Optimal development and sustainable management of groundwater resources

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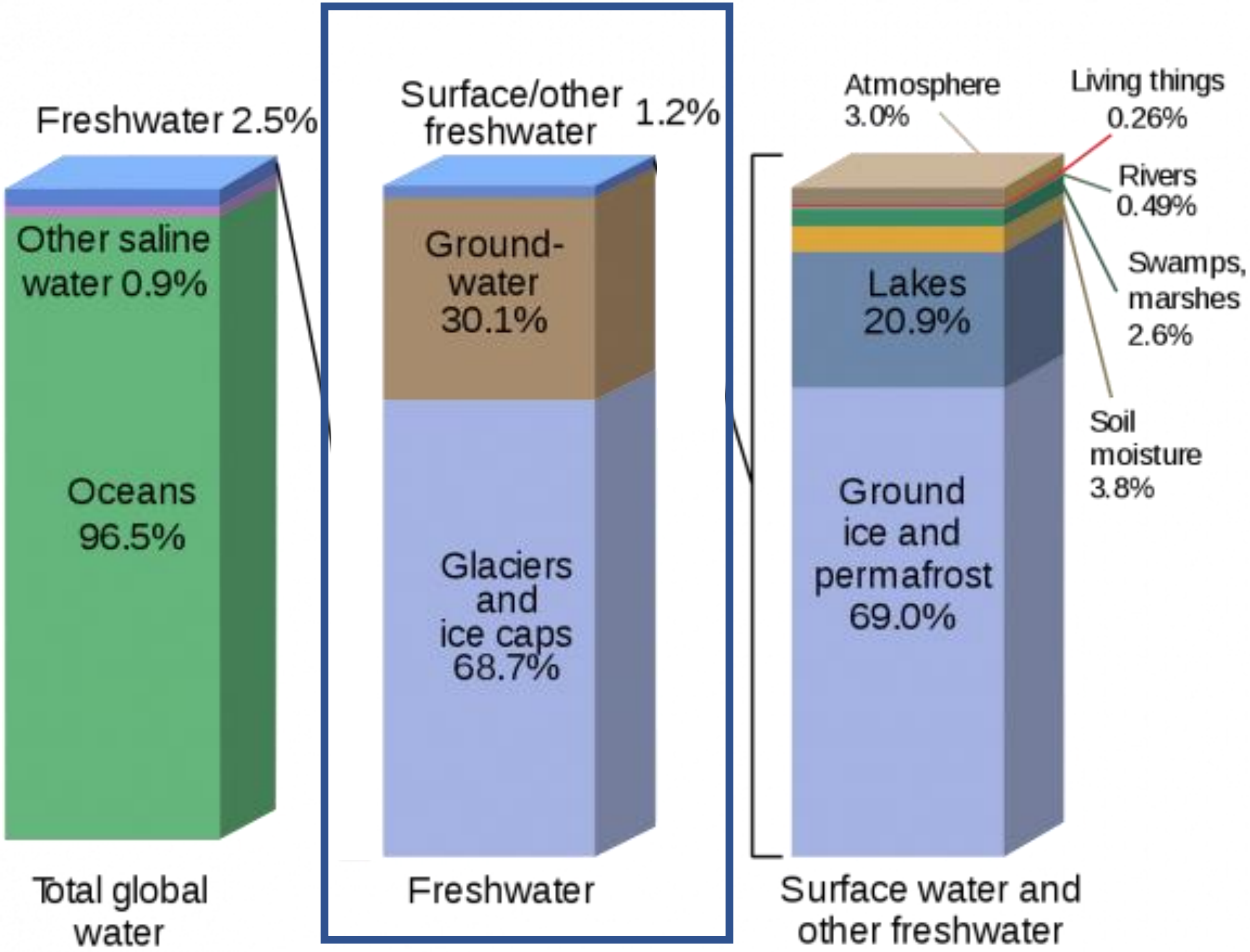
Hydrogeologist

6 June 2022

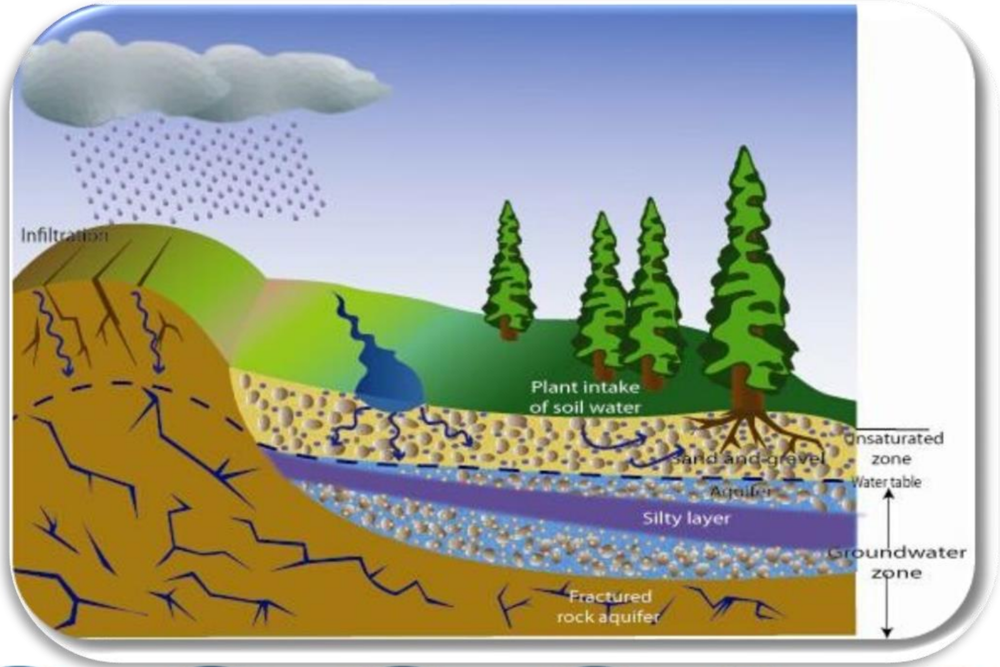
GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Where is Earth's Water?



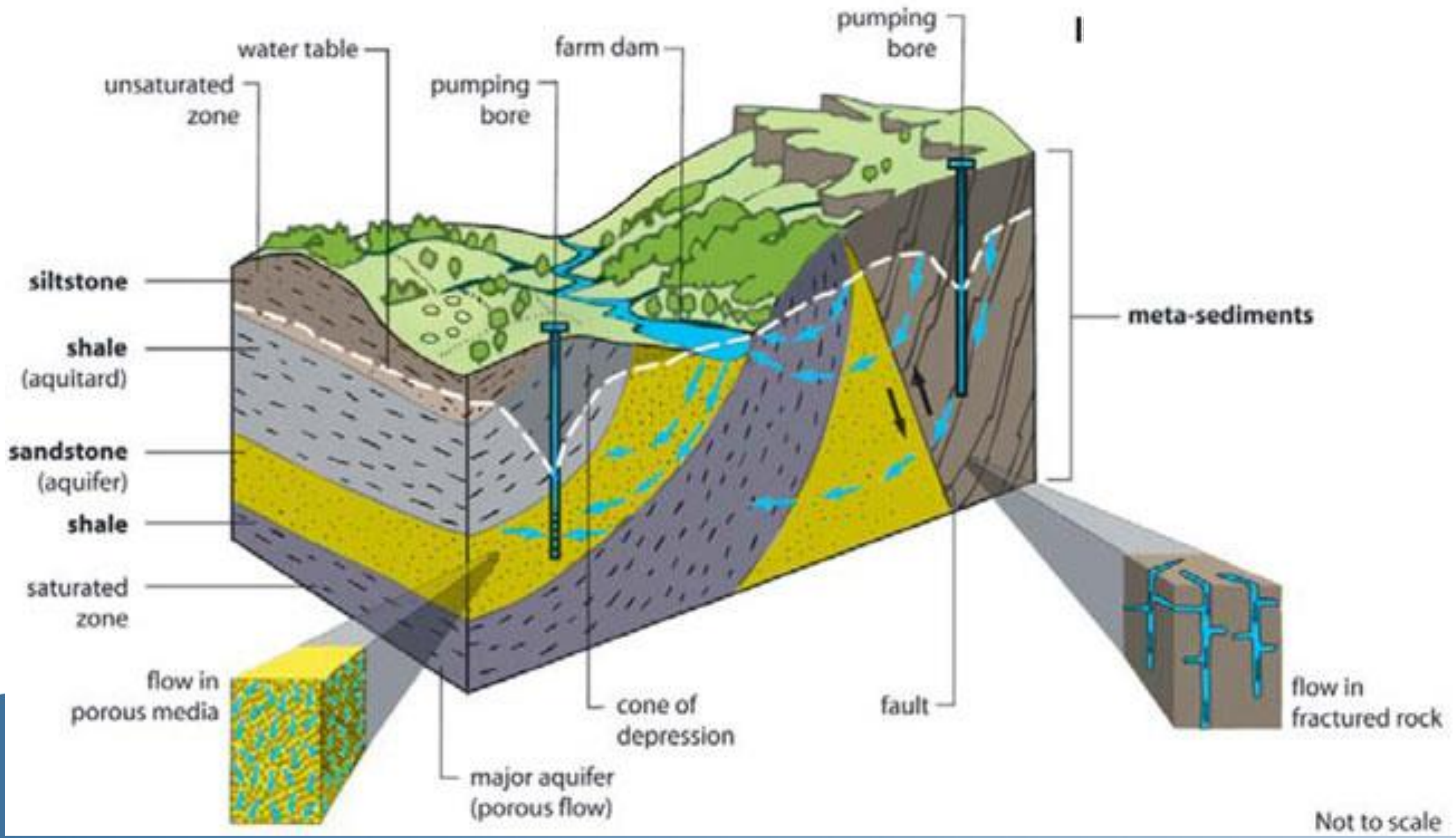
What is Groundwater?

- Groundwater is water that has infiltrated the ground to fill the spaces between sediments and cracks in rock
- “Water found in the subsurface in the saturated zone below the water table.”



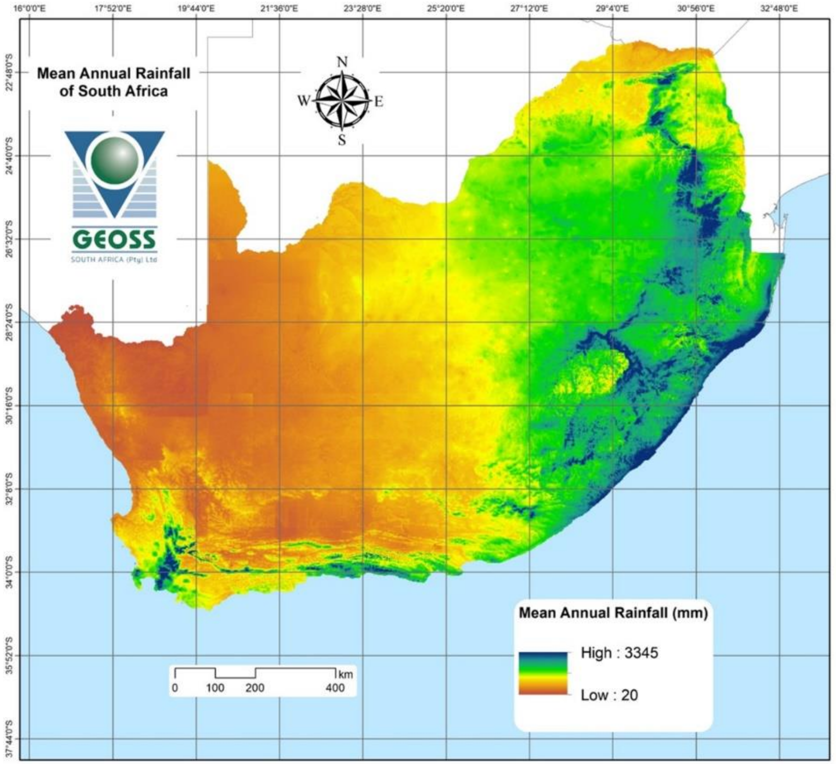
Where Does Groundwater Occur?

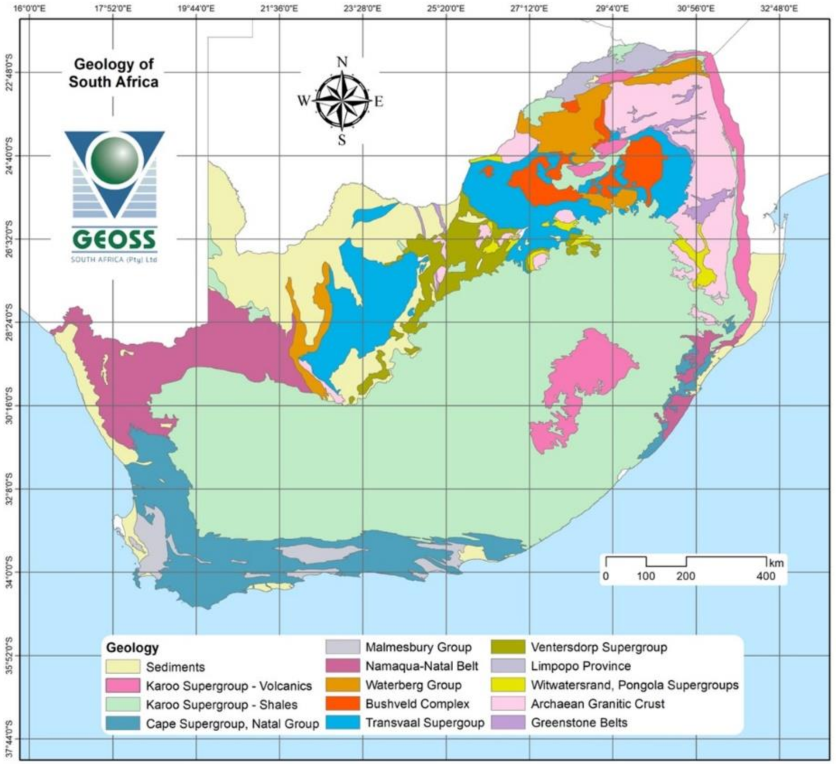
- <u>Aquifer</u> - a body of porous rock or sediment saturated with usable quantities of groundwater
- Groundwater will follow the <u>path of least resistance</u>.
- <u>Flow and storage</u> occur between unconsolidated sediments, solid rock particles (porosity & permeability) and between solid rock units (faults & fractures) - geology.

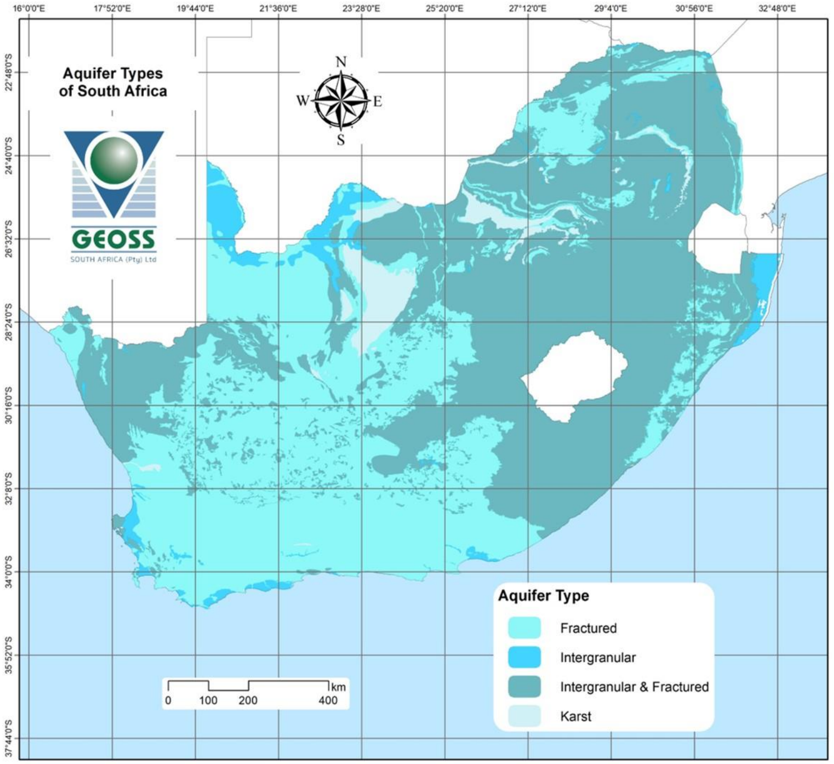


The <u>geology</u> of the subsurface controls how groundwater will flow.

