MINISTRY OF WATER RESOURCES
SIERRA LEONE WATER COMPANY (SALWACO)

RURAL WATER SUPPLY AND SANITATION PROJECT

RWSSI-TF Grant No.: 5800155001151
Contract number: S02/RWSSP/HM/2016

CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

Alessio Fileccia, hydrogeologist

Introduction

General outline of an hydrogeologic research

Understanding surface and subsurface

Main rock description

Igneous

Sedimentary

Metamorphic

Lithology of Sierra Leone

What is hydrogeology and what an hydrogeologist can do

Aquifer basics

Aquifer definitions

Examples of aquifer structures

Aquifer parameters and rank

Movement of groundwater (hydraulic gradient, Darcy law)

Piezometric map

General hydrogeology of Sierra Leone

The piezometric map of Sierra Leone

Overview of drilling operations

Well design

Construction methods

Screens

Water level measuring devices

Field data collection methods and field forms

General water well field form

(hand dug and boreholes)

Water point list

Borehole log

Example of field forms

Introduction

This short course is intended for SALWACO field technicians working for the improvement and maintenance of the National Groundwater Data Base.
The rationale behind is to serve both as an inventory of groundwater resources and to populate the wells and DB system.

To accomplish this goal we encourage the partecipants to gain some basic knowledge of the main topics illustrated.

A groundwater database requires a continuous implementation and revision of older data as new tools and information are available.

Needless to say that the transferring of field records such as water levels, borehole and pump-test logs to database format suitable to support mapping is a never ending and time consuming process.

Finally it must be underlined that data collected on the field are the «foundation» of the entire exercise and from their correctness and validity many exact (or wrong) evaluations will follow.

General outline of an hydrogeologic research

One of the many steps involved in a ground water exercise is the field data collection. This phase requires particular attention and need qualified personnel, joining preferably some hydrogeological practice.

In all groundwater studies there are some fixed and separate stages each built on the previous one and leading to a schematic (conceptual) representation of the underground environment.

The field reconnaissance of the study area is made at a preliminary stage after a desk study, and involves, among many, some simple and important steps like:

General knowledge of morphology, prominent topographic features and road condition

water points inventory

Surface hydrology

Borehole and hand dug distribution and characteristics

Water level measurements

Filling in the field forms

Data checking

To help students in their field task providing them with some capability to evaluate different information and judging the validity of the data to be handed over to the DB administrator the following topics will be briefly described during lesson time:

Main rock description
General geology of Sierra Leone
What is hydrogeology and what an hydrogeologist can do
Aquifer basics
Aquifer definitions
Example of aquifer structures
Aquifer parameters and rank
Movement of groundwater (hydraulic gradient, darcy law)
General hydrogeology of Sierra Leone
Main drilling methods
Field operation and borehole data processing

The final goal of the hydrogeologic exercise is therefore:

To understand surface (topography, geomorphology, hydrology)

and subsurface (geology, lithology, hydrogeology)

Main rock description

Rock or stone is a natural substance, a solid aggregate of one or more minerals.

For example, granite, a common rock, is a combination of the minerals quartz, feldspar and biotite.

The Earth's outer solid layer, the lithosphere, is made of rock.

Three major groups of rocks are commonly defined: igneous, sedimentary, and metamorphic.

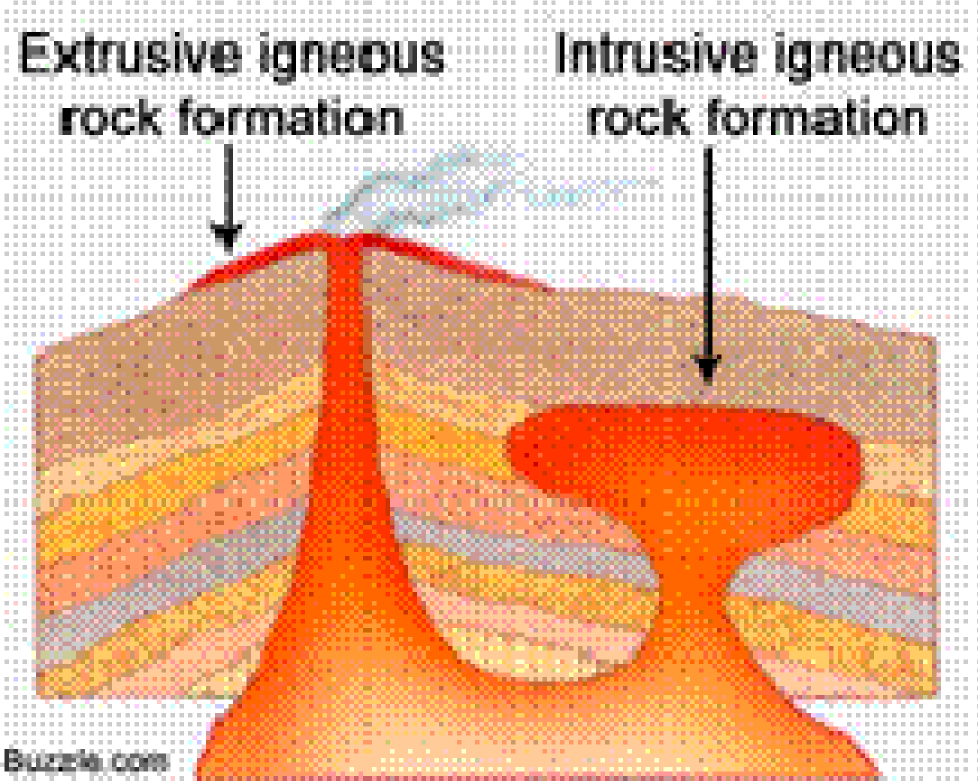
Igneous rock

Igneous rock forms through the cooling and solidification of magma or lava.

This magma can be derived from partial melts of pre-existing rocks in either a planet's mantle or crust.

Typically, the melting of rocks is caused by one or more of three processes: an increase in temperature, and or pressure, or a change in composition.

A common example of this type is granite. Magma slowly pushes up from deep within the earth into any cracks or spaces it can find, sometimes pushing existing country rock out of the way, a process that can take millions of years. As the rock slowly cools into a solid, the different parts of the magma crystallize into minerals..

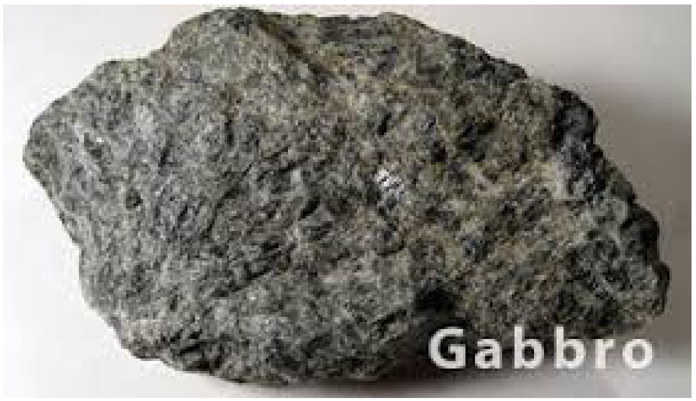


Igneous rocks are divided into two main categories: plutonic rock and volcanic. Plutonic or intrusive rocks result when magma cools and crystallizes slowly within the Earth's crust.

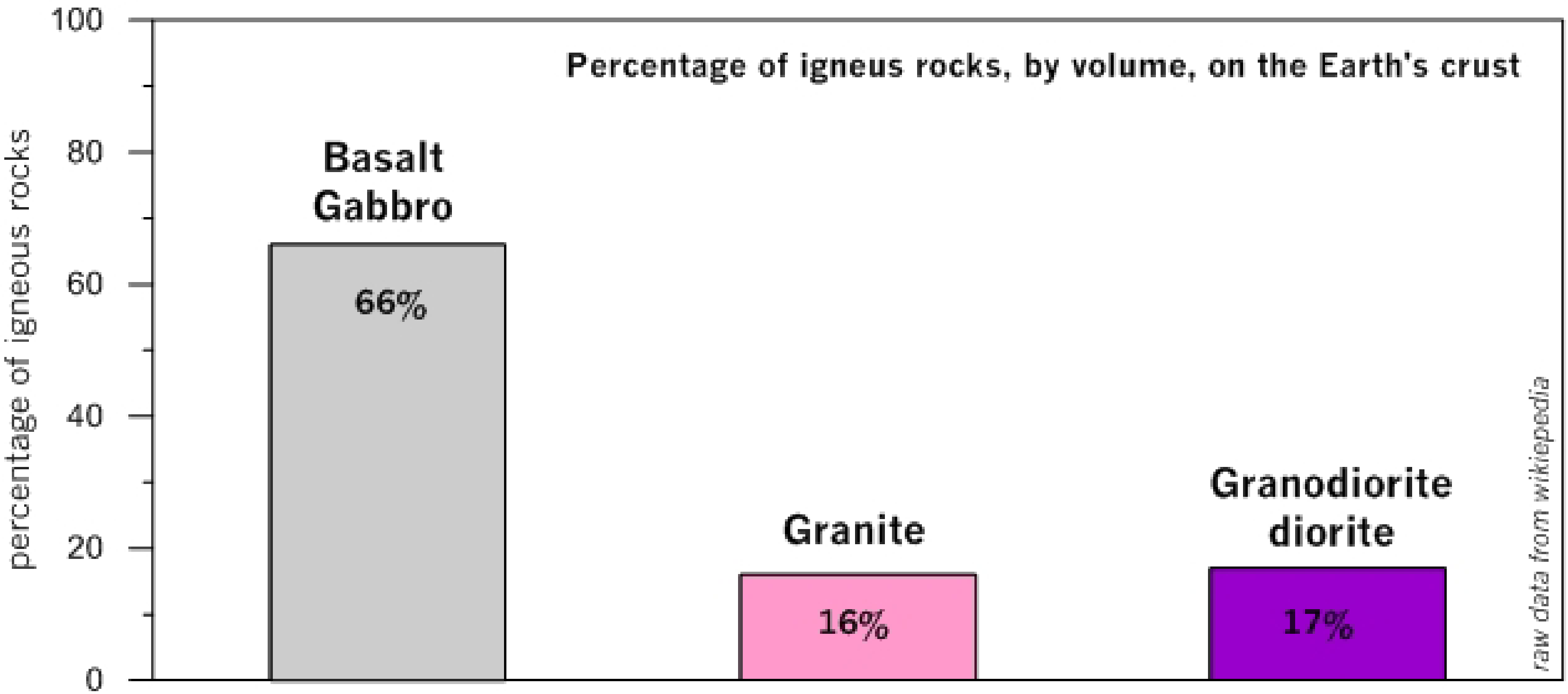
Intrusions are one of the two ways igneous rock can form; the other is extrusive rock, that is, a volcanic eruption or similar event. Technically speaking, an intrusion is any formation of intrusive igneous rock; rock formed from magma that cools and solidifies within the crust of the planet. In contrast, an *extrusion* consists of extrusive rock, such as pumice or basalt that are formed above the surface of the crust.

Intrusions vary widely, from mountain-range-sized batholiths to thin veinlike fracture fillings of aplite or pegmatite. When exposed by erosion, such batholiths may occupy huge areas of Earth's surface.
Large bodies of magma that solidify underground before they reach the surface of the crust are called plutons.

HydroNova
INNOVATING WATER PROSPERITY



About 64.7% of the Earth's crust by volume consists of igneous rocks; making it the most plentiful category.
Of these, 66% are basalts and gabbros, 16% are granite, and 17% granodiorites and diorites. 20



Igneous rocks are spread and common in Sierra Leone in the North Eastern and South Eastern regions.

Sedimentary rock

Sedimentary rocks are formed at the earth's surface by the accumulation and cementation of fragments of earlier rocks, minerals, and organisms or as chemical precipitates and organic growths in water (sedimentation). This process causes clastic sediments (pieces of rock) or organic particles (detritus) to settle and accumulate, or for minerals to chemically precipitate (evaporite) from a solution.

Before being deposited, sediments are formed by weathering of earlier rocks by erosion in a source area and then transported to the place of deposition by water, wind, ice, mass movement or glaciers (agents of denudation).

Conglomerate is a sedimentary rock formed from erosion, transportation and cementation of a preexisting material (igneous, sedimentary or metamoporhic rock).

The grains are usually coarse (gravel or cobble dimension)

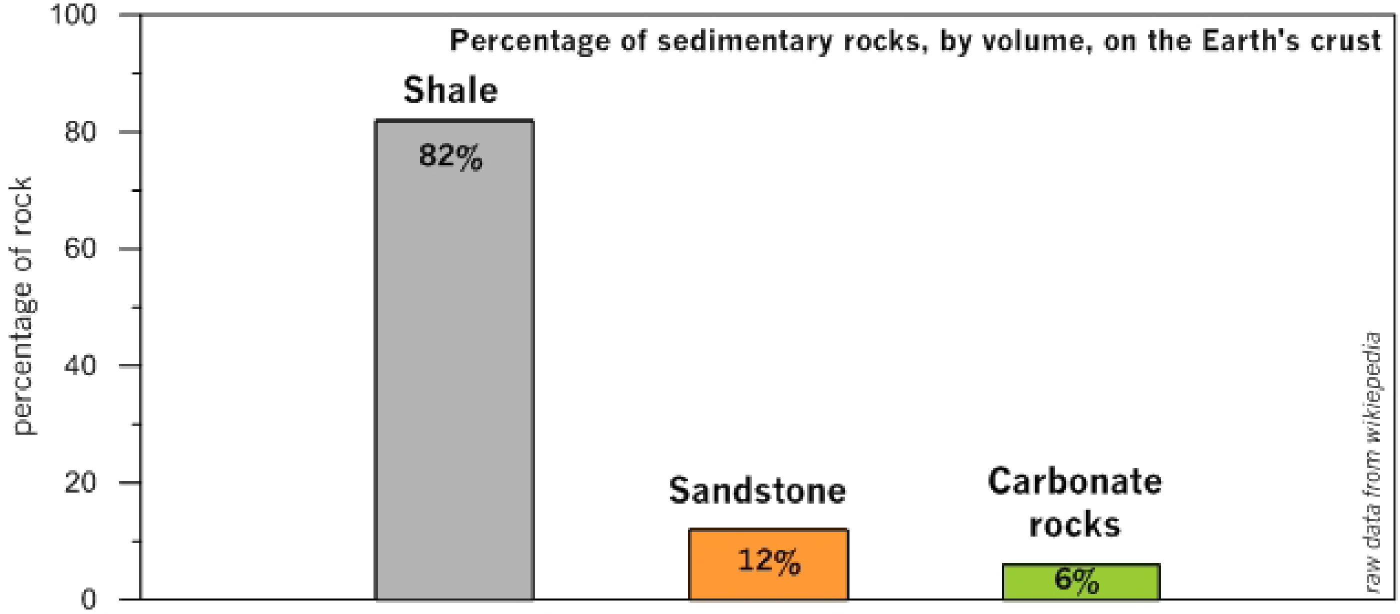
Sandstone, like the conglomerate, is a sedimentary rock formed from erosion, transportation and cementation of a preexisting material (igneous, sedimentary or metamoporhic rock).
The grains are smaller in dimension and sandy size.
They often have iron oxide bands

Clays also has a similar origin of the previous Two. In this case the grain dimension is smaller (they can hardly be seen by a naked eye)

Laterite is a soil and rock type rich in iron and aluminium, and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. They develop by intensive and long-lasting weathering of the underlying parent rock.

