Sustainable Yield Webinar

27 June 2023

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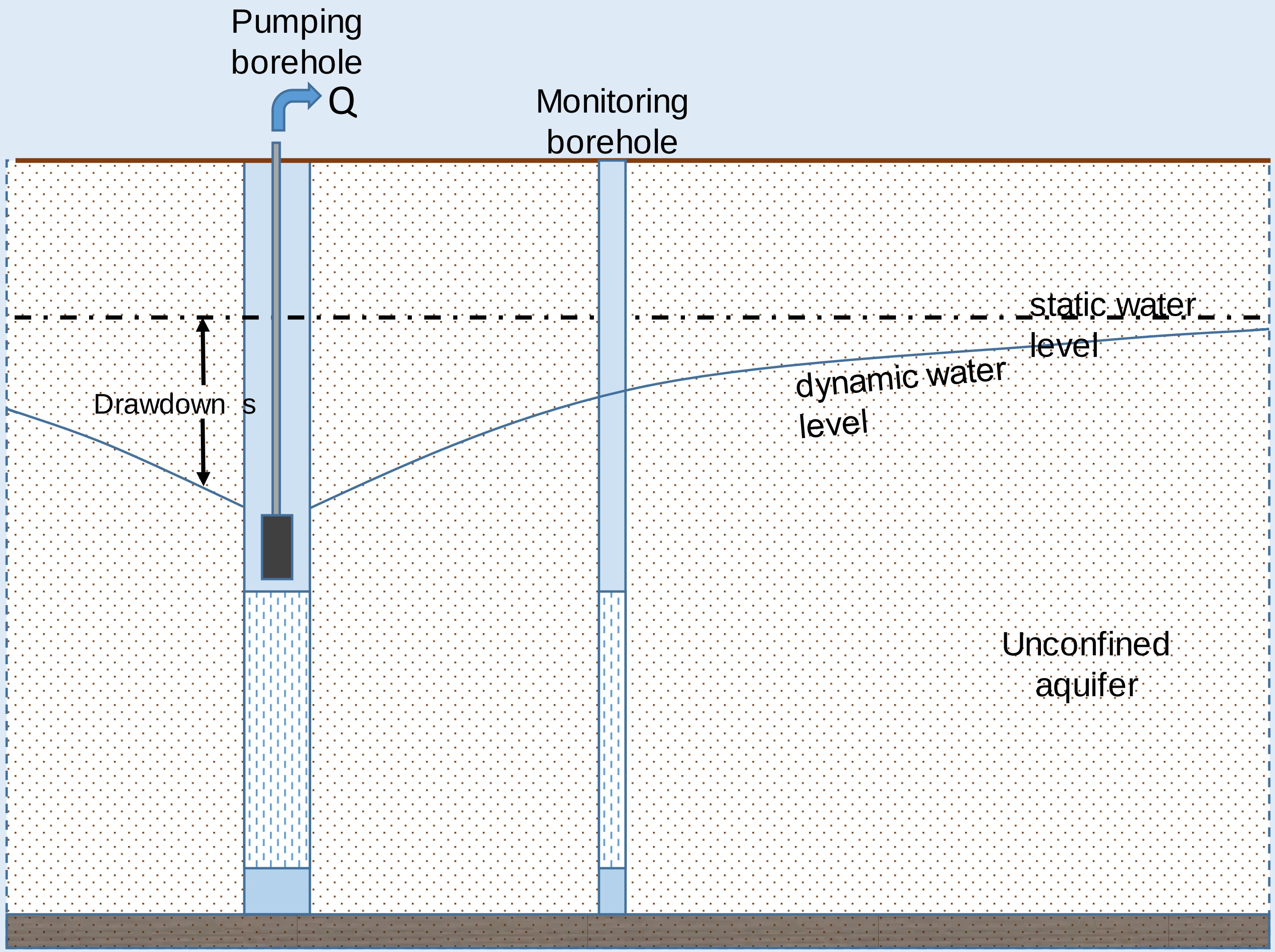
By:

- **Jay Matta, UNICEF HQ**
- **Richard Boak, Consultant**



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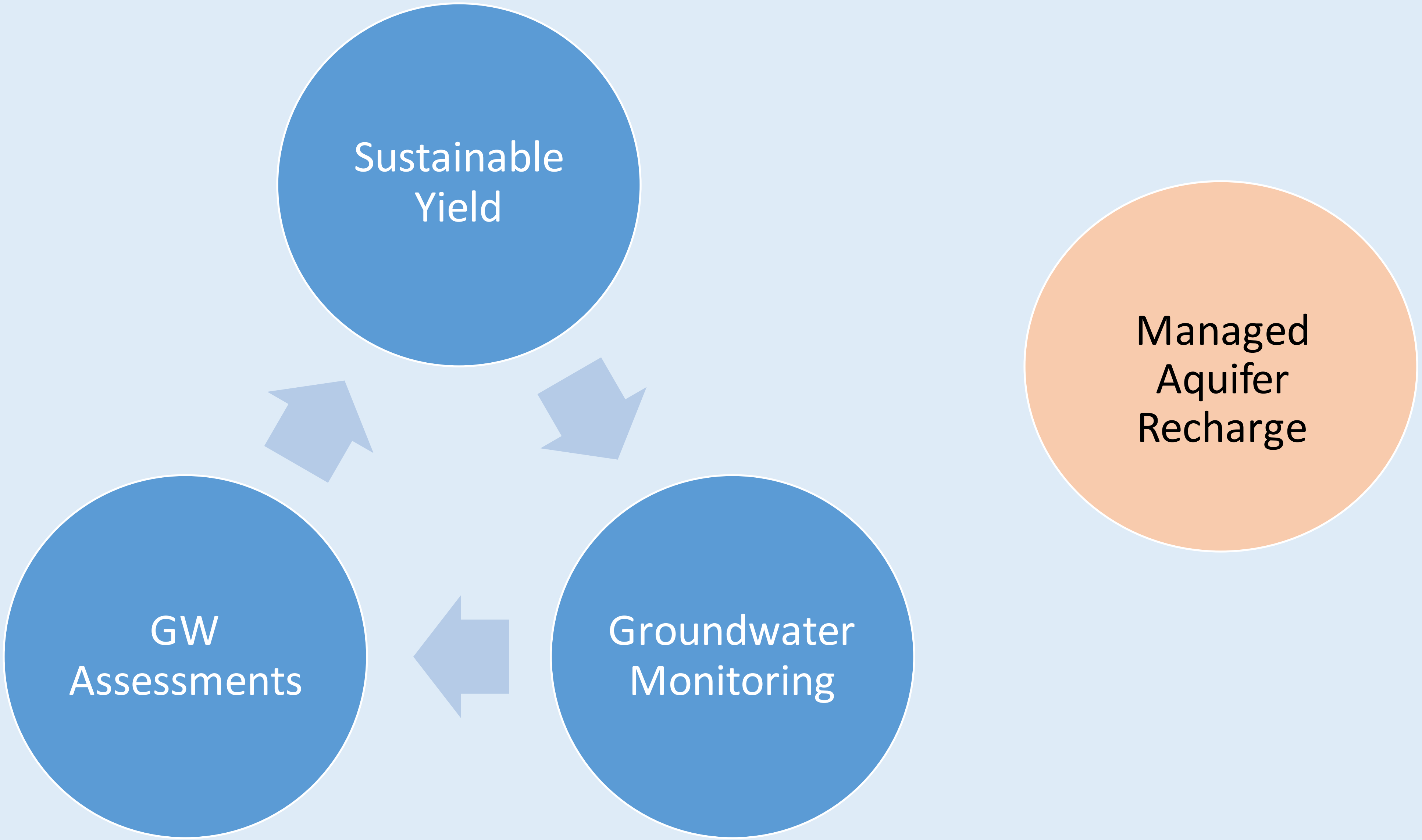
SPEAKERS

Jay Matta is an expert Hydrogeologist supporting UNICEF globally, regionally and at country level in water scarcity, climate resilient water services and hydrogeological support. His current focus is groundwater monitoring and system strengthening.