Rainfall + Geology = Regional Expectations







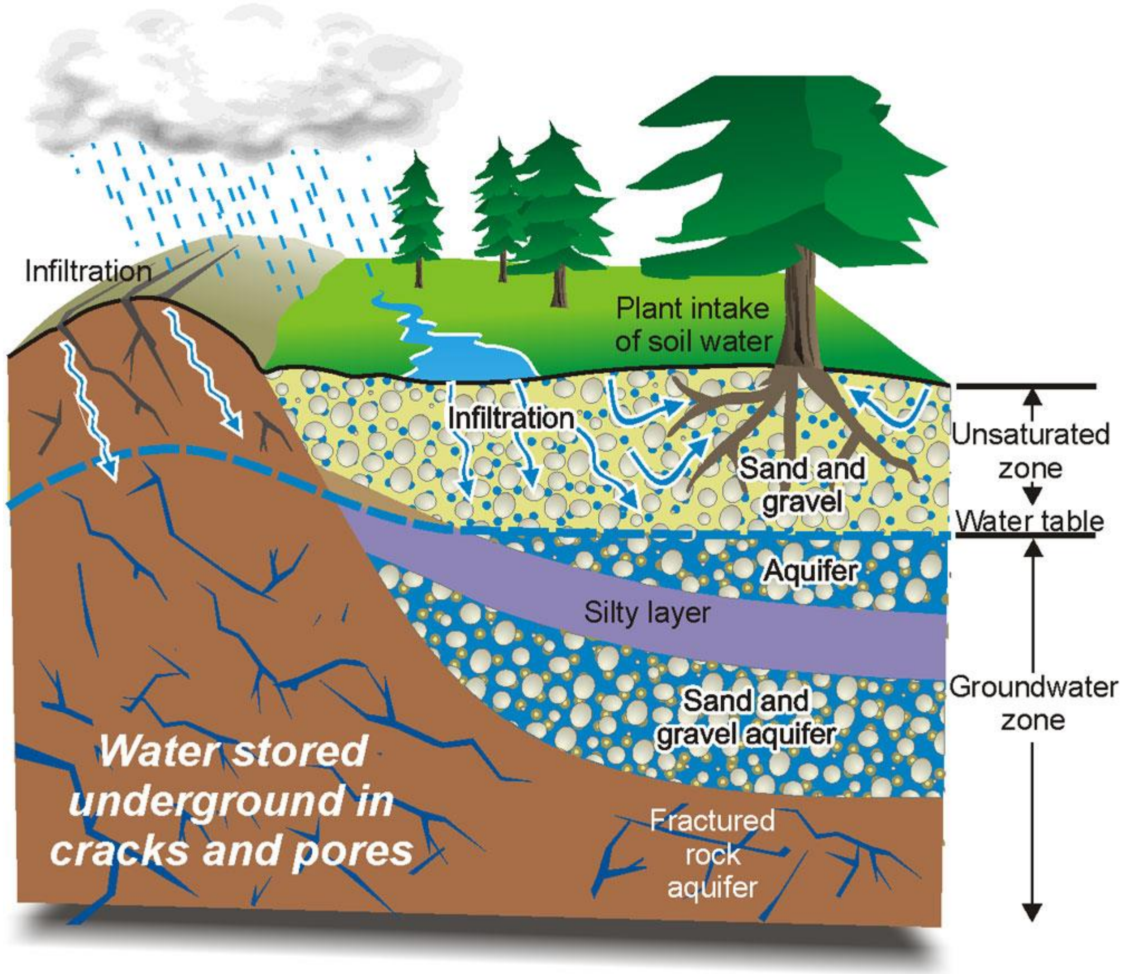
Types of aquifers

Two general types of aquifers:

1. Unconfined aquifers lie below a permeable layer of soil
2. Confined aquifers have a layer of impenetrable rock or clay above them.

- Many different types of sediments and rocks can form aquifers.
- Aquifers are sometimes categorized according to the type of rock or sediments of which they are composed.

1. Primary (intergranular/porous)
2. Secondary (fractured rock)
3. Karst (limestone/dolomite)



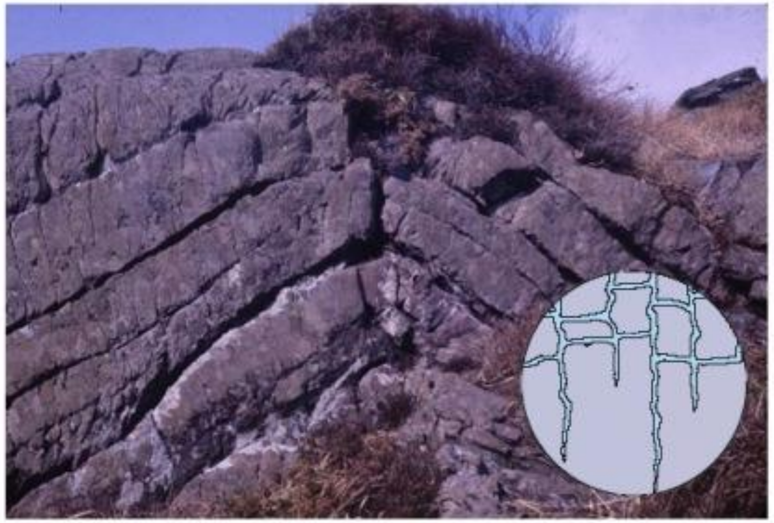
1. Primary Aquifer (Intergranular/Porous aquifer)

- Water moves through the integranular spaces formed at the same time as the geological formation.
- Comprising of unconsolidated material deposited by water, typically occurring adjacent to rivers and in buried paleochannels.
- Alluvial aquifers are generally composed of clay, silt, sand, gravel or similar unconsolidated material deposited by running water.
- Examples:
  - Cape Flats Aquifer (Philippi)
  - Atlantis Aquifer
  - Sandveld.

Sand and gravel deposit with primary, intergranular porosity and permeability

2. Secondary Aquifer (Fractured rock aquifer)

- Groundwater moves through secondary openings which developed after the rocks were formed.
- The secondary opening form as a result of weathering, fracturing, faulting and dissolution.
- A fractured aquifer is defined as a formation that contains sufficient fissures, fractures, cracks, joints and faults that yields economic quantities of water to boreholes and springs.
- Examples:
    - Table Mountain Group Sandstones & Quartzites



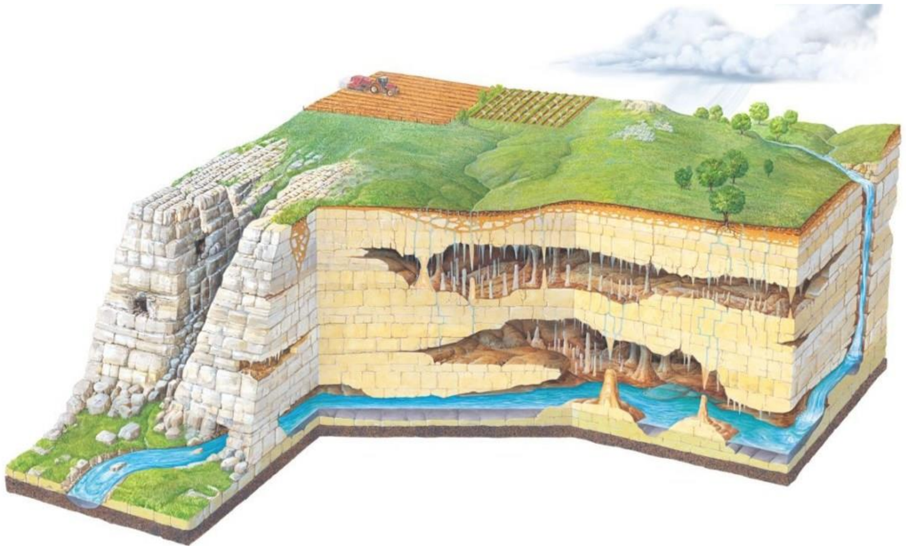
Folded, jointed and faulted bedrock with only secondary, fissure porisity and permeability

3. Karst Aquifer (Limestone/Dolomite)

- Special type of fractured rock aquifers (limestone & dolomite) in which the water in the fractures has dissolved the relatively soft rock, thereby significantly increasing the size of the fractures

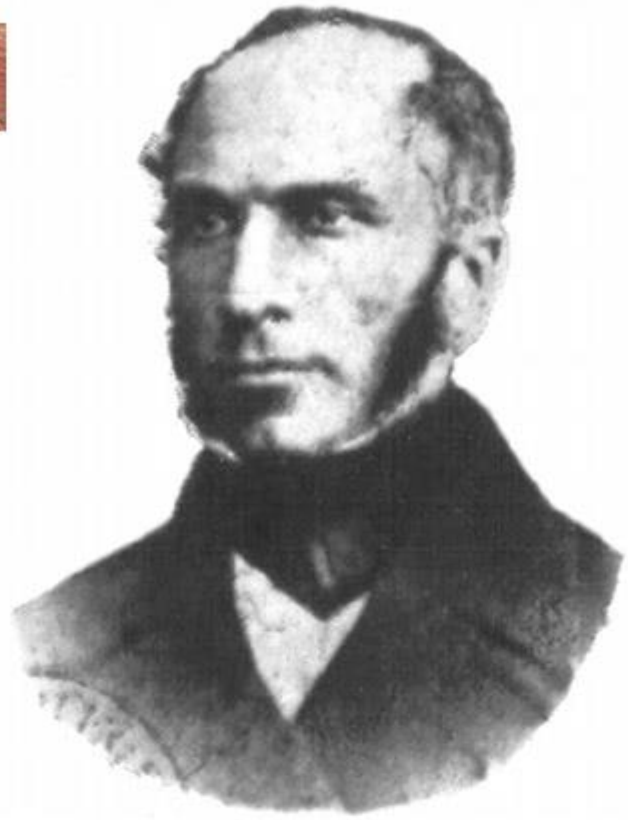
- The term karst is used to describe an area of limestone or other highly soluble rock, in which the landforms are of dominantly solutional origin and in which the drainage is underground in solutionally enlarged fissures and conduits (caves).

- Examples:
    - Vanrhynsdorp Karst Aquifer (Troe- Troe river)



FRENCH HYDRAULIC ENGINEER

HENRY DARCY

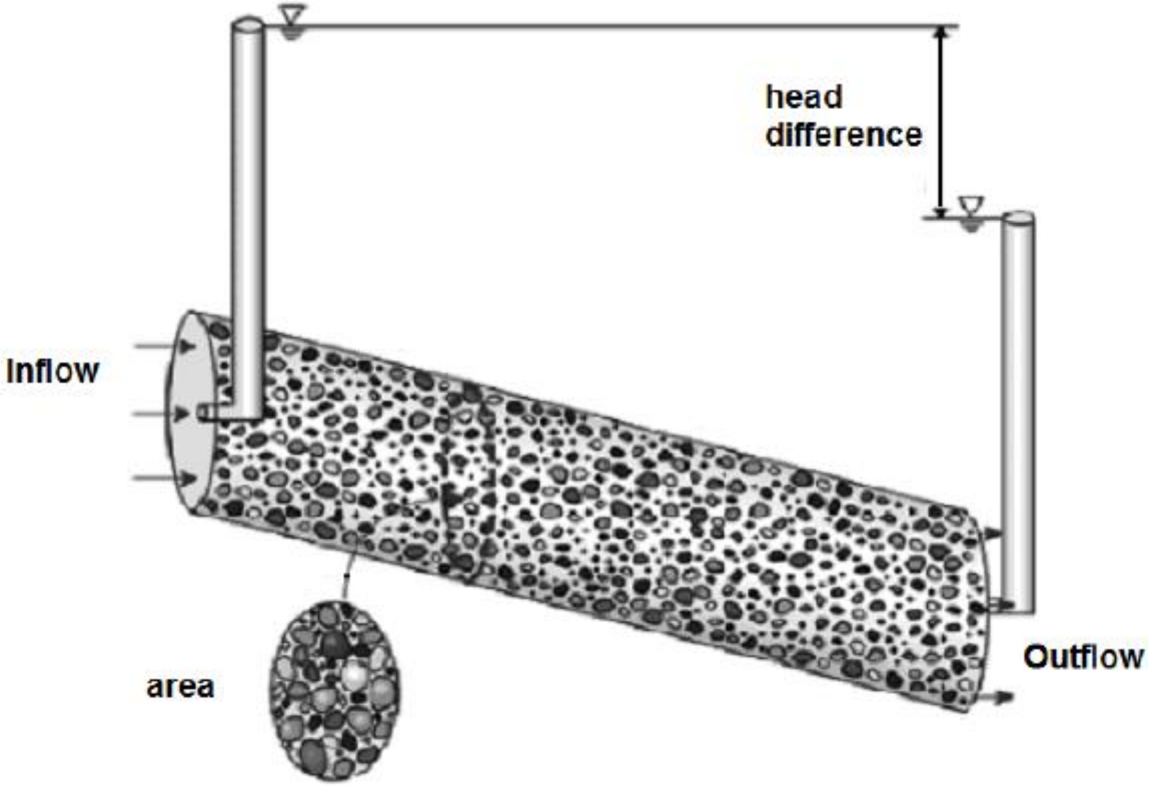


BORN 10TH JUNE 1803

WELL KNOWN FOR:

- DARCY'S LAW

- France
- Engineer
- Water delivery and treatment
- Darcy's Law for saturated flow in porous media (1856)



Darcy's Law

Groundwater Flow Rate

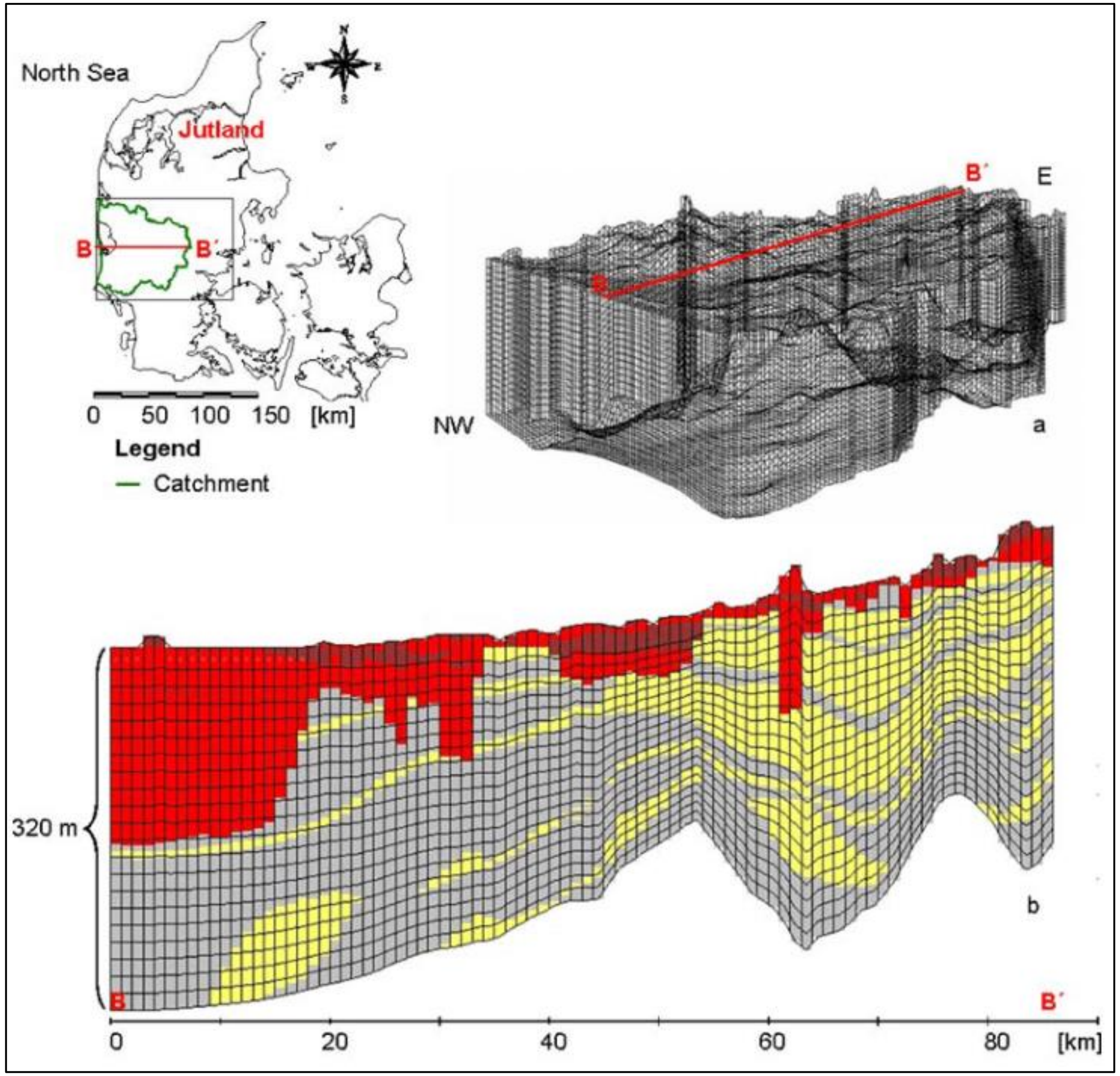
$$V = K \frac{dh}{dl}$$

V = flow
K = hydraulic conductivity
dh = head difference
dl = distance between points