An essential feature for the formation of laterite is the repetition of wet and dry seasons. Rocks are leached by percolating rain water during the wet season. Laterite formation is favoured in low topographical reliefs of gentle crests and plateaus which prevents erosion of the surface cover. Quartz is the most abundant relic mineral from the parent rock

About 7.9% of the crust by volume is composed of sedimentary rocks, with 82% of those being shales, while the remainder consists of limestone (6%), sandstone and arkoses (12%). The latter being a sandstone rich in feldspar.
Sedimentary rocks often contain fossils. Sedimentary rocks form under the influence of gravity and typically are deposited in horizontal or near horizontal layers or strata and may be referred to as stratified rocks.



Sedimentary rocks are located along the atlantic coast of Sierra Leone and made of thin loose grains of sand, silt and clay derived from erosion of the ancient mountain ranges.

Metamorphic rocks

Metamorphic rocks are formed by subjecting any rock type—sedimentary rock, igneous rock or another older metamorphic rock—to different temperature and pressure conditions than those in which the original rock was formed.

This process is called metamorphism; meaning to "change in form".

The result is a profound change in physical properties and chemistry of the stone.

The temperatures and pressures required for this process are always higher than those found at the Earth's surface: temperatures greater than 150 to 200 °C and pressures of 1500 bars.

Metamorphic rocks compose 27.4% of the crust by volume.

Depending on the structure, metamorphic rocks are divided into two general categories. Those that possess a texture are referred to as foliated; the remainders are termed non-foliated. The name of the rock is then determined based on the types of minerals present.

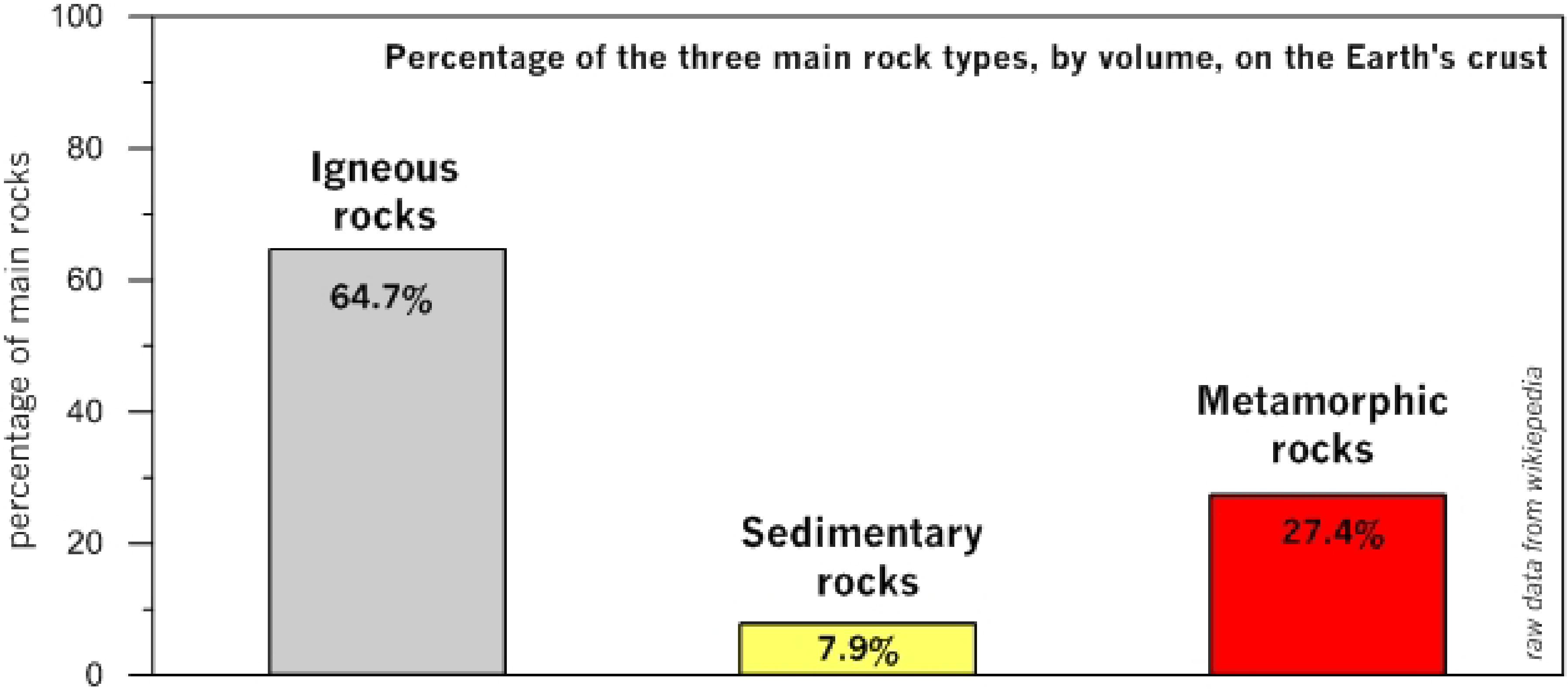
Schists are foliated rocks that are primarily composed of lamellar minerals such as micas. A gneiss has visible bands of differing lightness, with a common example being the granite gneiss.

Metamorphic banded gneiss

Migmatite is a rock that is a mixture of metamorphic rock and igneous rock. It is created when a metamorphic rock such as gneiss partially melts, and then that melt recrystallizes into an igneous rock, creating a mixture of the unmelted metamorphic part with the recrystallized igneous part.

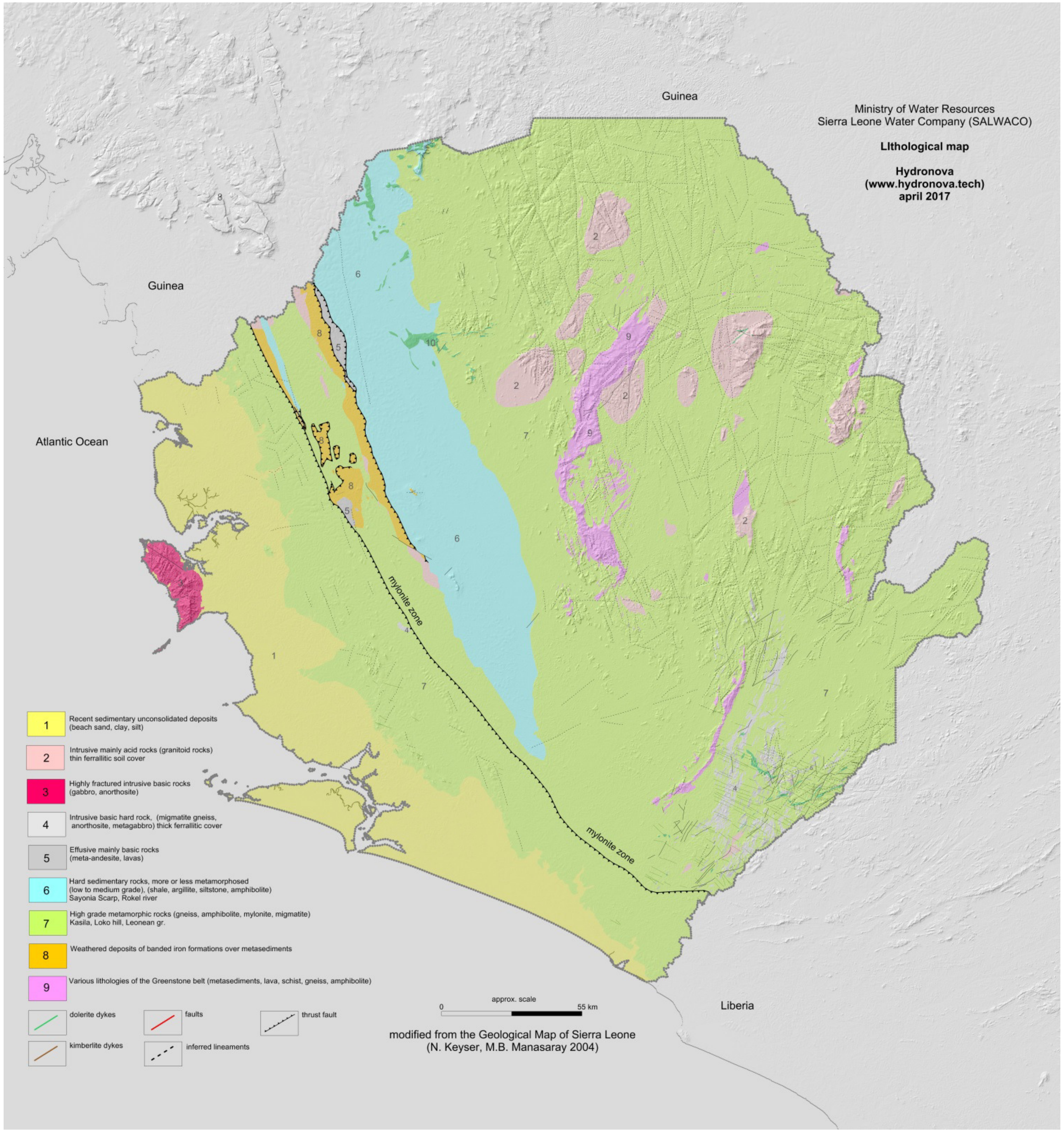
Migmatites often appear as tight veins and segregations of light-colored granitic composition, within dark-colored minerals (biotite) .
In Sierra Leone high metamorphic grade rocks such as migmatites, gneiss and foliated mylonites are located along a wide strip stretching NW to SE from Kambia, Port Loko, Moyamba to Pujehun.

The three major constituents on the Earth's crust are illustrated in the bar graph



CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

Lithology of Sierra Leone



What is hydrogeology and what an hydrogeologist can do

A hydrogeologic study or investigation is a study of the subsurface hydrologic and geologic conditions in an area or location. Data are collected about the type and thickness of geologic materials, the occurrence of ground water, how and where it flows in pore spaces and/or fractures, the quality of the ground water, and what can be expected at wells.

These studies are typically conducted by researching available published data from government and private sources and conducting the additional field work needed to understand the target environment. The field work may consist of test drilling to log the geology, well construction and pumping tests to determine hydrologic performance, running geophysics to refine or confirm geologic information, and water sampling for water quality analyses.

Aquifer basics

An aquifer is a geologic unit capable of storing and producing water of consumptive and economic importance. Consumptive means that it has not great amounts of dissolved solids, or in other words is potable or can be used for agricultural purposes. Some of the most important ground water sources are in unconsolidated sediments. Crystalline bedrock is generally low in well yield with water contained only in fractures, faults or in the upper weathered layer. Limestone and dolomite can store large amount of water especially when fractured and karstified.

The following table from Kasenow 2001, gives a generalized classification of rocks in regard to ground-water supply.

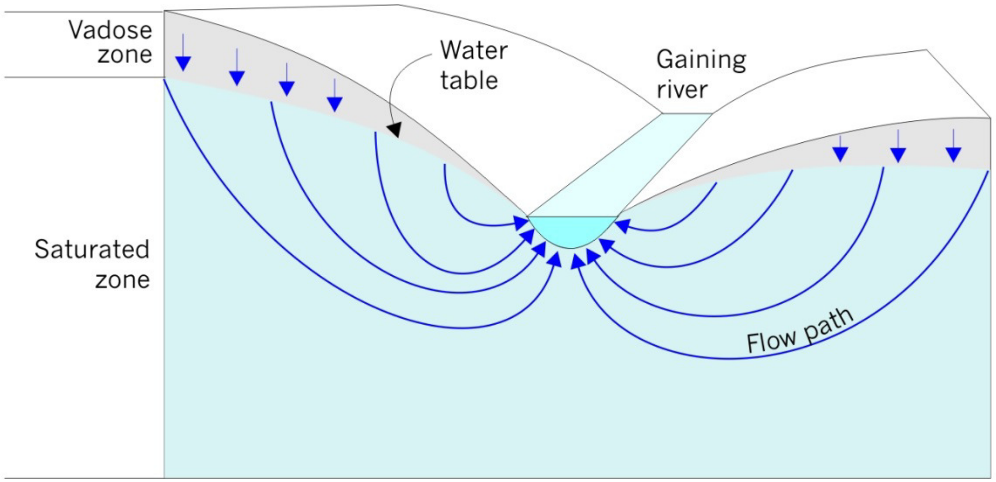
Table 1: Main ground water supply sources

Major sources		Small to moderate sources		Confining beds	
Sediment	Rock	Sediment	Rock	Sediment	Rock
Gravel (p)	Conglomerate (p, f, s)	Till (p)	Granite (f)	Clay	Shale
Sand (p) Breccia (p)	Sandstone (p, f, s) Limestone (p, f, s) Dolomite (f, s) Basalt (f)	Silt (p) Coquina (p) Silt (p)	Gneiss (f) Quartzite (f, s) Siltstone (f) Schist (f) Marble (f, s)	Marl	

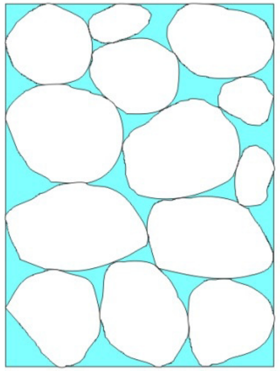
p = water in the pores; f = water in fractures; s= water in solution channels (modified from Kasenow 2001)

When precipitation hits the land surface, some water infiltrats the soil horizon. Water that accumulates on the surface faster than it can infiltrate becomes runoff. The rate at which water infiltrates or runs off is a function of the physical properties of the surficial soils, vegetation cover, slope angle etc. Some important factors appear to be thickness, clay content, moisture content, and intrinsic permeability of the soils' materials
Further vertical movement, eventually reaches the regional water table as recharge.