Email: vmatta@unicef.org

Richard Boak is an independent Hydrogeologist with over 40 years' international experience, with a strong focus on Africa. A specialist in water resources and groundwater development, he is the author of the ICRC guidelines for test pumping in water wells.

Groundwater Webinar Series



The puzzle of borehole yield

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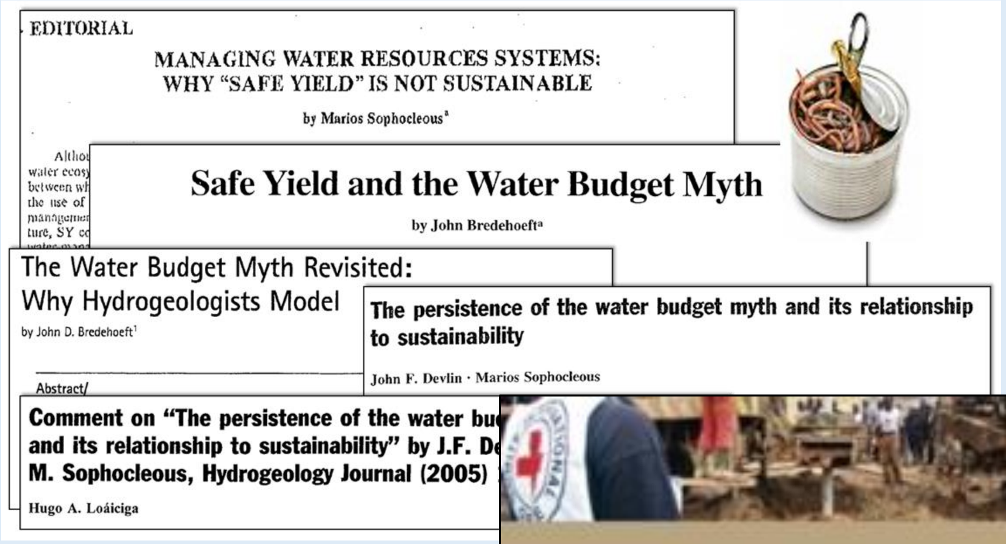
- Groundwater is often chosen as the most suitable source of drinking water
- Imagine you have just drilled a new borehole, or are considering rehabilitating a disused borehole
- You need to know how much water can this borehole yield, and what will be the dynamic water level (DWL) when pumping at that rate?
- The contractor gives you a test-pumping report, which declares that the ‘safe yield’ or ‘sustainable yield’ of the borehole is, for example, 4.6 L/s, for a DWL of 30 m
- But how do you know if that pumping rate and DWL are reliable in the long term?
- Will the yield be influenced by other boreholes or by the season?
- And what is ‘sustainable yield’ anyway?

Concept of sustainable yield

What is your understanding of sustainable yield:

- Abstraction ≦ long-term average recharge?
- Stable long-term dynamic water level?
- No deterioration in water quality?
- A certain percentage of maximum yield?
- No adverse environmental impacts?
- No adverse impacts on nearby water sources?

What about ‘groundwater mining’?



One definition:

“The maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head or deterioration in water quality in the aquifer.”

(Department of Water & Sanitation, South Africa)

- Test pumping is the main tool to help us answer these questions
- You can find further information in this publication →

What happens during a pumping test?

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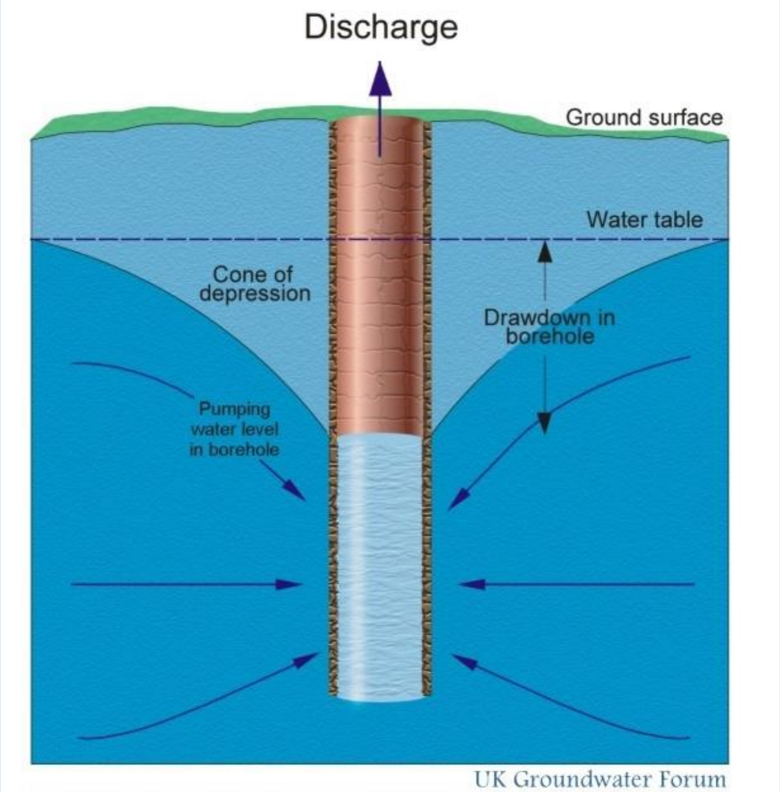

- The pump lowers the water level in the borehole (initially, the water just comes from storage in the borehole)
- Water flows into the borehole from the surrounding aquifer (driven by a head gradient)
- In turn, head is lowered in the aquifer and the effect spreads outwards to create a ‘cone of depression’
- As pumping continues, the cone continues to expand outwards and to deepen (unless and until it intercepts a source of water, or interference with a geological barrier or another pumping borehole)
- The rate and style of expansion of the cone of depression depend on the hydraulic properties of the aquifer (Transmissivity and Storativity)
- It follows that if we can observe the way the cone of depression expands, we can deduce things about the aquifer properties and the borehole characteristics
- However, we can normally only measure pumping rates and the water levels in the borehole