Groundwater Flow Volume

$$Q = A K \frac{dh}{dl}$$

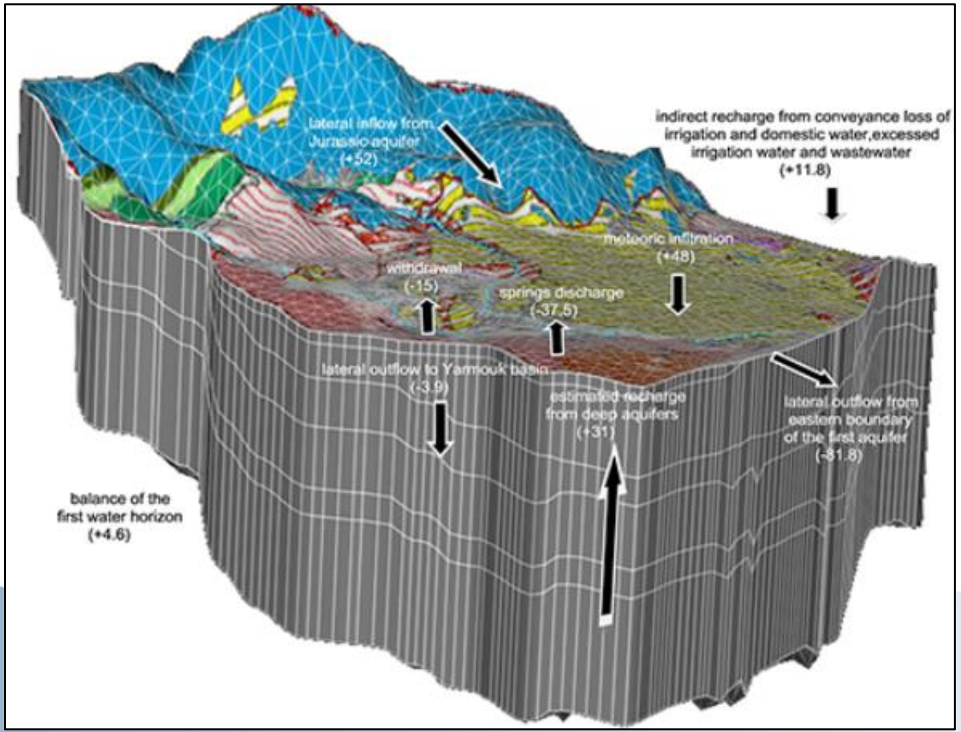
Q = discharge
A = aquifer cross-section area
K = hydraulic conductivity
dh = head difference
dl = distance between points



The main equation of groundwater flow

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) = S_s \frac{\partial h}{\partial t}$$

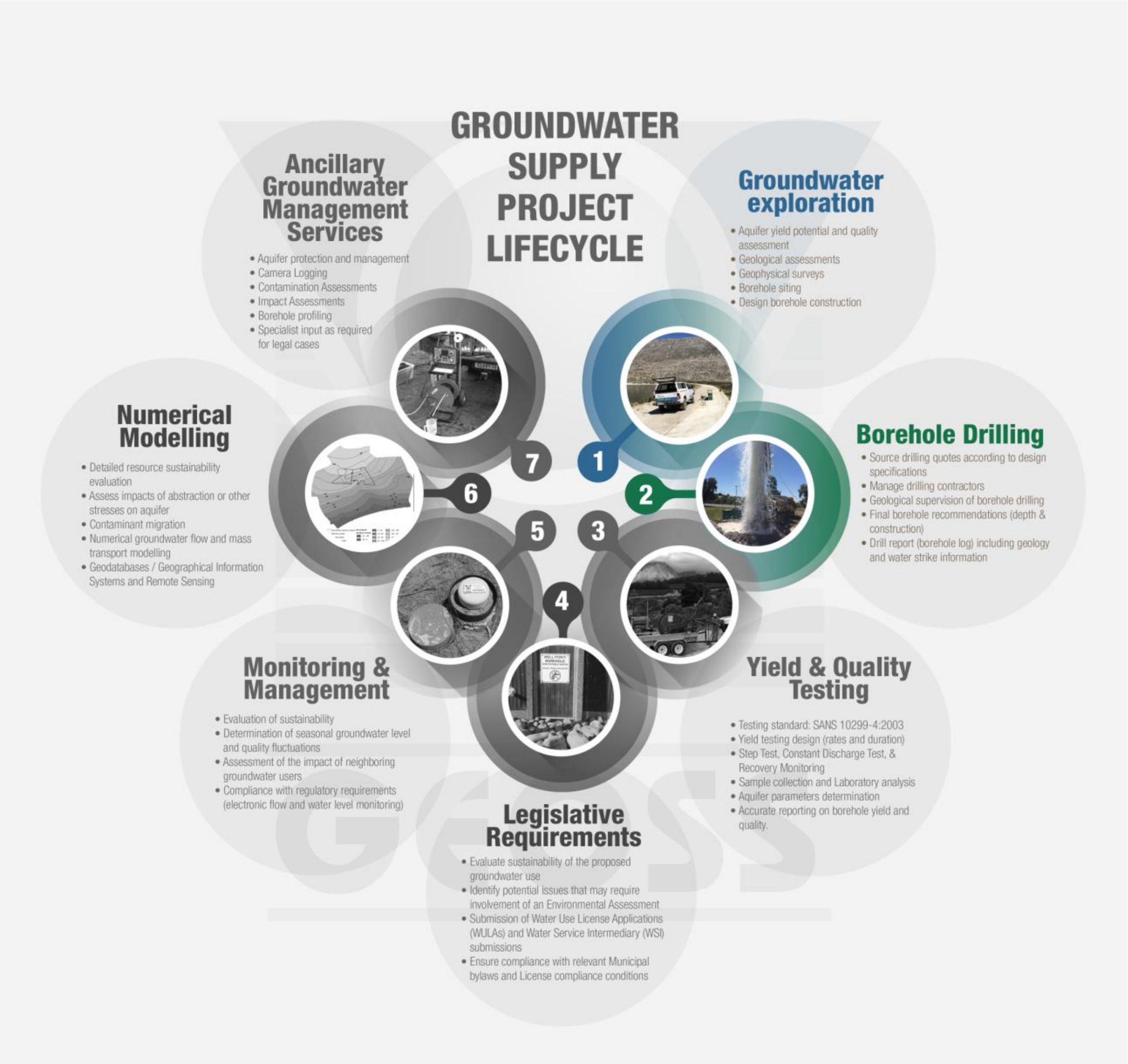
- This is a linear parabolic partial differential equation
- It's the main equation of groundwater flow in saturated media
- It is solvable only by numerical methods
- the solution of which yields *h (x,y,z,t)* in a heterogeneous, anisotropic confined aquifer.



Groundwater Exploration and Borehole Drilling

- Where do I drill and how?

Optimal development and sustainable management of groundwater resources



Where do I find Groundwater? **Where do I drill?**

…Appoint a Professional (hydrogeologist)

- Hydrogeological Investigation
    1) Desktop study: Satellite imagery (Google Earth – powerful and FREE). Geology maps
    2) Hydrocensus: Determine what the neighbouring groundwater use is
    3) Site visit: Critical
        1) Assessment of target features
        2) Geological mapping
        3) Geophysics

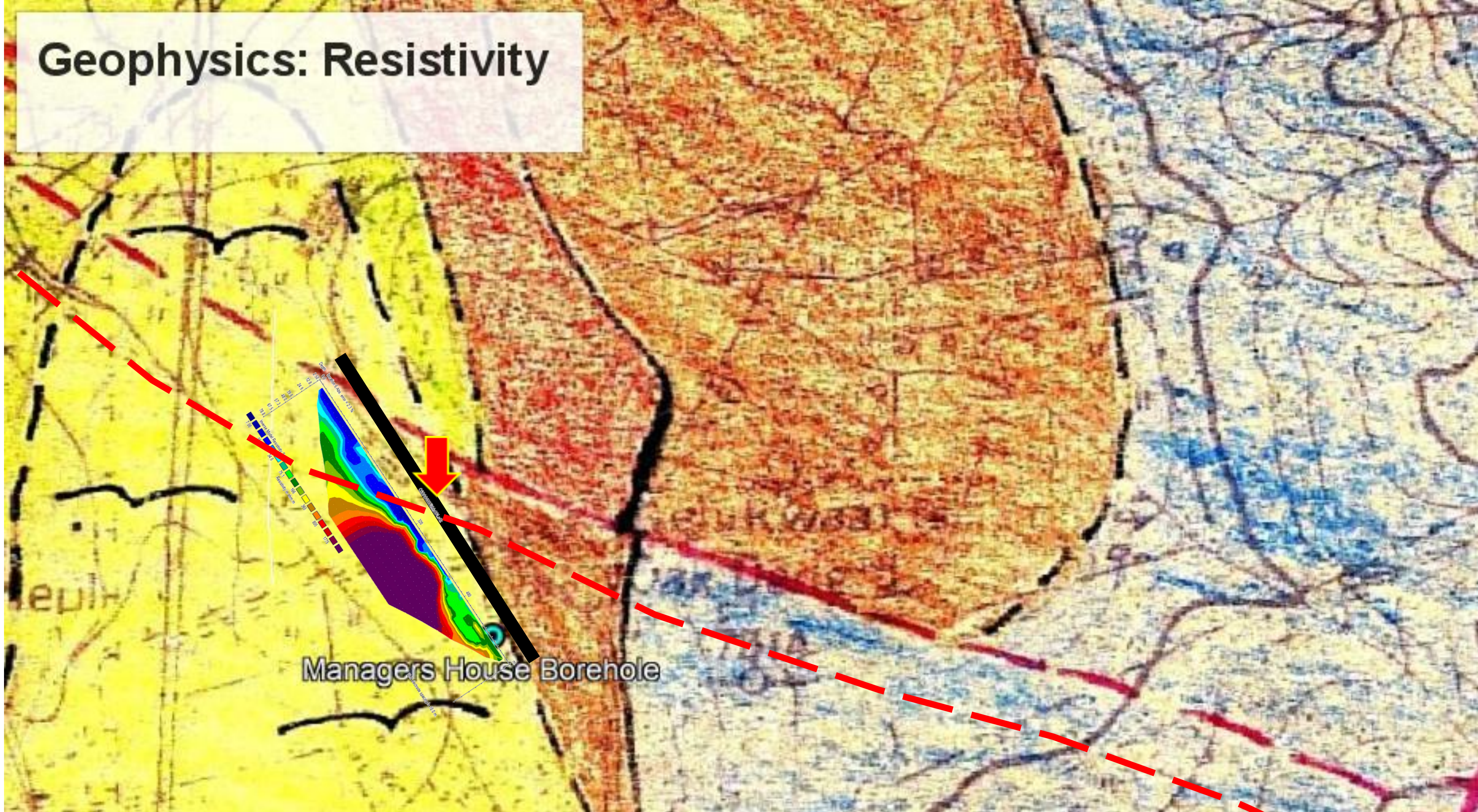
= **Drill here and here, OR don't drill**

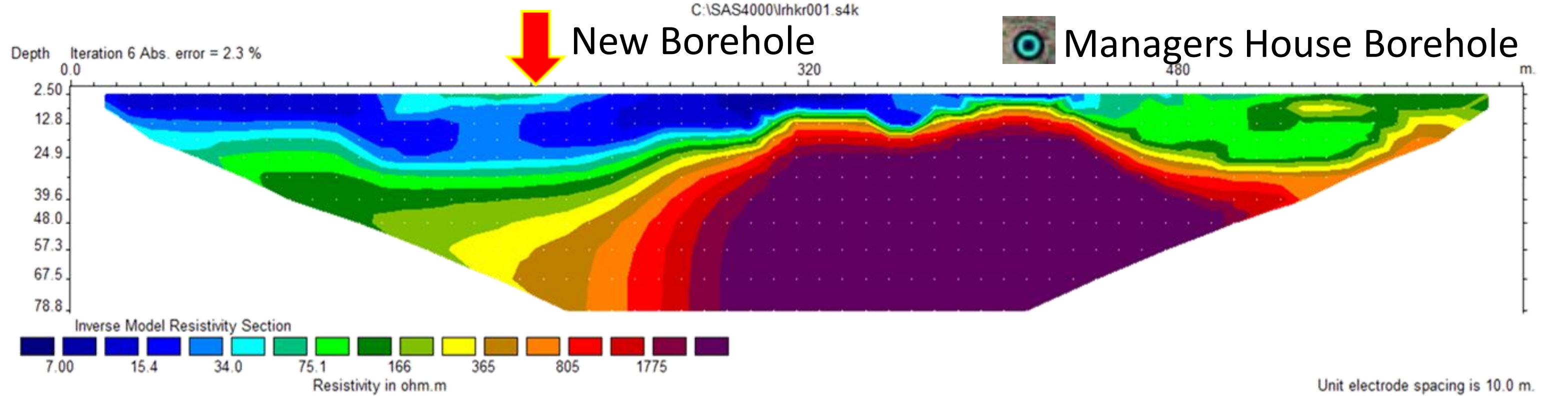
More on Geophysics

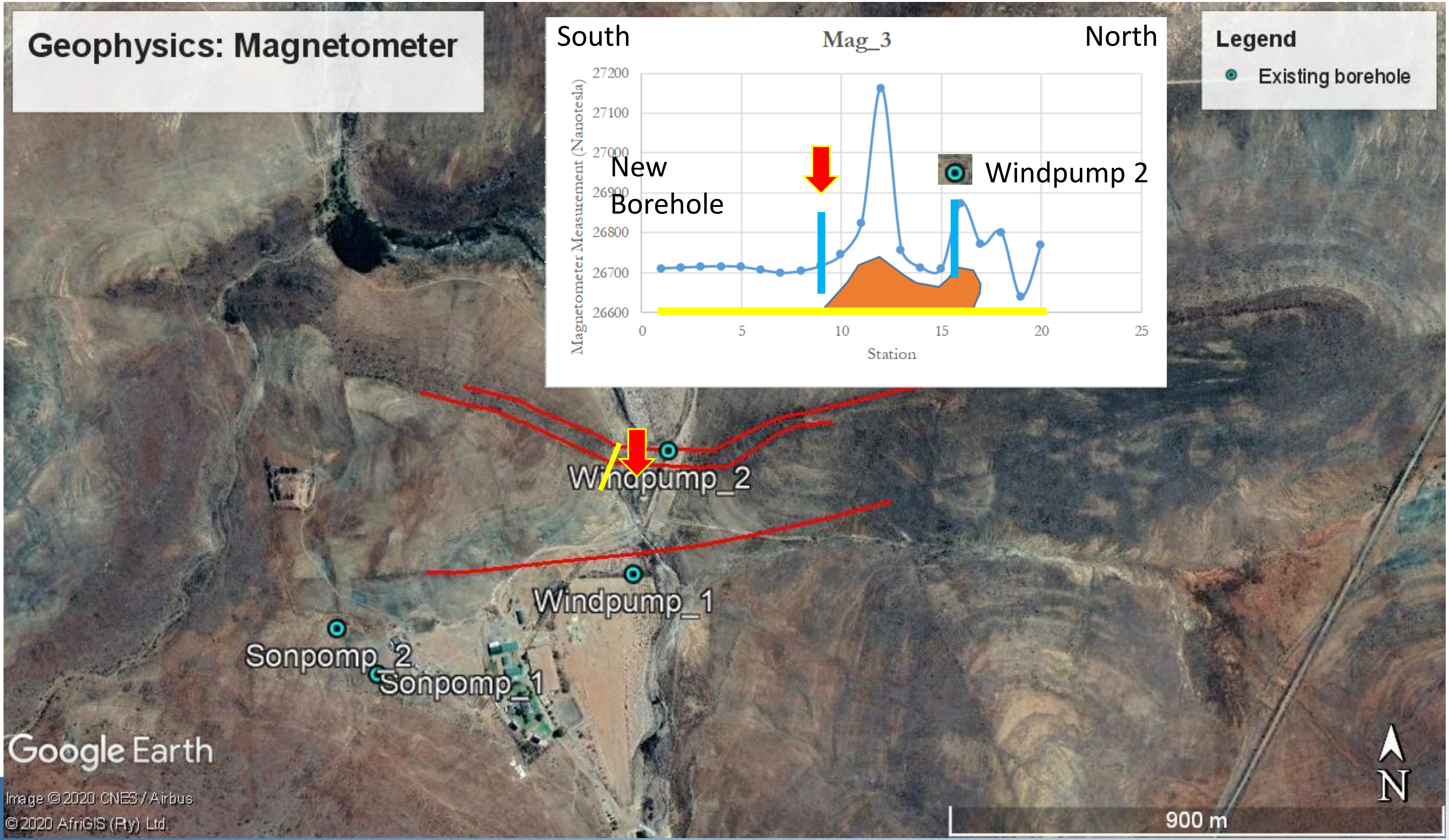
Geophysical Method	Application / Rock Type	Example	Advantage	Disadvantage
Magnetometer	Metal bearing rock	Dolerite in the Karoo	Simple to use, rapid	Rock must have a magnetic anomaly to work
Resistivity method	All	Sandstones of the Table Mountain Group	Detailed profiling of rock weathering	Inserting metal pegs into hard/rocky ground is challenging
Electromagnetic	All	Mixed rock types – good for identifying contacts between different rocks	Very rapid data acquisition	Positive readings for water and clay bearing rock

