for describing sedimentary rock samples and crystalline rock samples (Box 8 and Box 9). From the strata description, the Supervisor will prepare a graphic strata log which will form part of the final borehole report.

8. **Final borehole depth***:* It is the responsibility of the Supervisor to instruct the Driller to stop drilling when the right depth has been reached. The decision to end drilling will depend on the information gathered in the course of drilling. The factors will include:

   - what has been stipulated in the contract, which may be based on Client guidelines with respect to the average borehole depth in the area;
   - depth of the *water strikes/aquifer*;
   - *static water levels*;
   - estimated seasonal fluctuations in water levels i.e. changes in water levels as a result of recharge in the wet season(s) and groundwater discharge during the dry season(s);
   - the estimated yield from the borehole. See Box 10.

The typical signs for adequate yield and drilling depth vary with the type of formation and the drilling method. In the case of a yield which is obviously good, in a well that is to be installed with a handpump the final borehole depth should be at least 5 metres into the *aquifer*. It needs to allow for proper installation of the pump. It also should allow for 3 to 6 metres of sump (blank casing) below the screen as a sand trap.

However, if the yield is not clearly so good, continue to drill to the next strike horizon, until the yield is sufficient. The yield increments should be monitored with the V-plate. A 6m sump may be suitable where sand and silt are a problem. In cases where there is fine *saprolite* in the upper sections, these should be cased off to prevent silt from entering and filling the sump.

Box 9: Description and classification of crystalline rocks based on grades of weathering and dominant minerals

Grade	Classifier	Typical Characteristic
I	Fresh	Unchanged from original state
II	Slightly weathered	Slight discolouration, slight weakening and dislocation
III	Moderately weathered	Considerably weakened, penetrative discolouration Large pieces cannot be broken by hand
IV	Highly weathered	Large pieces can be broken by hand Does not readily disaggregate (slake) when dry sample immersed in water
V	Completely weathered	Considerably weakened Slakes Original texture apparent
VI	Residual soil	Soil derived in situ weathering but retaining none of the original texture or fabric

For example, the log from a granitic terrain might read as follows:

0 – 6 m	orange brown silty CLAY
6 – 16 m	grey brown clayey fine SAND
16 - 23 m	biotite granite GNEISS IV-III+
23 - 30 m	biotite granite GNEISS III+
30 – 43 m	biotite granite GNEISS I

9. **Drill Report:** The data from the drilling should be recorded both for the final design and as a reference for future borehole projects. The Driller needs to keep a daily drilling log which should be signed by the rig operator and the Supervisor at the end of each day. The Supervisor should insist that this is done - as Drillers often consider this an unnecessary intrusion into their work. The Supervisor should keep the record of the drilling activities and all measurements in a field note book. The most important data will go into the Casing and Well Completion Form (Appendix E3, *Code of Practice for Cost Effective Boreholes*), which will be collated, filed or bound together as part of the final project report and deposited with the appropriate office for future reference. Even data from dry or aborted holes needs to be recorded.

Box 10: Indications of adequate yield and depth

***Crystalline basement* geology:** Geophysical survey data should indicate the probable depth to fresh rock. On the *basement* complex of **West Africa**, this is usually not more than 60m because the *regolith* is rarely more than 30m deep and most joints close up by 50m depth. In **East and Southern Africa** the *regolith* may be as thick as 100m.

If the borehole is drilled with air, then *water strikes* will be obvious because the water shoots out of the hole. The yield of the borehole can be estimated as drilling progresses by making a small depression around the hole. The water blown out of the hole is channelled into a pipe. The yield is estimated by measuring the time it takes to fill a bucket of known volume, giving the yield in litres per second (l/s).

A handpump demand is about 0.3 l/s. If the yield is adequate for the demand, then the *static water level* is measured. If the borehole is drilled in the wet season, a depth allowance is added to cover for seasonal fluctuation in water levels. A further allowance is made for the *drawdown* caused by pumping. Thus, a borehole with a *static water level* of 10m might need an allowance of 15m for seasonal fluctuation and *drawdown*. In this case it would be 30m depth well.

The depth at which fresh rock is encountered may be a signal to stop drilling but if this is at shallow depth, not indicated in the geophysical survey it is necessary to continue drilling for another 5 to 10m to rule out the possibility of a boulder or *spheroidal weathering*. Fresh rock in hammer drilling comes out as fine or powdery material, dark or light coloured depending on the parent material.

Some *consolidated sediments* (sandstones, mudstones, shales): Can be highly compacted, hard and have to be drilled with down-the-hole hammer and air. Deciding at what depth to stop follows the same observations as in crystalline rock drilling. Some *consolidated sediments* are not so compacted and will follow the same method as with *unconsolidated* rocks.

***Unconsolidated* formations (gravels, sands):** It is not possible to see the *water strike* as in air drilling because the borehole is drilled with a drilling mud. The yield cannot be estimated until the borehole is lined and cleaned. The final borehole depth will depend on the pre-drilling hydrogeological information from existing boreholes and, sometimes, geophysical logging and the *lithological* types encountered during drilling. Close monitoring of the entire drilling process is required to find the water-bearing layers. Drilling can stop when the borehole reaches a continuously thick band of sand or fissured limestone below the zone of permanent saturation, at a depth correlating with the *aquifer*s screened in other nearby boreholes. It is best to penetrate as much of the *aquifer* as possible.

In *unconsolidated sediments*, careful observation of the drilling process will reveal one or more of the following signs indicating that a good water-bearing layer has been reached:

- sampling of drill cuttings shows a layer of sand or gravel has been reached (this needs careful sampling of drill cuttings)
- increase in the penetration rate
- bouncing of the drill string caused by a bed of gravels
- loss of *viscosity* in the *drilling fluid* (measured with a marsh funnel)
- sudden change of colour of the *drilling fluid*
- noticeable drop in the level of the *drilling fluid*
- *drilling fluid* temperature may drop due to groundwater inflow.

Step 6: On-site Design Modifications

Aim: To ensure that the finished borehole uses the *aquifer* efficiently, gives a long working life and low capital, maintenance and operation costs.

The Code of Practice for Cost Effective Boreholes (Danert et al, 2010) provides illustrations of different borehole designs. The provisional design should precede the signing of the contract, because the design gives rise to the specification. The specification informs the Driller what to bring to site. Any design work on site involves modifications to, or finalisation of, the design.

The Supervisor is responsible for on-site design modifications. Every borehole design is unique because it has to be adapted to the local geology, which cannot be predicted with absolute certainty. Borehole design involves selecting the appropriate dimensions and materials of the borehole, i.e. depth, casing and screen type and diameter, depth intervals of installation, and *gravel pack zone*. Borehole design factors are set out in Checklist 5 and described in further detail below. Most of the parameters listed above would have already been taken into consideration when writing the *technical specifications* of the borehole, but the information gathered in the course of drilling will steer the final design.

1. **Depth:** Taken from the Drill Report;

2. **Formation:** What type of *aquifer* is the borehole taking water from? Use local geological expertise and mapping where possible, but in general the three *aquifer* types are: *Basement Complex*; *Consolidated sediments*; and *Unconsolidated sediments;*

3. **Yield:** A borehole only needs to be drilled to a depth where the required yield can be sustained without contamination from surface water**.** Table 4 gives the ranges of yields from different formations. Selection of the other parameters, such as the borehole diameter and lining, should be geared towards meeting the required yield.

Table 4: Ranges of yields from various *aquifers*

***Aquifer* type**	**Rock types**	**Yield l/s**
Consolidated sediments	Sandstones, mudstones	0.1 – 4
Unconsolidated sediments	Sands, gravels	>4
*Basement complex**	Weathered granites	0.1 – 1

* *Basement* complex is also divided into (a) *Saprolite* (which frequently suffers from low yield and is prone to silt influx): (b) *Saprock* (frequently has a high yield) and (c) Bedrock (high yield potential where fractured).

4. **Drilled borehole diameter:** The drilled diameter of the borehole needs to be large enough so that pump, casing, screens, *gravel pack* and sanitary seal can all fit without snagging. For handpump-fitted boreholes there are different schools of thought with respect to diameter, with some favouring smaller diameters, such as 6" to 6.5" and others arguing that this is inadequate to enable *gravel packing* to be properly installed without bridging. Anscombe (2012), a Driller with years of experience in southern Africa, argues that the reality is that most Drillers simply do not use a *tremie pipe* when installing *gravel pack*, with the result that the *gravel pack* is not properly installed. He thus argues that wells need to be drilled at an 8" diameter. This view has cost implications.

Figure 7: Controlling the discharging waters

5. **Casing and screens:** Casings are blank pipes which prevent the borehole from collapsing. Screens are pipes which have slotted openings that allow water to flow into the borehole but prevent sediments from entering the borehole. The lining material can be galvanised steel, Polyvinyl Chloride plastic (PVC), Glass Reinforced Plastic (GRP) or bamboo. The two most often used are PVC and steel, and the choice between them depends on the depth of the borehole and the corrosiveness of the groundwater.

   A 100mm diameter borehole casing will accommodate a handpump. Submersible pumps may require larger diameter casing depending on the required yield. Pump manufacturers usually prepare sets of curves showing the capacity of their pumps in terms of yield at particular depths or pumping heads and the diameter of the borehole that will accommodate the pump. The Supervisor should therefore check the diameter of borehole casing suitable for the intended pump. Generally, for motorised schemes in rural communities, a 150mm diameter is adequate. In the case of boreholes for small town supplies, or agriculture, a larger diameter will be required.

   In boreholes that are deep but have high *static water levels* (i.e. shallow depth of water level), a larger diameter casing, say 300mm, may be installed in the upper reaches of the borehole to house the pump (called the pump chamber), whilst a smaller diameter, 100-150mm, is used to line the lower parts and the *aquifer*.

   In *consolidated rock* - such as the *basement complex* - the depth is rarely more than 60m. PVC casing and screens can withstand the pressure imposed by the formation. There is a school of thought that argues that the lower part of the drilled hole could be stable and can be left open and unlined. In such cases, only the top weathered horizon is lined with a casing. In such holes, the *annulus* between the casing and the drilled hole should be grouted. However, it has been argued that these holes are not always sustainable, with some prone to siltation.

In *unconsolidated* formations, the entire borehole is lined to prevent the borehole from collapsing. Where the *aquifer* is more than 100m deep, the pressure exerted by the water and the rock formation is great, and steel casing and screen should be installed. In deep *aquifer*s with slightly acidic water, Glass Reinforced Plastic may be considered as mild steel could corrode..

The Supervisor should ensure that the casings and screens supplied are new and conform to the specification. If in doubt, the diameter and the wall thickness should be checked with callipers. The Driller should provide a sample of the pipe cut in half, and the measurement taken in the middle. Measuring the thickness at the threaded end will not give the accurate figure. Table 5 gives the dimensions of casings, wall thickness and possible depths of installation from a pipe manufacturer.

It should be noted that drill pipes, casings, screens and other lengths are not always standard. Sometimes they are cut and re-threaded. Often, 3m "standard lengths" are actually 2.95m, or some other length.

Table 5: PVC casing and screen dimensions
(Source: manufacturer Boode b.v Netherlands).

Indication of installation depth m*	Outside x inside diameter in mm	Wall thickness in mm
50 – 75	110 x 103.4 (3½'')	3.3
75 – 100	110 x 101.6 (3½")	4.2
200 – 300	113 x 96.6 (4")	8.2
50 – 75	125 x 117.6 (4½")	3.7
75 – 100	125 x 115.4 (4½")	4.8

* Depths of installations mentioned are based on practical experience and may vary with ground condition.

6. **Screens:** are installed in the *aquifer* horizon. A borehole screen is a filtering device that serves as the intake portion of boreholes constructed in *unconsolidated* and semi-consolidated *aquifer*s. The screen permits water to enter the borehole from the *aquifer*, prevents sediments from entering the borehole and serves to support the *aquifer* material. Increasing borehole diameter does not have much impact on water flow into the borehole, but increasing the screen length significantly increases the yield. Therefore, as much of the *aquifer* as cost permits should be screened. There is not much difference in the prices of PVC casing and screen, but stainless steel screens are very expensive and should be used sparingly.

7. **Screen slot size:** The total open area of the screen governs the amount of water that flows into the hole. Slot sizes are not a big issue with handpumps as the required amount of water is relatively small. It is enough to ensure that the *aquifer* material will be retained by the selected screen slot size. This can be checked by doing a sieve analysis of the *aquifer* material, but a quick method is to rub a sample of the *aquifer* material against the screen. An adequate slot size will allow the *fines* to pass through, whilst the coarse material remains outside. It has been noted that in some southern Africa countries, locally available casing tends to be rather coarse (1mm slot size). This will not always be adequate. If the *aquifer* is laden with silt, and the slots allow it to pass through, it can result in the wearing of pump seals, and ultimately in siltation of the well.

   In motorised schemes where a high yield is required, a large diameter screen may be installed as the total open area increases. Water flows freely through a screen with a large intake area compared to one with limited open area. To prevent turbulent flow into the borehole which could cause encrustation and lower the lifespan of the screen, the velocity through the screen should not be more than 0.03 m/s. The minimum open area in the screen to permit non-turbulent flow can be calculated from the formula:

   $A = Q/30$

   where A is the open area in m^2 and Q is the water flow in l/s (Macdonald et al, 2005)

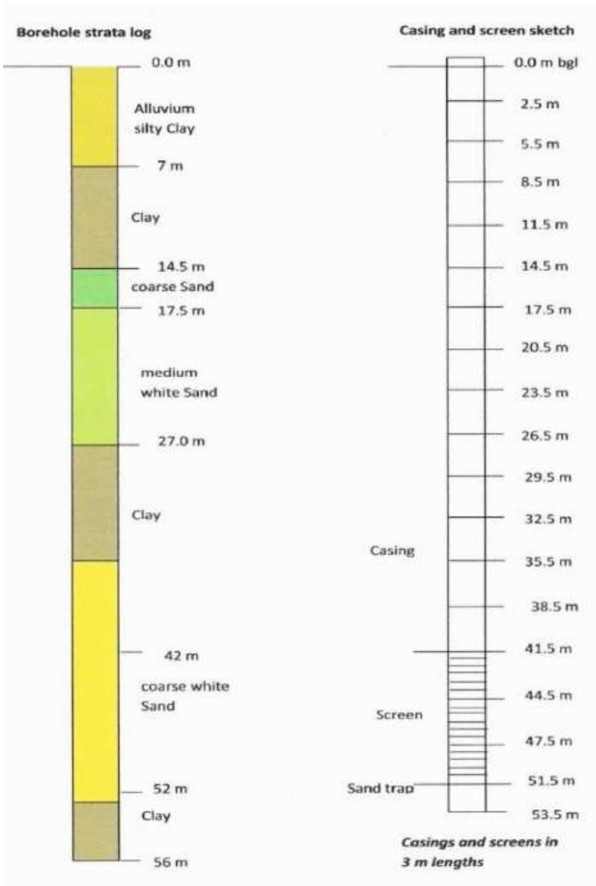
8. **Installing casing and screen** requires great care and attention as it is easy to install blank casing in the *aquifer* horizon. Once the depth of the borehole and the depth interval for screening are known, a sketch of the proposed assemblage of casing and screen should be made. The casings and screens should be laid out according to the sketch and measured individually, totalled and checked that they conform to the sketch. They should be placed next to the drill collar ready to go into the well. The Supervisor should take a photograph of the layout for the record. Figure 8 shows a sketch of a strata log with casing and screen assemblage in a sedimentary terrain. Once all of the materials are inserted, the drilled depth needs to be reconciled against the casing and screen depth. If the discrepancy is more than 3m, there is need to reconsider whether the screen is actually sitting where it is supposed to, or if there has been some collapse of the well. If something is wrong, the contractor must remove the casing, clean the well, and re-insert it until the Supervisor is satisfied.

   Joints should be strong enough to support the entire weight of the casing during installation. Threads should be intact. Both male and female threads should be properly cleaned with a brush and cloth before they are joined. Where non-threaded couplings are used, they should be cleaned and joined together by the solvent cement recommended by the manufacturer. **Before the casing is lowered into the borehole, the Supervisor should ensure that the recommended time for the cement to set and form a water tight seal is observed.**

   This is critical, but sometimes the Driller may be in a hurry to leave the site and so shorten the time. Steel casing and screen should be joined by threaded joints that are water-tight. Where welding is used, the weld should be fully penetrating and continuous. If possible, welding of casings should be avoided as the weld can be a point for rusting and casing failure. It is also time-consuming and can put the casing out of true line. In addition, steel casings which are torch slotted on site corrode much easier than those which are bench slotted beforehand.

   The casing and screen assembly should be lowered into the hole under the force of gravity. They should never be driven down. In fact, they should be lifted slightly (by 100mm) when they reach the bottom and held there while the gravel is inserted (see point 9). This ensures that they are straight in the hole and not spiralled. In some cases, centralisers are used to align the casing in the hole. A 3m length of sand trap should be part of the well design when boreholes are cased to the bottom and the bottom casing sealed with an end cap.

Figure 8: Casing and screen sketch in comparison to strata log



9. **Gravel pack:** is installed in the annular space between the borehole screen and the wall of the drilled hole. Often, the *aquifer* material is allowed to collapse against the screen, and the *fines* are washed out during development. This enables natural development to take place. Where the *aquifer* material is coarse and mobile, it is the preferred method. However, where this is not possible, artificial gravel packing is used. There are two types with different functions:

   - The **formation stabiliser** is coarse sand or river gravel installed in the hole to prevent the caving of formation material and damage to the screen. The material should be carefully chosen and sieved to make sure it is of uniform size and bigger than the slot size of the screen and will not flow into the borehole. It should not contain mica, clay or laterite. Large pieces should be sieved out as they can bridge in the *annulus* and prevent subsequent gravel from reaching the bottom. Granite chippings should not be used as *gravel pack* as they tend to be angular and may contain mica or harmful material that leach into the water. The material should be washed and carefully introduced into the hole through a *tremie pipe* to avoid bridging. It should extend several meters above the screened interval but stop at least 6m below ground surface.
   - A **filter pack is** installed around the screen in fine grained *unconsolidated* formations where an appropriate screen slot size cannot be found. The grain size of the filter pack material has to be selected in relation to that of the formation material. It should be coarser than the *aquifer* sand. The relationship, called the pack-aquifer ratio (P.A. ratio), is calculated from the formula:

     Pack Aquifer ratio = 50% size of gravel pack/50% size of *aquifer* material

     The ratio should be between 4 and 6. For the procedure for sieve analysis and selection of appropriate filter material the reader should consult Driscoll, 1986: 406-409.