Collection of background information

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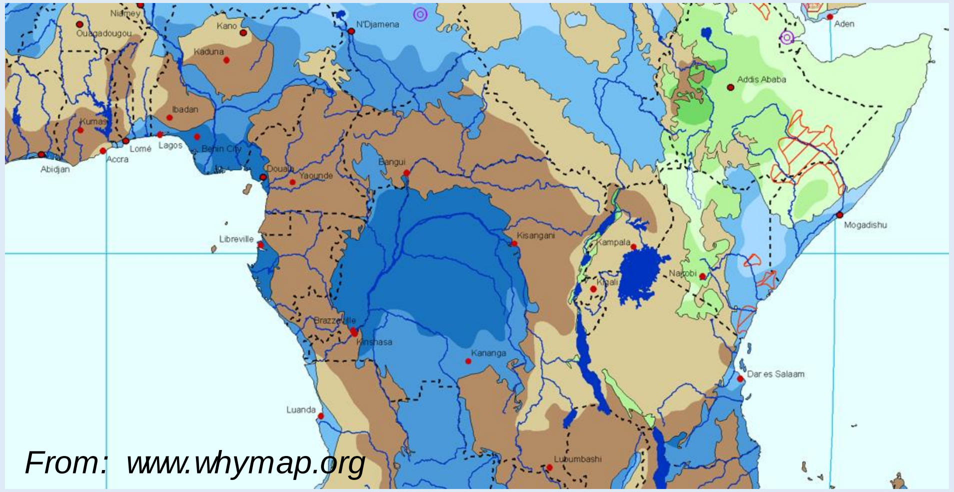
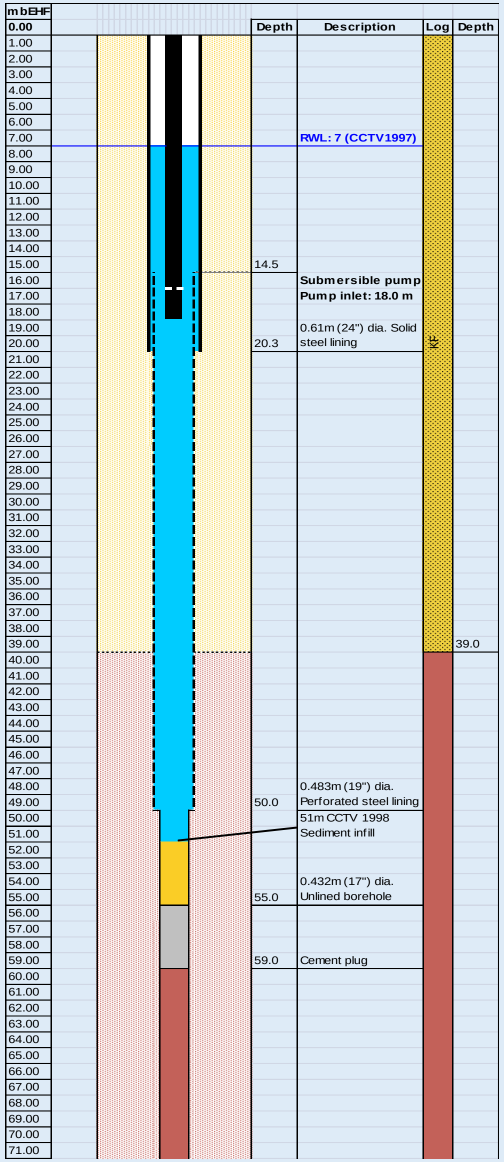
When planning a pumping test, gather background information about the borehole, the aquifer and the surrounding area, to improve your understanding of the groundwater system:

- Basic geology
- Aquifer configuration
- Borehole construction
- Installed equipment
- Historical water levels
- Historical yields
- Similar boreholes nearby
- Wet & dry season conditions
- Access for monitoring

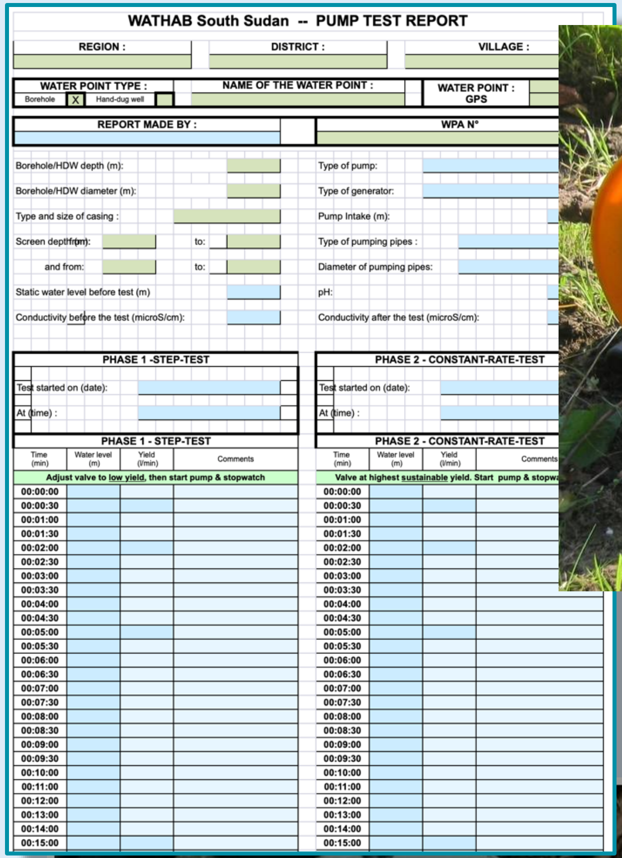
Local knowledge is very valuable



From: www.whymap.org



Preparation & equipment



WATHAB South Sudan -- PUMP TEST REPORT

REGION : | DISTRICT : | VILLAGE :

WATER POINT TYPE : Borehole X Hand-dug well | NAME OF THE WATER POINT : | WATER POINT : GPS

REPORT MADE BY : | WPA N°

Borehole/HDW depth (m): | Type of pump:
Borehole/HDW diameter (m): | Type of generator:
Type and size of casing : | Pump Intake (m):
Screen depth from: to: | Type of pumping pipes :
and from: to: | Diameter of pumping pipes:
Static water level before test (m) | pH:
Conductivity before the test (microS/cm): | Conductivity after the test (microS/cm):

PHASE 1 -STEP-TEST | PHASE 2 - CONSTANT-RATE-TEST
Test started on (date): | Test started on (date):
At (time) : | At (time) :

PHASE 1 - STEP-TEST				PHASE 2 - CONSTANT-RATE-TEST			
Time (min)	Water level (m)	Yield (l/min)	Comments	Time (min)	Water level (m)	Yield (l/min)	Comments
Adjust valve to low yield, then start pump & stopwatch				Valve at highest sustainable yield. Start pump & stopwa			
00:00:00				00:00:00			
00:00:30				00:00:30			
00:01:00				00:01:00			
00:01:30				00:01:30			
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00:14:00				00:14:00			
00:15:00				00:15:00			

Measuring techniques can be very simple!

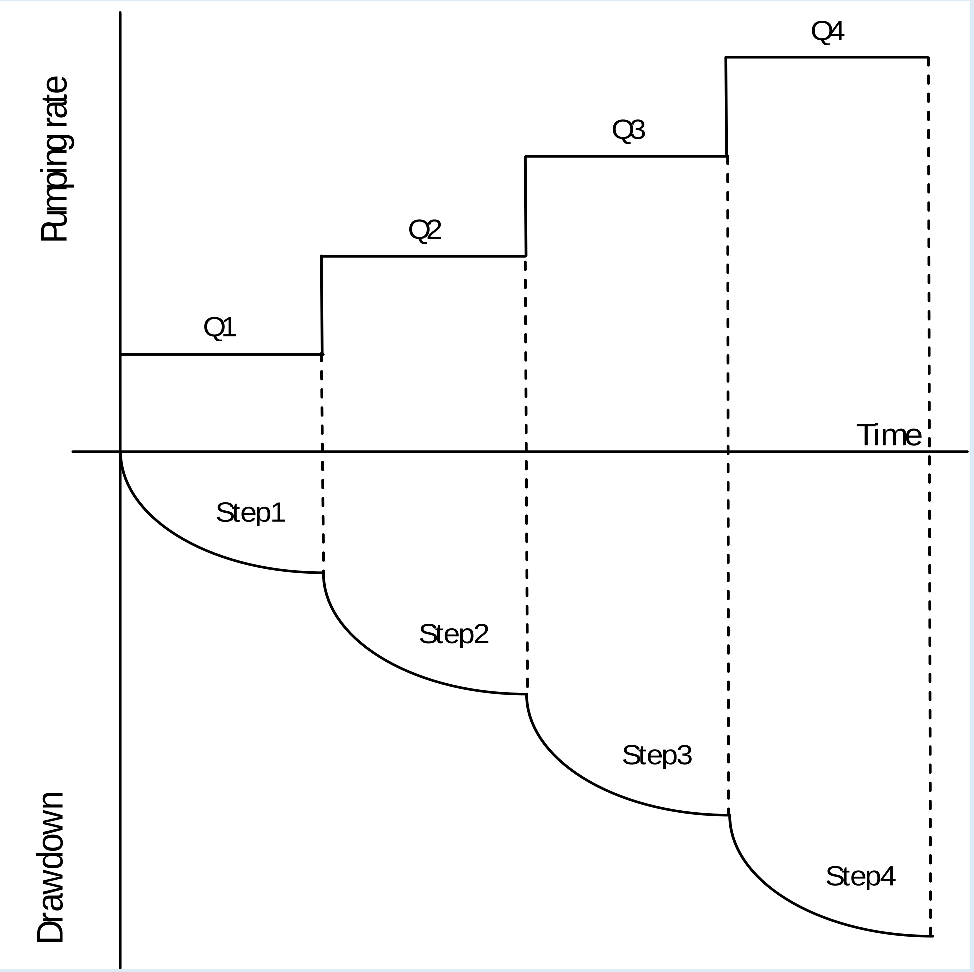
Need to measure the following parameters:

- Basic borehole dimensions (diameter & depth)
- Water levels in the borehole (including before the test)
- Pumping rate (must have a method of varying the rate)
- Basic water quality indicators
- Elapsed time

Test the pump and all equipment before the actual pumping test (the day before, ideally)

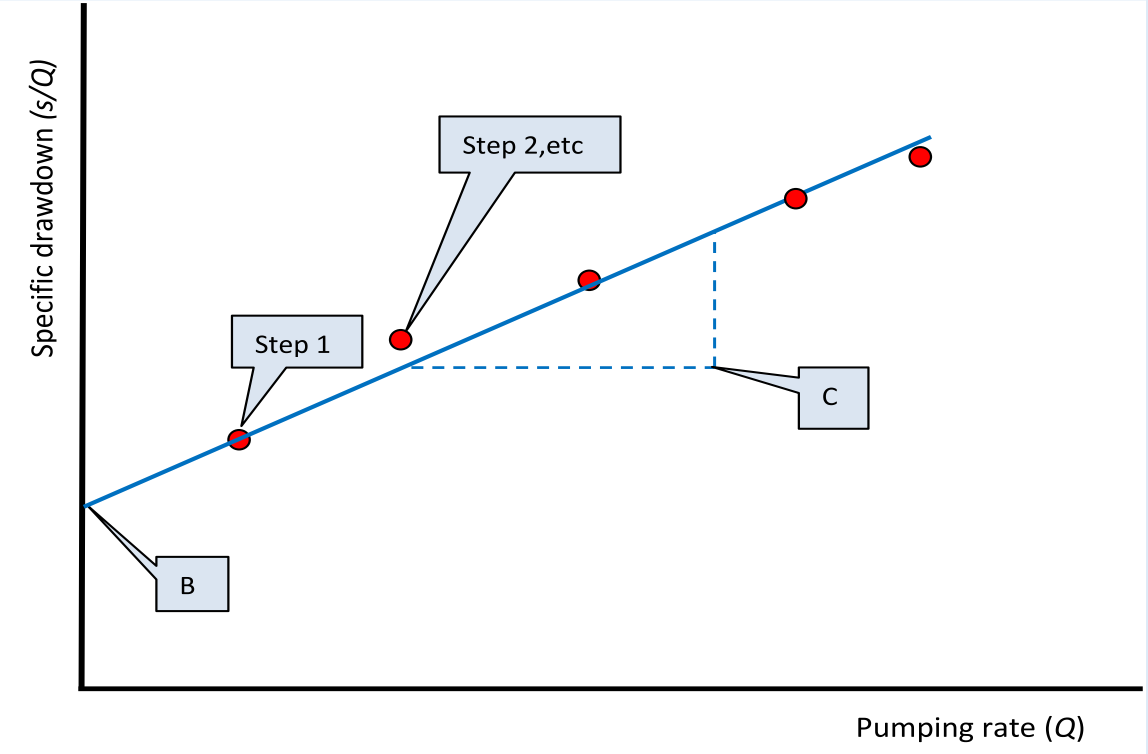
Step test

A typical pumping test consists of a step test, a constant-rate test and a recovery test. The step test is designed to establish the short-term relationship between borehole yield and drawdown, and to ‘challenge’ the borehole at different pumping rates; this is how it works:



- Jacob’s equation

$s_w = BQ + CQ^2$ $s_w/Q = B + CQ$



Constant-rate test

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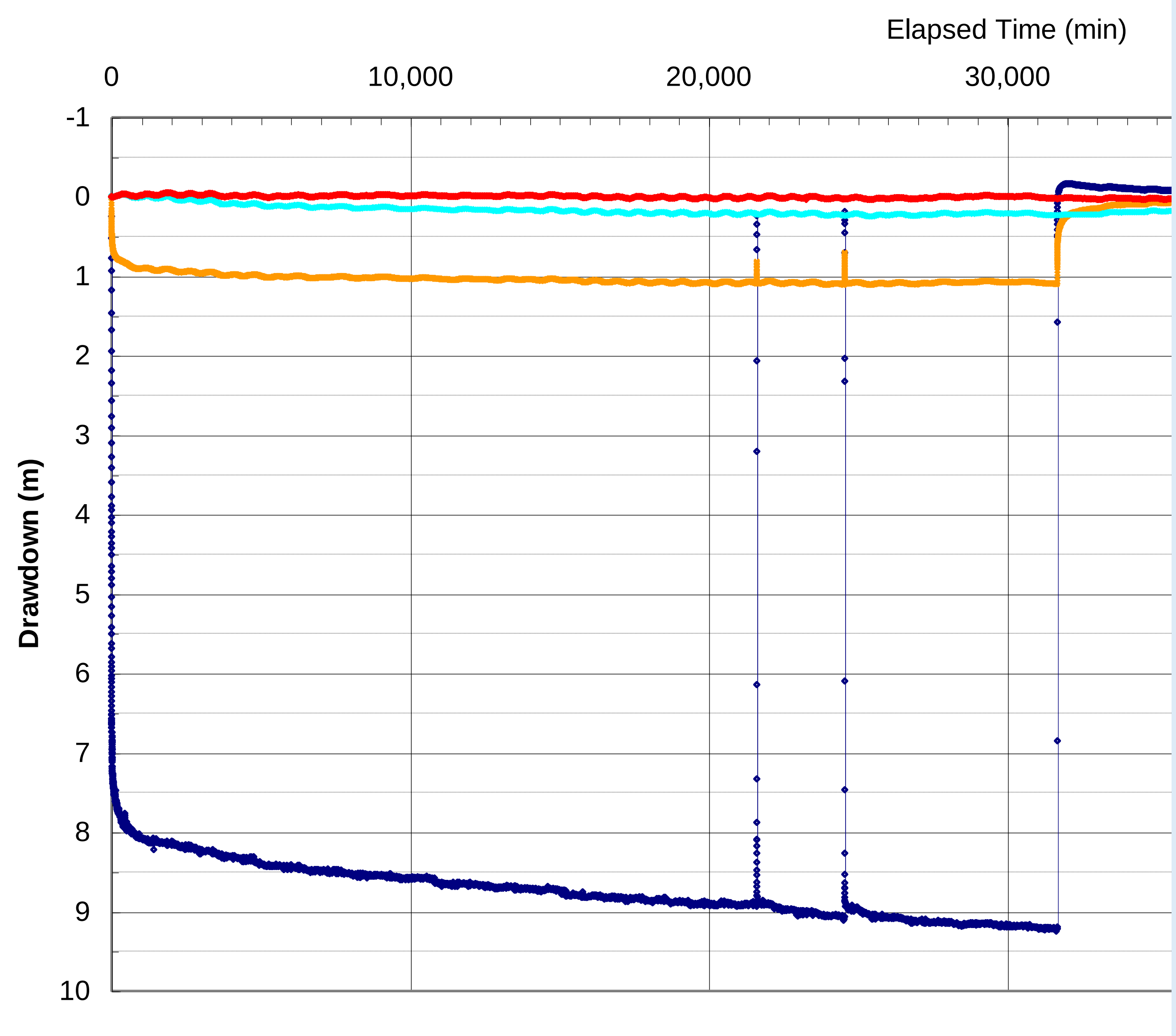
The most common type of pumping test:

- Use step-test results to help plan the pumping rate
- Pump at constant rate for an extended period (several hours to several weeks)
- Monitor water levels, pumping rate and water quality
- Ideally, there should be one or more observation boreholes
- Data can be analysed to obtain aquifer hydraulic properties
- Also commonly used to investigate impacts of abstraction and long-term ‘safe yield’

Pumping rate is usually set at the intended operational rate, or a bit higher



Recovery test

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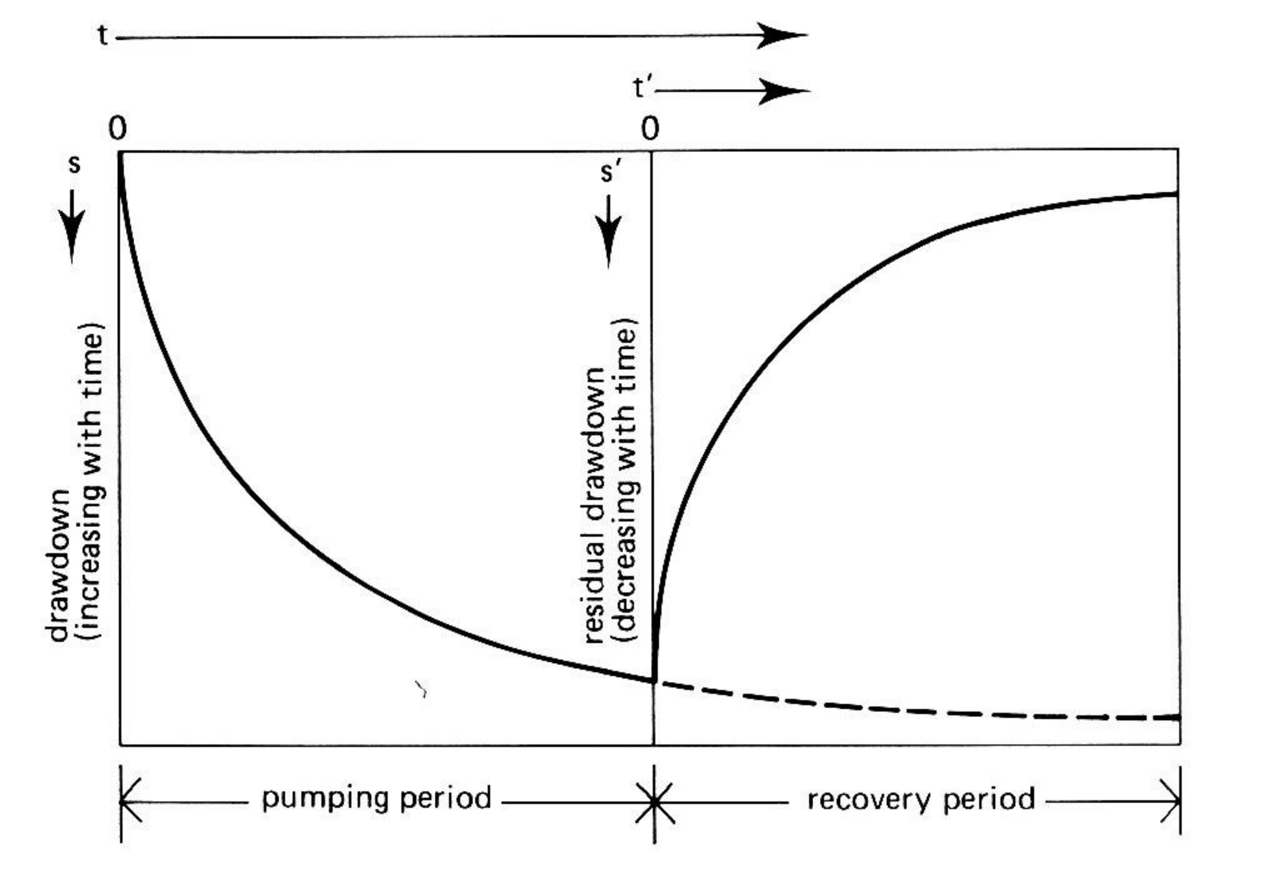
Not strictly a pumping test, but don't miss the opportunity to gather more data…

- Monitor recovery of water levels immediately after pumping stops
- Useful check on results of constant-rate test
- Recovery smooths out pumping rate variations
- Start of test much 'cleaner'
- Water levels easier to measure (no turbulence)
- In theory, should be mirror image of pumping phase, but recovery can be incomplete

Good option for operational boreholes



Borehole performance diagram

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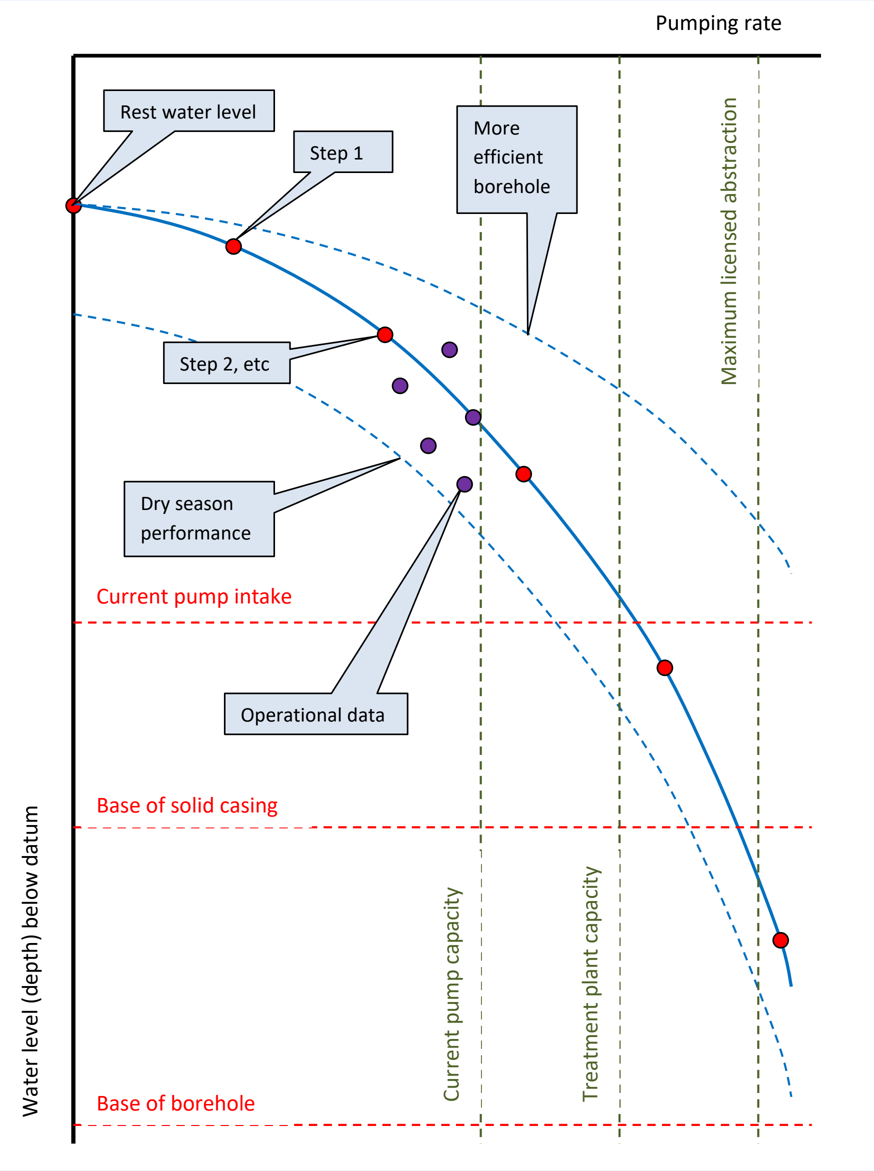