Between the soil horizon and the regional water table is an area referred to as the vadose zone (unsaturated zone). The ability of the vadose zone to hold water depends upon the moisture content and grain size. Wells completed in the vadose zone will have no water in them, even though the geologic materials appear to be wet, while wells completed in saturated fine-grained soils will eventually contain groundwater.

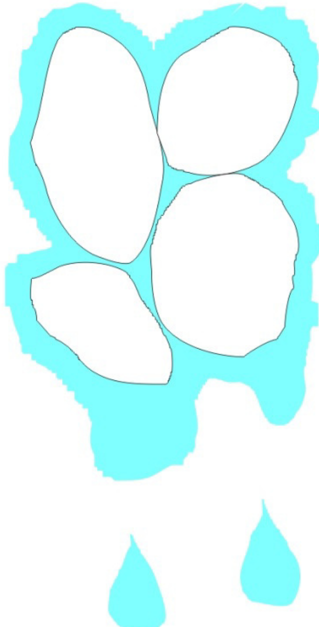


Movement of groundwater in a uniform permeable soil. Above: rain enters the ground by infiltration in the vadose zone and fill up the aquifer from bottom up



When grain sediments are small (e.g. < 0.004 mm) all water remains around the surface due to molecular attraction and do not take part to the flow

When grains have bigger diameter (e.g. > 0.05 mm) a bigger percentage of water can move freely among the pores, but still some water can stick to the grain surface



(A. Fileccia, 2000)

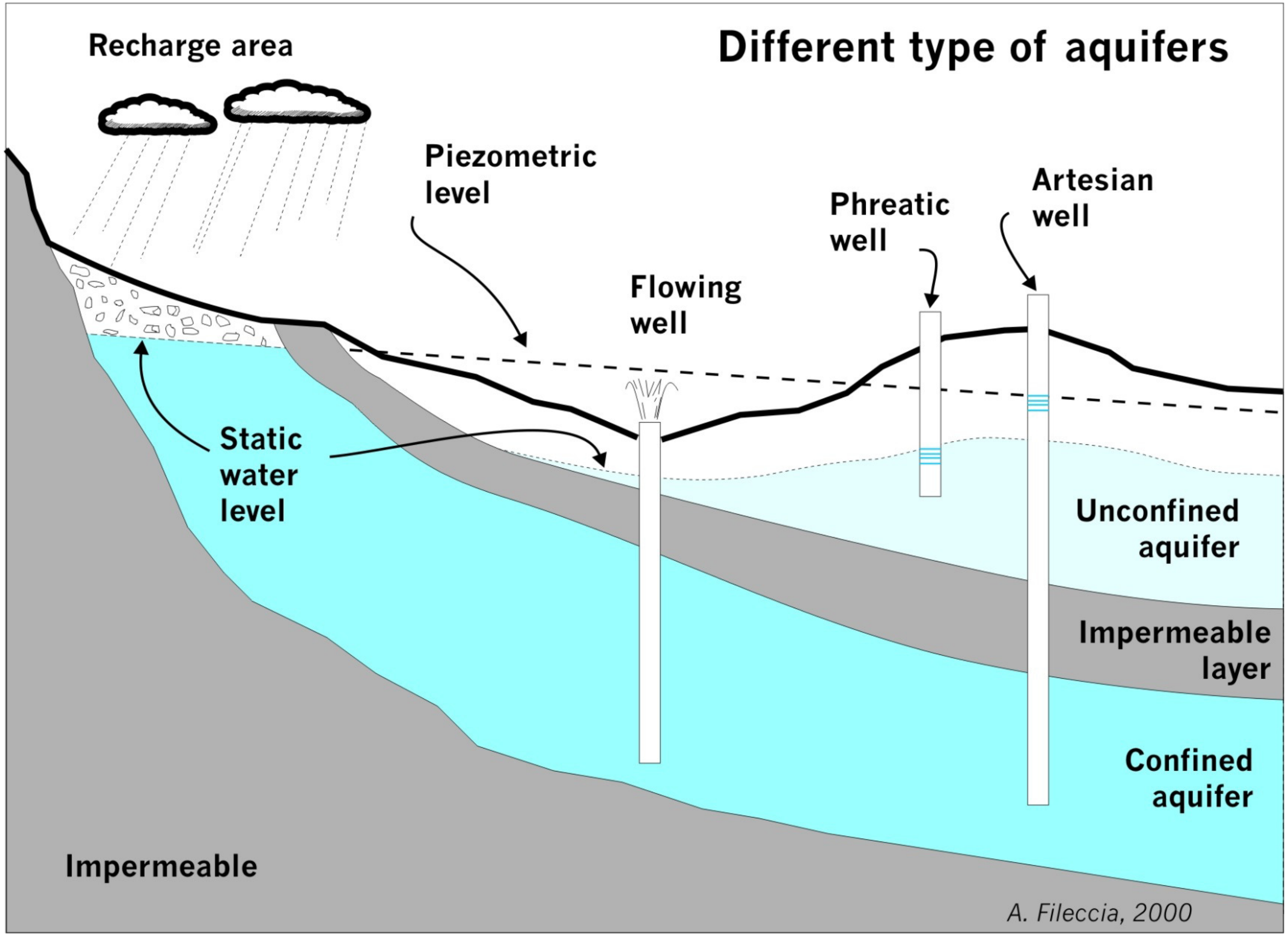
HydroNova
INNOVATING WATER PROSPERITY

Aquifer definitions

Three main types of aquifers are recognized by hydrogeologists.

A confined aquifer is the one bounded above and below by impermeable beds.
An unconfined aquifer, also known as free aquifer or water table aquifer has its top at atmospheric pressure in contact with a permeable material.
An aquitard is a saturated geologic material with low permeability, allowing the transmission of small quantities of water through different geologic units.
A leaky confined or semiconfined aquifer, develops when ground water seeps through an aquitard into an adjacent aquifer.
This type of flow is often accelerated during artificial pumping.
An aquiclude is simply an impermeable layer preventing any flow exchange between adjacent units.

The parameter that best represent the ability to transmit water through various layers is called hydraulic conductivity (K), the rate at which a geologic material can transmit a liquid under a hydraulic gradient.


Recharge area
Different type of aquifers
Piezometric level
Artesian well
Phreatic well
Flowing well
Static water level
Unconfined aquifer
Impermeable layer
Confined aquifer
Impermeable
A. Fileccia, 2000

Examples of aquifer structures

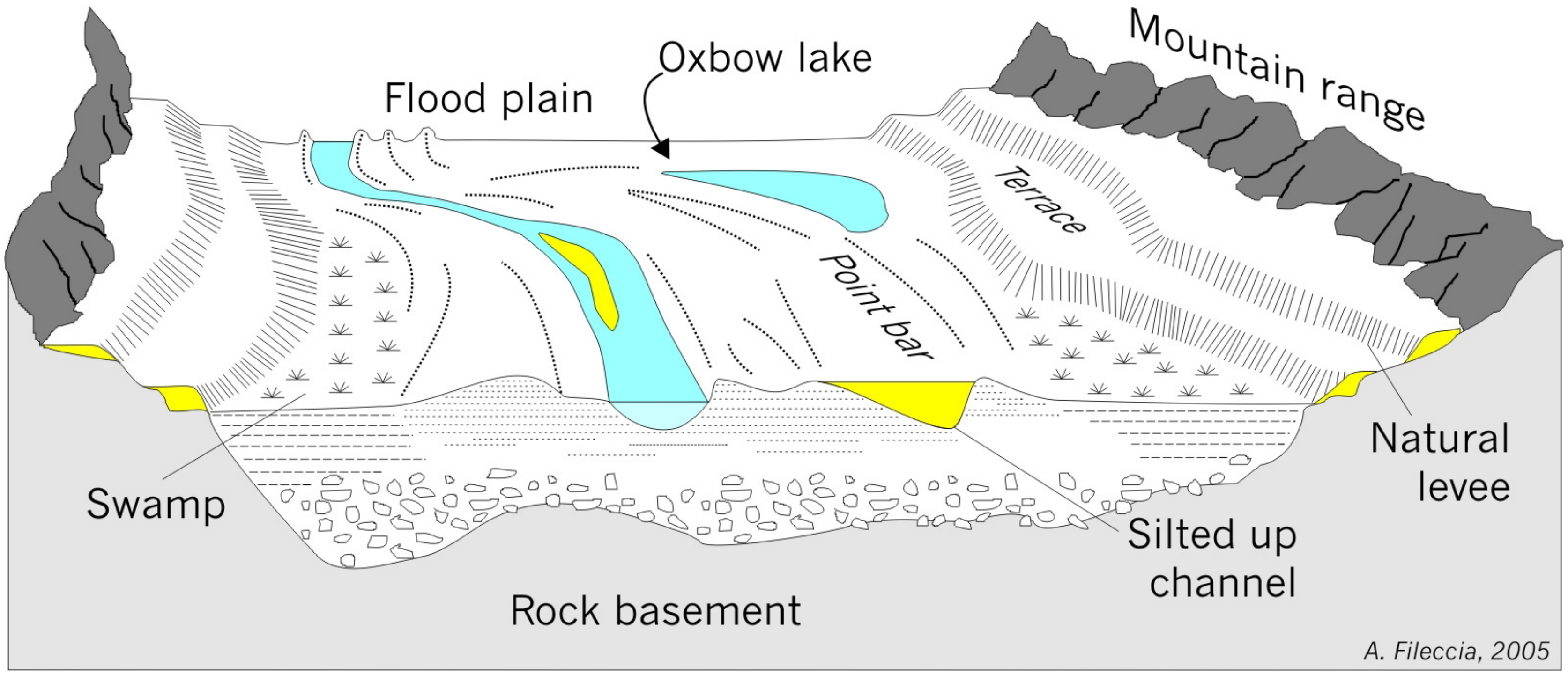
From what was described it follows that water can be stored in loose unconsolidated deposits but also in hard fractured rock formations.
From this point of view this brings to a general classifications of two main aquifer types:

Porous and fractured aquifer.

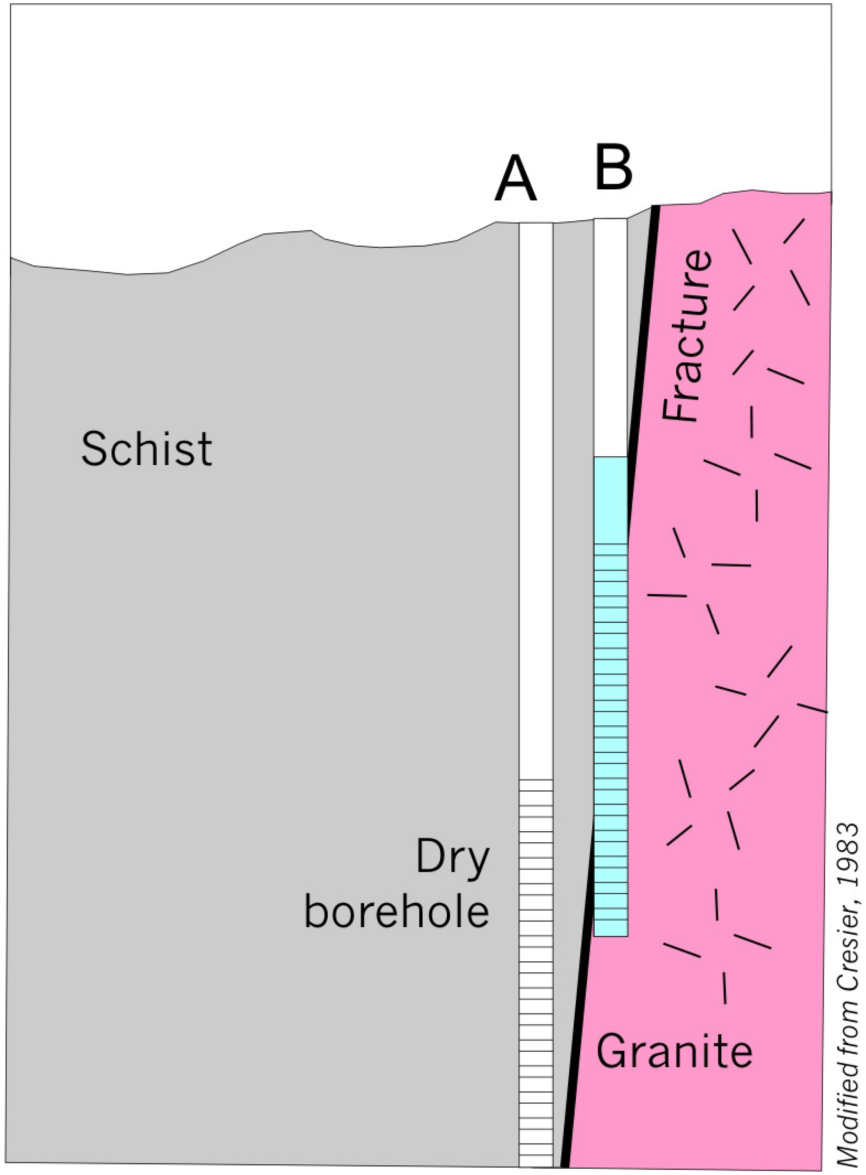
In the first type of aquifers water can be thought as occupying the pores among the grains continuously like in a sponge.

Fractured aquifers host water only in limited spaces (the fractures) that can or cannot be connected.

Morphological features can generally be grouped into highlands and lowlands. The former are usually the recharge area, characterized by a downward flow of water, while lowlands are the discharge areas characterized by an upward flow. In the figure the recharge areas are the former and present natural levees, point bars and terraces;
the discharge areas are the swamps and older partly silted-up meanders.