     It is essential that the casing, screen and *gravel pack* are available on the site once drilling commences. Once the drilling pipes are withdrawn, the hole has a potential to collapse. Thus the casing and *gravel pack* need to be placed without delay. Under no circumstances should this wait until the following morning. In the words of Anscombe (2012): "*Rods out – casing and gravel in – fast and efficient*".

10. **Geotextiles**: In some cases, *geotextiles* can be used to prevent fine materials from entering the screen.

Step 7: Borehole development and site completion

Aim: To prepare the borehole for use and install the pump and ancillary headworks and structures

Checklist 6 (Annex B) sets out the key aspects of borehole development and site completion:

1. **Borehole Development Method:** Borehole development is about cleaning the area of the *aquifer* immediately around the screens. The method of development should be stated in the *technical specification*. Figure 9 shows an example of *air lifting*. Air jetting can use a galvanised pipe, plugged at one end, with 8mm holes along the length so that the air-jet streams in the borehole are horizontal. This pipe, connected to the *compressor*, is raised and lowered repeatedly over the screen section, finishing in the sump.

Figure 9: Cleaning the borehole with an air-jetting tool

2. **Borehole Development Success:** The Supervisor's duty is to ensure that eventually, the water coming out from the borehole is clear of mud and is sand free. Samples of the water are collected in a clear container and checked to see that there are no sediments collecting at the bottom of the container. As part of this, the Supervisor needs to decide whether a borehole should be accepted or declared abortive. If the borehole is to be aborted, the Supervisor also needs to determine whether the Driller should re-drill the borehole at his own expense or not. This will depend on the terms and conditions of the contract.

   Although some contracts specify the duration of development (the minimum number of hours that must be spent on developing the hole), this actually depends on the time it takes for the water to be clean. Development should continue until the Supervisor is satisfied that the water coming out of the borehole is clean and sand free. Some boreholes clear within a couple of hours, some may take days to several weeks. Some only clear after several months of pumping. The latter is likely if air-percussion drilling has been used in very loose, clay-rich, silty, micaceous and saturated conditions – in other words not the right drilling technique.

3. **Sanitary seal:** It is essential to prevent contamination of the *aquifer* and to ensure that the users obtain safe, clean drinking water. When the Supervisor is satisfied with the yield, and development has settled the formation stabiliser or filter pack, then the *annulus* of the borehole is back-filled with the cuttings, or clayey soil, up to 6m below the ground surface. A *sanitary seal* is placed in the top 6m to prevent surface water which may be polluted from flowing down the borehole *annulus* into the *aquifer*. The *sanitary seal* should be cement slurry in the mixture of 25l of water to 50kg of neat cement, or bentonite.

4. **Pumping test** provides the means to determine the likely success of the borehole in terms of yield and *drawdown*. It provides information on the properties of the *aquifer* and on the borehole itself.

   Two types of pumping test can be conducted. A constant-discharge or *aquifer* test should always be carried out. This gives information about the *drawdown* resulting from a specific pumping rate (usually a little greater than the design discharge). The test data can also be interpreted in terms of the *aquifer* properties. For a handpump, a 3- to 6-hour constant discharge test is adequate. If the borehole is going to serve a large population and a high yield is required, then a longer test of say 24 to 72 hours, or even longer (up to 14 days) may be undertaken.

   A constant discharge test provides information about the *aquifer* in the vicinity of the well. The results of the constant discharge pumping test enable the short term performance of the well to be determined. However, it does not provide any information about recharge, seasonal fluctuations or long term performance. In other words, the pumping test does not give information about the long-term (multi-year) sustainable yield of the borehole. The long-term yield is the subject of groundwater resources evaluations, which focus on recharge and its variability from year to year.

   The second type of test is a variable-discharge or well test, also known as a step-test. This type of test is used to determine the hydraulic performance of the well. The data from a step-test can be used to calculate the well efficiency. Step tests are rarely carried out on low-discharge (e.g. hand-pump) wells. However, in the case of a production well or for motorised schemes, the step test is very useful. Provided that the data are kept, undertaking another step test say five years later can enable a comparison to be made. Thus it is possible to find out whether the well has clogged up over time.

   In a step-test the well is pumped at a succession of increasing discharges, each carried out for the same duration, typically one or two hours. There will usually be at least four steps, such as at 1/3, 2/3, 1 and 4/3 of the expected design pumping rate of the well.

   National or international standards (e.g. BS ISO 1468:2003) should be used in the design of both constant-discharge and step pumping tests. These standards specify test pumping duration, discharge and other aspects of the conduct of the test, including measurement methods.

   During the pumping test, the Driller usually measures the water levels, discharge and time. The Supervisor is responsible for ensuring that the pumping test is carried out correctly. The Code of Practice for Cost Effective Boreholes (Danert et al, 2010) provides guidance on pumping tests, including a recording format in Annex E7. The pumping rate and the water level are measured at the same time and recorded along with the time of measurement. The pumping rate can be measured with a flow meter, but it can also be established by recording the time it takes to fill a container of known volume. This is measured several times during the test.

   There are several ways of analysing pumping test data, and some are quite complicated. However, for the purpose of this guidance note, what is important to the Supervisor is whether the borehole will deliver the required amount of water for the required pumping duration or not. The *specific capacity* of the borehole, which expresses the relationship between the yield and the *drawdown*, is the most important quantity, i.e.

   Specific Capacity=yield /drawdown (m^3/h per m drawdown)

   This enables the Supervisor to predict the likely drawdown at different pumping rates and whether the borehole can deliver sufficient water. By calculating the drawdown incurred by different pumping rates, and comparing that drawdown to the available vertical interval between the rest water level and the top of the well-screen (while allowing for likely seasonal water level variations, the effects of extended dry periods, and the interval occupied by the pump itself) it is relatively easy to determine a viable discharge for the well as drilled. A *specific capacity* of around 1 m^3/h per m suggests that a borehole would be adequate for a handpump – a typical hand pump, drawing 1m^3/h would incur only 1m of drawdown in this example.

5. **Water quality testing**: Groundwater from boreholes is often of good quality, but sometimes it may contain contaminants which render it unsuitable for domestic use without treatment. The contamination could be due to minerals dissolved into it from the rocks through which it flowed but re-

sults more often from biological contaminants owing to human activities. If the borehole has been properly sited and constructed, it should be possible to eliminate biological contaminants.

The technical specification would have given the parameters to be tested. It is the Supervisor's duty to ensure that the samples are taken by the Driller in a clean bottle of at least 1l volume. Where the facilities are available, the sample should be analysed on site and then taken to an approved laboratory for further analysis. Note that some parameters change between sampling and reaching the lab and so need to be tested on, or close to the site (including pH, EC, dissolved oxygen, iron and micro-organisms).

Figure 10: Checking iron content at the wellhead

In taking the sample, the bottle is rinsed several times with the water being sampled, filled and securely corked and labelled. Some countries have developed drinking water quality standards, and the Supervisor should analyse the results of the water quality testing on that basis. Where there are no country standards, the WHO standards should be used.

Particular attention should be paid to the values of the pH, conductivity, iron, manganese, nitrates, fluoride, arsenic and thermo-tolerant coliforms (TTCs). Groundwater containing iron is often reddish brown or black if manganese is present. It may also taste bitter. It poses no threat to health, but the taste and colour of such water may make it unacceptable to the consumer. Acidic water corrodes metallic plumbing material. High conductivity indicates a high level of dissolved solids, Consumption of groundwater high in fluoride, arsenic and nitrates is toxic.

6. **Borehole disinfection** The borehole should be **disinfected** after construction to kill bacteria that might have entered during construction. Chlorine is normally used as the disinfecting agent, leaving a residual in the disinfectant water. The amount of chlorine required depends on the volume of water in the borehole. WHO (2012) recommend that a litre of 0.2% chlorine solution is used for every 100 litres of water in the borehole. This corresponds to a concentration of 20 mg/l. After adding the disinfectant, the borehole should not be pumped for at least 4 hours, if not longer. Care must be taken when mixing and adding chlorine to the borehole as it is poisonous when not diluted.

7. **Successful or abortive boreholes:** The Supervisor will decide whether a borehole should be accepted or declared abortive; and depending on the terms of the contract whether the Driller should re-drill the borehole at his/her own expense or not. The success and suitability of a borehole for acceptance will depend on the following:

   a) The **depth to pumping water level** is critical for handpumps as the maximum depth from which it is practical to lift water with a handpump is 80m. RWSN (2007) provides an overview of the operation depths of the various public domain handpumps. Since some allowance must be made for water level drawdown, for a hand pump, the *static water level* must be less than 80m below ground level. The *static water level,* together with national pump standards, will determine the handpump to be installed. Depth to static water level is beyond the control of the Driller and he/she should not be penalised for it. Such deep water levels may be encountered in sedimentary terrains. In the case of deeper water levels, motorised rather than hand pump will be required.

   b) A dry borehole or one with a lower yield than the desired should be declared abortive. This may not be the fault of the Driller, but if the agreement is that the Driller is only paid for successful boreholes, then re-drilling is at his/her own cost. However, even after attempting drilling in 3 locations in a community, the yield from the borehole may fall short of the minimum allowed. At this stage, a major reassessment of the drilling strategy may be required, with appropriate contracts drafted.

   In the meantime, where the shortfall is less than 30% of the minimum specified, and there are no other safe sources of water, then the Supervisor may decide to accept the borehole and complete it if there is no alternative to improve the water supply. However, this may not be a viable long-term solution for the community.

   c) The **sand content** of the water should not be more than 10 parts per million by volume. The Supervisor should collect three 20l samples at the end of the pumping test. The volume of sand in the samples should not exceed 0.2 cubic centimetres. If a borehole should be abandoned because of excessive sand content, then the Driller shall be responsible for constructing another borehole at his/her own cost. The wrong drilling technique or poor *gravel packs* and well development cause this.

   d) The **turbidity** of the water should not exceed the stipulated limit. In some circumstances, excessive turbidity is due to the characteristics of the *aquifer* and thus beyond the control of the Driller, who should not be held responsible.

   e) Every borehole should be cased **straight and vertical**. The Supervisor may ask the Driller to carry out a test for straightness and verticality. The Driller should provide the *plumb* and carry out the test. Should the *plumb* fail to move freely throughout the length of the casing to the required depth or should the borehole vary from the vertical in excess of two-thirds of the inside diameter of part of the borehole being tested per 30 metres of depth, the borehole should be re-drilled by the Driller at his/her own expense.

f) The Supervisor will determine whether the **chemical and bacteriological quality** of the water is adequate to serve as potable water supply. If the borehole becomes contaminated because of an action or inaction by the Driller, the Driller should be asked to disinfect the borehole and if necessary construct a new borehole at his/her own cost.

9. **Platform casting:** All boreholes need a concrete apron around the length of casing above the ground for protection against soil erosion and surface water flowing into the borehole. Handpumps also need a concrete platform to hold the pump stand, to drain away spilled water, and for water users to stand upon. There are several designs of pump platforms, some being circular and others rectangular (Figure 11). Some incorporate a drinking trough for animals or a wash pad for laundry. Platform casting is usually undertaken by a dedicated construction team and may take place after *demobilisation* of the drilling equipment. However, the Supervisor will be responsible for ensuring that platform is built to the design specified by the Client in the contract and that the quality of the materials and the construction is good and durable. For more information on platform design, see RWSN (2008) Platform Design for Handpumps on Boreholes - Construction Guidelines.

Figure 11: Rectangular pump platform (for wheelchair access)

Step 8: Demobilisation

Aim: To leave the site clean, safe and ready for use

On completion of the pump installation, the Supervisor must issue a Work Completion Certificate. For this, he has to ensure that the Driller has complied with all the stages, including the final ones, of the contract specification. See Checklist 7 (Annex B).

Before *demobilisation*, the Supervisor should check that the borehole record has been completed and all information filled in. Annex E of the Code of Practice for Cost Effective Boreholes provides a template for recording the borehole data.

Step 9: Complete documentation and handover

Aim: To provide a clear documented record to help future operation, maintenance and repairs and hand over the completed facility to the Community

The finalisation and submission of drilling records (to the appropriate national authority and local government) is essential. The submission of borehole construction data is Principle 8 of the Code of Practice for Cost Effective Boreholes (Danert et al, 2010). This should be an integral part of the drilling contract, and thus require approval before payment of the invoice.

When the Supervisor is satisfied that the borehole is ready for use, a day is set aside for **handing over** the borehole to the Community or the Client. It is common practice for the handing over certificate to be signed by three people: the Supervisor, the Driller and the Community representative.

During the **defects liability period**, the Supervisor will monitor and liaise with community members on the functionality of the boreholes during periodic visits. If there are any defects, they will instruct the Driller to make repairs at his own cost, depending on what is specified in the contract.

Final Remarks

At first, the drilling site is a mystery and a challenge to a new Supervisor, but after the first few boreholes, he/she will get to grips with the procedures and become more confident. Later, the drilling routine may seem monotonous - one of continuously lowering and pulling out of drill rods, watching rods rotate and cleaning mud pits - but there are continuous changes. The Supervisor therefore needs to be watchful at all times. There could be arguments later on, and if the Supervisor has not been vigilant, then he/she could be cowed or hoodwinked by experienced or unscrupulous Drillers.

Not all issues can be resolved on site and some may have to be deferred until later. To help, the Supervisor should make notes of all the different opinions on the issue and get them signed by all the parties. Although the Supervisor represents the Client, he/she is expected to display great professionalism and act with honesty and impartiality in any dispute over the contract.

A two-way relationship between the Supervisor and the Driller is necessary for an efficient and successful outcome to the project. The Supervisor should therefore strive to understand the Driller's technique, avoid being overbearing and not try to teach the Driller how to drill. Where cooperation is established, the Driller can give the Supervisor important information that is not always recorded in the driller's log, for example, a change in the sound of the drill string, a juddering, an abrupt fluctuation in penetration rate not always seen on the penetration rate log, a change in the level of the drill fluid in the mud pit. However, if a Driller is smarting from perceived injustice by the Supervisor (probably a younger person!), he/she will be less inclined to be helpful, which may be detrimental to the project.

Supervision of drilling is a vital aspect of borehole construction and as much support as possible should be given to the young drilling Supervisor. Occasional visits to the drill sites by senior project personnel will reinforce the Supervisor's authority with the Driller.

Glossary

Air Lifting – pumping water from a borehole with compressed air.

Annulus – the space between the two tubes, where one is inserted into the other, i.e. drilled hole and the lining material or drilled hole and the drill pipe.

Aquifer – an underground layer of water-bearing rock from which groundwater can be usefully abstracted via a well or borehole.

Backfill – putting back the material removed from the hole during drilling.

Basement Complex/Crystalline Basement – any rock below sedimentary rocks or sedimentary basins that are igneous and metamorphic in origin.

Bill of Quantities - a list of quantities of materials and activities. This is used to provide prices for itemised activities and materials.

Bit, or drill bit – the earth or rock cutting tool in a drilling rig or equipment.

Borehole – a small diameter water point made by drilling rather than digging.

Circulation pit – a pit in which the *drilling fluid* is mixed and from which it is pumped into the drilled hole and into which cuttings from the hole settle (sometimes referred to as settlement pit.

Compressor – a machine that produces compressed air providing pressure used in drilling.

Consolidated sediments – sediments cemented or compressed into a compact mass e.g. sandstone, mudstone.

Demobilisation – clear-up of drilling site, return of the drilling crew and equipment to their headquarters. Cleaning, repairing and storing equipment and completing paperwork.

Drawdown – the difference between the *static water level* and the pumping water level.

Drill Camp – the main base, crew accommodation and storage area for the duration of the drilling campaign. If more than a few hours' travel is involved, the drill crew may establish a *Satellite Fly Camp* while completing an individual borehole.

Driller – the Drilling Contractor, generally refers to the person responsible for decision-making.

Drilling fluid – material, either gas or liquid used to remove the cuttings and to support the hole from collapsing during drilling.

Fines – small grained particulate material, such as silt and sand.

Global Positioning System (GPS) – Dedicated GPS electronic devices, and some mobile phones, are able to give the users precise grid references for their location by using signals emitted from satellites in orbit around the Earth.

Geotextiles – permeable fabrics that can be used as a filter over the screen of a borehole.

Gravel pack – coarse sand or gravel placed around the borehole screen to prevent smaller particles from the formation migrating into the borehole.

Lithology – rock type e.g. granite, gneiss, mudstone.

Mobilisation – getting drilling crew and equipment ready, purchasing materials and deployment to the *Drill Camp*.

Plumb – a lead weight, usually suspended from a line, used for measuring water depth or for testing the verticality of a well or borehole.

Rotary table – a guide that centralises the drill pipe.

Regolith – the layer of weathered rock overlying bedrock, also called weathered mantle, consisting of saprolite and soil.

Sanitary seal – the top part of the borehole *annulus* filled with cement grout or bentonite to prevent surface water infiltrating into the *gravel pack* and screened depth.

Saprock – fracture bedrock with weathering restricted to the fracture margins

Saprolite – in situ chemically weathered bed rock.

Satellite Fly Camp – temporary camp used by the drill crew for the duration of drilling a borehole.

Shoe plug – A stopper at the base of the borehole casing.

Specific capacity – a measure of the productivity of the well calculated by dividing the yield by the drawdown.

Specifications or echnical specifications – the particulars of how a borehole should be drilled, lined, developed and completed to achieve its functions.

Spheroidal weathering – weathering in which concentric layers of decomposed rocks are successively separated from a block of rock resulting in a formation of rounded boulder.

Static water level – the level of water in a borehole that is not being pumped.

Tremie Pipe – A funnel and pipe to direct gravel into *the annulus* so that the gravel does not get stuck part way down, creating gaps in the *gravel pack*.

Unconsolidated sediments – loose sediments not compacted, such as gravels, sands and clays.

Viscosity – the property of a substance to offer resistance to flow.

Water strike – depth at which water is encountered during drilling usually observable in hammer air drilling.