Another method of displaying test-pumping data:

- Plot step-test data & draw smooth curve – this is the characteristic borehole performance curve
- Plot any operational data (data pairs of pumping rate and dynamic water level – one for each visit)
- Illustrate constraints as straight lines (horizontal = water-level constraints; vertical = pumping-rate constraints)
- What if…? (lower pump intake, bigger pump…)
- Compare the performance of different boreholes (more efficient borehole has a flatter curve)
- Plot future step tests & look for long-term changes (in borehole performance or aquifer conditions)
- Not always a smooth curve - may drop suddenly above a certain pumping rate

Use this diagram as a long-term tool, to build up a picture of how this borehole performs

Water-quality monitoring

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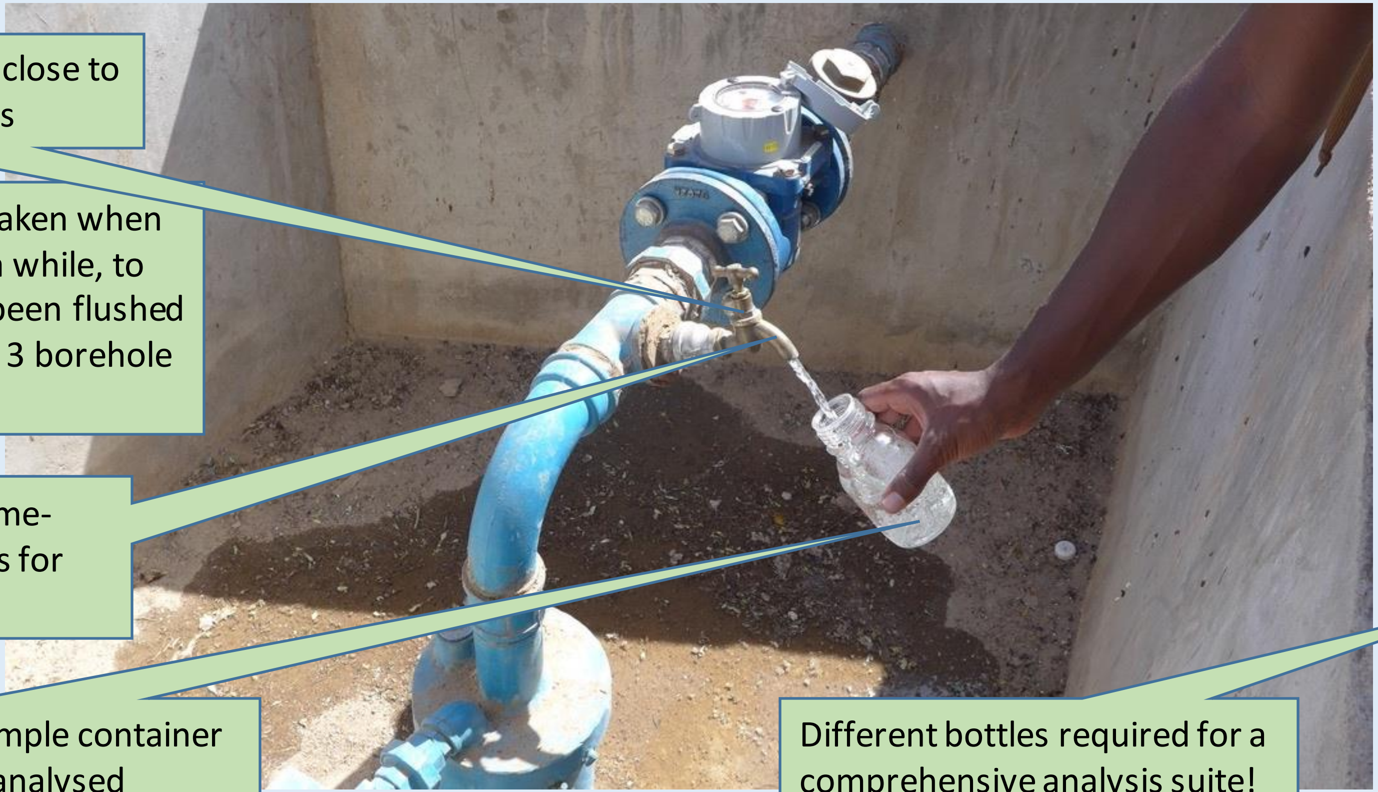
Most pumping tests focus on water levels and pumping rates, but water quality is also important:

- Is the water quality suitable for the intended use (particularly for drinking water)?
- Is the water quality stable in the long term?
- Does the water quality change with pumping rate?
- Is there a pumping rate above which the water quality suddenly deteriorates?
- Is any treatment necessary before the water can be put into supply?

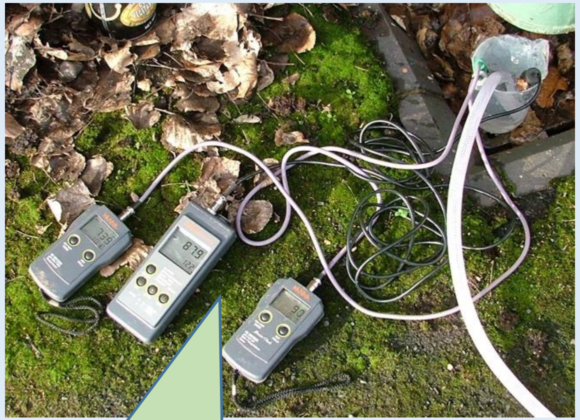


Dedicated sampling tap fitted close to where the rising main emerges

Water quality samples are best taken when the pump has been running for a while, to ensure that stagnant water has been flushed from the borehole itself (at least 3 borehole volumes pumped out)

Brass tap, so that it can be flame-sterilised when taking samples for microbiological analysis

Always use the correct sample container for the parameters to be analysed



Some parameters must be measured on the spot (Temp, pH, EC, DO)

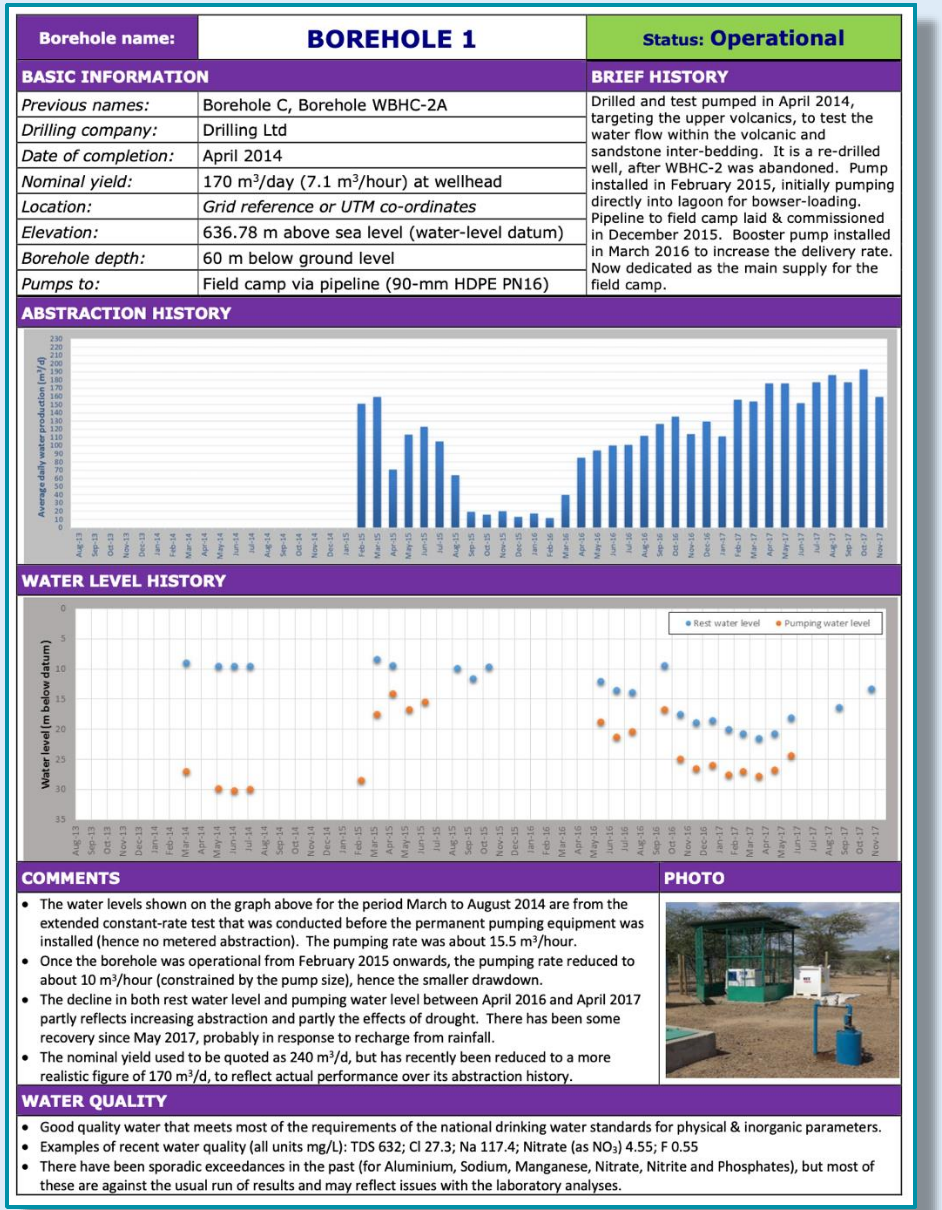
Different bottles required for a comprehensive analysis suite!

Long-term monitoring

Long-term groundwater monitoring is *essential* for a full understanding of aquifer behaviour (and sustainable yield):

- Keep good records, with boreholes clearly identified
- Ensure that the measuring datum is clear
- Be careful about units
- Update the borehole performance diagram
- When designing a system, include access points for future monitoring
- Good practice to maintain a borehole summary report

Access hole for dipping water levels, with screw cap



Borehole name:	BOREHOLE 1	Status: Operational

BASIC INFORMATION

Previous names:	Borehole C, Borehole WBHC-2A
Drilling company:	Drilling Ltd
Date of completion:	April 2014
Nominal yield:	170 m^3/day (7.1 m^3/hour) at wellhead
Location:	*Grid reference or UTM co-ordinates*
Elevation:	636.78 m above sea level (water-level datum)
Borehole depth:	60 m below ground level
Pumps to:	Field camp via pipeline (90-mm HDPE PN16)

BRIEF HISTORY

Drilled and test pumped in April 2014, targeting the upper volcanics, to test the water flow within the volcanic and sandstone inter-bedding. It is a re-drilled well, after WBHC-2 was abandoned. Pump installed in February 2015, initially pumping directly into lagoon for bowser-loading. Pipeline to field camp laid & commissioned in December 2015. Booster pump installed in March 2016 to increase the delivery rate. Now dedicated as the main supply for the field camp.

ABSTRACTION HISTORY

WATER LEVEL HISTORY

COMMENTS

- The water levels shown on the graph above for the period March to August 2014 are from the extended constant-rate test that was conducted before the permanent pumping equipment was installed (hence no metered abstraction). The pumping rate was about 15.5 m^3/hour.
- Once the borehole was operational from February 2015 onwards, the pumping rate reduced to about 10 m^3/hour (constrained by the pump size), hence the smaller drawdown.
- The decline in both rest water level and pumping water level between April 2016 and April 2017 partly reflects increasing abstraction and partly the effects of drought. There has been some recovery since May 2017, probably in response to recharge from rainfall.
- The nominal yield used to be quoted as 240 m^3/d, but has recently been reduced to a more realistic figure of 170 m^3/d, to reflect actual performance over its abstraction history.

PHOTO

WATER QUALITY

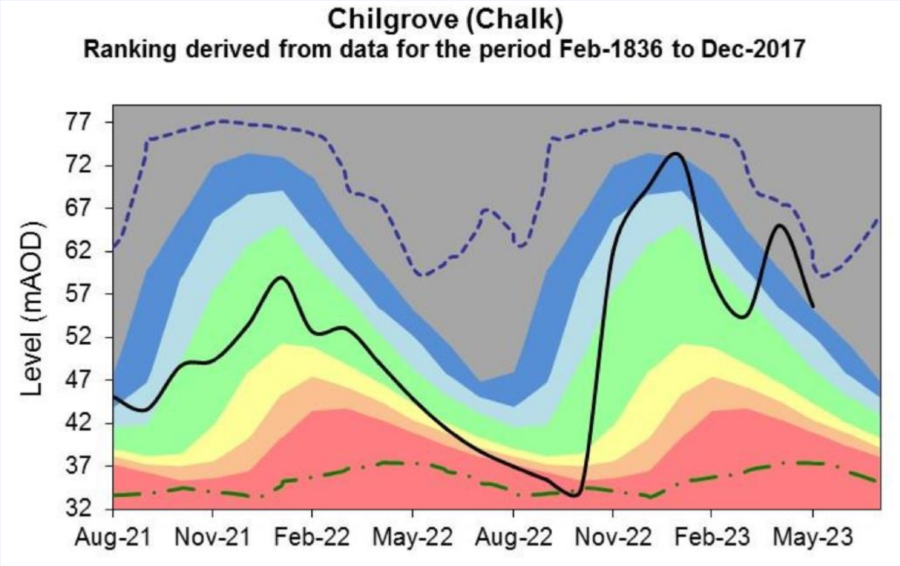
- Good quality water that meets most of the requirements of the national drinking water standards for physical & inorganic parameters.
- Examples of recent water quality (all units mg/L): TDS 632; Cl 27.3; Na 117.4; Nitrate (as NO_3) 4.55; F 0.55
- There have been sporadic exceedances in the past (for Aluminium, Sodium, Manganese, Nitrate, Nitrite and Phosphates), but most of these are against the usual run of results and may reflect issues with the laboratory analyses.