NB – Each method and tool has a specific application, however without correct interpretation, they do not work

Geophysics: Resistivity






Geophysics: Magnetometer
South
Mag_3
North
Magnetometer Measurement (Nanotesla)
27200
27100
27000
26900
26800
26700
26600
0
5
10
15
20
25
Station
New
Borehole
Windpump 2
Legend
Existing borehole
Windpump_2
Windpump_1
Sonpomp_2
Sonpomp_1
Google Earth
Image © 2020 CNES / Airbus
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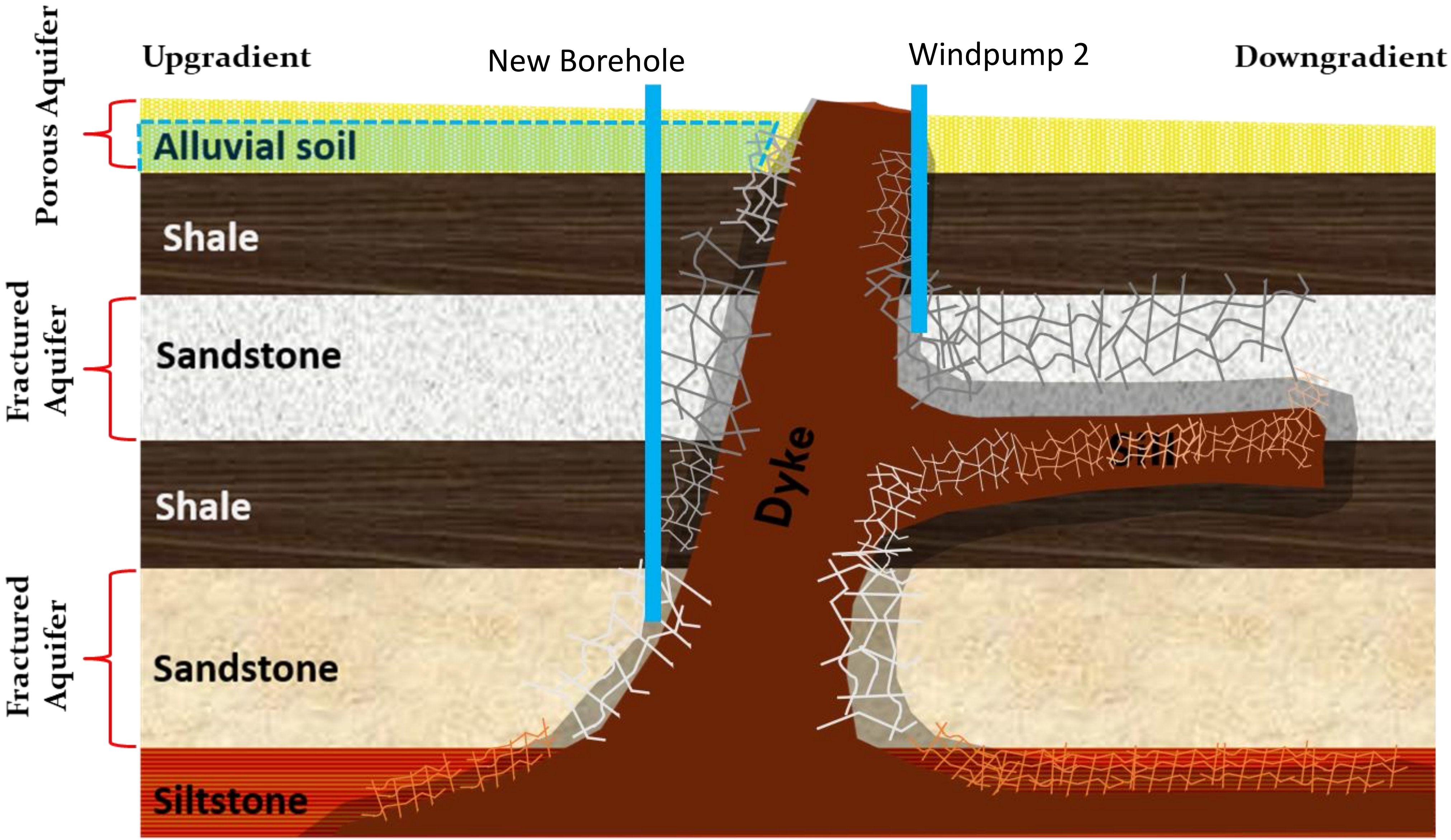


Windpump2 = Veesuiping water 200 L/hr
Borehole sited using hydrogeology and geophysics = 30 000 L/hr

X Marks the Spot, Now we drill

1. Get a reputable driller (references)
2. Capable for the relevant formation
3. Understands what “Borehole Development” means
4. Compiles a Drill Certificate after borehole completion
    - Borehole depth
    - Water strikes
    - Blow yield
    - Basic description of bore chips
    - Concerns (if any)
    - Date
    - Location
    - Name

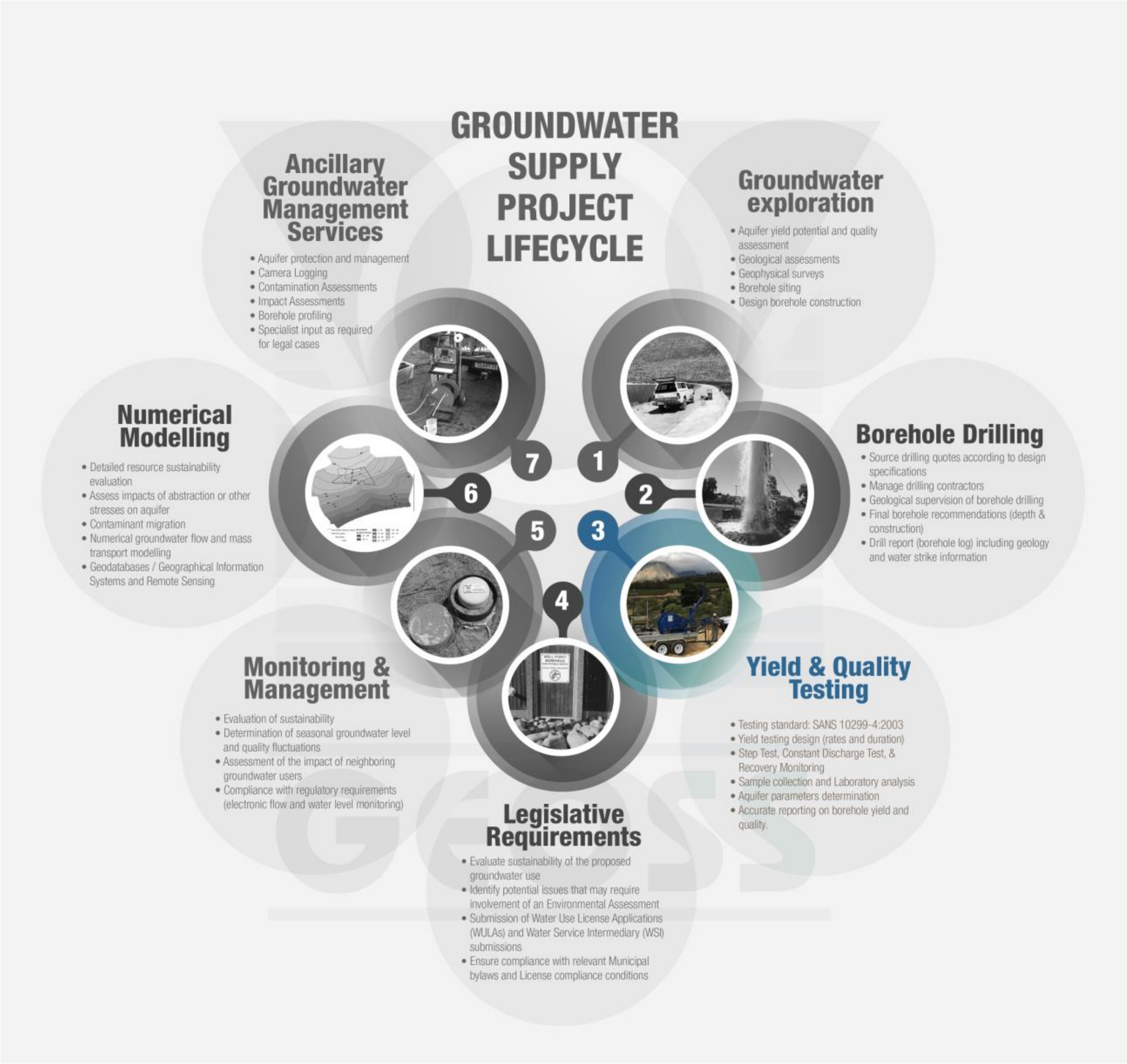
Some Groundwater Pics . . .

Artesian water

SANS 10299 yield testing and SANS 241 quality testing

- Benefits of doing SANS approved borehole testing.

Optimal development and sustainable management of groundwater resources



Benefits of SANS 10299 yield testing

- Sustainable yield
  - What does that mean?
- Properly equip the borehole
  - Pump installation depth
  - Cut off switch depth
  - Proper datum point for pump selection
  - Pumping schedule
- Impact on surrounding boreholes
  - Monitoring borehole
  - Aquifer parameters
  - Cooper Jacob method

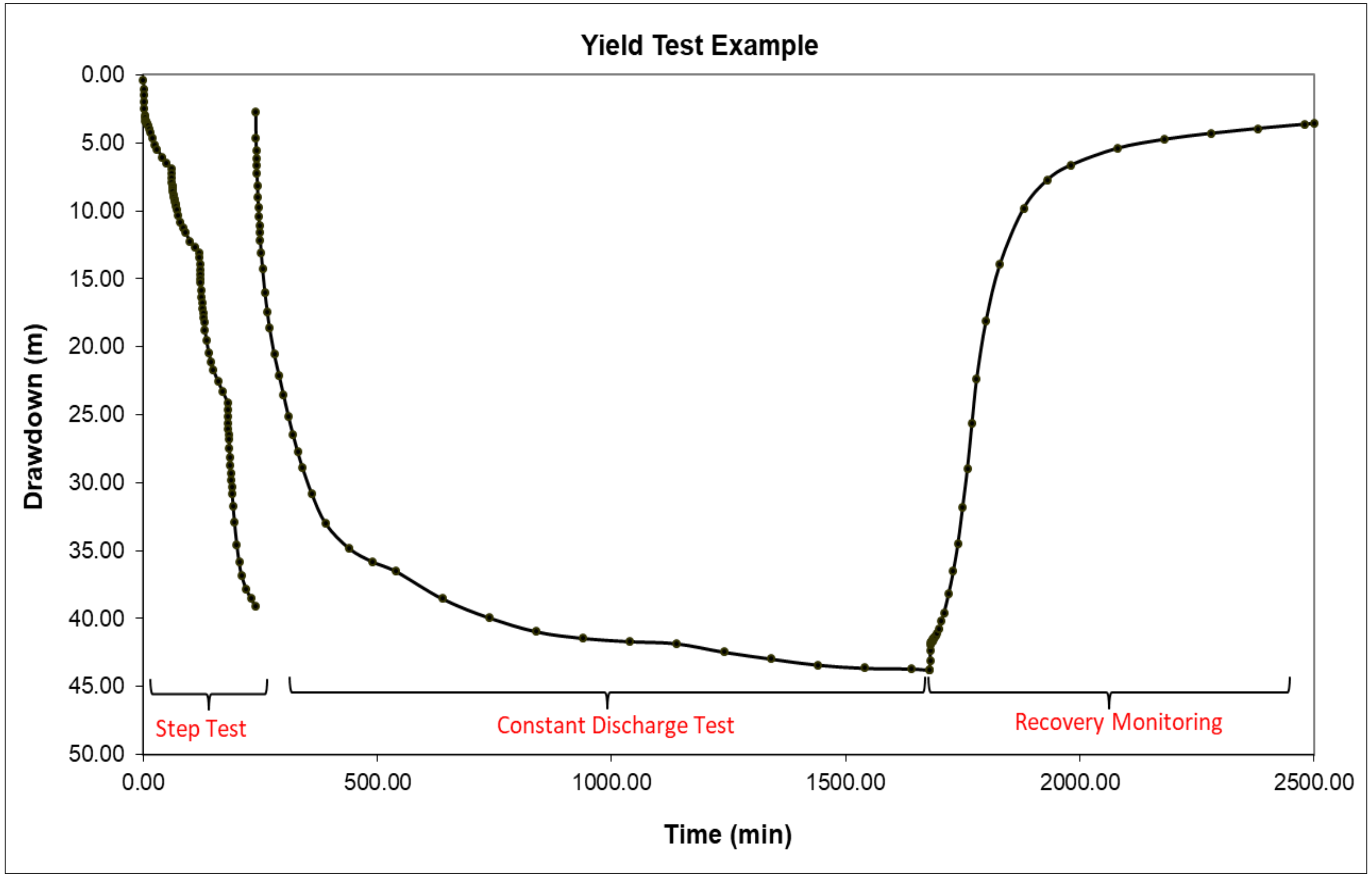
SANS 10299 requirements

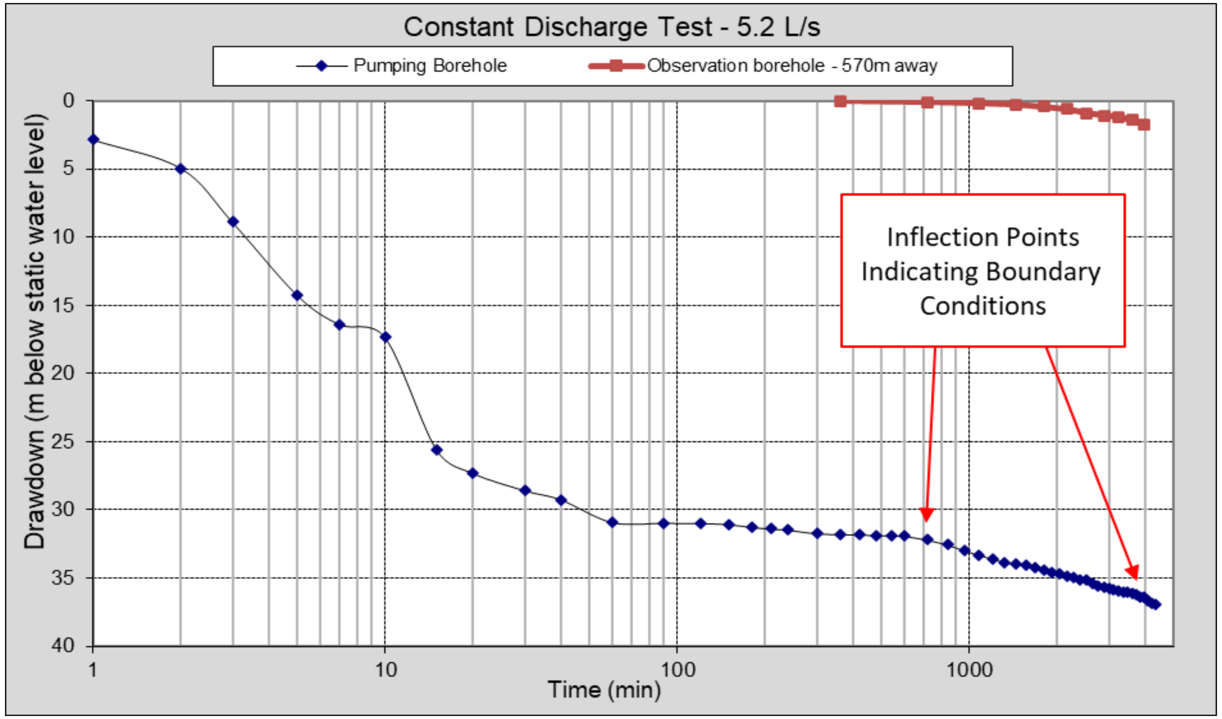
- Constant discharge test
  - Not a constant head test
- Duration of the test is dependent on supply type
- Three part test
  - Step test
  - Constant discharge test
  - Recovery test