Figure 12: Drill rig with drilling fluid channel

Annex A: Project Checklist for the Driller

Step	Checklist
1. Pre- contract	☐ Driller's equipment approved
	☐ Driller's personnel approved
	☐ Driller's field operation observed
2. Pre-Mobilisation Meeting	☐ Contract checked
	☐ Questions asked and clarifications made
3. Mobilisation	☐ Community has been mobilised
	☐ Programme of work submitted and approved
	☐ Materials checked and approved
	☐ Driller has been shown the site
	☐ Data collection forms approved
	☐ Filing system set up
4. Siting	☐ Geophysical equipment checked and approved
	☐ Siting supervised
	☐ Report submitted and approved
5. Drilling	☐ Rig location approved
	☐ All safety measures taken
	☐ Samples are collected and kept
	☐ Drilling completed
	☐ Borehole logged
6. Borehole design	☐ Casing and screen installation approved
	☐ Gravel pack installation approved
	☐ Sanitary seal approved
7. Borehole development	☐ Water sample checked for sand content
	☐ Pumping test carried out
	☐ Borehole disinfected
	☐ Water quality analysed
	☐ Borehole successful or abortive
8. Demobilisation	☐ Site restored to its original state
	☐ Circulation pits *backfilled*
	☐ Abandoned borehole sealed
	☐ All pieces of equipment removed from site
	☐ Rubbish disposed of properly
9. Complete documentation	☐ The Driller has carried out all tests and submitted the reports.

Annex B: Checklists of Drilling Steps for the Supervisor

Checklist 1: Pre-contract checklist

Equipment	**Checklist**
☐ Drilling rig	Year of Manufacture:
	Manufacturer:
	Lifting capacity:
	☐ Raise mast.
	☐ Start and run for an hour without problem.
	☐ Check for oil leaks and get any fixed before giving approval.
☐ Compressor	Year of Manufacture:
	Manufacturer:
	☐ Start and run for an hour without problem.
☐ Mud pump and generator	☐ Check rating against estimated borehole depths.
	☐ Test pumps and generator.
☐ Water tanker	☐ Check for leaks.
☐ Support trucks	☐ Check that the Driller has the necessary working support vehicles.
☐ Drill pipes	☐ Check that there are adequate lengths of drill pipes to drill the deepest hole.
☐ Drill bits (and hammer depending on the type of drill rig)	☐ Correct diameter.
	☐ Right drill bits available for likely ground conditions.
	☐ Check condition.
☐ Geophysical surveying equipment	☐ Geophysical equipment working correctly
	☐ Personnel competent in use of geophysical surveying equipment
Personnel	**Checklist**
☐ Drilling manager	Years of experience:
	Experience of similar assignments:
☐ Hydrogeologist	Qualifications:
	Years of experience:
	Experience of similar assignments:
☐ Rig operator	Years of experience:
☐ Driver	Years of experience:
☐ Mechanic	Years of experience:
☐ Rig assistants	Number of assistants:
	Years of experience:
☐ Record Taker	Years of experience:

Checklist 2: Siting

Activity	Checklist	
☐ 1. Water User priorities – based on Community engagement	☐ Proximity to point of use:	
	☐ Equitable access for all water users, especially women and most disadvantaged in the Community	YES / NO
	☐ Land ownership and access rights for users and maintenance teams established and confirmed in writing	YES / NO
☐ 2. Geological favourability - based on hydrogeological assessment	☐ Sufficient yield for the intended purpose:	YES / NO
	☐ Sufficient renewable water resources for the intended purpose Appropriate water quality for the intended purpose	YES / NO
	☐ Interference with other groundwater sources and uses avoided	YES / NO
	☐ Interference with natural groundwater flows avoided	YES / NO
	☐ Chance of success (Annex 1 of *Siting of Drilled Water Wells*)	HIGH / MEDIUM LOW
☐ 3. Contamination risk	☐ Is the *aquifer* confined?	YES / NO
	☐ No potential pollution sources within minimum distances	YES / NO
☐ 4. Drilling logistics	☐ Access allowed and possible for Driller team, equipment and vehicles	YES / NO

Checklist 3: Mobilisation

Activity	Checklist
☐ 1. Contract	☐ Contract Signed
☐ 2. Programme of work	☐ Programme of work submitted and approved
☐ 3. Community liaison	☐ Explain details of drilling process.
	☐ Community member roles, contributions and responsibilities
	☐ Exchange details of main contact persons or community representatives.
	☐ Driller's representative introduced to the Community
☐ 4. Equipment is appropriate and in working condition	☐ Drill rods are adequate
	☐ Hammers and bits are of the right diameter (measure).
	☐ Temporary casing diameter is correct.
☐ 5. Samples of materials meet with technical specifications	☐ Drilling fluid
	☐ Sample box
	☐ Casing and screen (measure length and diameter)
	☐ Filter pack and gravel materials
	☐ Screen
☐ 6. Data collection forms	☐ Format of data entry forms agreed (Refer to Annex E of Code of Practice for Cost Effective Boreholes, RWSN 2010)
☐ 7. Project filing system	☐ Driller given Master Project Checklist (Annex B)
☐ 8. *Drill Camp / Satellite Fly Camp* layout	☐ Location of vehicle and rig parking ☐ Maintenance garage ☐ Site office and living accommodation ☐ Fuel storage and spillage control measures ☐ Water supply source ☐ Sanitation facilities ☐ PVC casing and screens protected from direct sunlight

Checklist 4: Drilling

Activity	Checklist
☐ 1. Health and Safety	☐ Rig set up away from traffic hazards and power transmission lines
	☐ Rig and support vehicle not positioned on a steep slope
	☐ Public safety barrier (bright coloured tape).
	☐ Drilling team wearing personal protective clothing: boiler suits, hard hats, boots, eye protection and gloves
	☐ Inflammable items such as petrol or chlorine etc should be kept in approved containers, properly marked and stored away from sources of heat.
	☐ Mast not raised during thunderstorm (lightning strike risk)
	☐ Lifting of very heavy or bulky loads which could lead to back strain should be avoided. Lifting should be done using the legs and not with the back.
	☐ Equipment should be kept in good working order.
	☐ Area around the drilling rig is kept tidy.
	☐ Borehole should be securely capped on completion to prevent tools and other debris falling into the hole and children throwing stones and corn stalks into it which could render it useless.
	☐ On completion, the site should be restored as far as possible to what it was before the drilling, mud pits filled in and compacted.
	☐ Drill crew should drink plenty of fluids regularly to prevent dehydration, which can lead to poor judgement.
	☐ First Aid kit checked
	☐ Emergency procedure in case of major injury and need for hospitalisation
☐ 2. Rig position	☐ Rig positioned over pegged site.
	☐ Rig drill mast vertical (checked with spirit level).
	☐ Check ground stability for softness that could entrap the rig or cause it to tilt during drilling
☐ 3. Drilling Depth	☐ Depth measurements being conducted and logged properly
☐ 4. Penetration Rate	☐ Penetration rates being measured properly
☐ 5. Drilling Fluid	☐ Type of drilling fluid being used:
	☐ Driller using Marsh funnel to measure drilling fluid viscosity
☐ 6. Drill Cutting Samples	☐ For Rotary mud-flush drilling, check that the circulation mud pits (or portable tanks) have a volume that is at least three times the volume of the borehole – see Annex D.
	☐ Ensure that the Driller prevents sample contamination due to poor circulation, borehole erosion or caving.
	☐ Ensure that mud pits are kept clean to prevent re-circulation of cuttings.
	☐ Samples taken at regular intervals and properly washed, bagged, labelled, logged and stored in sample box.
	☐ Photograph samples
☐ 7. Strata Log	☐ Use samples to prepare a Strata Log.
☐ 8. Final borehole depth	☐ Water table depth (m):
	☐ Final borehole depth (m):
☐ 9. Drill Report	☐ Daily drilling log signed by rig operator and Supervisor.
	☐ Record necessary data and information required to complete a Casing and Well Completion Form (Appendix E3, *Code of Practice for Cost Effective Boreholes*).

Checklist 5: Borehole Design

Design Criteria	Value
☐ 1. Borehole Depth (metres):	
☐ 2. *Aquifer*/Rock Type	Basement/Consolidated/Unconsolidated
☐ 3. Yield (litres per second)	
☐ 4. Drilled borehole diameter (mm)	
☐ 5.a Type of borehole casing and screens:	PVC / GRP / Steel / Bamboo / Other:
☐ 5.b Wall diameter and thickness (mm) check diameter and wall thickness with callipers	
☐ 5.c Quantity of borehole casing & screens (m)	
☐ 6. Screening length (m)	
☐ 7. Screen area (m^2)	
☐ 8. Installation of casing and screens	☐ Produce sketch of proposed assemblage of casing and screen.
	☐ Layout casing and screening on the ground, check against sketch and photograph.
	☐ Check joints between casing pipes.
☐ 9. Gravel Pack	☐ Ensure that gravel pack design is adhered to (formation stabiliser or filter pack).
	☐ Check that formation stabiliser does not contain mica, clay or laterite.
☐ 10. Sanitary Seal	☐ Check sanitary protection design, proper depth and material composition.

Checklist 6: Borehole development and site completion

Activity	Checklist	
☐ 1. Development method used	Use Annex E4 and E5 from Code Practice for Cost Effective Boreholes.	
☐ 2. Borehole development success	☐ Duration of development:	
	☐ Borehole development successful (water runs clear):	YES / NO
	☐ If NO then should the Driller re-drill the borehole?	YES / NO
	☐ If YES a re-drill is needed, should it be at the Driller's cost?	YES / NO
☐ 3. Platform casting	☐ Shuttering is properly anchored and layout matches designs. ☐ Correct sand : cement : aggregate ratios (1:2:4) ☐ Correct drainage slope (1:50) ☐ Surface towelled smooth ☐ Borehole number, date of completion, yield and water levels embedded in the wet concrete ☐ Concrete kept moist for 72 hours to allow proper curing ☐ Is the finished platform acceptable?	YES / NO
☐ 4. Pump Testing	Use forms in Annex E7 of the Code Practice for Cost Effective Boreholes).	
☐ 5. Water Quality Testing	Use forms in Annex E5 of the Code Practice for Cost Effective Boreholes).	
☐ 6. Borehole Disinfection	a. Depth to static water level unacceptable?	YES / NO
	b. Dry borehole or inadequate yield?	YES / NO
	c. Unacceptable sand content of pumped water?	YES / NO
	d. Unacceptable turbidity of pumped water?	YES / NO
	e. Borehole straight and vertical?	YES / NO
	f. Unacceptable chemical or bacteriological quality of the pumped water?	YES / NO
	FINAL DECISION ON BOREHOLE: SUCCESSFUL / ABORTIVE	

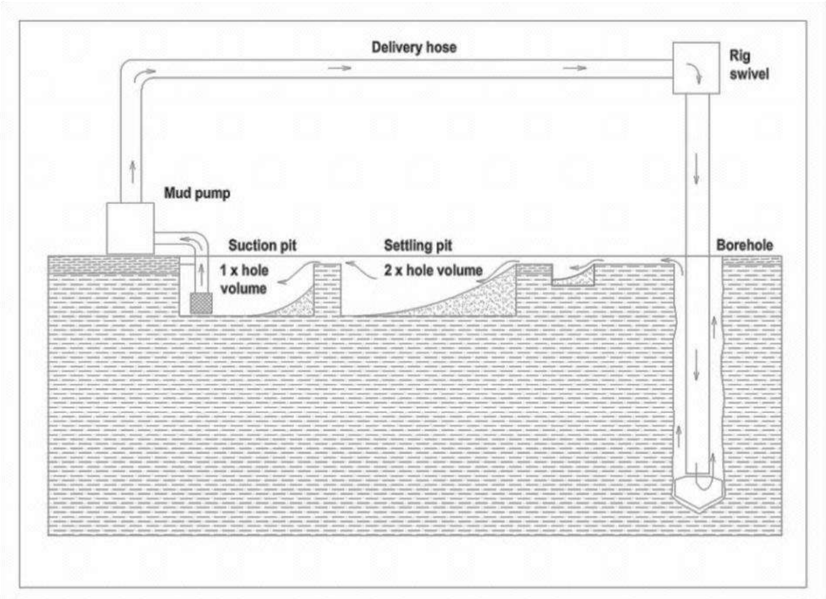
Checklist 7: Demobilisation

Activity	Checklist
☐ 1. Work complete	☐ All installation work complete and approved by Supervisor
	☐ All testing completed and documentation and data handed over to Supervisor
☐ 2. Drilling site cleared	☐ All litter, liquid and solid waste disposed of responsibly so as not to cause nuisance
	☐ Circulation pits filled in
	☐ Equipment cleaned and packed away
	☐ Unused materials taken away (check with contract who owns or pays for unused materials, such as casing, filter packs etc.)
	☐ Public barrier taken down.

Checklist 8: Development and Site Completion

Activity	Checklist
☐ 1. Reporting	☐ Drilling report completed and copies given to Client, the Community and the Regulator/Government water or geology ministry
☐ 2. Handover	☐ Agree handover date with Driller, Community and Client. ☐ Organise signed handover of borehole to the Community or Client.
☐ 3. Defect Liability Period	☐ Agree monitoring schedule. ☐ Undertake site visits to check that pump is still working and that there are no problems with the borehole performance. ☐ Report any problems found, or reported by the Community to the Client. If necessary, mobilise the Driller to undertake repair work.
☐ 4. Invoicing and payment	☐ At end of defects liability period, submit supervision invoice to Client and give approval for final payment to Driller (depending on contract).

Annex C: Circulation/Settling pits layout



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About the Author

Dotun Adekile is a Nigerian consultant with over 30 years of experience siting and supervising borehole construction, as well as training field geologists and technicians. He has contributed to developing the Code of Practice for Cost Effective Boreholes in three countries and the preparation of several guidance notes.

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Support and Acknowledgement

Although this document derives from the author's years of drilling supervision, similar works on the subject were consulted in its preparation. Some of the authors are mentioned in the text but for brevity of presentation others are not. All the sources consulted are listed in the bibliography. The author gratefully acknowledges their contribution.

Particular gratitude goes to Kerstin Danert, Ron Sloots, Robin Hazell, Richard Carter, André Olschewski and Jim Anscombe who reviewed this document.

This document was supported by UNICEF and Skat Foundation

The document was edited by Sean Furey and Kerstin Danert

Layout was undertaken by Martin Laeng

Photo Credits: The author, Richard Carter, Hazel Jones, WEDC and Jim Anscombe.

Schweizerische Eidgenossenschaft
Confédération suisse
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ISBN: 978-3-908156-42-0

www.we-consult.info	**LOG FOR DEEP WELL**	

Project name:		Borehole No:		Page	of
Project No:		Location:		Other ID No:	
Xcoordinates(1):				Source Name:	
Ycoordinates:				Village code:	
UTM_Datum or other					
Altitude(m):				Ves No:	
Geological unit:				Map No:	

(1):Mark: UTM ARC60,ARC70/WGS84 or decimal Degrees (dD)/Degrees Minutes Seconds (DMS), or Degrees decimal Minutes (DdM)

Date start:		Date end:		Contractor:		Driller / Unit:	

Table height 1 (m):		Table height 2 (m):		Table height 3 (m):	
1. Temp. casing type:		Size ID/OD (mm):	/	Length (per piece/total):	/
2. Temp. casing type:		Size ID/OD (mm):	/	Length (per piece/total):	/
Perm. casing type:		Size ID/OD (mm):	/	Length (per piece/total):	/
Drillrod 1 diameter(m):		Length per rod:		Number on site:	
Drillrod 2 diameter(m):		Length per rod:		Number on site:	

1.Hammer & Bit (m):		1. Diameter/Type	/	4. Hammer & Bit (m):		4. Diameter/Type	/
2.Hammer & Bit (m):		2. Diameter/Type	/	5. Hammer & Bit (m):		5. Diameter/Type	/
3.Hammer & Bit (m):		3. Diameter/Type	/	6. Hammer & Bit (m):		6. Diameter/Type	/

Date/Time	Drilling (m)			Rate	Formation log and activities	Remarks
	Pipe No.	Depth (m)	Min.	m/min	(lithology, fracturing, drilling method, bit, well development)	(collapsing, delays, water strike, yield, problems)

Signature Supervisor:

WEconsult *www.we-consult.info*	**LOG FOR DEEP WELL**	

Project name:		Borehole No:		Page of

Date/Time	Drilling (m)			Rate	Formation log and activities	Remarks
	Pipe No.	Depth (m)	Min.	m/min	(lithology, fracturing, drilling method, bit, well development)	(collapsing, delays, water strike, yield, problems)

Signature Supervisor:

WEconsult

www.we-consult.info

BOREHOLE DRILLING & INSTALLATION

Project name:		Borehole No:		Page of

DRILLING SPECIFICATIONS

Depth (mbgl)		Actual bit diameter[1]	Bit type / Nominal size in Inches[2]				Drilling method			
from	to	(mm)	Tricone Roller	Drag	Button	Odex	Air	Mud	DTH-hammer	Odex

LINING INSTALLED

Length of casing above the ground (m):

Depth (mbgl)		Diameter (mm)	Casing/ Screen	Material	slot size	Remarks
from	to	Inner/Outer	(C or S)	PVC, Steel	(mm)	(plain, ribbed, continuous)
		/				
		/				
		/				
		/				
		/				
		/				
		/				
		/				

FILLING

Depth (mbgl)		Gravel Pack size	Back fill material	Type of seal		Packer	Bottom plug
from	to	(mm)		cement	bentonite		

Signature Supervisor:

[1] Actual size: measure the actual size and record in mm.
[2] Nominal size: size of bit when new.

www.we-consult.info	BOREHOLE YIELD, LITHOLOGY & DEVELOPMENT	

Project name:		Borehole No:		Page of

YIELD TEST DURING DRILLING

Size of bucket in litres:

Depth (mbgl)		Time to fill bucket	Total Yield Q	Aquifer yield	Aquifer type (Saprolite, Fracture, Sand, Gravel etc.)	Remarks (method of measurement etc)
from	to	(sec)	litre/hour	litre/hour		

LITHOLOGY DESCRIPTION SUMMARY (see lithology sheet for details)

Done by: ( ) Driller ( ) Hydrogeologist

Depth (mbgl)		Particle size	Overall colour	mineral colours			Remarks	Interpretation
from	to	(dust, grain size, chunks)		1	2	3	(Hardness, sticky, slates, glistening, particle shape)	(check manual for details)