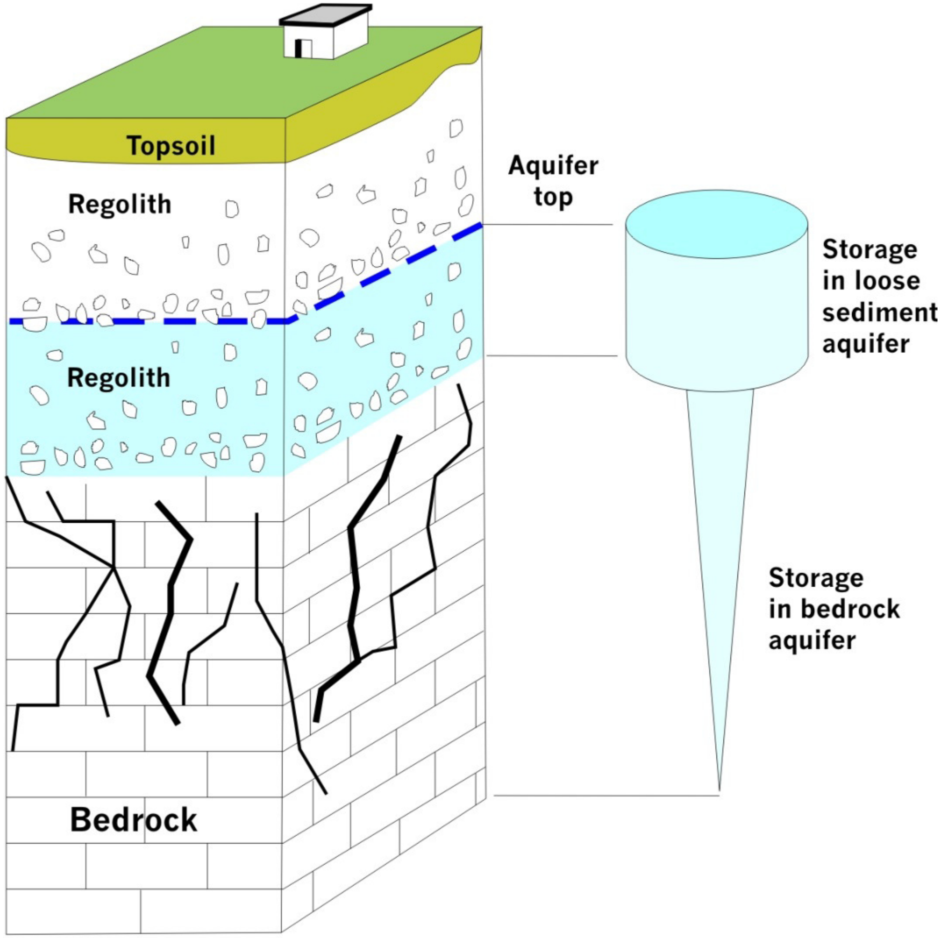


Fractured systems, especially those with thin or absent overburden, may have large conduits acting as pipelines where water accumulates and eventually may be easily attainable. This is of much importance because wells that do not intersect fractures may be of a low yield or dry. In the figure the well on the right is productive because the intake point is hydraulically connected, through small fractures, with the temporary surficial basin.



Bedrock aquifers have also low storage values, but in this case this is due to the lower overall porosity

Difference in storage capacity in regolith, made of loose particles with high intergranular porosity(primary porosity), andBedrock, showing secondary porosity. In this last case, voids are concentrated in the upper part of the formation where beds are less compressed



Modified from Heath, 1984

Aquifer parameters and rank

The terms permeability (*P*) and hydraulic conductivity (*K*) are often used interchangeably. Both are measurements of water moving through the soil or an aquifer under saturated conditions. The hydraulic conductivity, defined by Nielsen (1991), is the quantity of water that will flow through a unit cross-sectional area of a porous media per unit of time under a hydraulic gradient of 1 (measured at right angles to the direction of flow)
at a specified temperature.

In practice K is used in conjunction with an hydraulic gradient ; whereas permeability is used in the absence of a gradient.

A more convenient term to represent the transmission capability of the entire thickness of an aquifer is the transmissivity.

Transmissivity is the product of hydraulic conductivity (permeability) and the aquifer's saturated thickness: $T= Kb$

where *T is the* transmissivity of an aquifer, (m2 /d)

$K =$ hydraulic conductivity(m/d)

$b=$ thickness of aquifer,(m)

Transmissivity (T) and hydraulic conductivity (K) definitions. T = rate at which a rock/sediment can transmit a liquid through a unit prism extending through the aquifer's entire thickness
K = rate at which a rock/sediment can transmit a liquid under a hydraulic gradient
B = aquifer thickness.

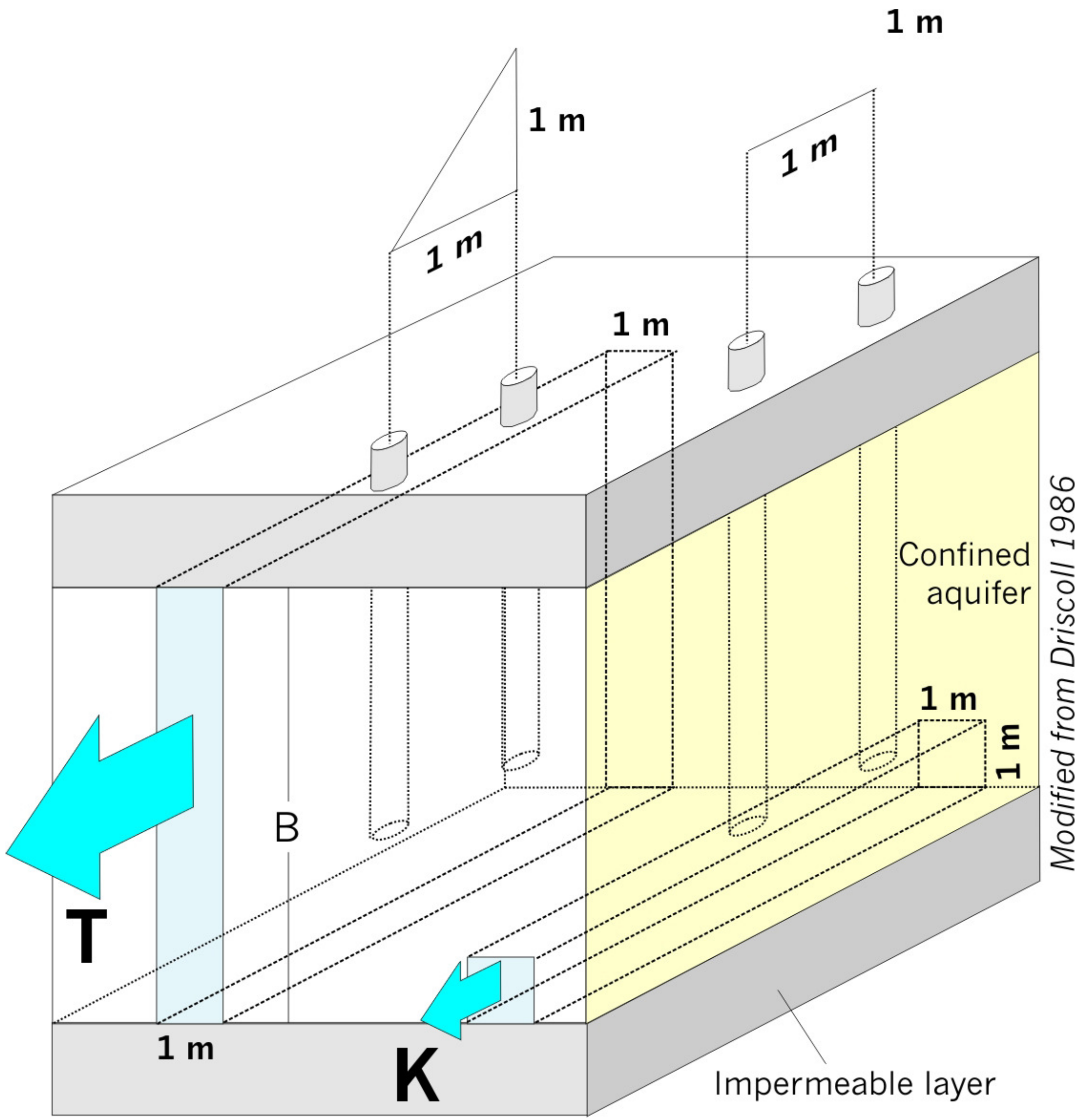


Table 2 from Krasny, indicates main aquifers based on their T values.

T (m^2 /d)	Class	Quality	Use
> 1500	I	exceptional	natural resource
1000-1500	II	very high	high regional interest
100-1000	III	high	regional interest
10-100	IV	intermediate	local interest
1-10	V	low	low local interest
0,1-1	VI	very low	private use
<0,1	VII	n.n.	not an aquifer

Aquifer classification based on transmissivity (Krasny)

HydroNova
INNOVATING WATER PROSPERITY

Movement of groundwater (hydraulic gradient, darcy law)

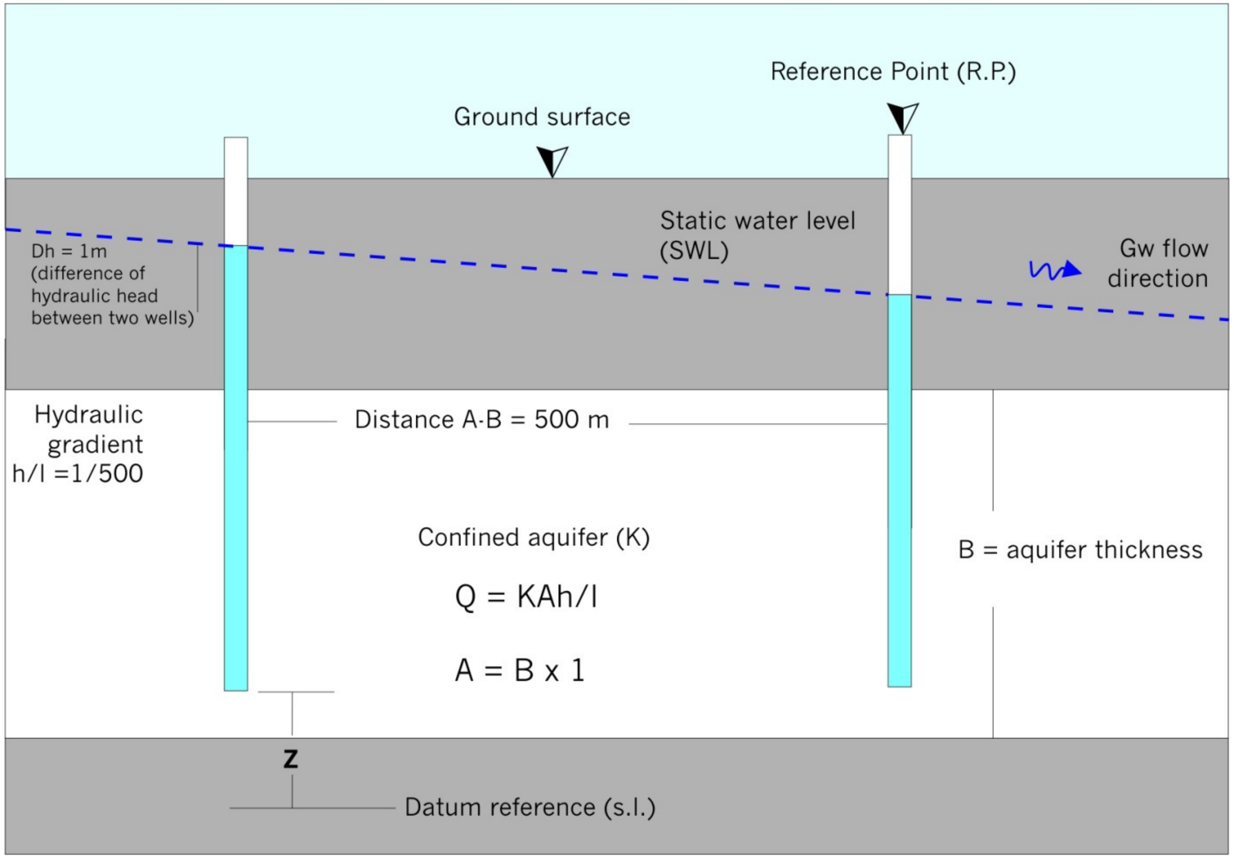
Groundwater flows through an aquifer are driven by the imbalance in water pressure (or *head*) over the aquifer. The difference in groundwater levels is called *head loss* (*h*) and is usually expressed in metres. The slope of the water table is called the *hydraulic gradient* (*h/l*), and is the dimensionless ratio of head to distance. The equation which relates the groundwater flow rate (*Q*) to the cross-sectional area of the aquifer (*A*) and the hydraulic gradient (*h/l*) is known as the *Darcy equation* (*or Darcy's law*) and has the following form:

$$Q = KAh/l = KAi \quad (i = \text{hydraulic gradient})$$

In the equation, *K* is the *hydraulic conductivity*. The usual units of hydraulic conductivity used by hydrogeologists are metres per day (m/d). Hydraulic conductivity is also expressed in metres per second (i.e. m/s).

The flow of ground water between well A and B is calculated with Darcy's law. The cross sectional area has a unit width and K is the hydraulic conductivity Darcy's equation can also be written as

$$v = Q/A = K\,h/l = K\,i$$



In this equation *v* is the *apparent velocity* of the water flow, also known as the *Darcy velocity* or *groundwater flux*.

The equation assumes that the flow takes place over the whole cross-sectional area of the aquifer and ignores the relative proportion of the solid parts to the pore spaces.