1	2	3	4
Identification of use	**Type of test**	**Duration of test**	**Period of recovery**
Livestock or domestic	Extended step	Total 6 h	As given in 5.2.3
Hand pump	Extended step	Total 6 h	As given in 5.2.3
Irrigation (low cost consequence if failure occurs)	Step CD	4 x 1 h 24 h	As given in 5.2.3
Irrigation (high cost consequence if failure occurs)	Step CD	4 x 1 h 48 h or more	As given in 5.2.3
Engine-driven pump for rural village water supply	Step CD	4 x 1 h 48 h	As given in 5.2.3
Town water supply (low yield borehole)	Step CD	4 x 1 h 48 h	As given in 5.2.3
Town water supply (high yield or main borehole)	Step CD	4 x 1 h 72 h or more	As given in 5.2.3
Factory (water supply not critical to production)	Step CD	4 x 1 h 48 h	As given in 5.2.3
Factory (water supply critical to production)	Step CD	4 x 1 h 100 h or more	As given in 5.2.3
Power station and similar water user	Step CD	4 x 1 h 48 h to 30 d	As given in 5.2.3
Key CD = constant discharge test Step = step-drawdown test Extended step = extended step-drawdown test			

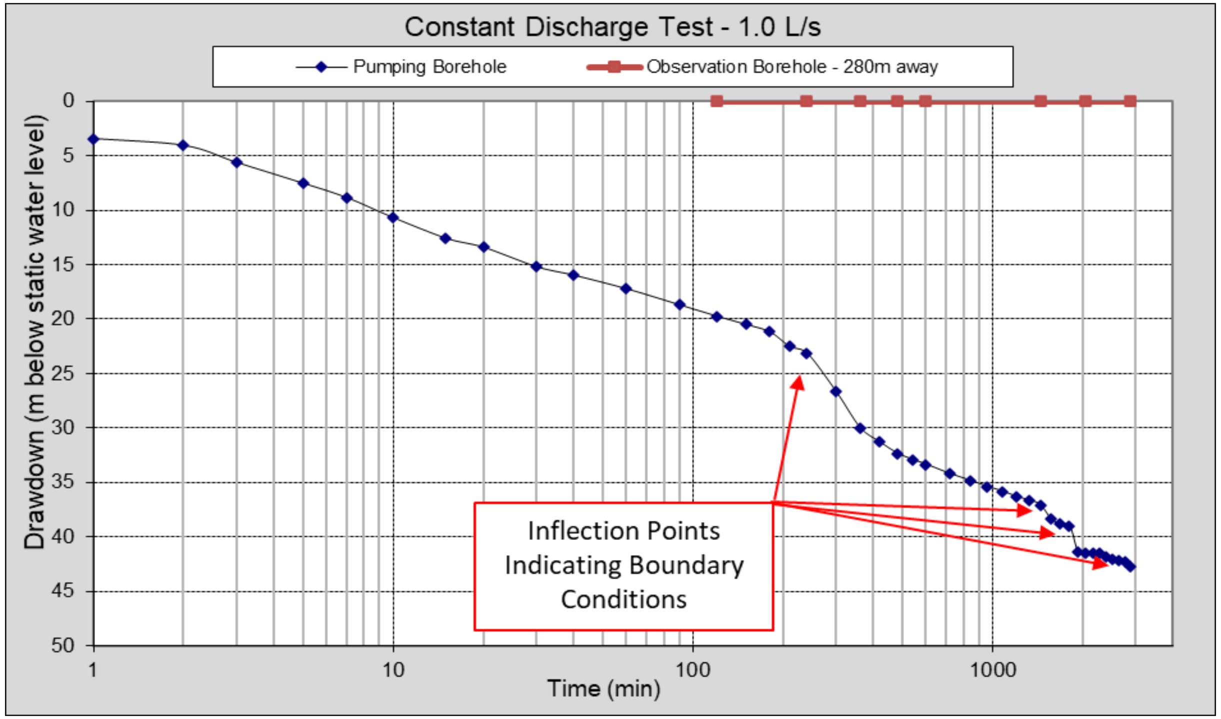
Amdt 1

Three part SANS 10299 yield test

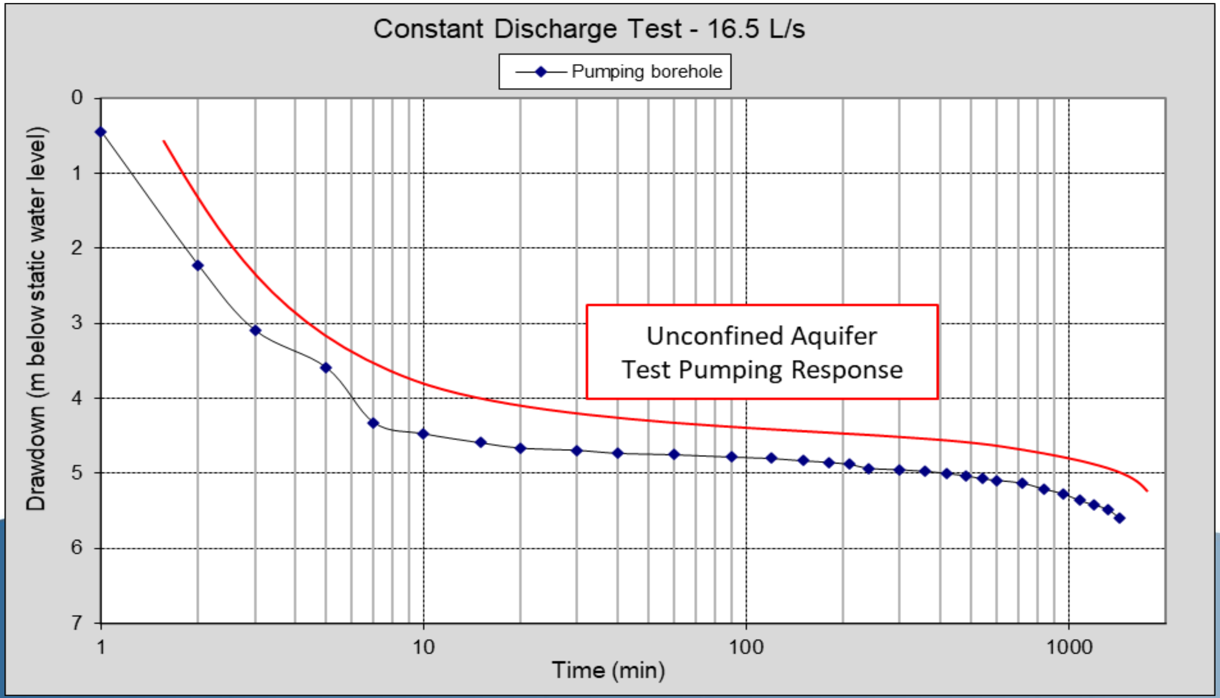




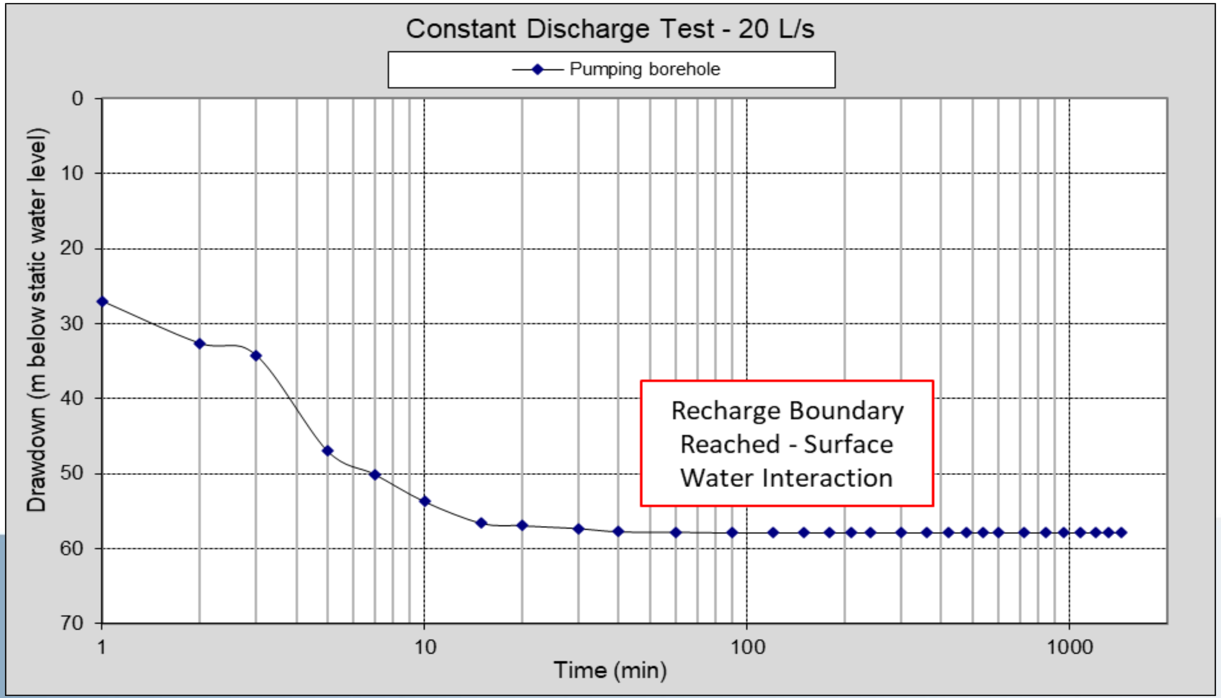
Constant Discharge Test - 5.2 L/s
Pumping Borehole
Observation borehole - 570m away
Inflection Points Indicating Boundary Conditions
Drawdown (m below static water level)
Time (min)



Constant Discharge Test - 1.0 L/s
Pumping Borehole
Observation Borehole - 280m away
Inflection Points Indicating Boundary Conditions
Drawdown (m below static water level)
Time (min)



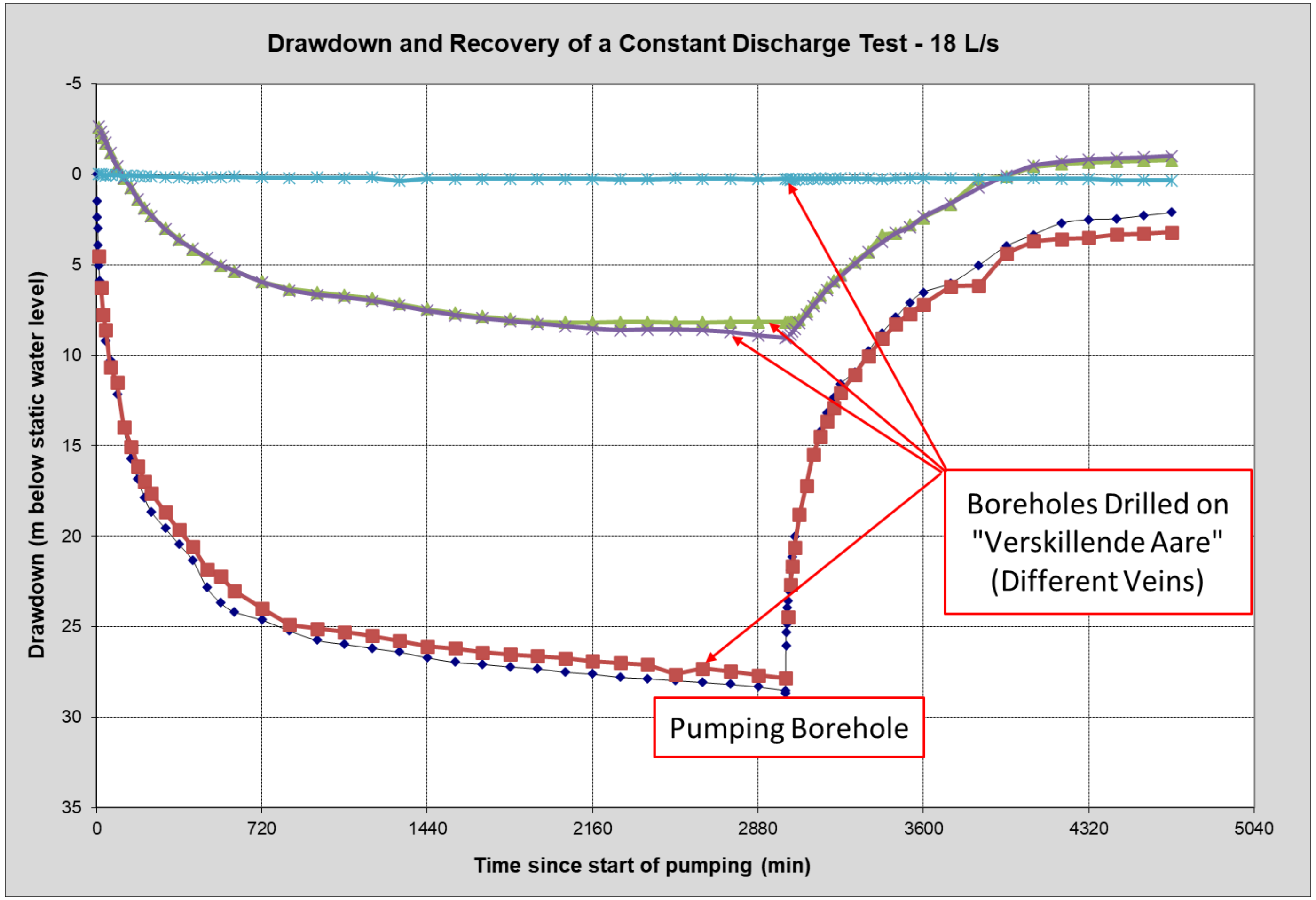
Constant Discharge Test - 16.5 L/s
Pumping borehole
Unconfined Aquifer Test Pumping Response
Drawdown (m below static water level)
Time (min)



Constant Discharge Test - 20 L/s
Pumping borehole
Recharge Boundary Reached - Surface Water Interaction
Drawdown (m below static water level)
Time (min)

Groundwater Flow Equations

- Theis (1935) - Confined
- Cooper-Jacob (1946)
- Neuman (1975) – Unconfined
- Barker (1988) – Fractured Rock
- Van Tonder (2001) – FC Method