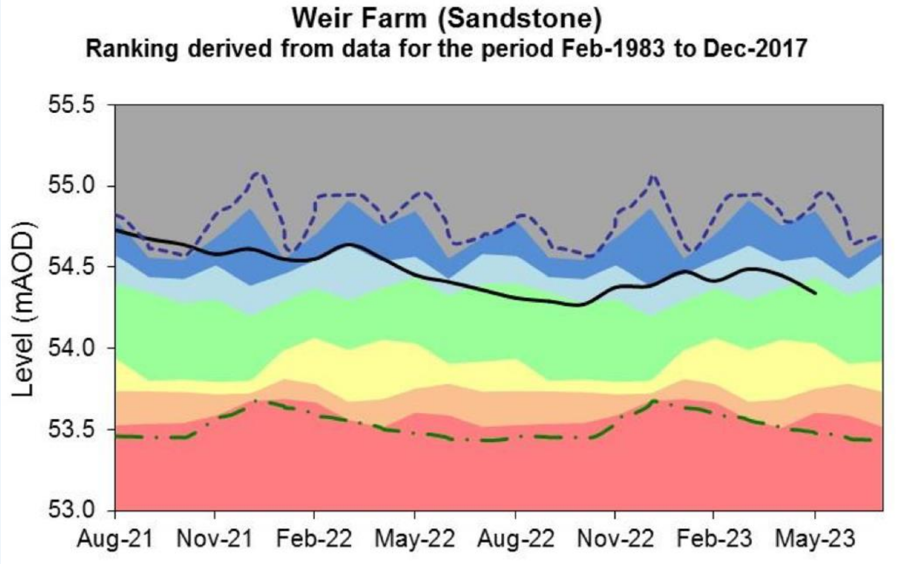
Final comments

- In reality, there is no single value for sustainable or safe borehole yield, and no simple formula for calculating it
- If one value is all you have for an unfamiliar borehole (from a contractor's report, for example), then go ahead and use it for the system design, but remember that the yield will probably change over time, depending on many factors, including the condition of the borehole, natural seasonal groundwater behaviour, & climate change

1) Be realistic about interpreting test-pumping results
2) Design the borehole headworks so that you can easily monitor water levels, pumping rates, & water quality
3) Organise a long-term monitoring programme
4) Repeat pumping tests periodically, to check for deterioration in borehole performance
5) Keep good records

Reliable long-term yield may be a better term to use!





From: Environment Agency of England & Wales

Other resources

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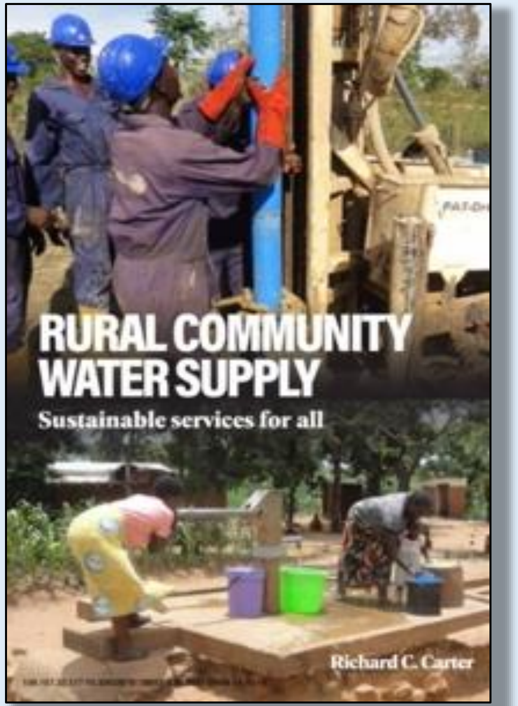
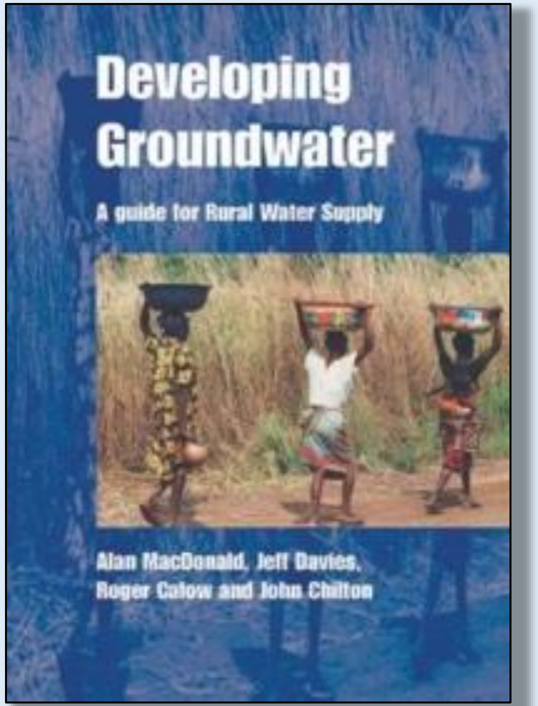
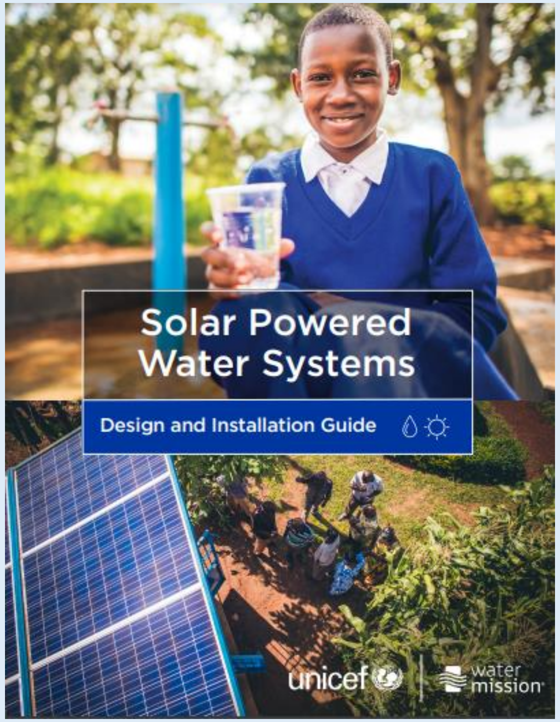
Further resources on groundwater development, boreholes, & rural water supply:







UNICEF’s Environmental and Social Safeguards (ESS)

- UNICEF’s ESS system is scheduled to be released in late 2023 and to be effective by 1 July 2024
- Comprises of eight standards (UN Model Approach) – including **Resource Efficiency**, **Community Health** and **Biodiversity**
- Screening at different stages of our work
- Risk Rating will be applied
- Standards may be triggered with associated management plans
- Designed to help us identify the risks associated with our programming (and operations); to identify options to mitigate these risks and assess the effectiveness of these
- Large abstractions can cause harm if not properly located, designed and constructed
- Proper groundwater assessment, drilling, sustainable yield calculation and groundwater monitoring promote more sustainable programming

TAKE AWAY MESSAGES – GW ASSESSMENTS

- We need to make sure make groundwater visible based on sound **evidence**
- Take advantage of open data and remote sensing data
- At more local scales, a combination of remote sensing and **field level surveys** are required
- Geophysics needs to be used with other geological and hydrogeological data to be of use
- Approaches need to be tailored to meet context and objectives – e.g Managed aquifer recharge
- Need **local expert support** in the process – hydrogeologists, hydrologists, geophysicists, water engineers etc
- This capacity needs to be built locally
- Stakeholder engagement is fundamental to success
- Don't forget National standards and policy when planning
- Is the resource renewable or is there a risk we contribute to mining

TAKE AWAY MESSAGES – GW MONITORING

- To minimise the **impact** of our programming, we need to understand the impact of our abstractions on the environment and effective groundwater monitoring allows us to do this
- But to do this effectively (and to minimise the impact of our programming!), we need to understand the groundwater characteristics through water resource assessments (and so these are both connected)
- The impact of climate change and the demand and competition for water are increasing and already impacting the systems we have installed – we need to understand these and incorporate these risks into our programming, and groundwater monitoring can support this
- Have we linked GW monitoring to service delivery and water regulation?


QUESTIONS?