DEVELOPMENT

Depth Tool	Method			Time spent	Remarks
(mbgl)	Airlift	Jetting	surging	(hours)	(clearing, yield increase, possible cause not clearing)

Signature Supervisor:

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BOREHOLE PENETRATION RATE, LITHOLOGY & DESIGN

Project name:		Borehole No:		Page of

PENETRATION RATE
meters per minute

LITHOLOGY

WELL DESIGN

Time (min/m)

DESCRIPTION/
H_20 STRIKES

Diameter in inches
4 8 12 14

REMARKS

Depth (m)

Signature Supervisor:

WEconsult *www.we-consult.info*	**DAILY INSTRUCTIONS TO DRILLING CONTRACTOR**	

Project name:		Borehole No:		Page	of
Location:		Subcounty:		District:	
Parish:		County:		Source Name:	

Date:		Contract No:		Contractor:	
Time:		Project No:		Driller / Unit:	

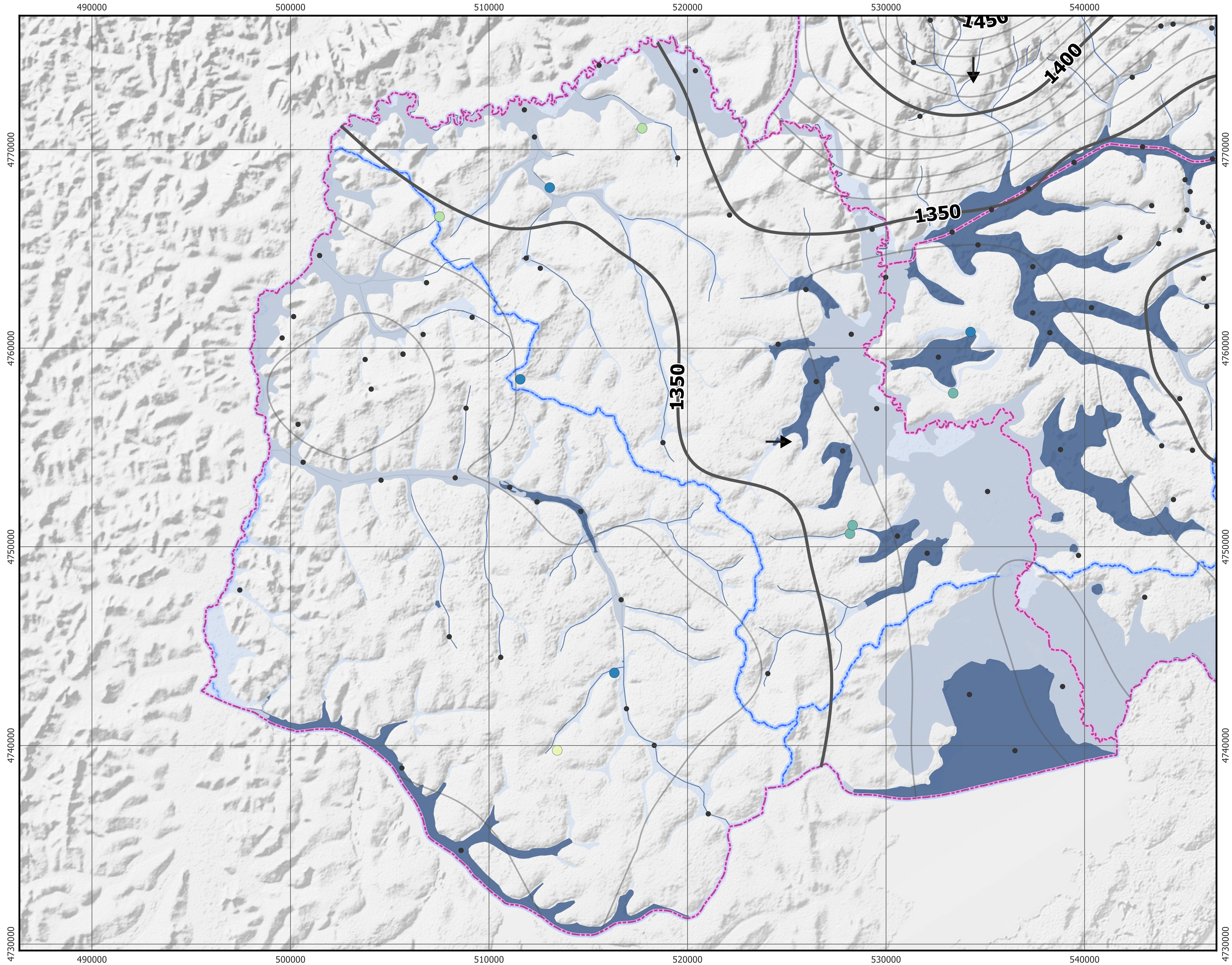
INSTRUCTIONS

( ) DRILLING **( ) WELL DEVELOPMENT** **( ) TEST-PUMPING**

Driller:		Signature:	
Supervisor:		Signature:	

Annex 7. A3 format maps

Groundwater and Recharge and Storage Enhancement in Eastern Province of Rwanda - Bugesera



Piezometric ground water level, based on topography

Legend

- Datapoints
- Ground water contour
- 201811_Isohyp_GW flow 10m_contour
- Ground water flow direction

Boreholes (SWL m bgl)

- 0 - 12
- 12 - 24
- 24 - 35
- 35 - 47
- 47 - 59
- 59 - 71
- 71 - 82
- 82 - 94

- District
- Open water
- river
- Wetlands
- Topographical boundary

Elevation m amsl

- 1250
- 1500
- 1800
- inf

23 0 23 46 69 92 km

Coordinate system

Projection: Transverse_Mercator	Geographic Coordinate
false_easting: 500000	System: GCS_WGS_1984
false_northing: 5000000	Datum: D_WGS_1984
central_meridian: 30	Prime Meridian:
scale_factor: 0.9999	Greenwich
latitude_of_origin: 0.0	Angular Unit: Degree
Linear Unit: Meter	

Credits

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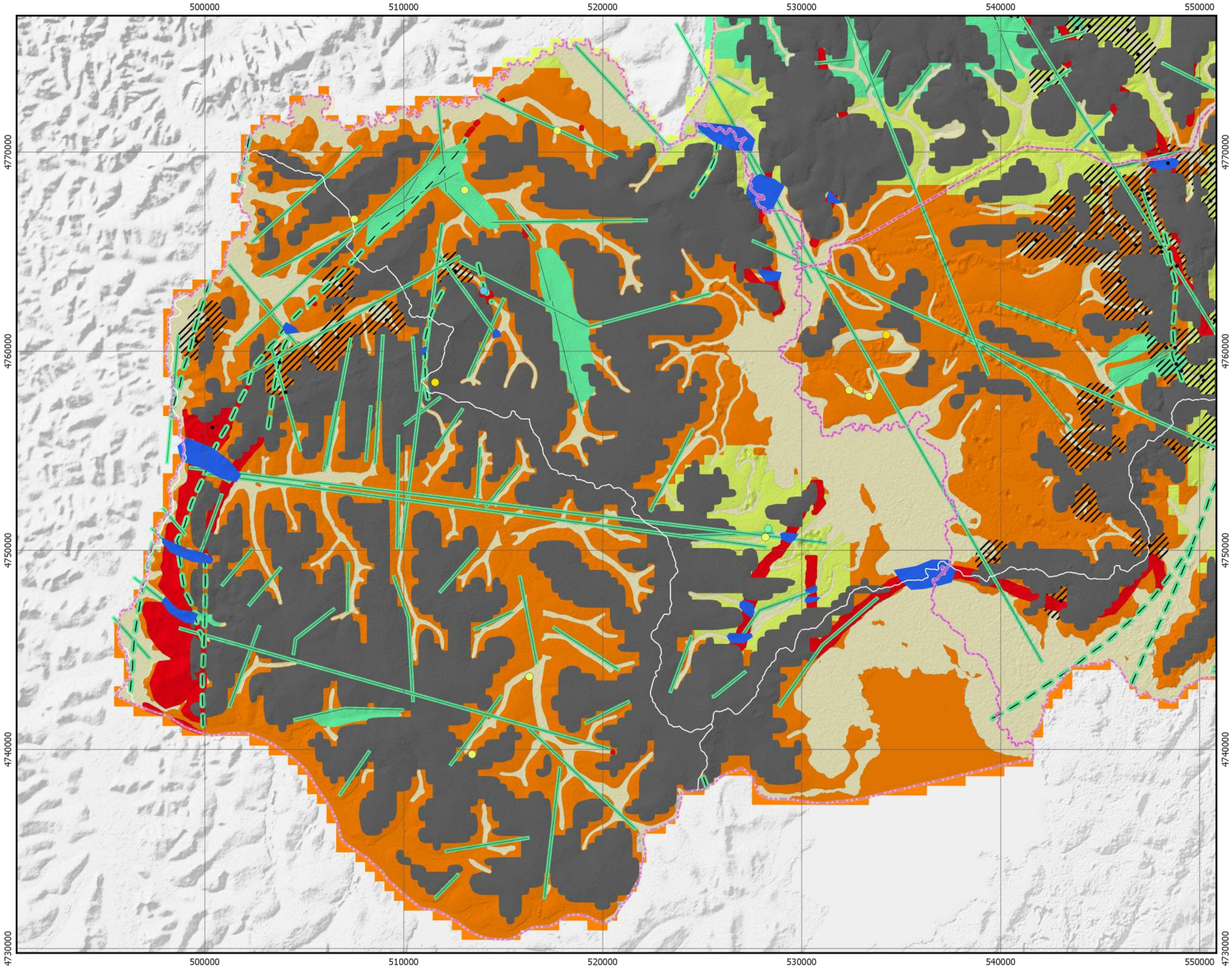

Ground water potential

Legend

Boreholes (m3/h)

- > 0.3 - 0.5
- > 0.5 - 1
- >1 - 3
- >3 - 5
- >5 - 10
- >10 - 15
- >15
- Springs
- District
- Topographical boundary
- Faultlines
- Lineaments
- Alluvium
- Major potential > 10m3/h
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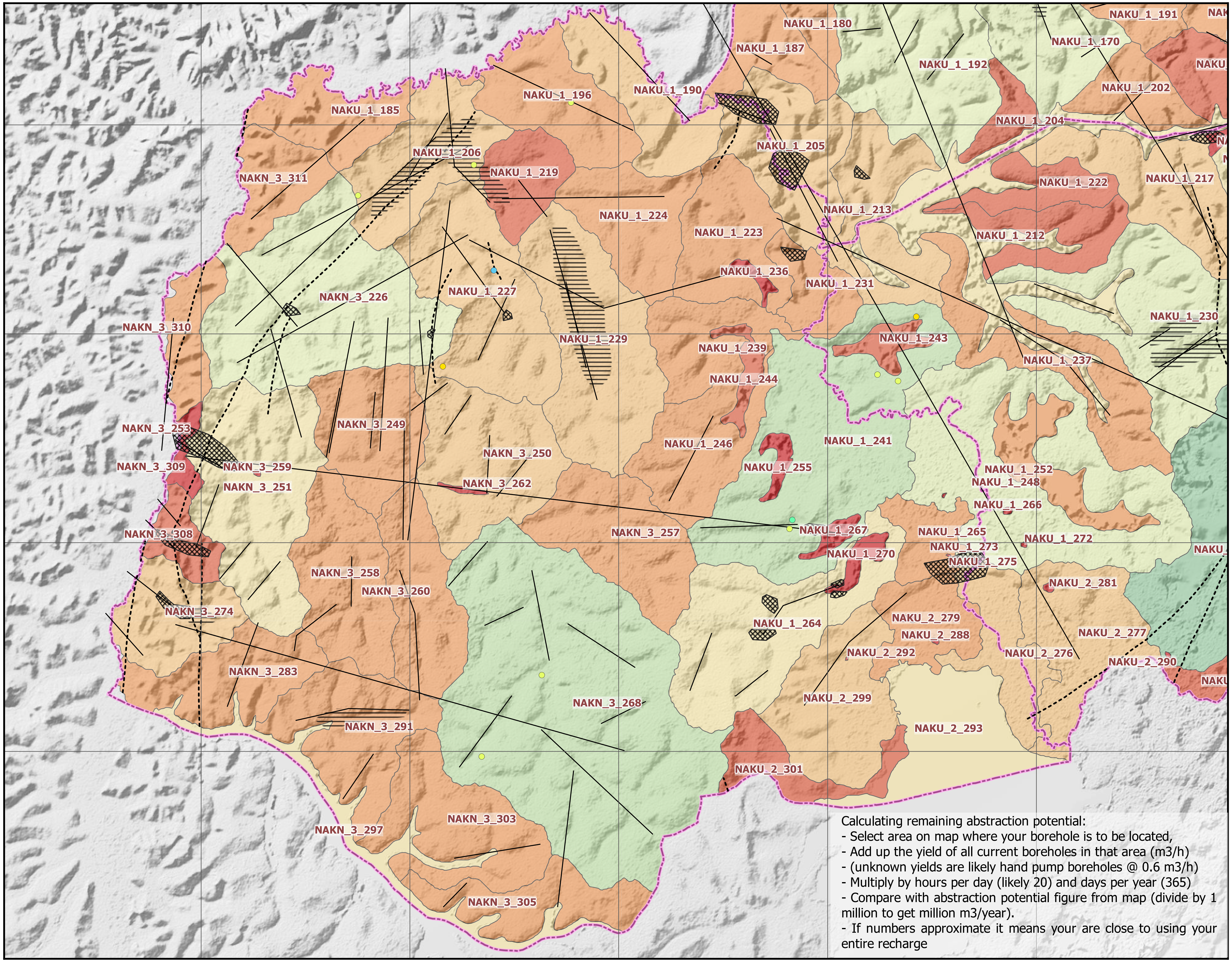

Abstraction potential

Legend

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- >15
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- District

Abstraction potential (million m3/year)
- 0.00 - 0.56
- 0.56 - 1.53
- 1.53 - 2.85
- 2.85 - 4.33
- 4.33 - 6.27
- 6.27 - 8.33
- 8.33 - 11.55
- 11.55 - 14.23
- 14.23 - 20.73
- 20.73 - 26.43

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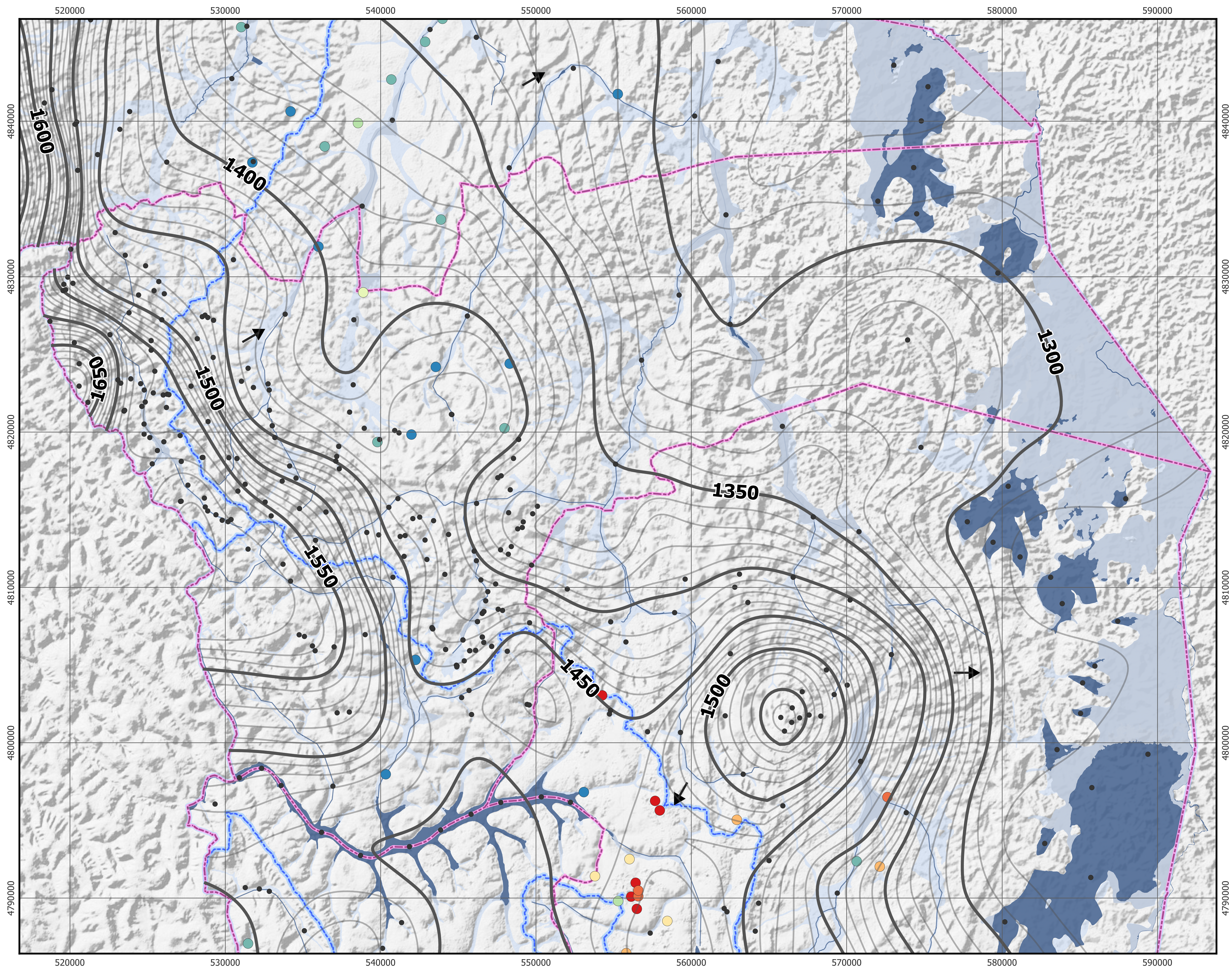