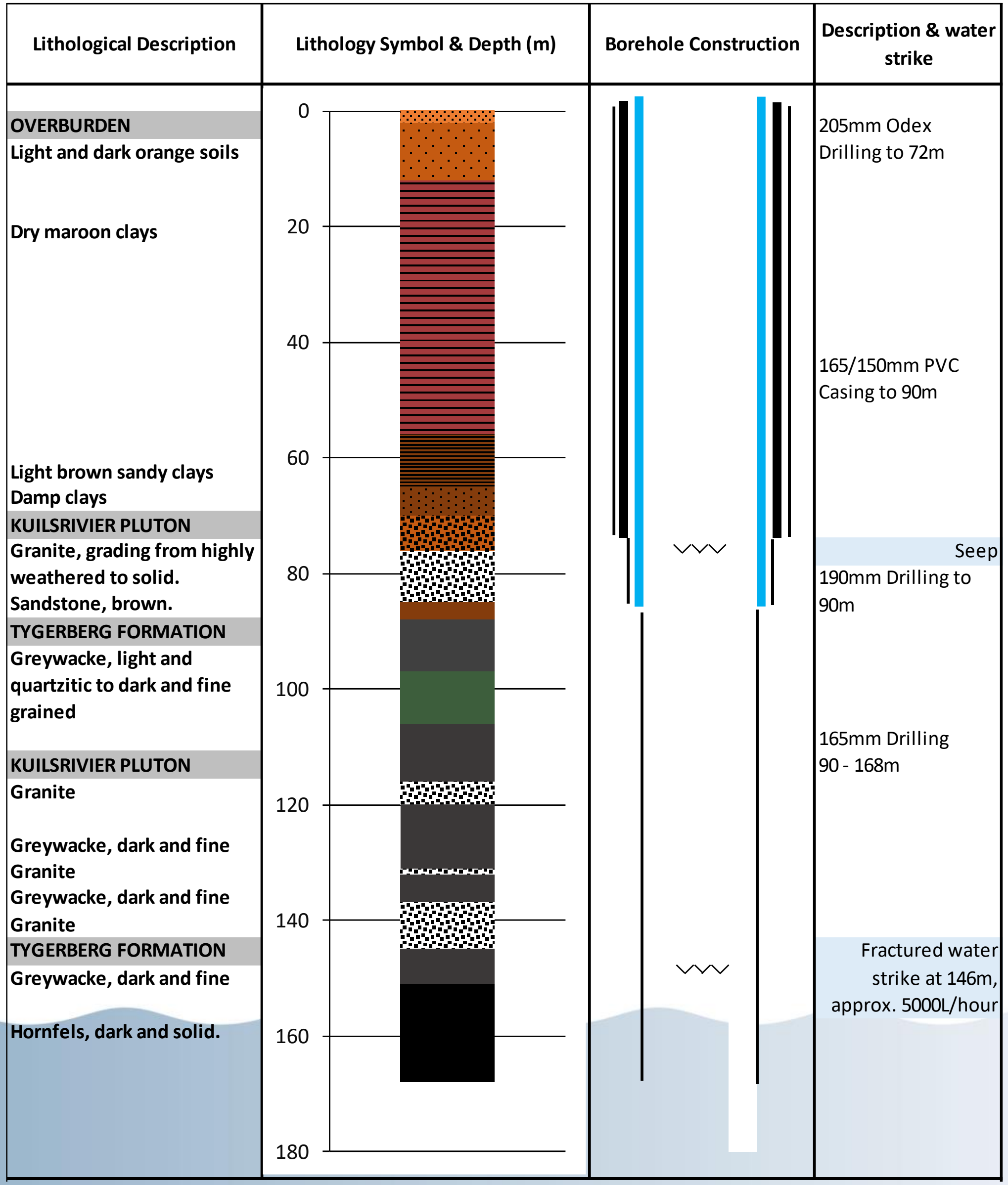


Beneficial information obtained from SANS 10299 testing

Borehole Details				
Borehole Name	Latitude (DD)	Longitude (DD)	Borehole Depth (m)	Inner Diameter at pump depth (mm)
Example_BH01	-33.964323°	18.839742°	166	165

Abstraction Details				
Borehole Name	Abstraction rate (L/s)	Abstraction Duration (hours)	Recovery Duration (hours)	Possible Volume Abstracted (L/d)
Example_BH01	4.5	16	8	259 200

Pump Installation Details				
Borehole Name	Pump Installation Depth (mbgl)	Critical Water Level (mbgl)	Dynamic Water Level (mbgl)*	Rest Water Level (mbgl)
Example_BH01	100	85	70 - 75	2.5



Beneficial information obtained from Sans 10299 testing

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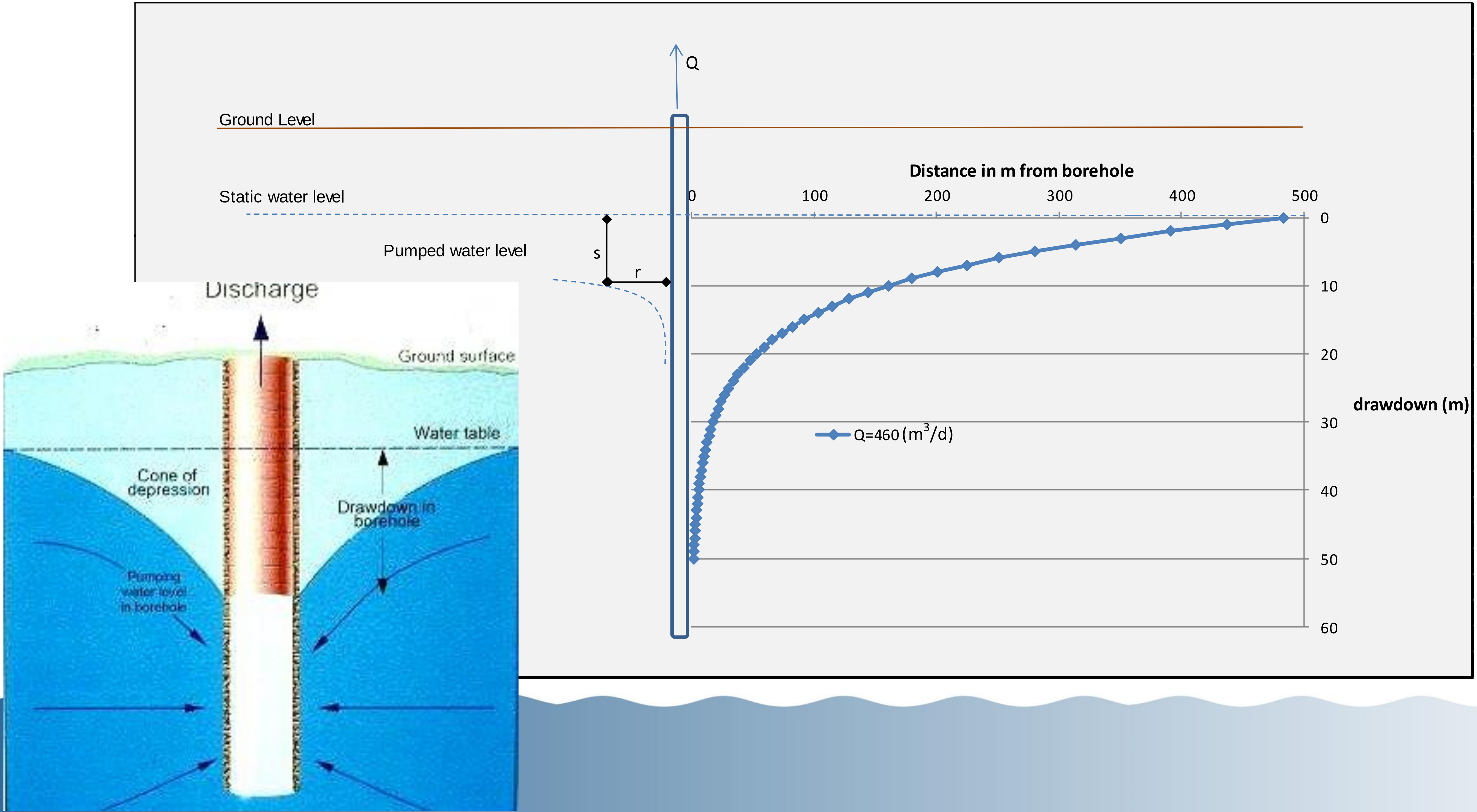
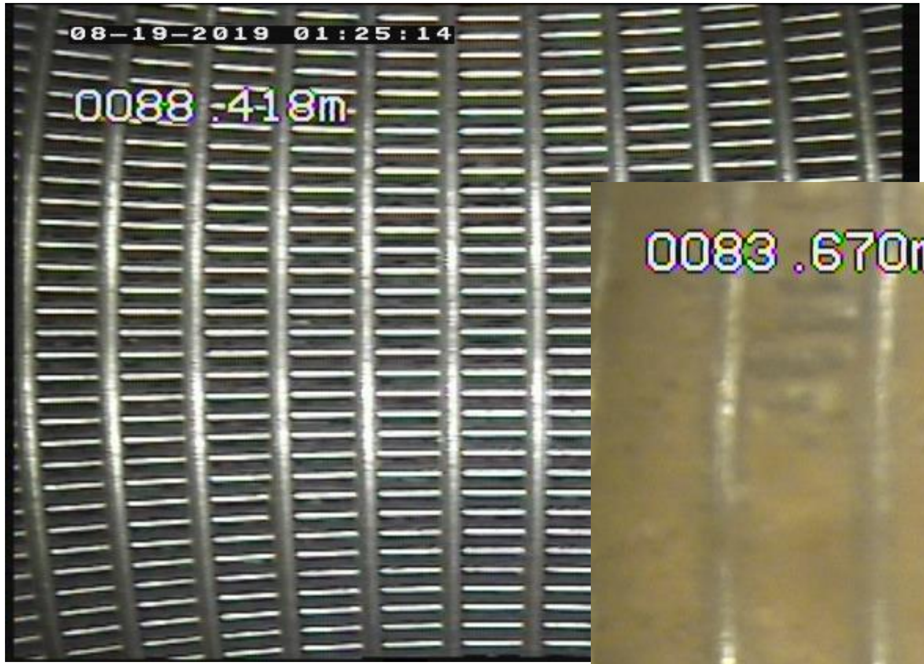
Impact on surrounding boreholes



Camera logging

- Inspect drilling standards
- Inspect old boreholes
- Determine the cause of obstructions or collapse
- Determine fracture depths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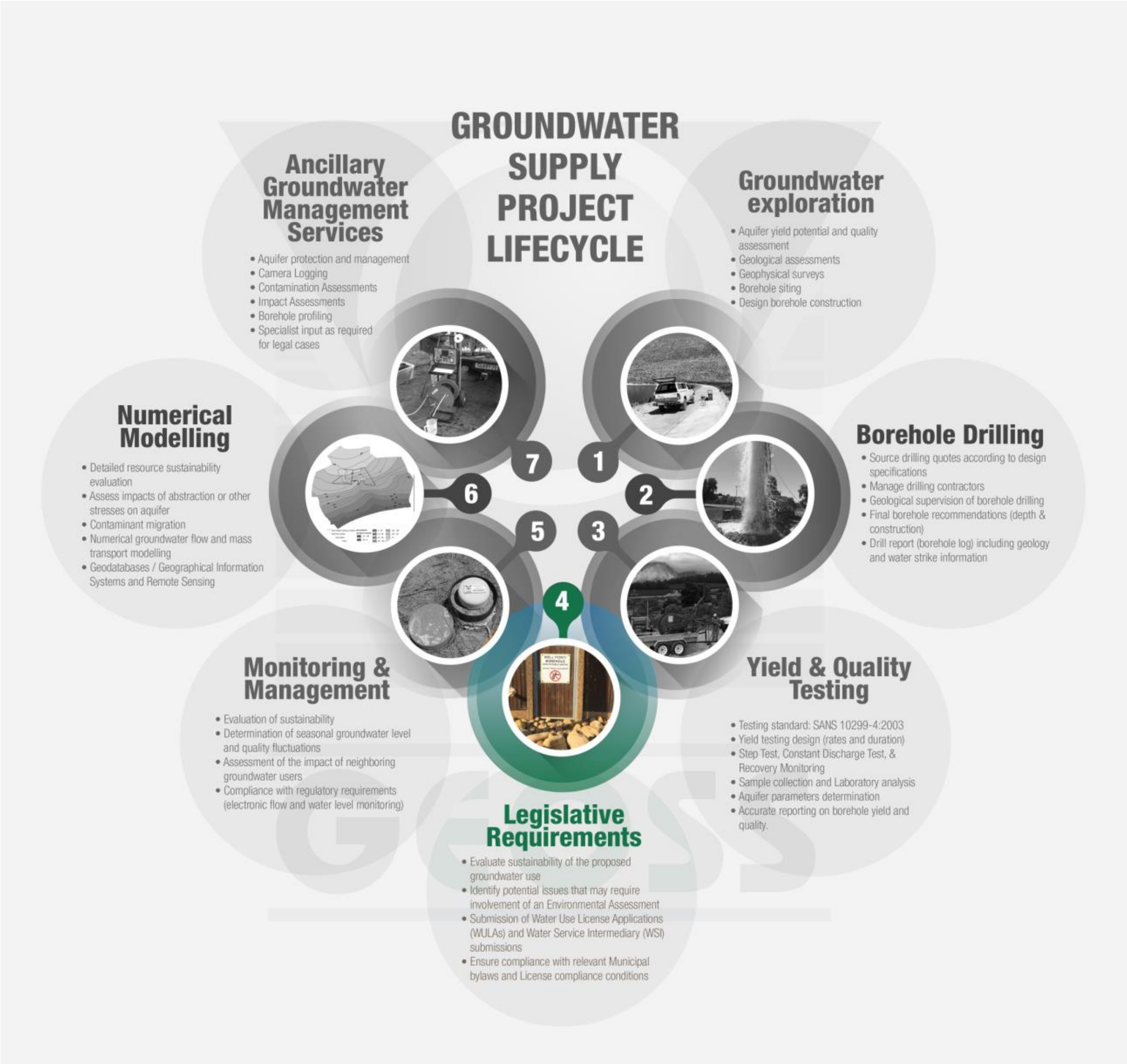
Legislative Requirements

- What does the legislation require when abstracting groundwater?



Optimal development and sustainable management of groundwater resources

The National Water Act

(Act no 36 of 1998)

- The act aims to ensure that the nation's water resources are **protected, used, developed, conserved, managed and controlled** in accordance with certain factors
- Through the Department of Water and Sanitation (DWS)
- Chapter 4 of the NWA deals with the water use authorisation

REPUBLIC OF SOUTH AFRICA

GOVERNMENT GAZETTE

STAATSKOERANT

VAN DIE REPUBLIEK VAN SUID-AFRIKA

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VOL. 398 — CAPE TOWN, 26 AUGUST 1998 / KAAPSTAD, 26 AUGUSTUS 1998 — No. 19182

OFFICE OF THE PRESIDENT

N(). *1091.* 26 August 1998

It is hereby notified (hat the President has assented to the following Act which is hereby published for general information:—

No. 36 of 1998: National Water Act, 1998.

KANTOOR VAN DIE PRESIDENT

No. 1091. 26 Augustus 1998

Hierby word bekend gemaak dat die President sy goedkeuring geheg het aan die onderstaande Wet wat hierby ter algemene inligting gepubliseer word:—

No. 36 van 199X: Nasionale Waterwet. 199X,

What is a water use according to NWA?

21. For the purposes of this Act, water use includes -

(a) taking water from a water resource;
(b) storing water;
(c) impeding or diverting the flow of water in a watercourse;
(d) engaging in a stream flow reduction activity contemplated in section 36;
(e) engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1);
(f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
(g) disposing of waste in a manner which may detrimentally impact on a water resource;
(h) disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;
(i) altering the bed, banks, course or characteristics of a watercourse;
(j) removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people; and
(k) using water for recreational purposes.

How can I get authorisation to use water

- Section 22(1) if NWA allows a person to use water in terms of the following:

Schedule 1

- Reasonable domestic use in that persons house
- Small gardening
- Not for commercial purposes
- Watering of animals within grazing capacity of land (excluding feedlots)
- No permission or registration required

Existing Lawful Water (ELU) Use

- Water use that was lawfully exercised in the two years prior to the commencement of the NWA on 1 Oct 1998
- ELU must be registered with Department of Water and Sanitation (DWS)

General Authorisation (GA)

- Section 39 of the NWA allows small scale abstraction within the conditions of GA
- Can include commercial use
- Conditions are based on property size and Quaternary Catchment
- Current GA volumes are 0, 45, 75, 150, 275, 400 $m^3/ha/a$
- Maximum limit is 40 000 m^3/a

Water Use Licence

- When water use is above the GA limit
- Water use licence Application (WULA) submitted to DWS
- Water use must be within the licence conditions
- Reviewed every 5 years
- Issued for 20 years (max 40 years)

The eWULA process

Application procedure (300 days)

Pre-application enquiry

Link to client with basic water use information, i.e., Applicant details, water use(s) being applied for, equity information, signed affidavit

Phase 1

Submission of water use information online i.e., co-ordinates, volume per abstraction, water use, property details and administrative documents (ID, Title deeds, business registration certificate, etc.)

Phase 2

Site inspection by DWS

Phase 3

Submission of technical reports and completion of DW forms, i.,e., Geohydrological assessment report, Section 27 Motivational report and other documents requested by DWS

DWS Processing procedure

Specialist

The application is reviewed by and receives inputs from relevant DWS specialists

Presentation at WUAAAC

The application is scheduled for and presented at the WUAAAC (Water User Authorization Assessment Advisory Committee) sitting

Regional Finalisation

The application is finalised at the regional DWS office. Hereafter, it is sent to Head Office (Pretoria) for a final decision

Head Ofice (Pretoria)

The application is sent to Head office for final approval

WARMS

If approved, the water use(s) are captured into the WARMS (Water Authorisation and Registration Management System) database.

Monitoring and Management

- How and why to monitor and manage groundwater?