In reality, the flow is restricted to the pore spaces, so the actual average velocity (V_a) is much greater than the Darcy velocity and is defined

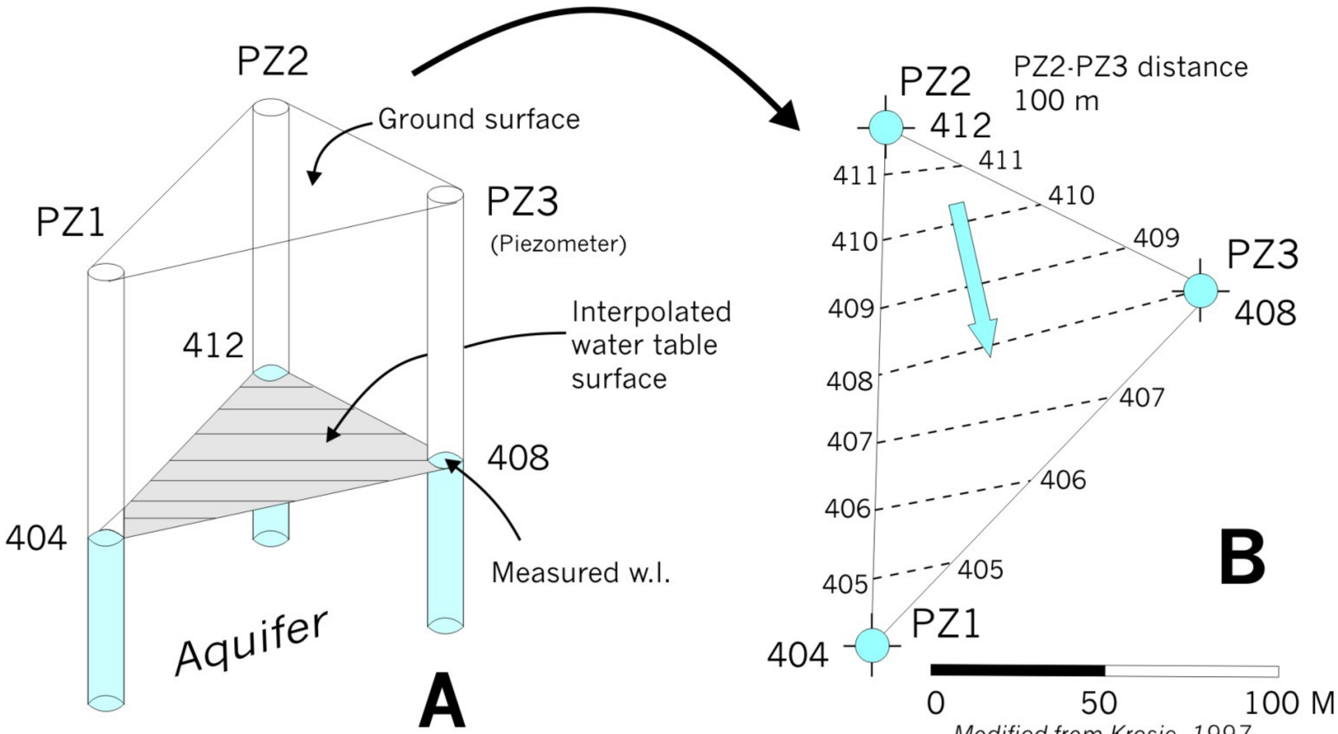
as $V_a = Q/n_e A$

where n_e is the effective porosity of the aquifer.

Piezometric map

Also defined as piezometric map, potential map, groundwater contour map, or water table map (in the case of unconfined aquifers) , it represents the elevation (total hydraulic head) the water will rise in a well.
The potentiometric surface is represented on a map by a series of contour lines (equipotential lines) that connect points of similar head in an aquifer.
These lines are similar to the ground contour lines on a topographic map.
The perpendicular to a potential line is called flow line, represented as an arrow pointing towards lower hydraulic head and giving the flow direction of the ground-water from the higher to the lower head.
The manual contouring method described in the figure is based on triangular linear interpolation and it should be utilized as a first approach in ground water studies.
The setting up of piezometric maps requires that water level be taken in the shortest time, depending on the area extent but usually half a day or better, less.

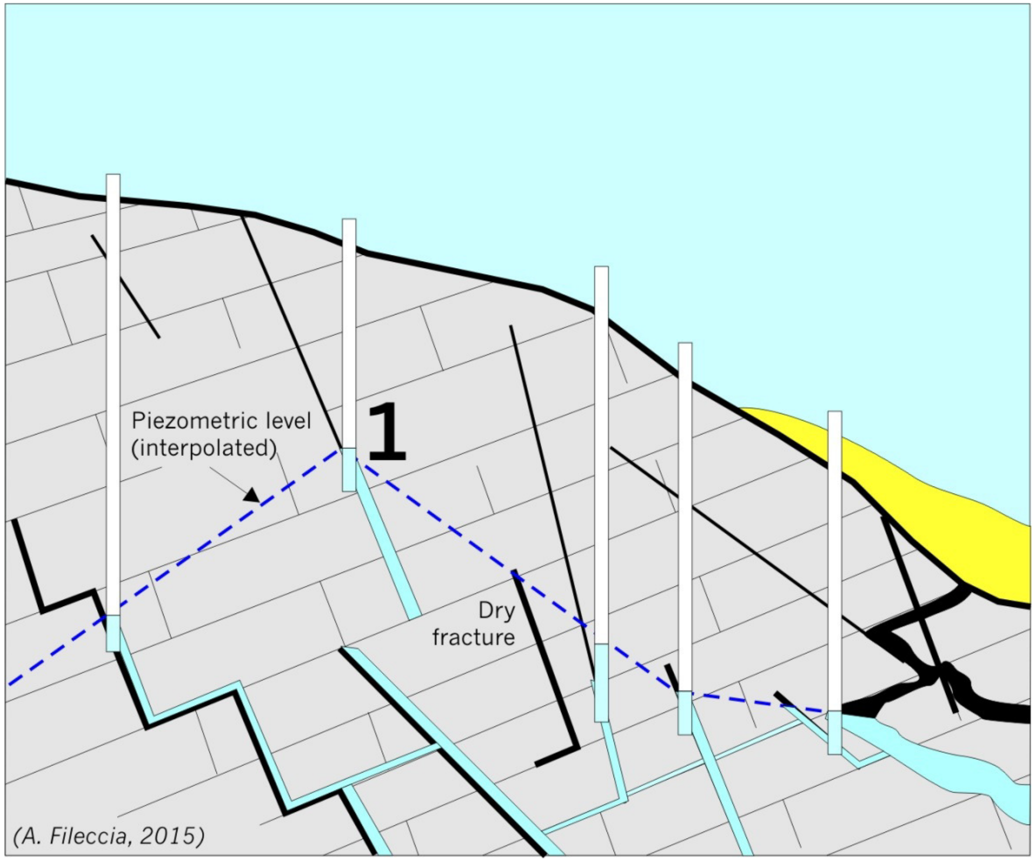
The flow direction can be determined when at least three recordings of water table elevations are available A: Water table contour map obtained through linear interpolation; B: graphical method to calculate water elevations between measured wells (PZ1 - PZ2 - PZ3); connect all water points with a triangular net and divide each line between two wells, in short equal lenghts segments in proportion to the difference in elevations of the two water points. In the example shown the w.l. in Pz1 is 4 m lower than Pz3 and 8 m lower than PZ2.



Modified from Kresic, 1997

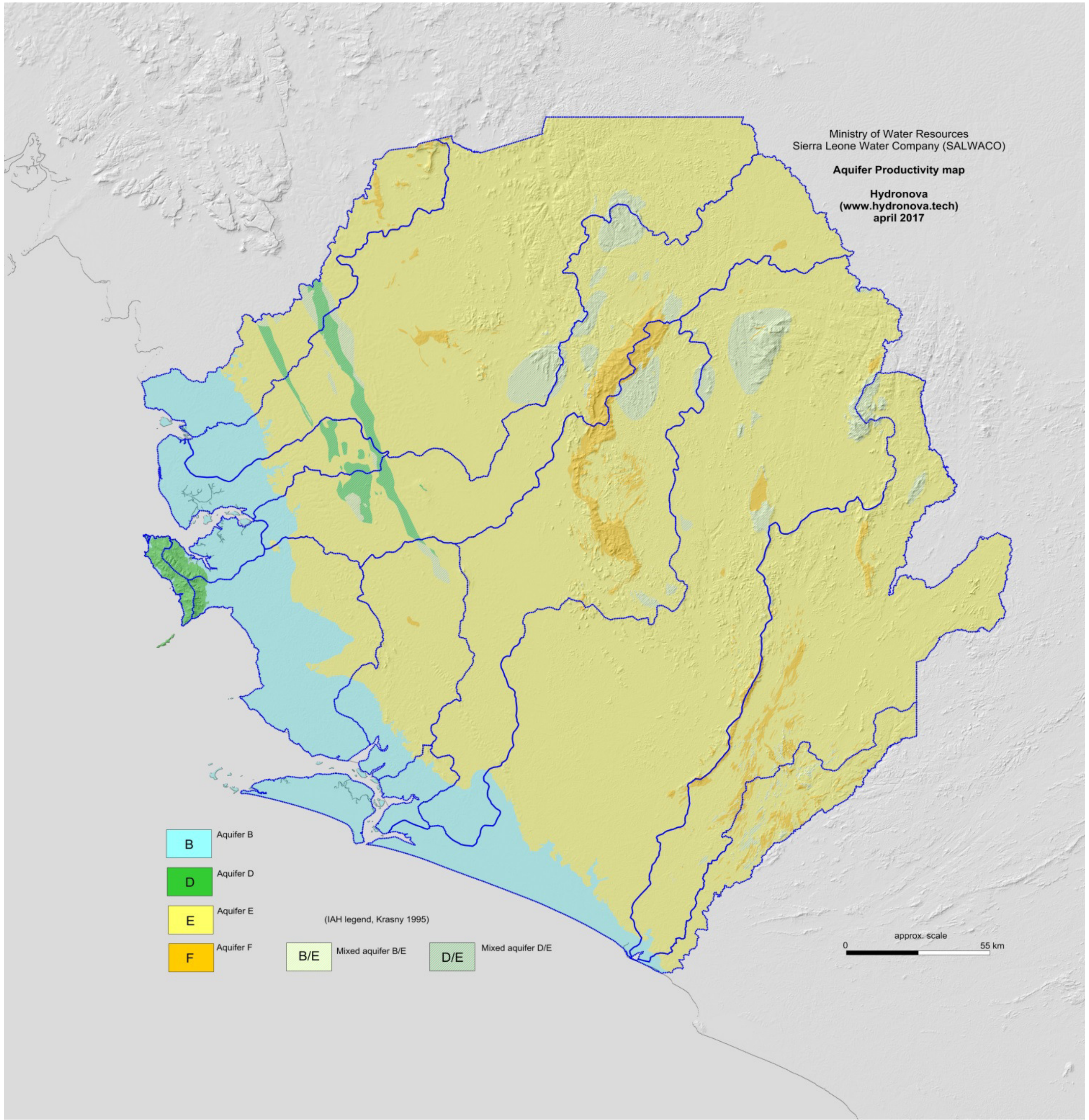
The interpretation of such a map can easily give information on recharge and discharge areas, groundwater divides, zones of high drawdown or infiltration, contaminant directions, surface to ground-water interactions,
K heterogeneities etc.
Moreover it allows a first selection of target areas for siting a water well.
The description we have made on piezometric maps refers to porous aquifer, those with primary porosity mainly. Fractured aquifers have a different structure and behavior, with strong and often erratic distribution of hydraulic conductivity. Not all wells drilled into fractured formations yield abundant water, and many of them have strong seasonal fluctuations in their discharge. There are two main reasons for that. Some of these areas have solution cavities of a few centimeters or millimeters that may, or may be not, interconnected, while in the same area large caverns may have developed. Therefore a well drilled where the karst phenomena are well distributed will give a significant water supply. A similar well into small solution cavities, may yield nothing. It is for this reason that piezometric map for karst or fractured formations must be considered with caution, unless the karst erosion is at a late stage and has created a porous-like medium.

The figure illustrates a theoretical situation with a group of wells intersecting some saturated fractures. Except well n. 1, tapping a cavity not connected to the local system, all fractures are interconnected. The piezometric level reconstructed using also the water level of well n. 1 is therefore uncorrect.



CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

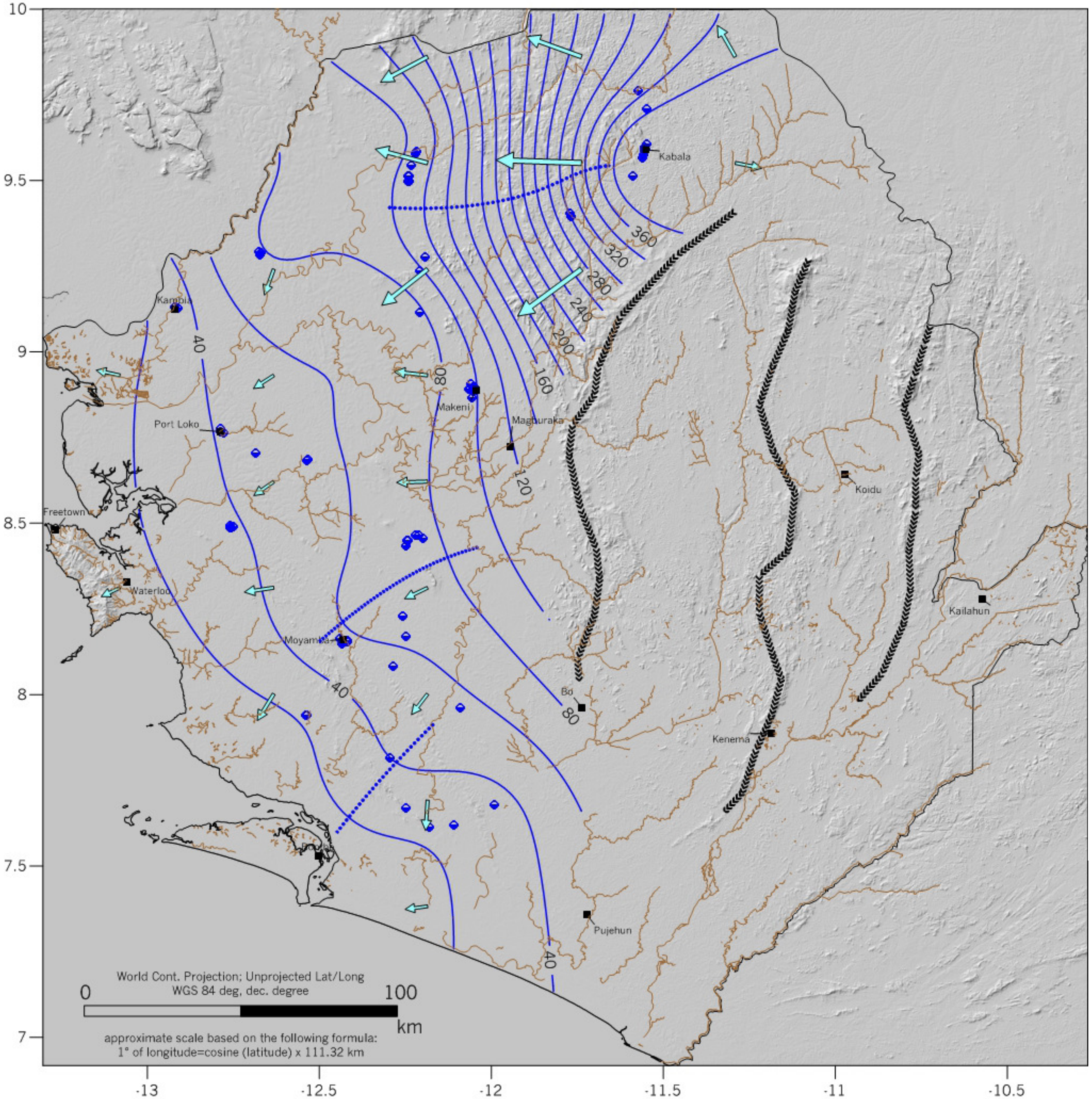
Aquifer productivity map



CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

HydroNova
INNOVATING WATER PROSPERITY

Piezometric map



Piezometric map
for the unconfined aquifer
date readings
from 7 to 10 december
2016
water levels above sea level
contour interval 20 m

main groundwater flow direction

250 water table contour line (m asl) inferred from direct readings

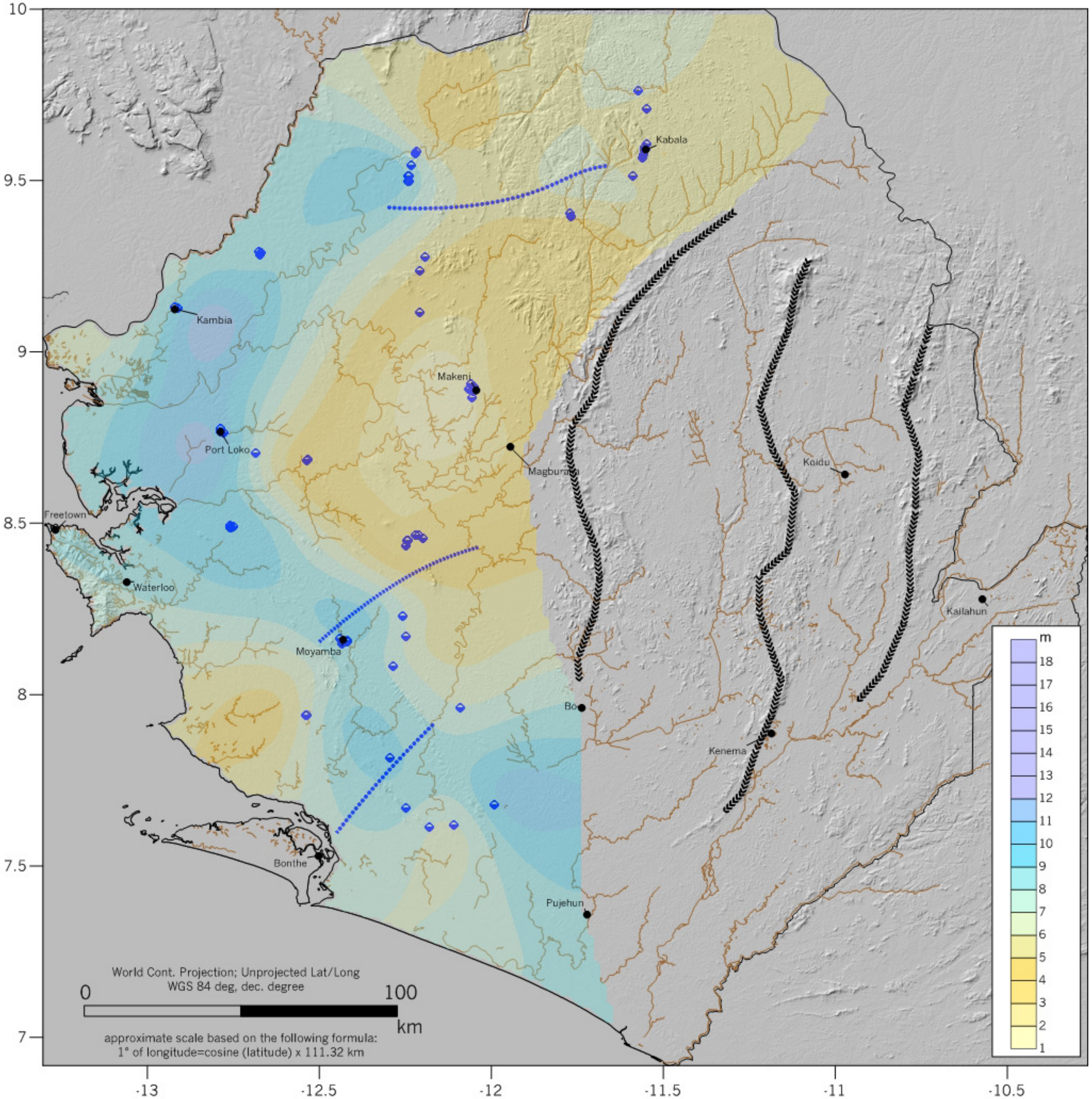
measured Hand Dug well

hydraulic gw divide (varies during the year, inferred from w.t. readings)

physical gw divide, fixed during the year (inferred from topographic relief and river pattern)

CONSULTANCY S ERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

Rest Water level Map



measured Hand Dug well

hydraulic gw divide
(varies during the year,
inferred from w.t. readings)

physical gw divide, fixed during the year
(inferred from topographic relief
and river pattern)

readings from 7 to 10 december 2016
water levels in m bgl
colour interval 1 m

Overview of drilling operation

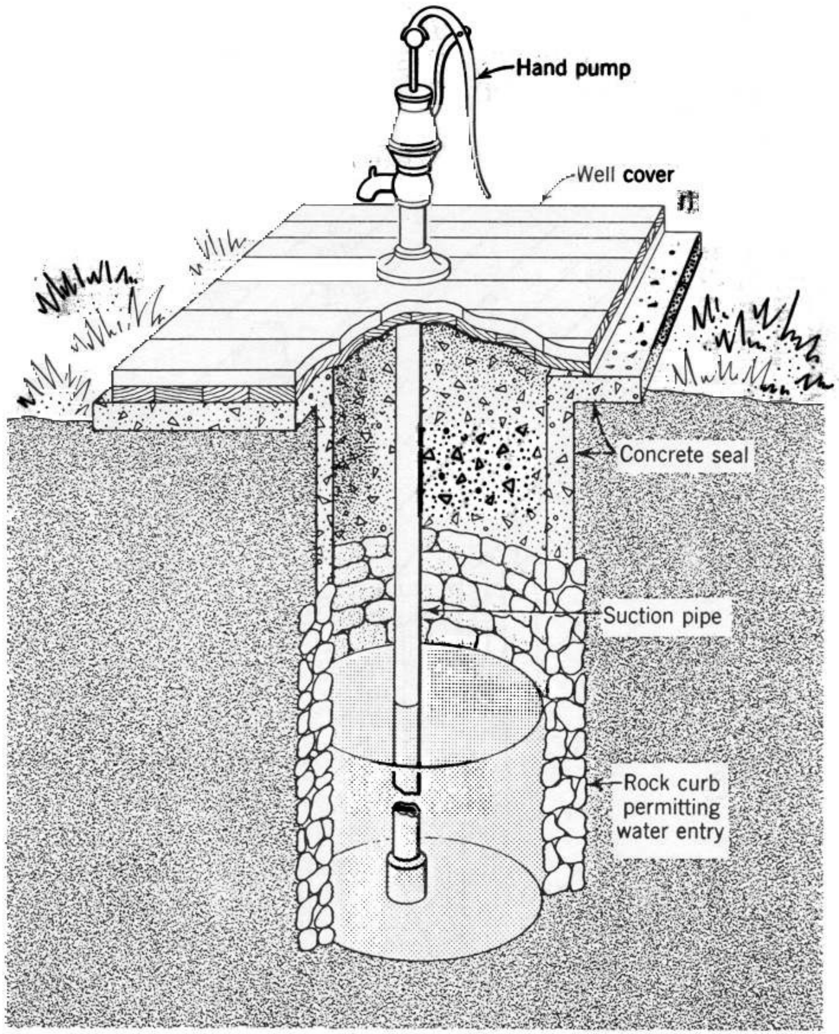
Broadly speaking, a "well" can be any construction that permits access to the local ground water for extraction at the surface. Specifically a well is a hole or shaft, usually vertical, excavated below the ground surface for bringing groundwater. Occasionally wells serve other purposes, such as for subsurface exploration and observation, artificial recharge, and disposal of wastewaters. Any methods exist for constructing wells and selection of a particular method depends on the purpose of the well, the quantity of water required, depth to groundwater, geologic conditions and economic factors. Shallow wells are dug, bored, driven or jetted; dep wells are drilled by cable tools or rotary methods. Drilling is one of the first process, and after that the well should completed, developed for optimum yield and tested. Wells should also be sealed against entrance of surface pollution and given periodic maintenance. Most modern well construction are made of the drilled tubular well consisting of the tube casing, and sometimes a well screen designed to pass water, but retain the formation

The principle objectives of a properly designed well are:
1) pumping of water at the lowest cost;
2) pumping of water that is free of sand and silt;
3) minimum operation and maintenance costs;
4) a long and economic lifetime.
5) For water supply wells, good quality water with proper protection from contamination is an important additional objective.

Hydrogeologic information required for a proper design includes: stratigraphical information concerning the aquifer and overlying sediments, aquifer-test analyses of the physical properties of the aquifer, water-balance analyses of the sustainable yield, grain-size analyses of unconsolidated aquifer materials, and groundwater quality (Boonstra, 2006).

Before drilling a well in a new area, it is common practice to put down a small diameter test hole. The purpose of a test or pilot hole is to determine depth to groundwater, its quality, physical characteristics an aquifer thickness, without the expenses of a large diameter production well. During drilling of a test hole a careful record or log is kept of the various geologic formations and the depths at which they are encountered.

A general method is to collect samples of cuttings, labeling each with the depth. Later they can be analyzed for grain size distribution and will serve for the selection of the screen type.

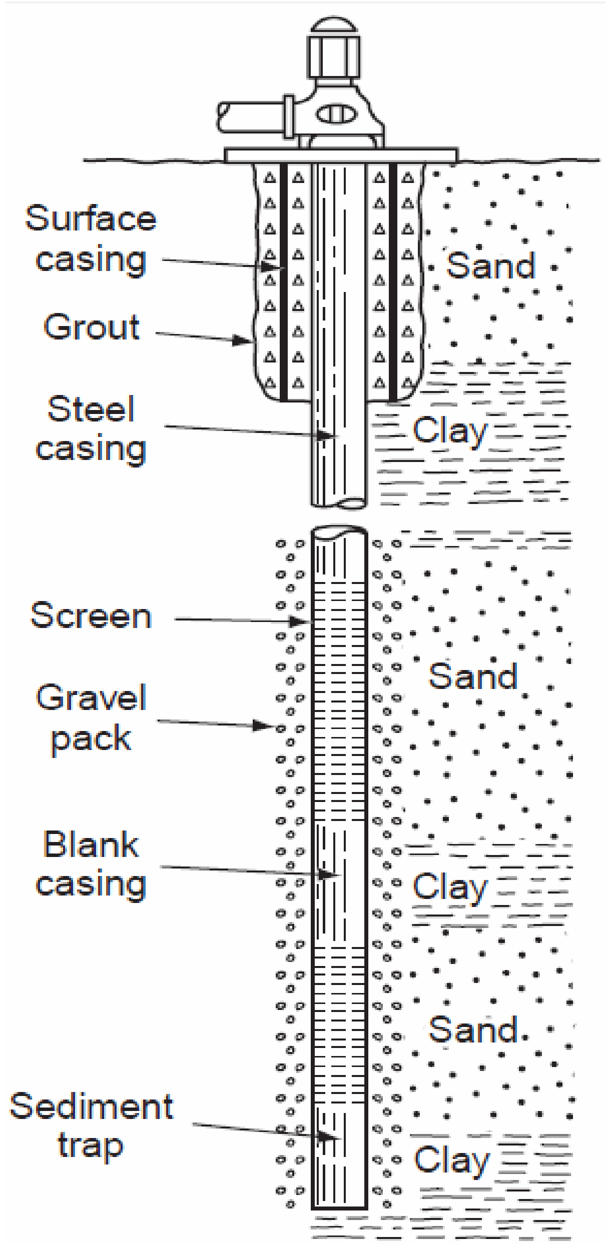


A simple domestic dug well with rock curb, a concrete seal to reduce bacterial pollution from above, a suction pipe and a hand pump of low yield (Todd, 1980)

Well design

Well design includes the selection of the well diameter, total depth of the well, screen or open hole sections, gravel pack thickness and method of construction. The pumping rate determines the pump size, which in turn determines the well diameter. Well pump manufacturers provide information on the optimum well diameter and size of pump bowls for several anticipated well yields. Generally water enters a well through a wire screen or a louvered or shuttered perforated casing. The screen diameter is selected so that the entrance velocity of the water does not exceed 0.03m/s.

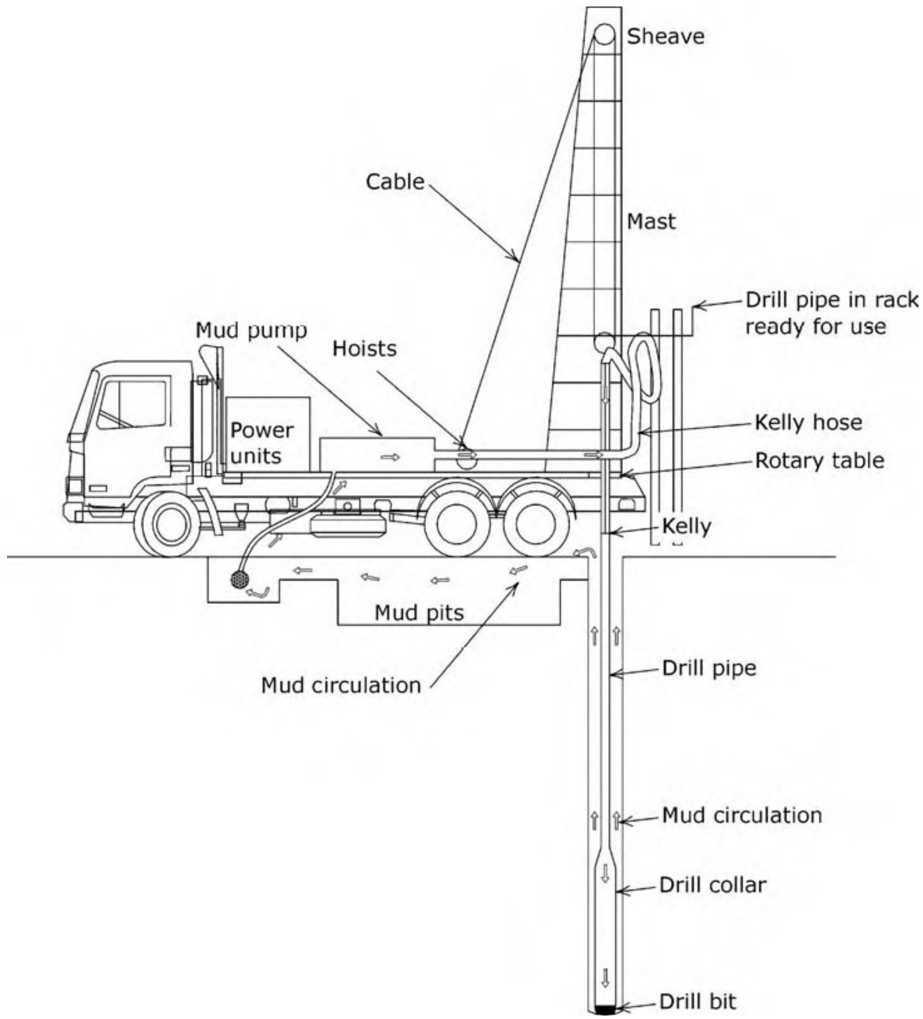
A gravel envelope or gravel pack is used around the screen to prevent fine material from entering the well



Supply well with multiple screen and gravel pack

Construction Methods

During the last 30 years, the use of direct rotary and reverse circulation rotary drilling methods has come to dominate the construction of higher capacity water production wells. Both rotary methods are linked with the gravel envelope well design. With the direct rotary method, a rotating bit under controlled loading is applied to the formation. Water with additives to provide weight and viscosity is pumped down the drill pipe, through the bit, and circulates up the hole carrying the cuttings, which are separated and removed at the surface.

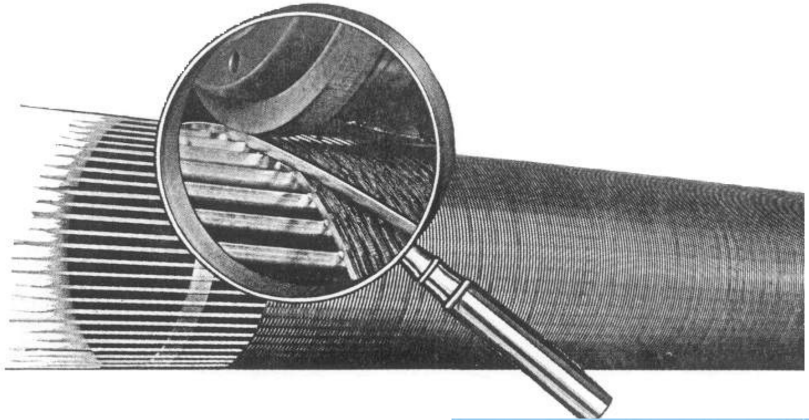


Direct circulation rotary rig ([Misstear, Banks, Clark, 2006]).

The screen is selected and designed according to information gained through analysis of the cuttings and electric logging. It is then installed with the casing in a continuous operation. Selected gravel is placed in the annular space between the casing and enlarged hole to stabilize the formation and provide a filter against fine sand or silt which might be present.

Screens

Several types of screens are available on the market: punched, stamped, louvred, bridge-slot, continuous- slot wire-wrap, prepack



various types of screens
Top: continuous-slot wire-wrap; Center: vertical slotted; Bottom: bridge-slot

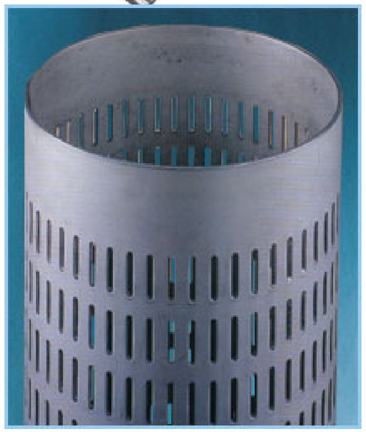


Table 3. *Percentage of open area for different types of screens. High values of open area can facilitate water entrance, minimize well losses, reduce drawdown during pumping, and increase the operational life of the water well.*

Screen diameter ID			Filter type and percent open area					
in	**cm**	**Slot size**	**Continuous slot %**	**Louvered %**	**Bridge slot %**	**slotted pipe %**	**plastic continuous %**	**Slotted plastic %**
4	10.16	20	25	-	-	-	13	-
		60	52	-	12	5	30	11
8	20.3	30	25	-	-	-	18	8
		60	41	3	6	5	29	14
		95	51	5	-	7	-	-
12	30.48	30	16	-	3	-	-	-
		60	28	4	7	5	-	11
		95	38	7	-	7	-	-
		125	45	9	14	9	-	-
16	40.64	30	16	-	3	-	-	9
		60	28	4	6	5	-	-
		95	38	6	-	7	-	-
		125	45	8	13	9	-	-
					modified from Groundwater and wells, 2007			

HydroNova
INNOVATING WATER PROSPERITY

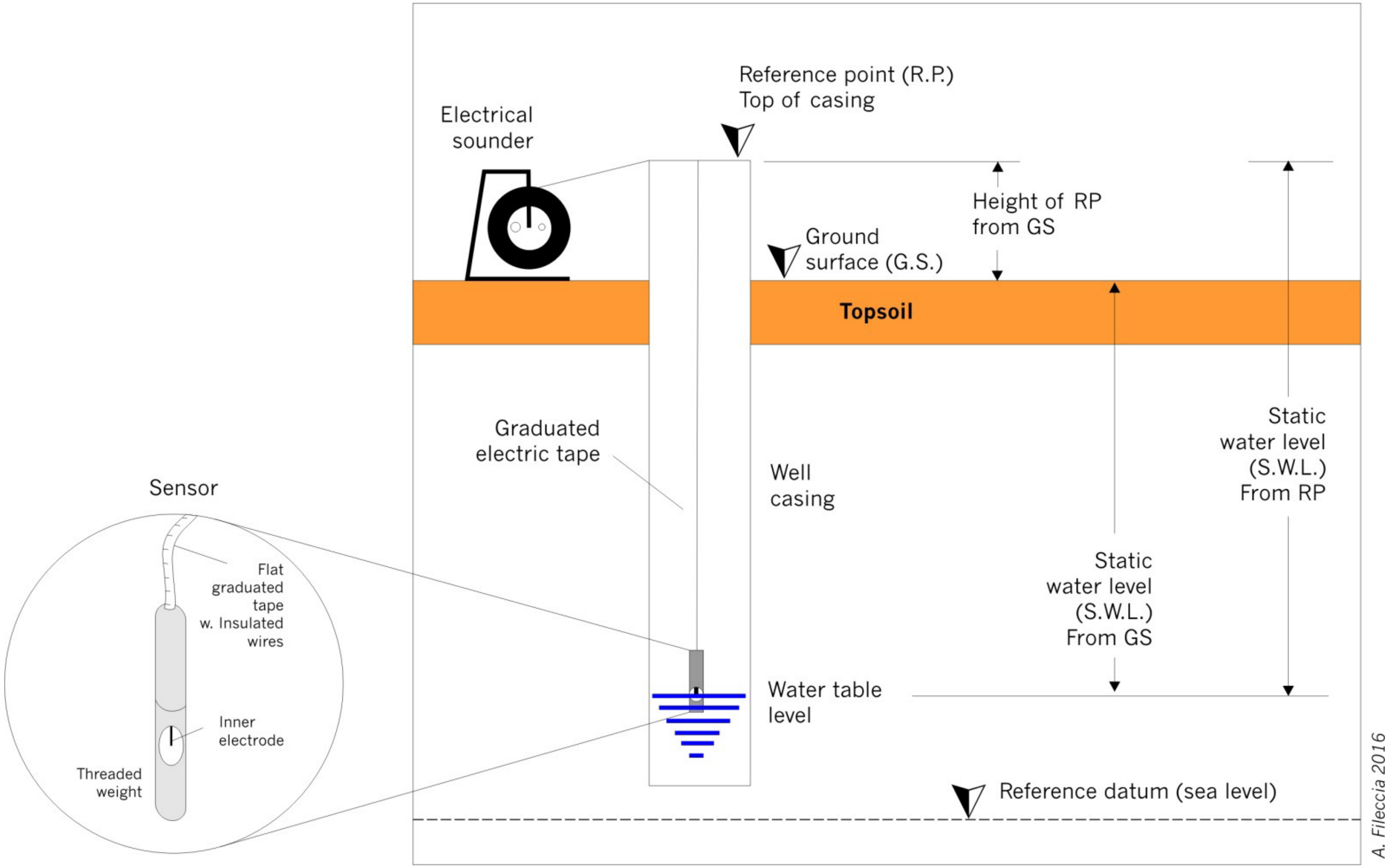
Field data collection

Water level measuring devices

The most accurate recordings of water-level changes are made with fully-automatic microcomputer-controlled systems This system uses pressure transducers for continuous water-level recordings, which are stored on a data logger. Fairly accurate measurements can be taken by hand, but then the instant of each reading must be recorded with a chronometer. On the field a widely used method is the one with an electrical sounder, or water-level dipper. A proper use allows a 0.5 cm precision.

An electric tape, double-wired and graduated in m and cm. Electric tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed

Example of different readings that could be taken with an electric tape. The static water level (SWL) or dynamic water level (D.W.L.) during a pumping test, can be referred to a reference point on top of casing (preferred) or on ground surface. For further use, all readings should be referenced to a common datum (sea level).



HydroNova
INNOVATING WATER PROSPERITY
www.hydronova.tech

Well inventory form

Site ID other site ID

Project title: **Client:**

Date of survey: **Recorded by:** **Report n:**

Owner/Tenant: **Ref. Name:**

Drilling Contractor: **NOTE:**

Position

District: Town:

Community:

Map type:

Ref. System:

Coordinate East:

North:

Topographic sketch

Well

elevation: +/- from s.l.
height of R.P.: +/- from g.l.
depth: water use:
completion date: Av. Discharge:
w.l. can be recorded ?
water can be sampled ?

Photo

Top of well sketch

Casing

from	to	Casing/screens and diameter

from	to	**Simplified log**

Water level records

date	W.L. from R.P.	Din. W.l. from R.P.	Discharge l/s	

Hydrochemical parameters

sample depth	Temp.	El. Conduct.		

Continue overleaf (e.g. log...)

CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

HydroNova
INNOVATING WATER PROSPERITY

Field data collection methods and field forms

General water well field form (hand dug and borehole)

Water point list

HydroNova
www.hydronova.tech

Water points survey

well/spring/surf. Basin

Report n.

Client:

Project:

Date:

Locality:

4 = ground surf. El. (m.a.s.l.); 5 = height of ref. point (R.P.) meters above-below ground;
6 = height of R.P. m.a.s.l. 7 = static water level (S.W.L.) +/- from R.P.; 8 = S.W.L. +/- from sea level
x,y coordinate system type:

1	2	3	4	5	6	7	8	9
ID	**x**	**y**	**z = g.el.**	**R.P. from g.surf.**	**R.P. from sea level**	**S.W.L. from R.P.**	**S.W.L: from sea level**	**Note**

HydroNova
INNOVATING WATER PROSPERITY

Borehole log

HydroNova – INNOVATING WATER PROSPERITY – www.hydronova.tech	Project: Client:	ID: Associated report:
Owner: Start/End date: Drilling method: Drilling Company: Depth: SWL:	District: Chiefdom: Town: Elevation: Map reference: Coordinates (WGS84 system) X: Y: Surveyor:	map inset (alternatively you can draw a sketch by hand)

Notes: general information regarding pump test, chemical analysis, accessibility etc.

Well design	Pen. Rate m/min	Depth	Log	Lithology description
describe how the well has been completed blank casing from.. to.. screens from... to... surface grout fill bentonite end cap etc.	when available make a graph of the speed of the drilling bit (it helps recognise depth of hard rock basement)	0 5 10 15 20 25	SWL describe the lithology using approved symbols and colours	more detailed description of lithology using words and statements fractures encountered, colour, water strikes... draw static water level line at the end of drilling operations

HydroNova INNOVATING WATER PROSPERITY www.hydronova.tech

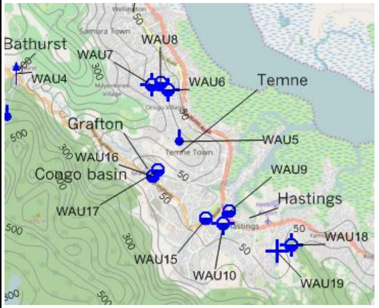
Well inventory form

Site ID	**WAU15**	other site ID	
Project title: Groundwater mapping of Sierra Leone		**Client:**	
Date of survey: 7/11/2016	**Recorded by: dr Desmondd Alie**	**Report n:**	
Owner/Tenant:		**Ref. Name:**	
Drilling Contractor:	hand dug well	**NOTE:**	

Position

District:	W area	Town:	Kossoh
Community:			
Map type:			
		Ref. System: WGS 84	
		(use deg. Dec deg.)	
Coordinate		East:	-13.14919
		North:	8.38893

Topographic sketch

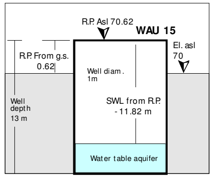


Well (use m, l/s as units)

elevation:	70	+/- from s.l.	
height of R.P.: 0.62		+/- from g.l.	
depth: 13	water use:	domestic	
completion date:		Av. Discharge:	
w.l. can be recorded ? Yes			
water can be sampled ? Yes			

Photo

Top of well sketch (use m as units)



Casing		**(use m, mm as units)**
from	to	Casing/screens and diameter

from	to	**Simplified log**

Water level records (use m as units)

date	W.L. from R.P.	Din. W.l. from R.P.	Discharge l/s	
7/11/2016	11.82			

Hydrochemical parameters

sample depth	Temp.	El. Conduct.		

Continue overleaf (e.g. log...)

HydroNova INNOVATING WATER PROSPERITY

CONSULTANCY SERVICES FOR GROUNDWATER MAPPING

Training course on field data collection and entry

Example of completed field forms

Hand Dug well no. WAU15

HydroNova
INNOVATING WATER PROSPERITY
www.hydronova.tech

Well inventory form

Site ID **967** other site ID

Project title: Groundwater mapping of Sierra Leone **Client: IPCS**

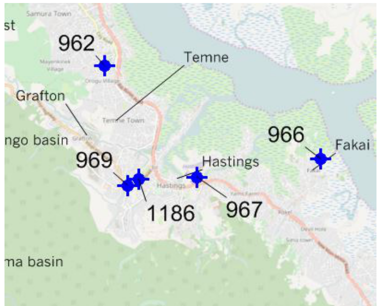
Date of survey: 11/11/14 **Record by: dr Desmond Alie** Rep. n: Warea_BH_PT_WQ_Hastings_IPCS_1pdf

Owner/Tenant: Int. Procurement Constr. Services **Ref. Name:**

Drilling Contractor: Edal. Www.edalltd.com **NOTE:**

Position			
District:	W area	Town:	Hastings
Community	Hastings air field		
Map type:			
		Ref. System: WGS 84	
		(use deg. Dec deg.)	
Coordinate		East:	-13.13076
		North:	8.38951

Topographic sketch



Well (use m, l/s as units)				
elevation:	51		+/- from s.l.	
height of R.P.:			+/- from g.l.	
depth:	100	water use:	domestic	
completion date:		11/11/14	Av. Discharge:	0.28
w.l. can be recorded ? Yes				
water can be sampled ? Yes				

Photo

Top of well sketch (use m as units)

Casing		(use m, mm as units)
from	to	Casing/screens and diameter
0	73	blank casing plastic
73	97	slotted screen plastic
97	100	blank casing (end cap)

from	to	Simplified log
0	50	greyish mudstone highly compact
50	68	sandstone
68	100	hard gabbroic rock

Water level records (use m as units)				
date	W.L. from R.P.	Din. W.l. from R.P.	Discharge l/s	
12/11/14	-8.92	-41.2	0.28	

Hydrochemical parameters				
sample depth	Temp.	El. Conduct. microS/cm	TDS ppm	Iron mg/l
	28.7	78.7	39.4	0.9

Continue overleaf (e.g. log...)

CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

HydroNova
INNOVATING WATER PROSPERITY

Borehole field form no. 967

Water point list

HydroNova
www.hydronova.tech

Water points survey

Orugu river basin

Report n. GW mapping of Sierra Leone

Client: SALWACO

Project:

(use m as units)

Recorded by: Dr Desmond Alie

Date: 7/11/2016

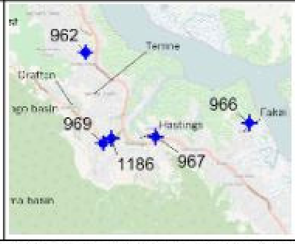
Locality: Grafton Freetown urban area

4 = ground surf. El. (m.a.s.l.); 5 = height of ref. point (R.P.) meters above-below ground;
6 = height of R.P. m.a.s.l. ; 7 = static water level (S.W.L.) +/- from R.P.;
8 = S.W.L. +/- from sea level; x,y coordinate system type: **(use WGS 84 deg, dec deg. as system)**

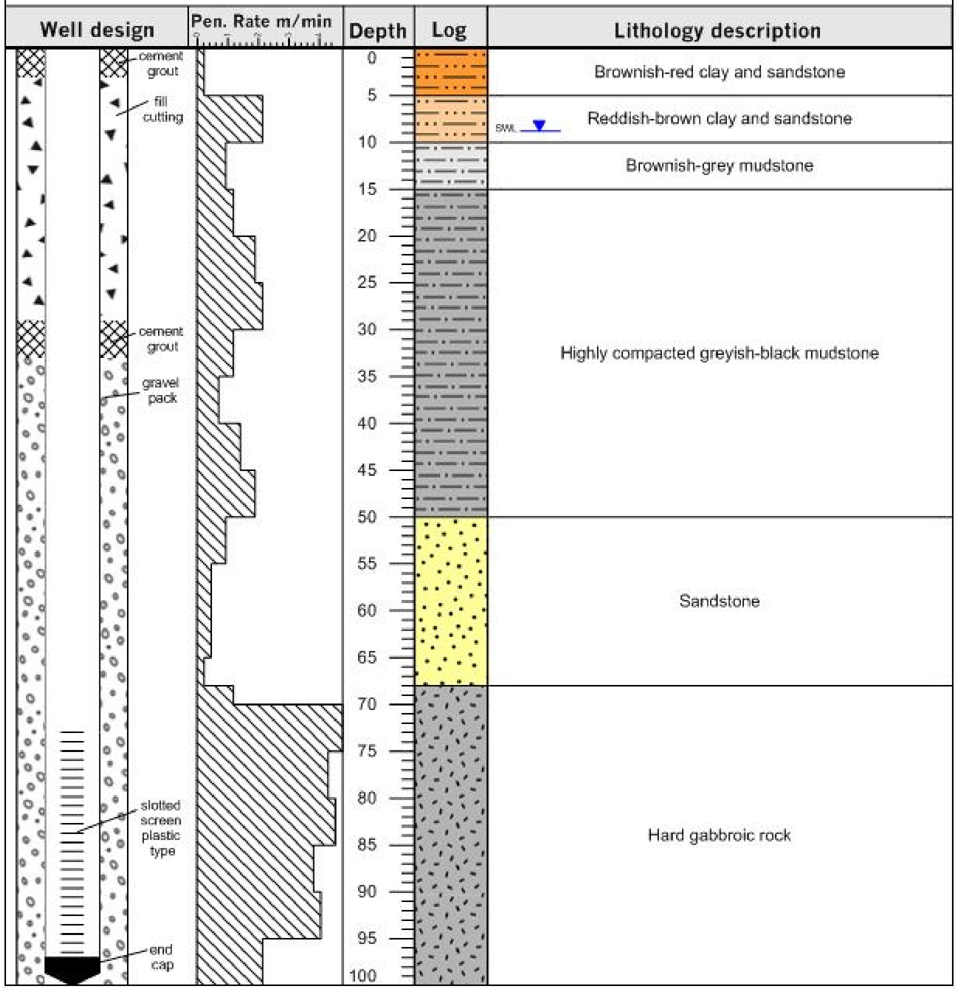
1	2	3	4	5	6	7	8	9
ID	**x**	**y**	**z = g.el.**	**R.P. from g.surf.**	**R.P. from sea level**	**S.W.L. from R.P.**	**S.W.L: from sea level**	**Note**
WAU8	-13.16193	8.42672	95	0.46	95.46	10.73	84.73	never dry
WAU9	-13.14265	8.39083	45	0.33	45.33	11.99	33.34	never dry
WAR15	-13.14919	8.38893	70	0.62	70.62	11.82	58.8	never dry
WAU16	-13.16415	8.40071	63	0.42	63.42	8.14	55.28	never dry
WAU17	-13.16272	8.40228	52	0.35	52.35	17.55	34.8	never dry

water level readings must be taken in the shortest period of time

(e.g. a few hours or 1-2 days when boreholes are many on a wide area)

HydroNova www.hydronova.tech	Project: Borehole drilling / Pumping test, Hastings Ebola Treatment Center Client: International Procurement Construction Services (IPCS), 8 Ecowas Street, Freetown	ID: 967 Edal's report: Warea_BH_PT_WQ_Hastings_IPCS_1.pdf
Owner: International Procurement Construction Services (IPCS) Start/End date: 10/29/14-11/11/14 Drilling method: mud & air Drilling Company: Edal, Freetown www.edalltd.com Depth: 100 m SWL: -8.92m (below RP) 12/11/2014	District: Western Area Rural District Chiefdom: Western Area Town: Hastings (Airfield) Elevation: 51 m. asl Map reference: Coordinates (WGS84 system) X: -13.13076 Y: 8.38951 Surveyor: Kemoh Alie Bayoh	

Notes: Prepared from the original report in january 2017. Main information: stratigraphic log (BH), Pump test (PT), water analysis (WQ). Chemical parameters out of WHO limits are pH (below), Turbidity (above), Iron (above), Sulphide(above).



CONSULTANCY SERVICES FOR GROUNDWATER MAPPING
Training course on field data collection and entry

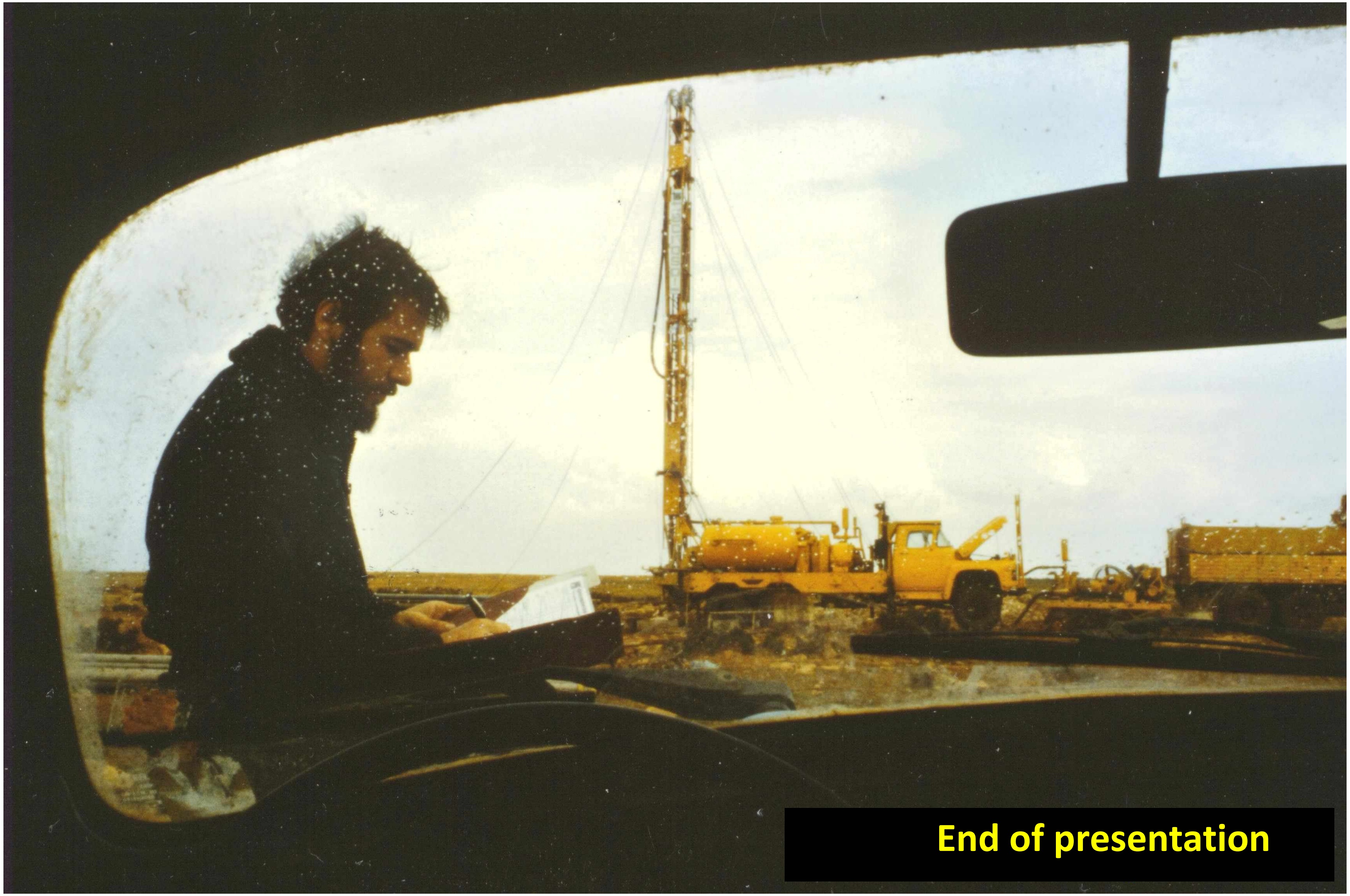
Borehole log no. 967

Borehole Data Base

ID	X	Y	Z (ground el.)	DISTRICT	CHIEFDOM	TOWN	DATA TYPE	SWL BELOW R.P.	DATE OF READING
1186	-13.14919	8.38893	70	Western area		Hastings	HD	11.82	7/11/2016
962	-13.15984	8.42465	92	Western area		Freetown	BH	15.96	10/3/2015
966	-13.09173	8.39521	34	Western area		J. Thhorpe	BH	7.4	12/1/15
967	-13.13076	8.38951	51	Western area		Hastings	BH	8.92	11/12/14
969	-13.15254	8.38684	49	Western area		Kossoh	BH	10.33	7/17/15

HEIGHT OF R.P. ags	WL asl	DWL BELOW R.P.	DD	PUMP DEPTH	PUMP DISCHARGE (CUM/D)	SPECIFIC CAPACITY (CUM/D/SQM)	DATE OF SC TEST	BOREHOLE DEPTH
0.62	-11.82							13
	76.04	44.92	28.96		24.96	0.86	10/3/2015	60
		30.9	23.5		101.76	4.33	12/1/15	50
		41.2	32.28		135.2	4.18	11/12/14	100
		28.15	17.82		123	6.9	7/17/15	56

TOP FRACTURATED ROCK DEPTH	BASEMENT DEPTH	CONTRACTOR	ASSOCIATED FILE	NOTE
				WAU15
15	23	Edal	Warea_BH_PT_WQ_Allen_Town_Concern.pdf	
silty sand	silty sand	Edal	Warea_BH_PT_WQ_John_Thorpe_Concern.pdf	
68	70	Edal	Warea_BH_PT_WQ_Hastings_IPCS_1.pdf	
25	25	Edal	Warea_BH_PT_WQ_Kossoh_Akker.pdf	


End of presentation