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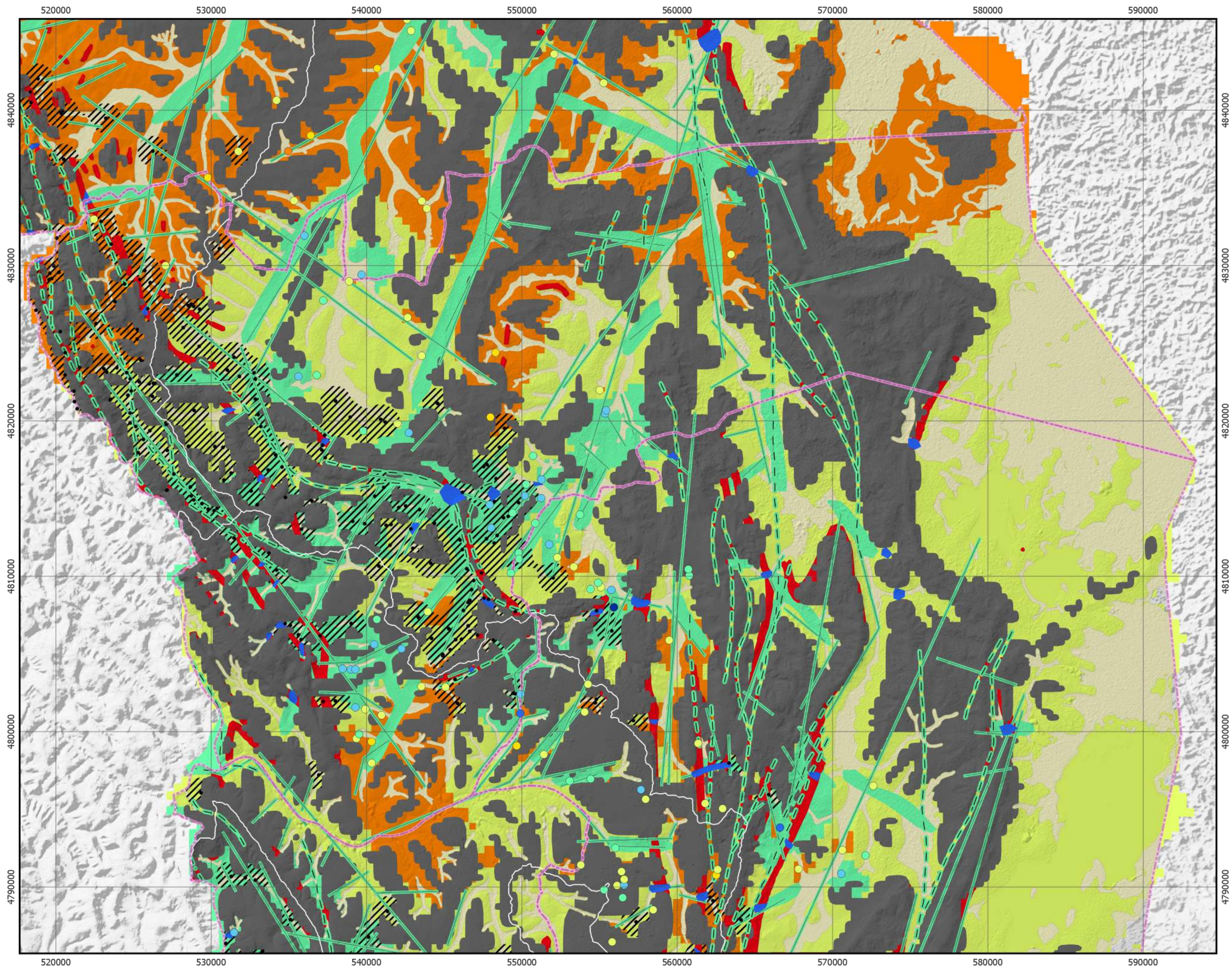

Ground water potential

Legend

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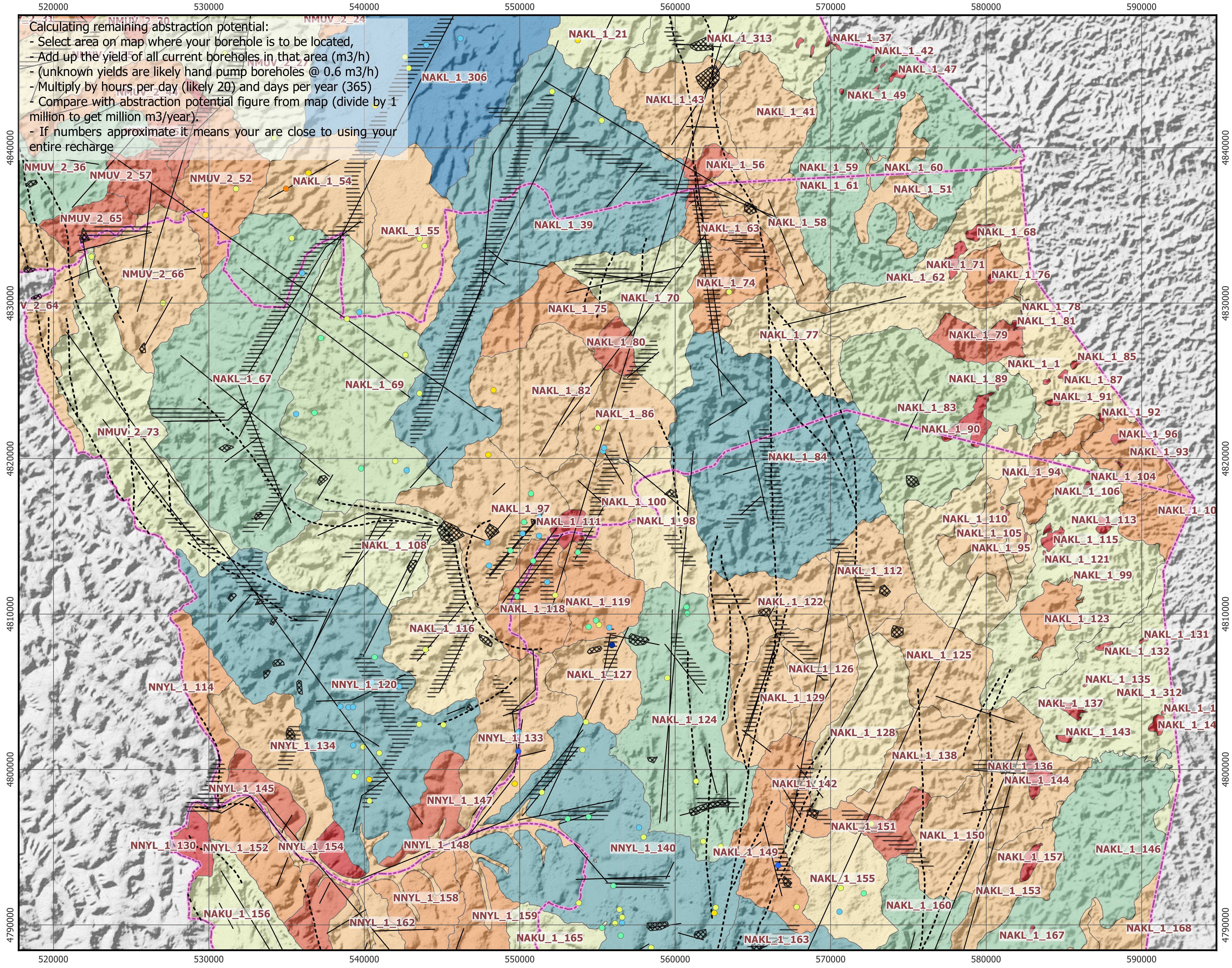

Abstraction potential

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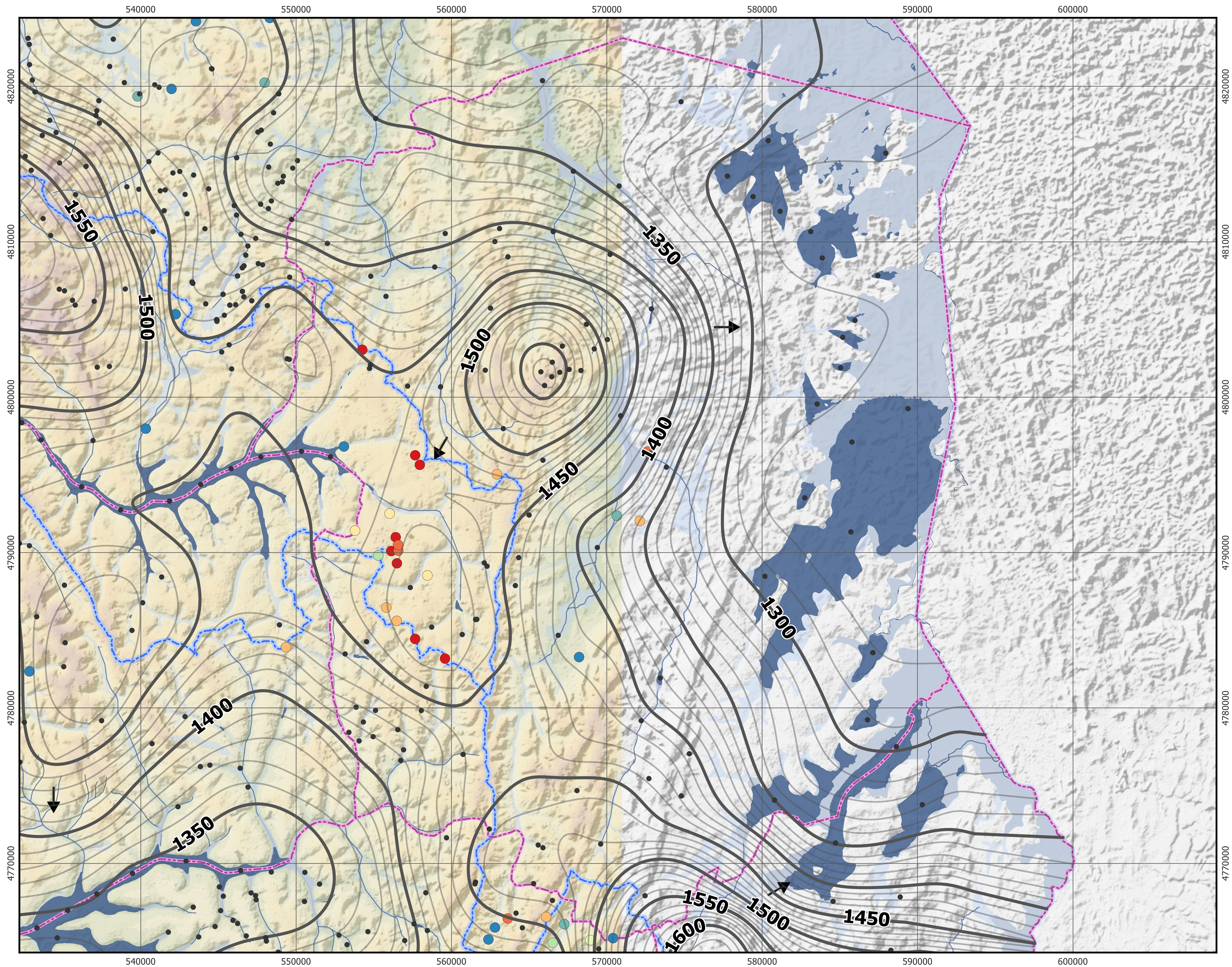

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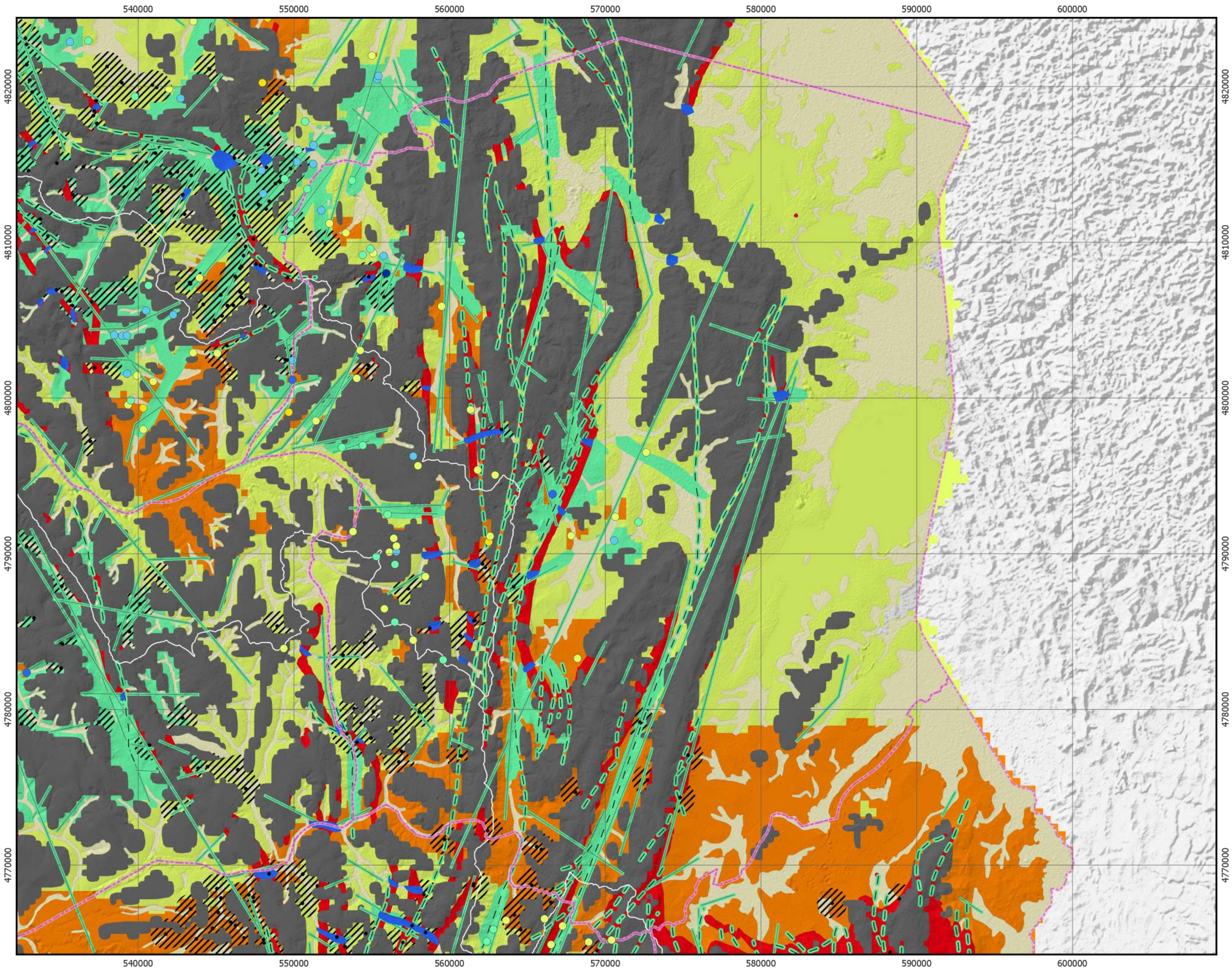

Ground water potential

Legend

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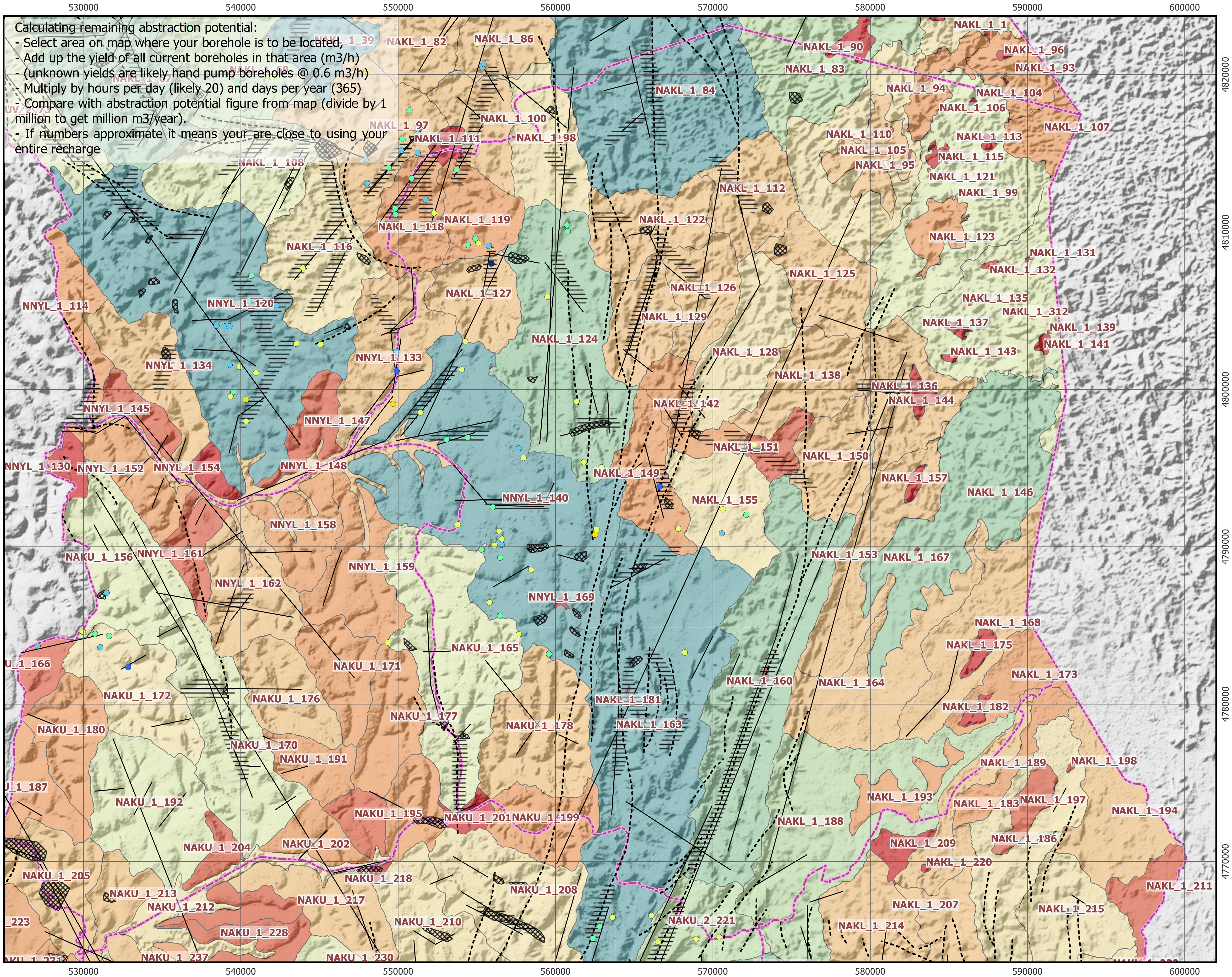