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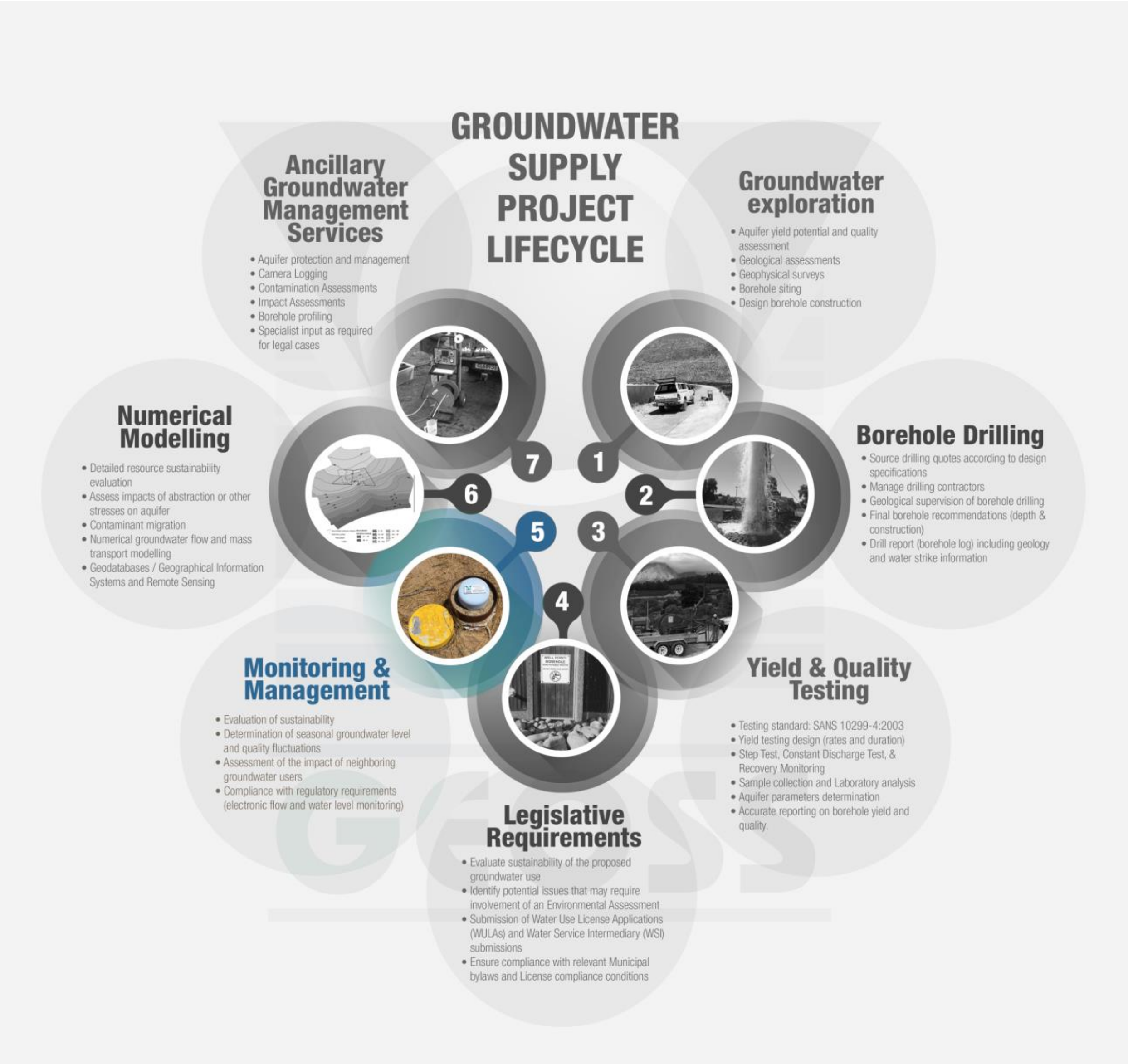
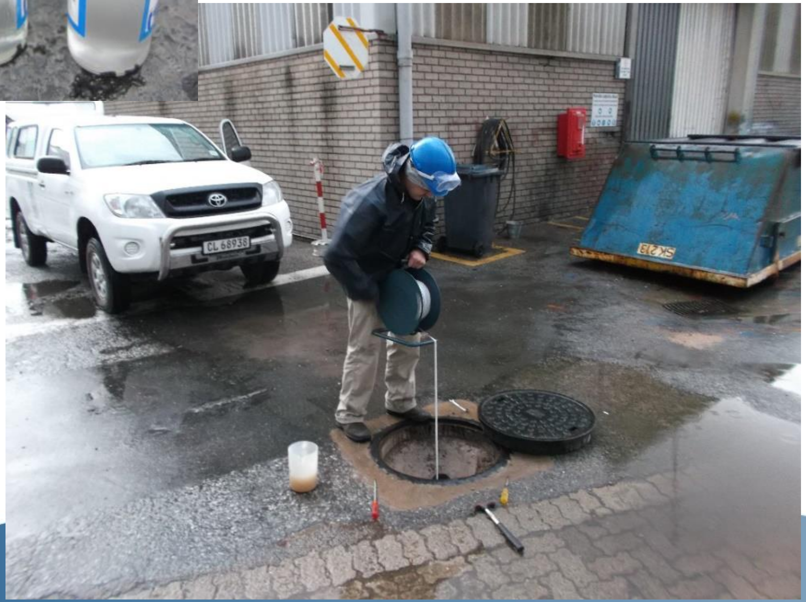
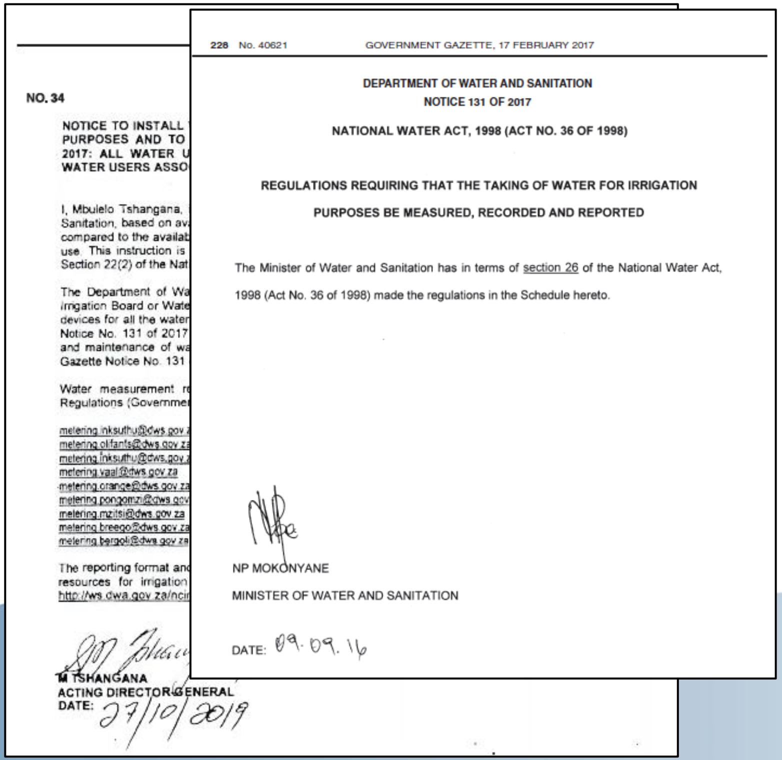


Groundwater Monitoring

Why do we monitor groundwater?

- Contamination
- Compliance (regulations)
- Environmental
- Abstraction optimization
- Assessment of aquifer health (sustainability of abstraction)





NO. 34

NOTICE TO INSTALL
PURPOSES AND TO
2017: ALL WATER U
WATER USERS ASSO

I, Mbulelo Tshangana,
Sanitation, based on av
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use. This instruction is
Section 22(2) of the Nat

The Department of Wa
Irrigation Board or Wate
devices for all the water
Notice No. 131 of 2017
and maintenance of wa
Gazette Notice No. 131

Water measurement r
Regulations (Governme

metering.inksuthu@dws.gov.z
metering.olifants@dws.gov.za
metering.inksuthu@dws.gov.z
metering.vaal@dws.gov.za
metering.orange@dws.gov.za
metering.pongomzi@dws.gov
metering.mzitsi@dws.gov.za
metering.breego@dws.gov.za
metering.bergoli@dws.gov.za

The reporting format an
resources for irrigation
http://ws.dwa.gov.za/ncir

M TSHANGANA
ACTING DIRECTOR-GENERAL
DATE: 27/10/2019

228 No. 40621 GOVERNMENT GAZETTE, 17 FEBRUARY 2017

DEPARTMENT OF WATER AND SANITATION
NOTICE 131 OF 2017

NATIONAL WATER ACT, 1998 (ACT NO. 36 OF 1998)

REGULATIONS REQUIRING THAT THE TAKING OF WATER FOR IRRIGATION
PURPOSES BE MEASURED, RECORDED AND REPORTED

The Minister of Water and Sanitation has in terms of section 26 of the National Water Act, 1998 (Act No. 36 of 1998) made the regulations in the Schedule hereto.

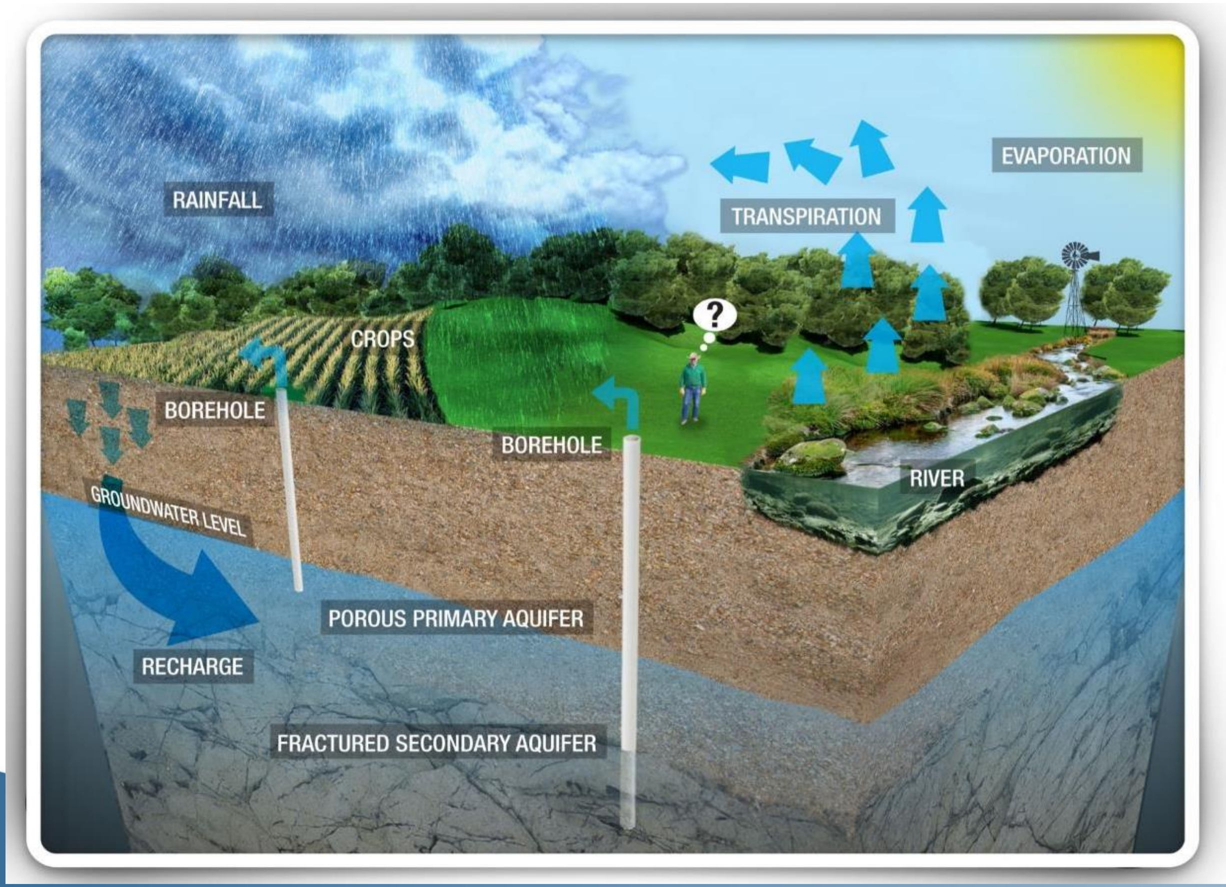
NP MOKONYANE
MINISTER OF WATER AND SANITATION

DATE: 09.09.16

Groundwater Monitoring

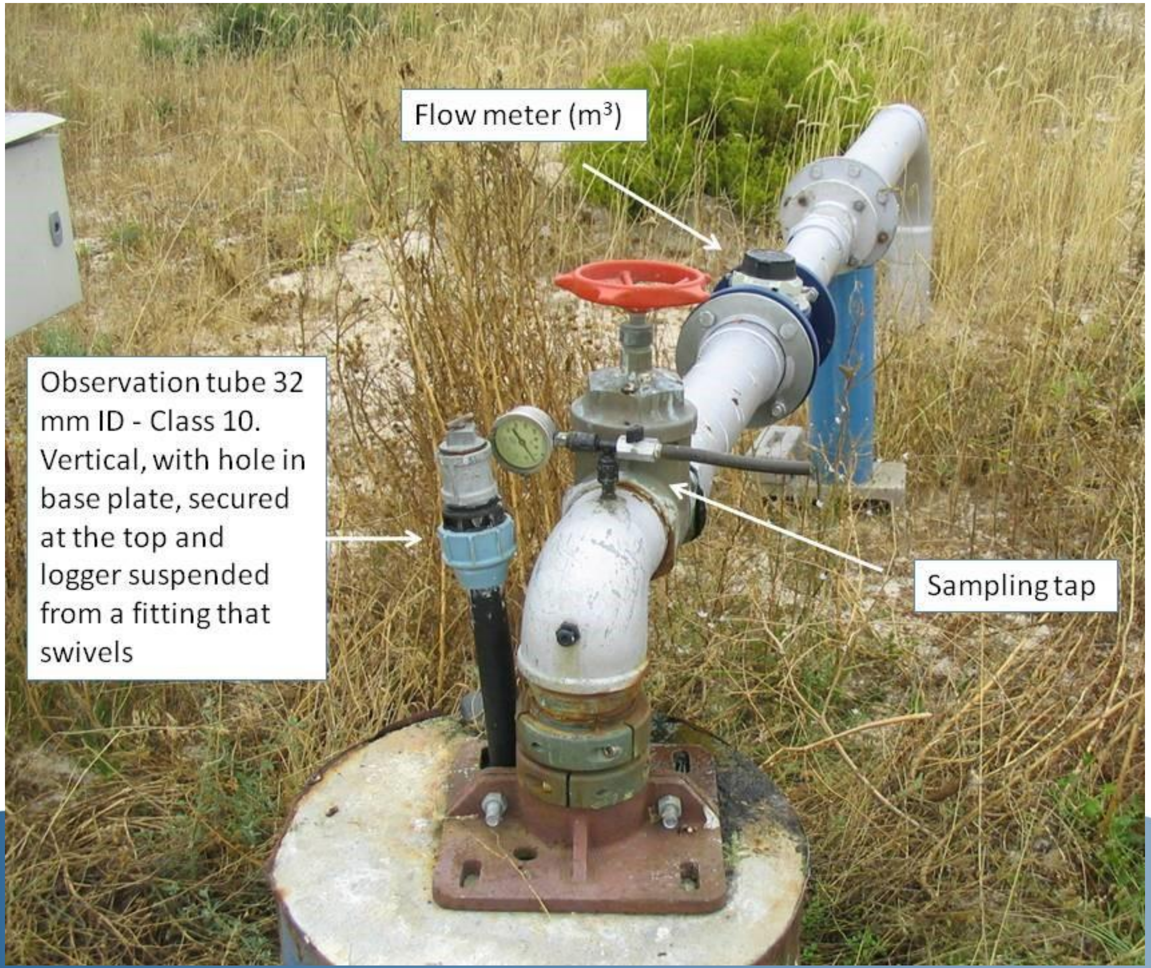
When we talk about groundwater monitoring, what do we mean?