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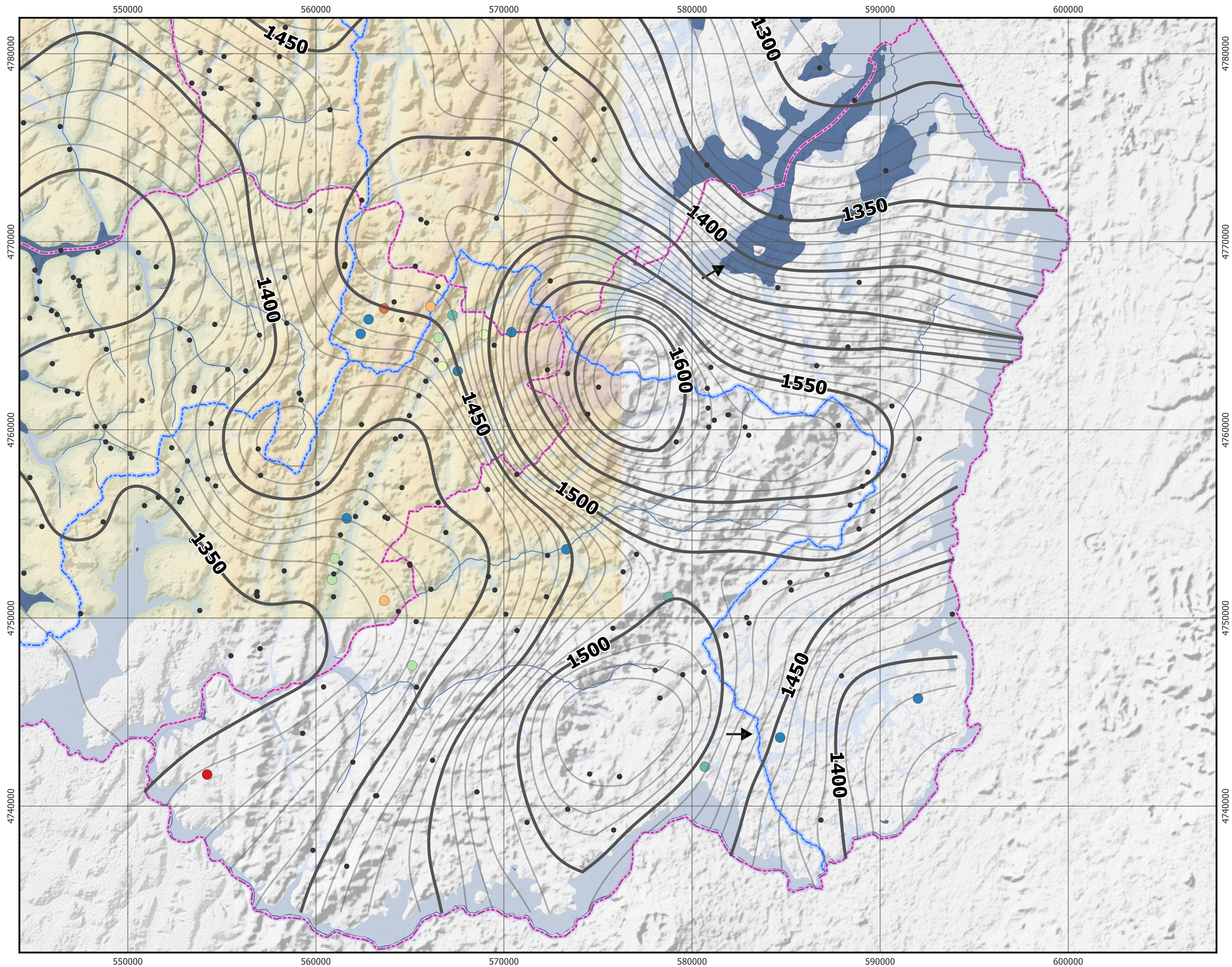

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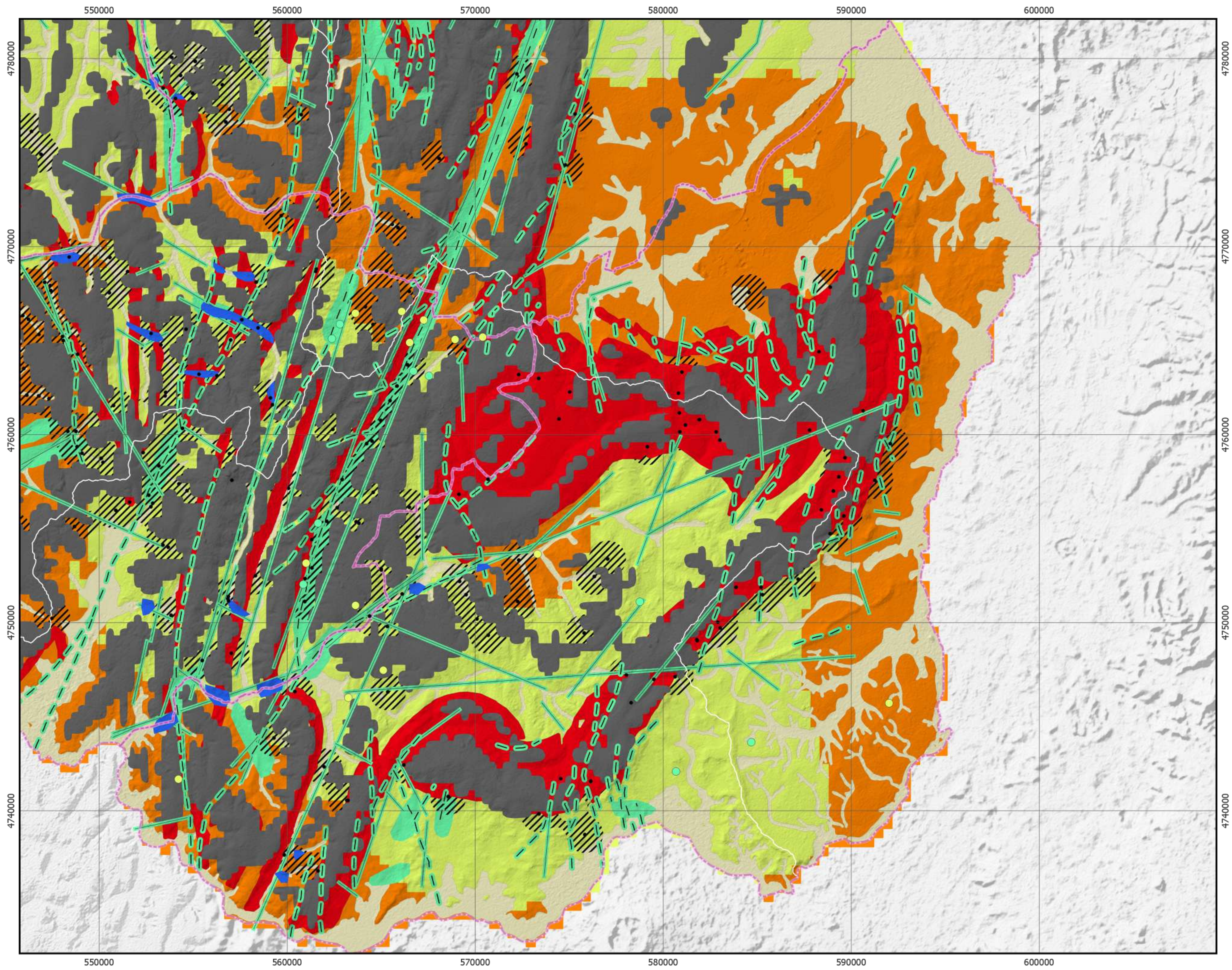

Ground water potential

Legend

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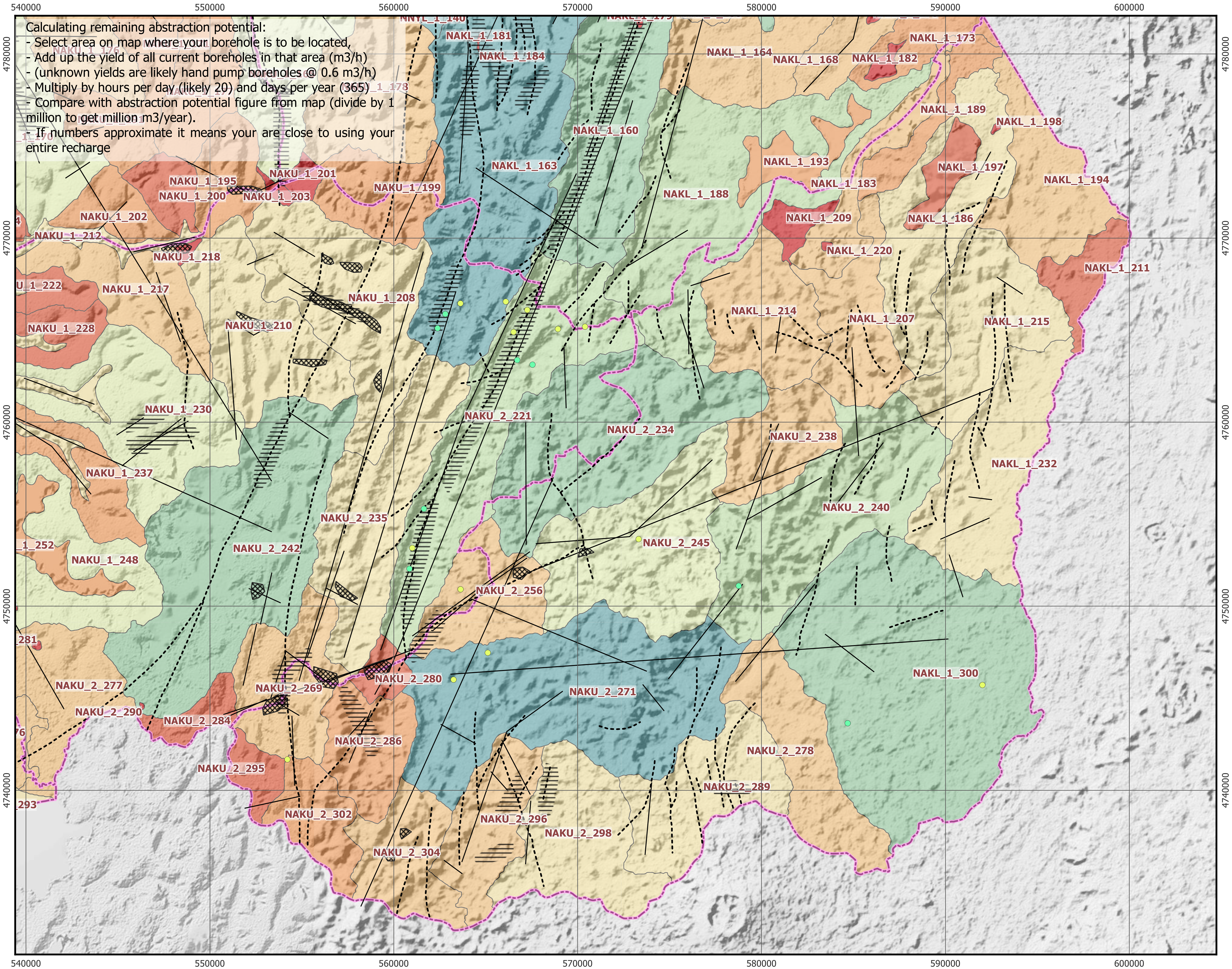

Abstraction potential

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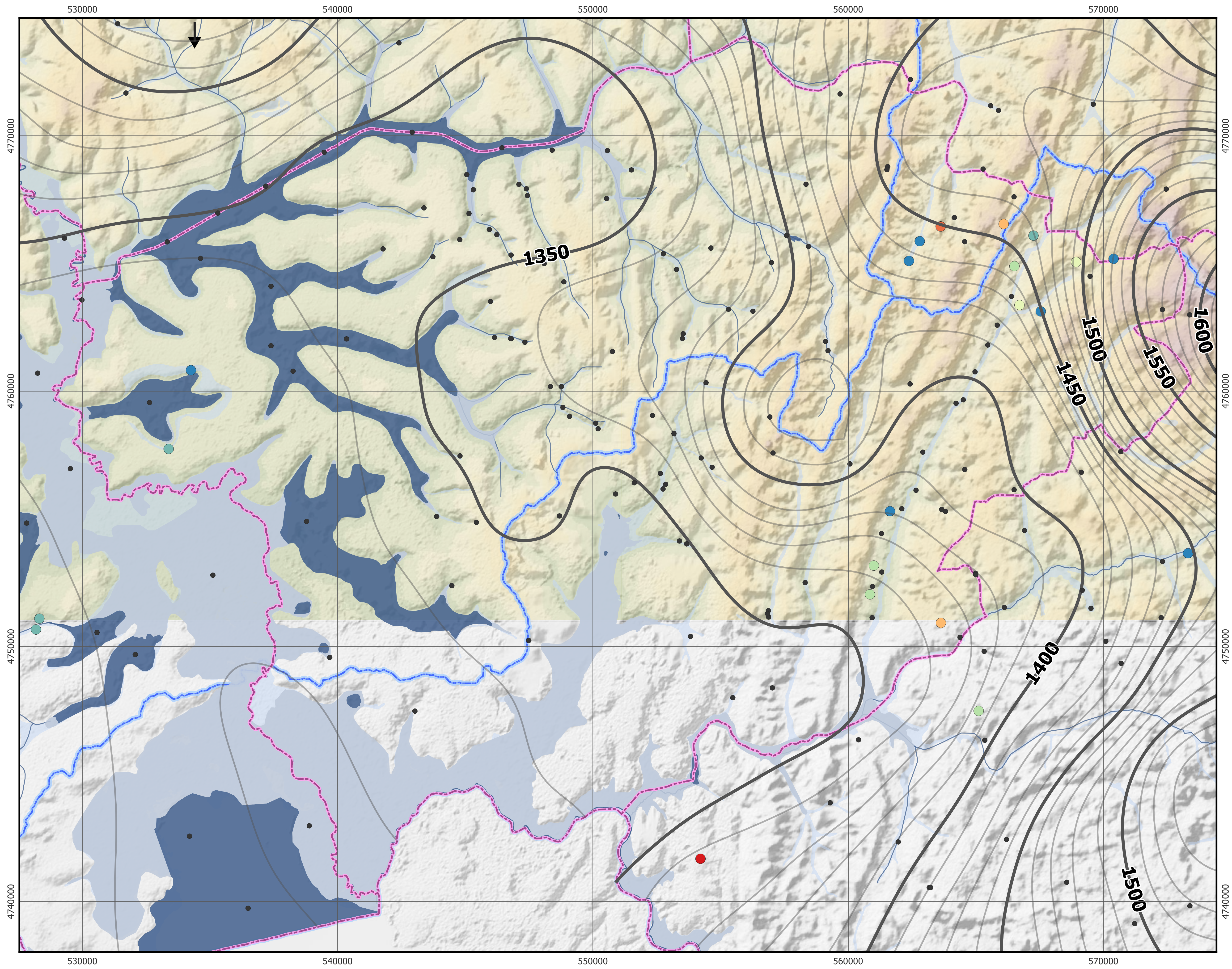

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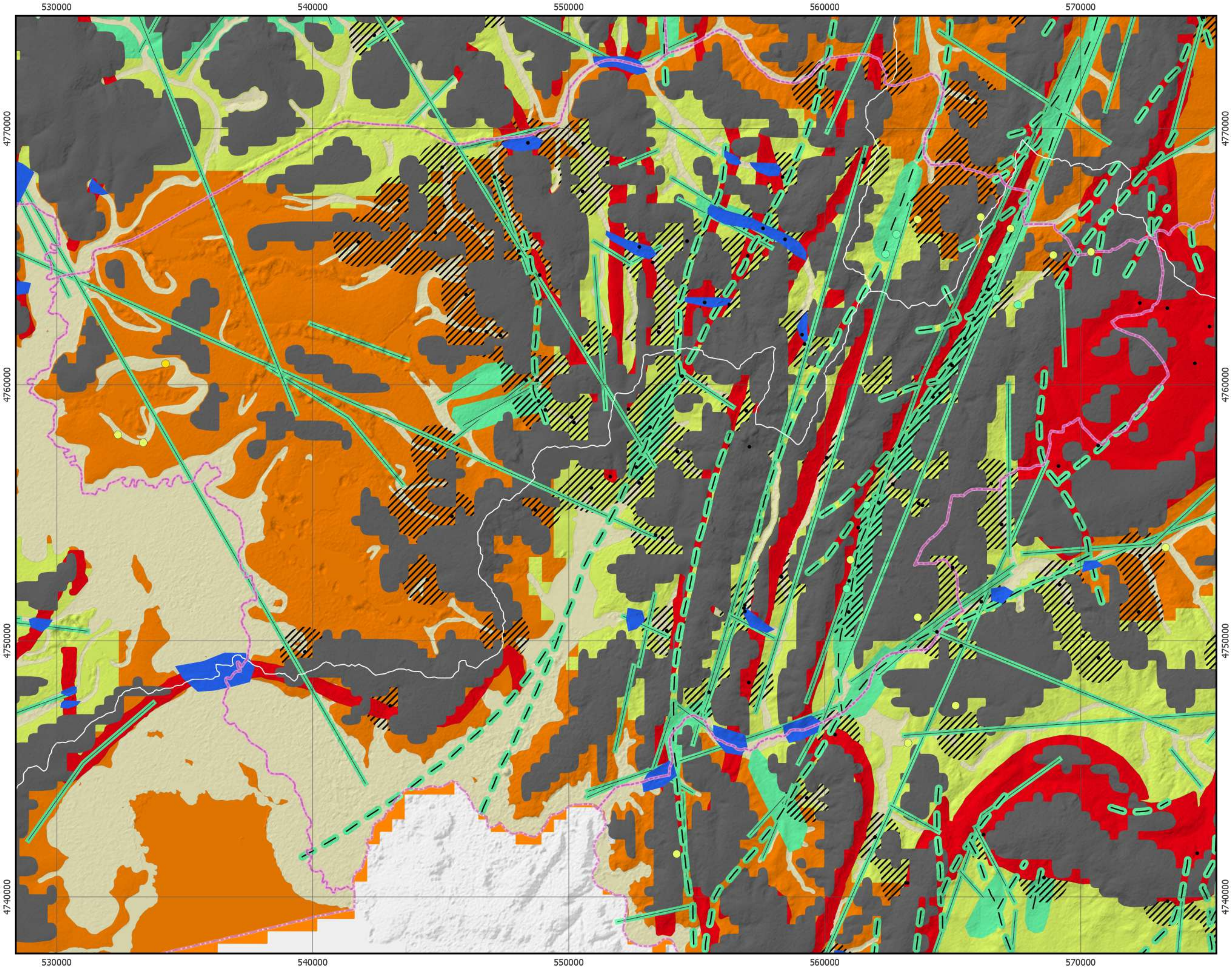

Ground water potential

Legend

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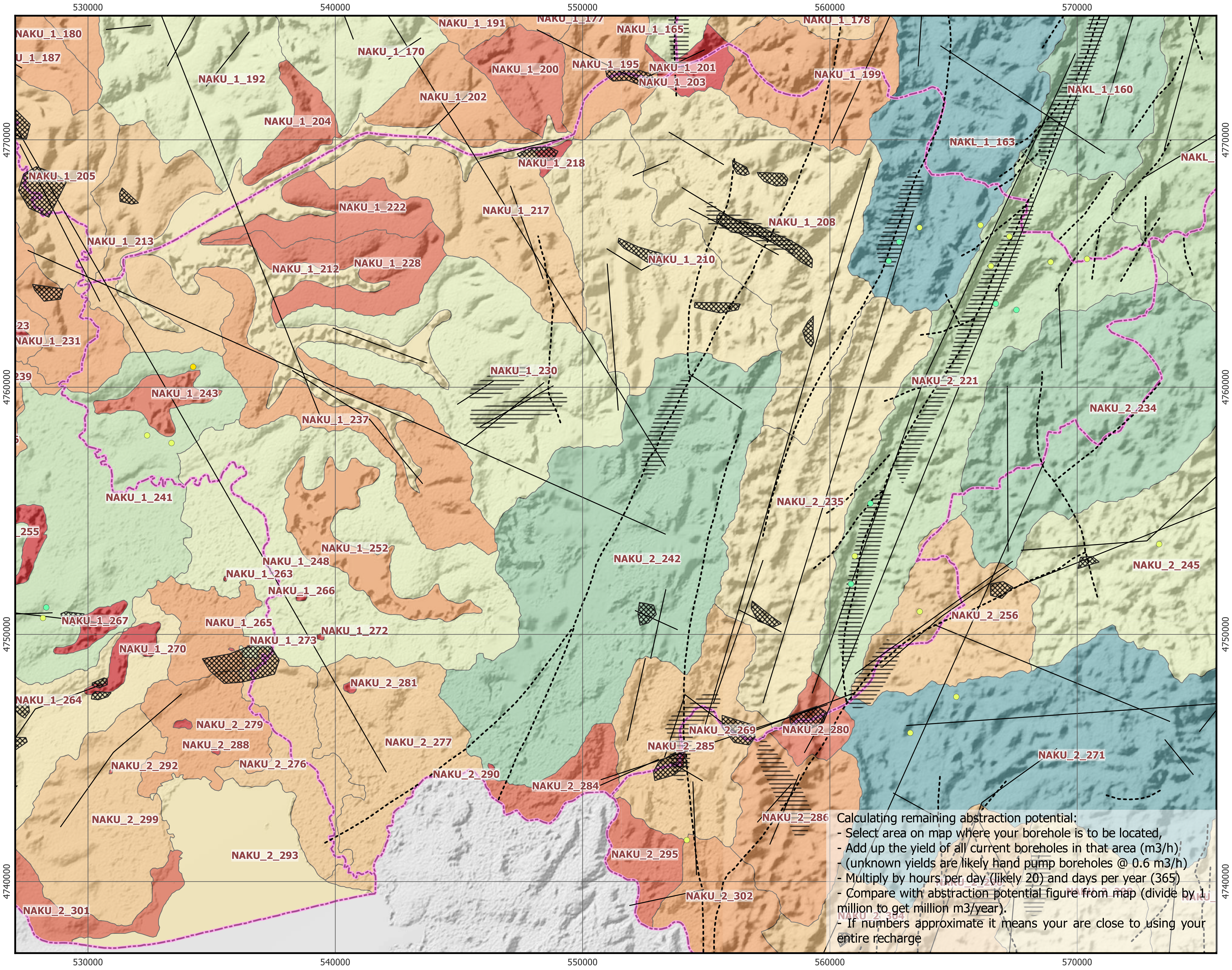

Calculating remaining abstraction potential:
- Select area on map where your borehole is to be located,
- Add up the yield of all current boreholes in that area (m3/h)
- (unknown yields are likely hand pump boreholes @ 0.6 m3/h)
- Multiply by hours per day (likely 20) and days per year (365)
- Compare with abstraction potential figure from map (divide by 1 million to get million m3/year).
- If numbers approximate it means your are close to using your entire recharge

Abstraction potential

Legend

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- 2.85 - 4.33
- 4.33 - 6.27
- 6.27 - 8.33
- 8.33 - 11.55
- 11.55 - 14.23
- 14.23 - 20.73
- 20.73 - 26.43

23 0 23 46 69 92 km

Coordinate system

Projection: Transverse_Mercator
false_easting: 500000
false_northing: 5000000
central_meridian: 30
scale_factor: 0.9999
latitude_of_origin: 0.0
Linear Unit: Meter

Geographic Coordinate System: GCS_WGS_1984
Datum: D_WGS_1984
Prime Meridian: Greenwich
Angular Unit: Degree

Credits

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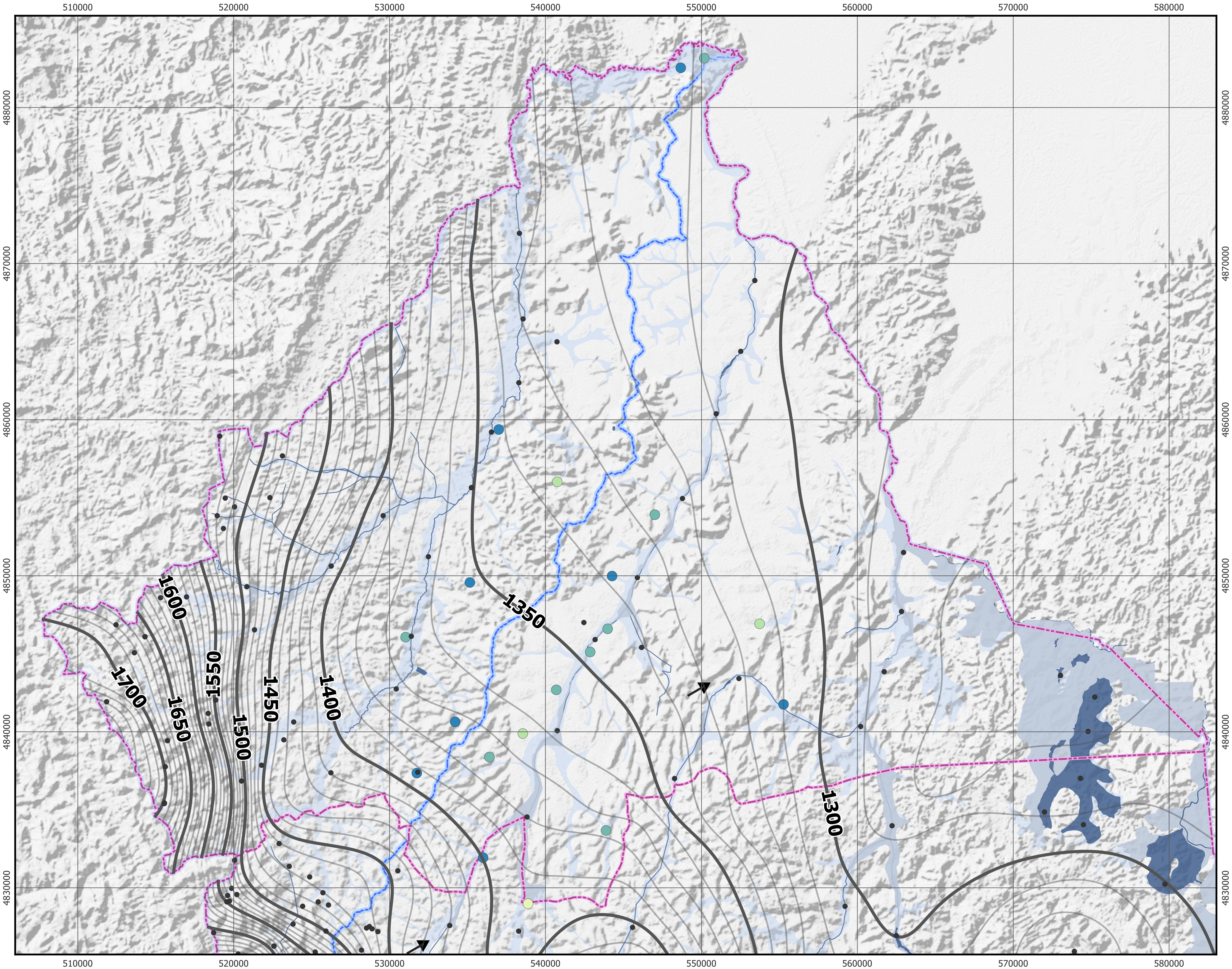
Groundwater and Recharge and Storage Enhancement in Eastern Province of Rwanda - Nyagatare



Piezometric ground water level, based on topography

Legend

- Datapoints
- Ground water contour
- 201811_Isohyp_GW flow 10m_contour
- Ground water flow direction

Boreholes (SWL m bgl)

- 0 - 12
- 12 - 24
- 24 - 35
- 35 - 47
- 47 - 59
- 59 - 71
- 71 - 82
- 82 - 94
- District
- Open water
- river
- Wetlands
- Topographical boundary

Elevation m amsl

- 1250
- 1500
- 1800
- inf

23 0 23 46 69 92 km

Coordinate system

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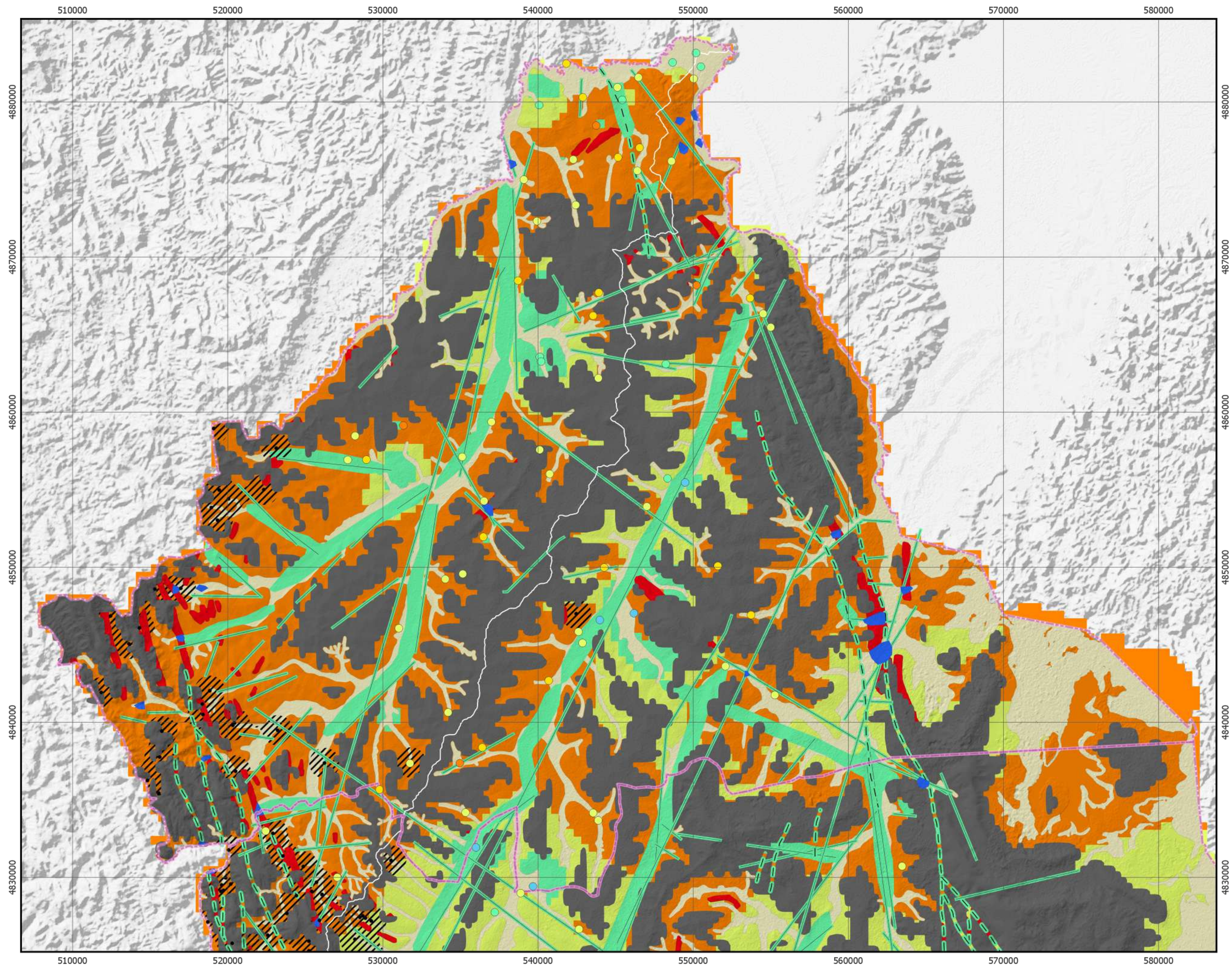

Ground water potential

Legend

Boreholes (m3/h)

- > 0.3 - 0.5
- > 0.5 - 1
- >1 - 3
- >3 - 5
- >5 - 10
- >10 - 15
- >15
- Springs
- District
- Topographical boundary
- Faultlines
- Lineaments
- Alluvium
- Major potential > 10m3/h
- High potential > 5 m3/h
- Medium potential > 3 m3/h
- Low potential > 1 m3/h
- Very low potential < 0.5 m3/h
- Spring potential
- SWL beyon 50 m below ground level

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- (unknown yields are likely hand pump boreholes @ 0.6 m3/h)
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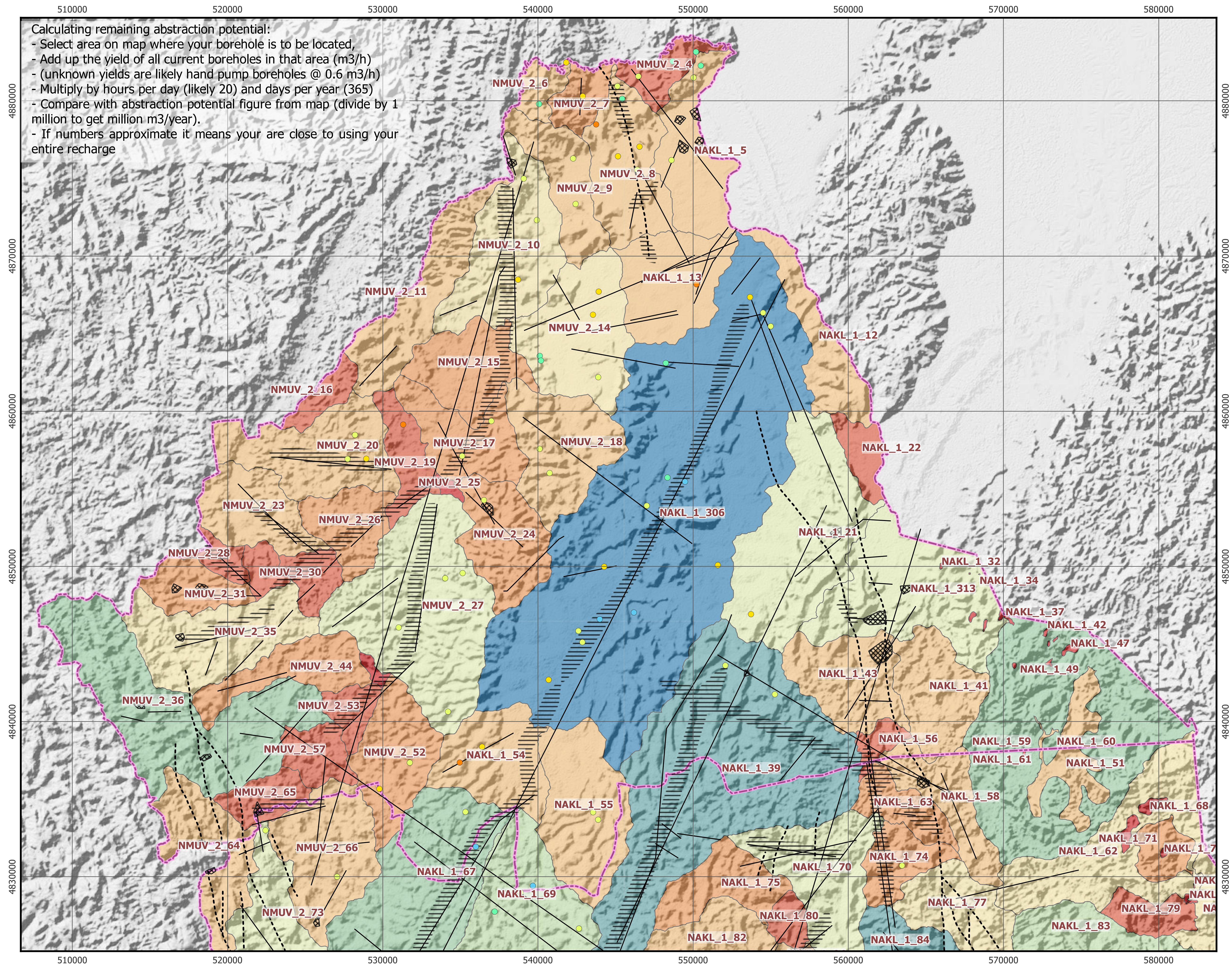

Abstraction potential

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- >5 - 10
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- >15
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- Lineaments
- District

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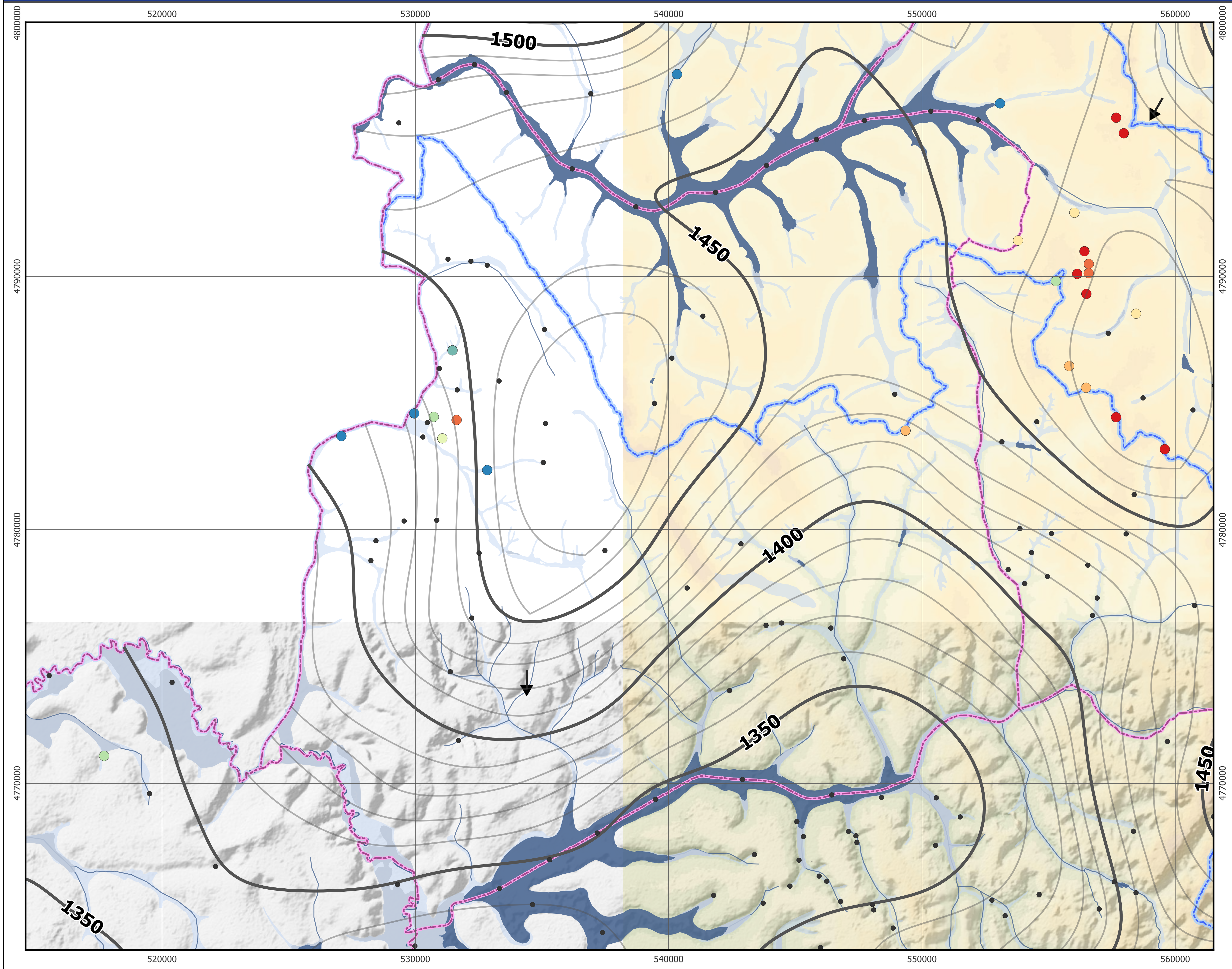
Groundwater and Recharge and Storage Enhancement in Eastern Province of Rwanda - Rwamagana



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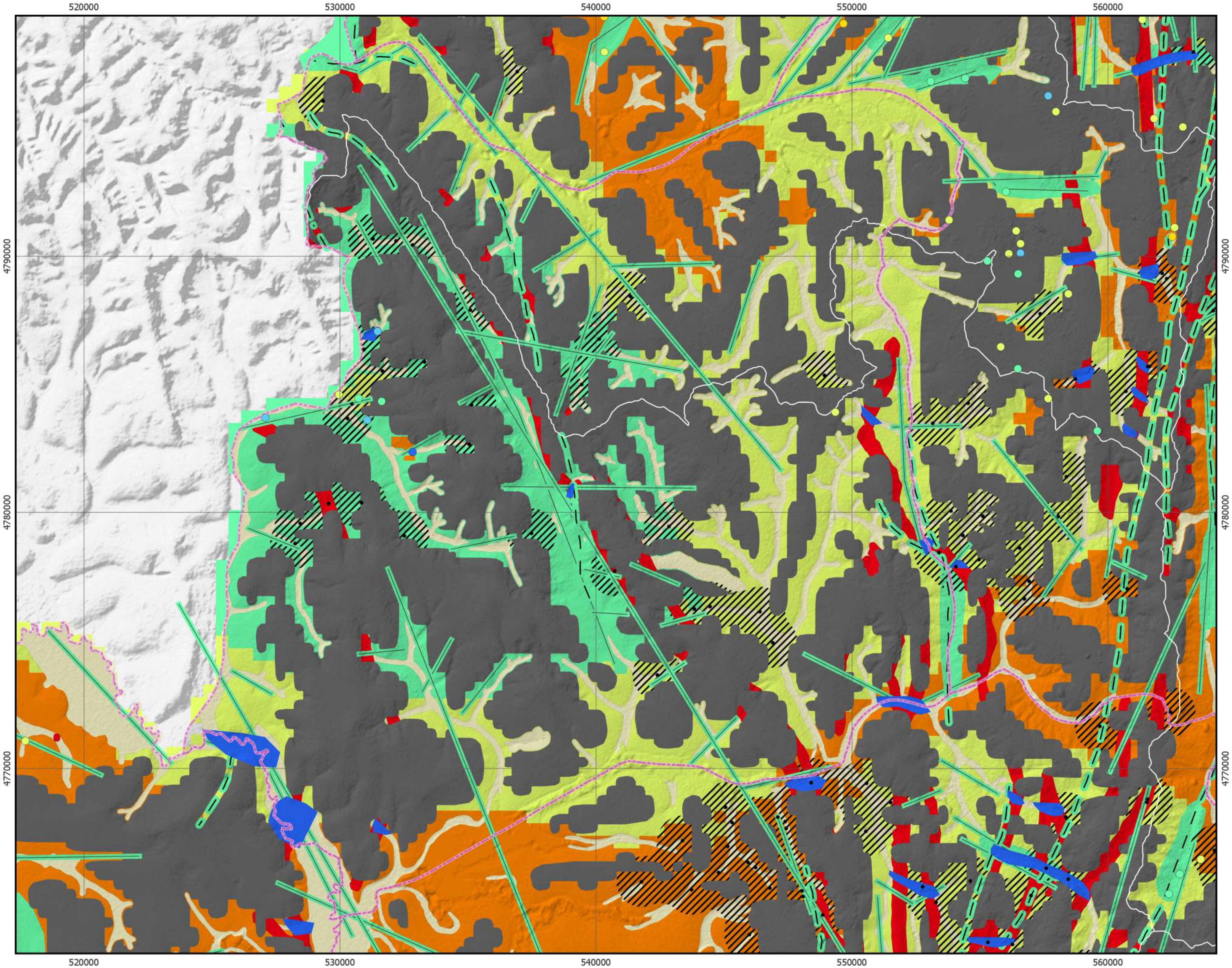

Ground water potential

Legend

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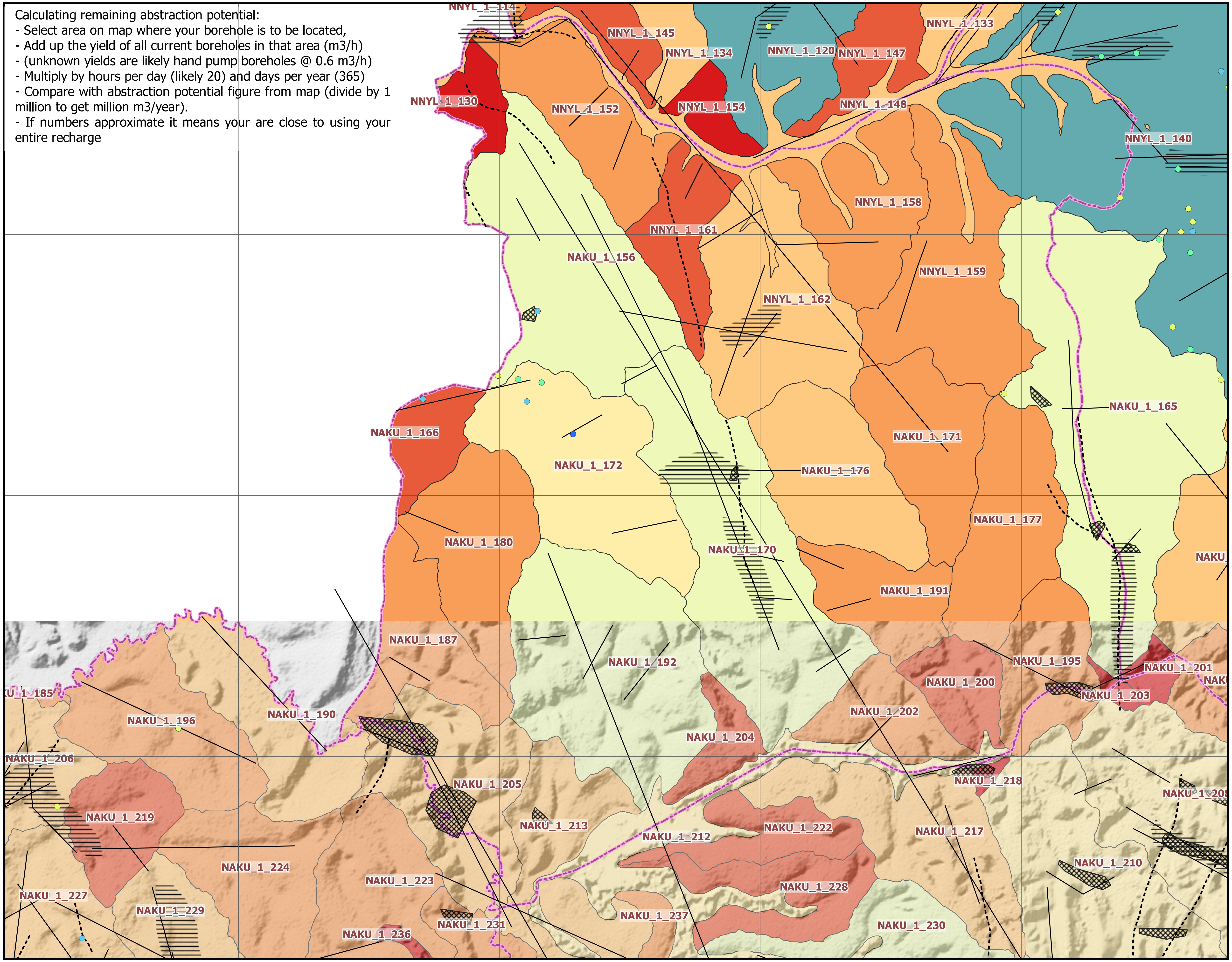

Abstraction potential

Legend

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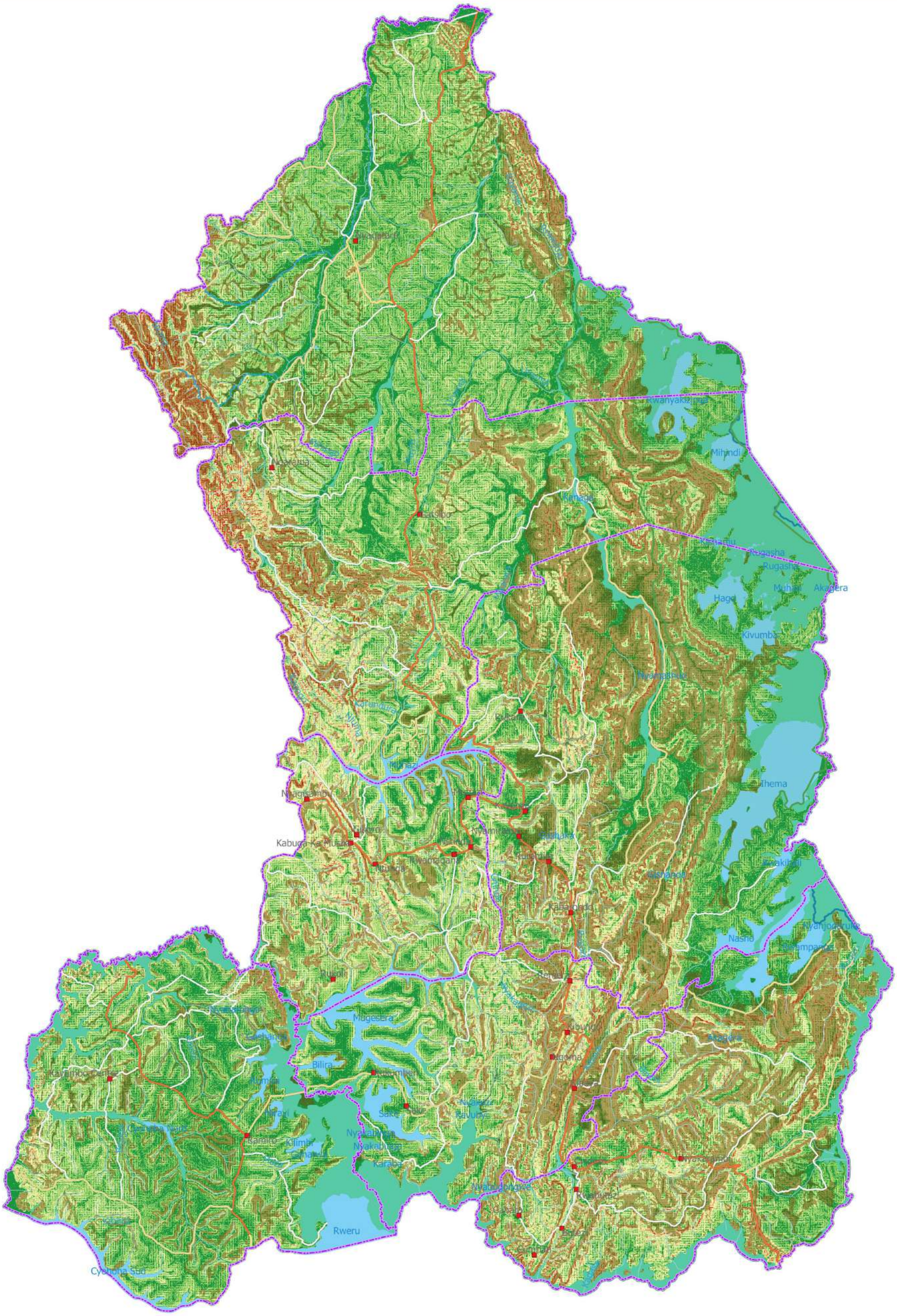
Potential for Recharge and Storage Enhancement in Eastern Province of Rwanda



Type	Interventions for conservation	Interventions for storage/recharge
Stream	Streambank protection, riverine buffer, check-dams	Dam, water diversion for irrigation
River	Controlled use of floodplains, adapted agriculture, controlled grazing and buffer zone/ riverine buffer with protection of riverine vegetation	Riverbank infiltration, floodwater spreading, valley tanks in floodplains,
Main river	Protection of floodplains and buffer zone/ riverine buffer with protection of riverine vegetation	Riverbank infiltration, floodwater spreading
Open water bodies, lakes, rivers	Protection of floodplains and buffer zone/ riverine buffer with protection of riverine vegetation	Riverbank infiltration
Marshlands	Protection, restricted use of products	No interventions (natural buffer), riverbank infiltration

General legend

- District boundaries
- Akagera National Park
- Towns

Rivers and streams
- Main river
- River
- Stream

Roads
- primary
- secondary
- trunk
- tertiary

Recharge and storage enhancement zones

Deep soils (>0.5m)

Slope	Class	Interventions for land and water conservation (Recharge enhancement)	Interventions for storage
0-6%	I	Agroforestry + Contour ploughing + Alley cropping combined with grass strips	Valley tanks, ponds, MAR, floodwater spreading
6-16%	II	- Progressive terraces - Perennial crops, coffee, tea, banana, fruit trees	Valley dams, hillside dams, ponds
16-40%	III	- Bench terraces (or progressive terraces if parent material is not stable) reinforced by agroforestry hedges and grass strips - Perennial crops, coffee, tea, banana, fruit trees	Valley dams, hillside dams
40-60%	IV	- Narrow cut terraces (or progressive terraces if parent material is not stable) reinforced by agroforestry hedges and grass strips - Perennial crops - Forestation	Storage in closed tanks
>60%	V	- Forestation - Perennial crops	-

Shallow soils (<0.5m)

Slope	Class	Interventions for land and water conservation (Recharge enhancement)	Interventions for storage
0-6%	VI	- Agroforestry + Contour ploughing + Alley cropping combined with grass strips - Forestation where soil depth is too limited and unsuitable for crops - Perennial crops, coffee, tea, banana, fruit trees	Valley dams, small ponds, rock catchments
6-16%	VII	- Progressive terraces - Perennial crops, coffee, tea, banana, fruit trees - Forestation where soil depth is too limited and unsuitable for crops	Valley dams, rock catchments
16-40%	VIII	- Progressive terraces / Contour bunds (4-5 m spacing between terraces) reinforced by agroforestry hedges and grass strips - Forestation where soil depth is too limited and unsuitable for crops - Perennial crops, coffee, tea, banana, fruit trees	Valley dams, rock catchments
40-60%	IX	- Forestation	Rock catchments, storage in closed tanks
>60%	X	- Natural vegetation	-

0 2.5 5 7.5 10 km

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Location Map

Credits

Developed by: Reinier Visser, 12/12/2018 |Soil depth RWFA| Slopes were calculated from SRTM DEM | WDPA |

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