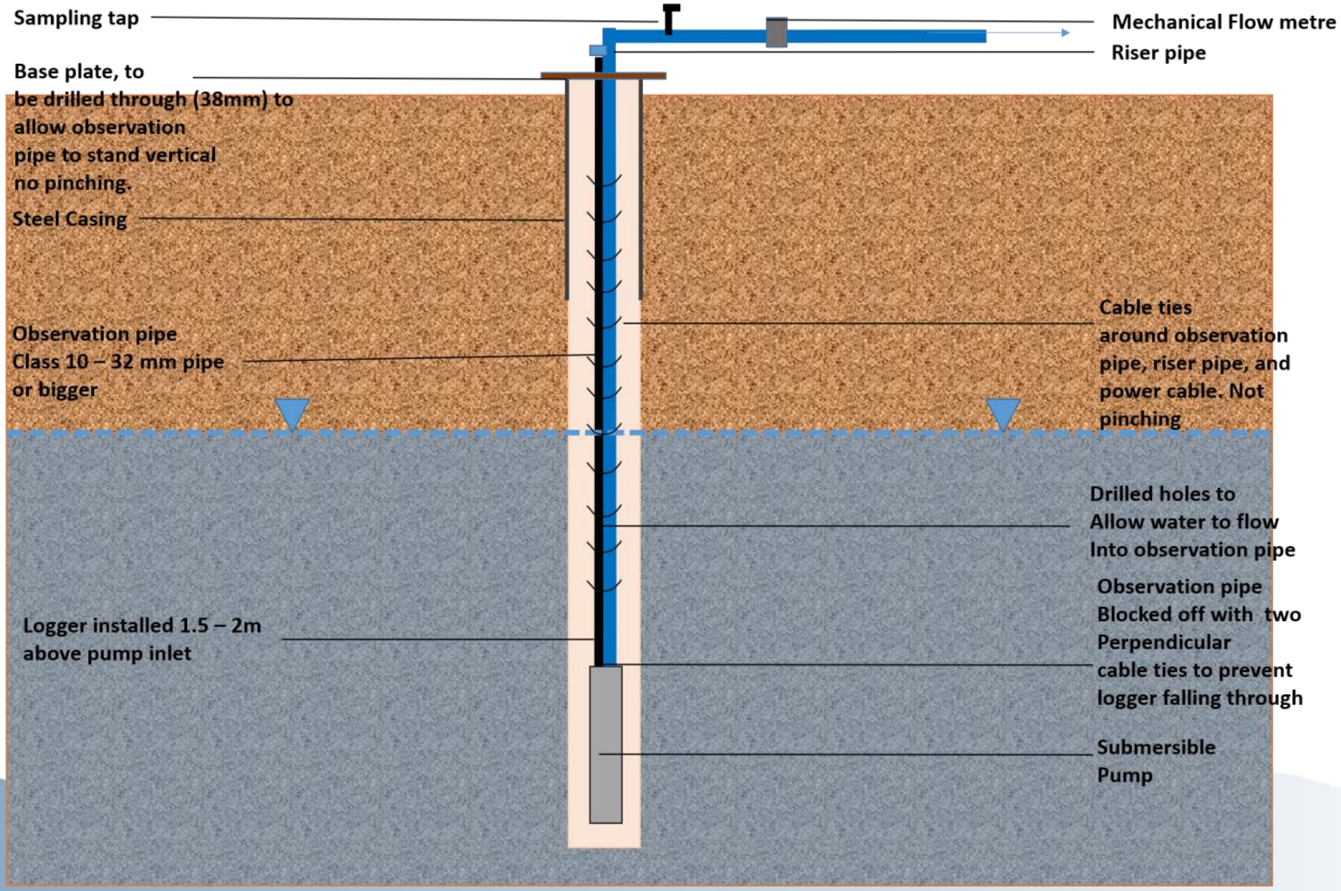
- Quantity (Aquifer water levels and abstraction volumes if relevant)
- Quality (Groundwater chemistry and contamination)



Monitoring and Management

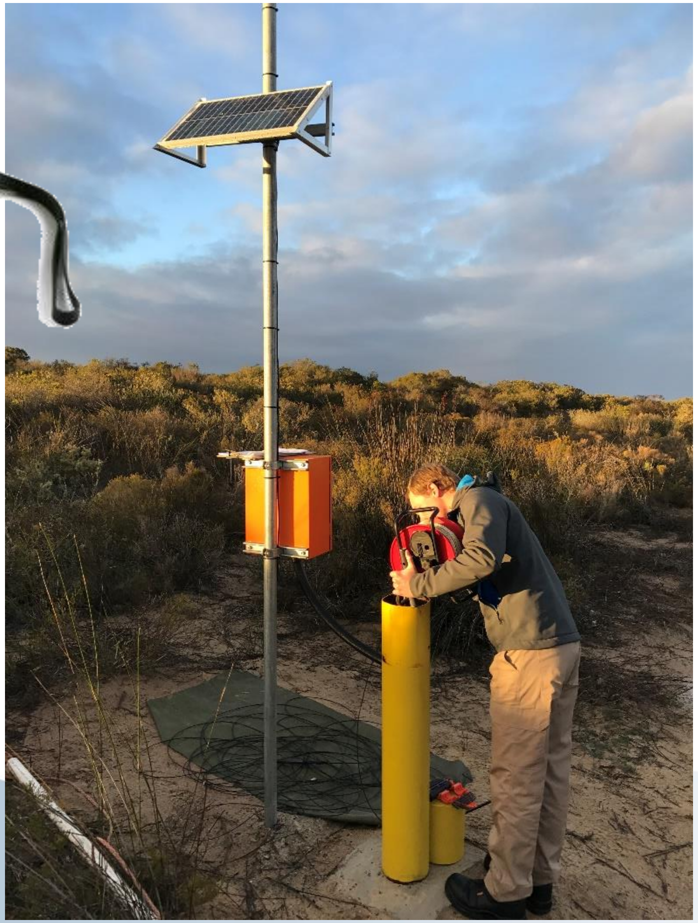
- Typical monitoring infrastructure (for abstraction borehole)





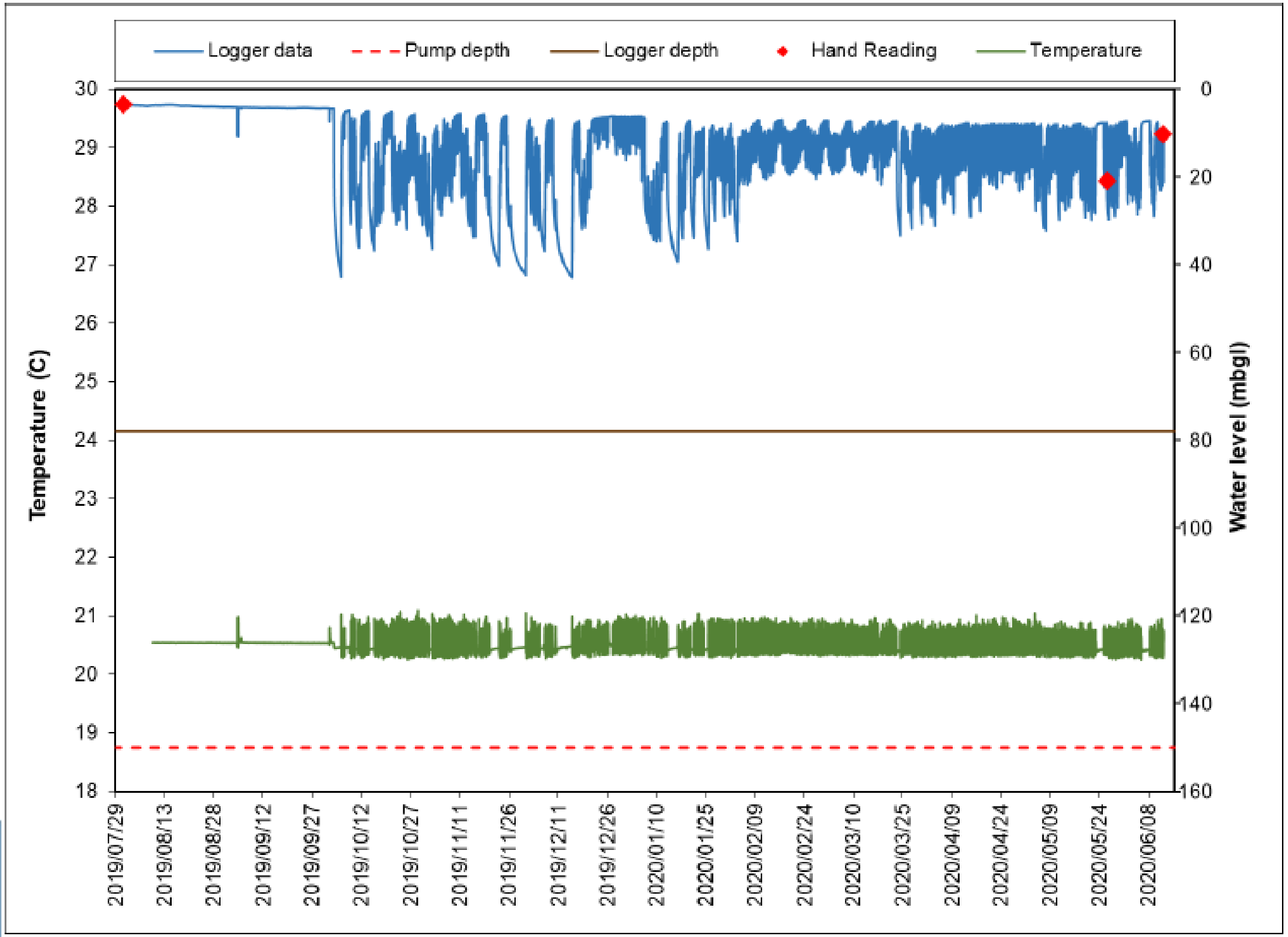
Monitoring and Management

- Typical monitoring infrastructure
- (for water level monitoring, and flow in the case of a pumped borehole)



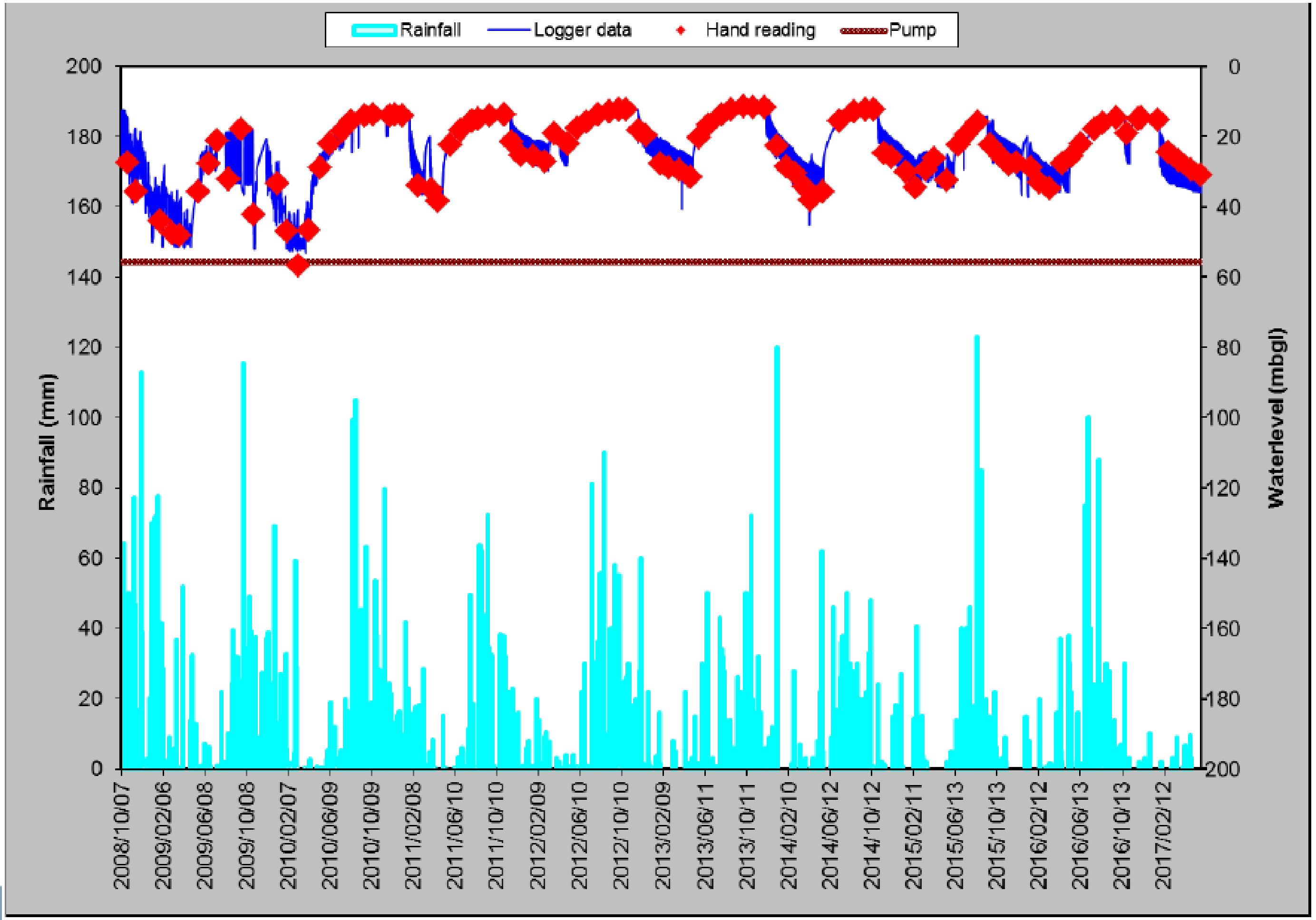
Monitoring and Management

- Real time, monthly, quarterly



Monitoring and Management

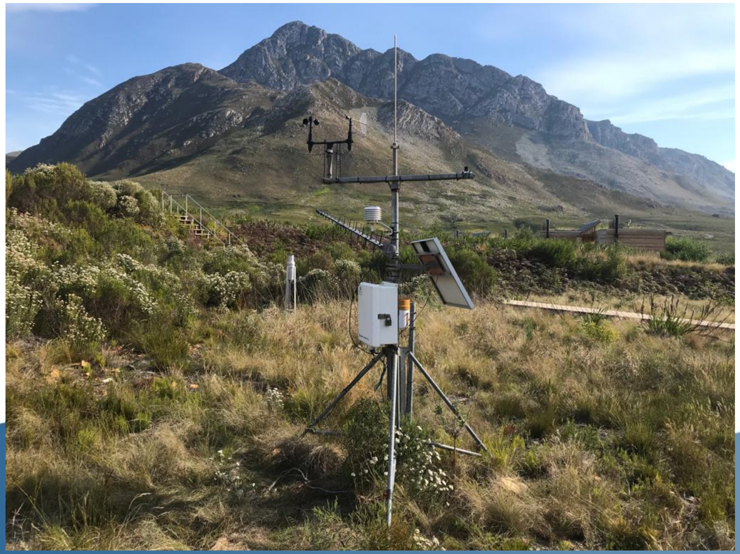
- Monitoring enables optimization of abstraction
- Assessment of sustainability
- Characterization of the aquifer
- Drought impacts



Monitoring and Management

Why should I monitor?

- Sustainable use
- Optimal use
- Infrastructure management and protection
- Informed management



GROUNDWATER SUPPLY PROJECT LIFECYCLE

1. Groundwater exploration

- Aquifer yield potential and quality assessment
- Geological assessments
- Geophysical surveys
- Borehole siting
- Design borehole construction

2. Borehole Drilling

- Source drilling quotes according to design specifications
- Manage drilling contractors
- Geological supervision of borehole drilling
- Final borehole recommendations (depth & construction)
- Drill report (borehole log) including geology and water strike information

3. Yield & Quality Testing

- Testing standard: SANS 10299-4:2003
- Yield testing design (rates and duration)
- Step Test, Constant Discharge Test, & Recovery Monitoring
- Sample collection and Laboratory analysis
- Aquifer parameters determination
- Accurate reporting on borehole yield and quality.

4. Legislative Requirements

- Evaluate sustainability of the proposed groundwater use
- Identify potential issues that may require involvement of an Environmental Assessment
- Submission of Water Use License Applications (WULAs) and Water Service Intermediary (WSI) submissions
- Ensure compliance with relevant Municipal bylaws and License compliance conditions

5. Monitoring & Management

- Evaluation of sustainability
- Determination of seasonal groundwater level and quality fluctuations
- Assessment of the impact of neighboring groundwater users
- Compliance with regulatory requirements (electronic flow and water level monitoring)

6. Numerical Modelling

- Detailed resource sustainability evaluation
- Assess impacts of abstraction or other stresses on aquifer
- Contaminant migration
- Numerical groundwater flow and mass transport modelling
- Geodatabases / Geographical Information Systems and Remote Sensing

7. Ancillary Groundwater Management Services

- Aquifer protection and management
- Camera Logging
- Contamination Assessments
- Impact Assessments
- Borehole profiling
- Specialist input as required for legal cases

Optimal development and sustainable management of groundwater resources?

- Scientific borehole siting
- SANS methods for yield testing
- SANS for water quality assessments
- Analytical and numerical calculations and models can be used to characterize flow and chemical behaviour
- Authorisation
- Monitoring
- Management

Optimal development and sustainable management of groundwater resources

Julian Conrad
Hydrogeologist

6 June 2022

Thank you

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd