SDG indicator 6.3.2
Caribbean Working Group
23rd June 2022

Monitoring and Reporting for Groundwater

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Introduction

This presentation is aimed at practitioners seeking further clarification on how to implement the indicator methodology in their own country.

This presentation:

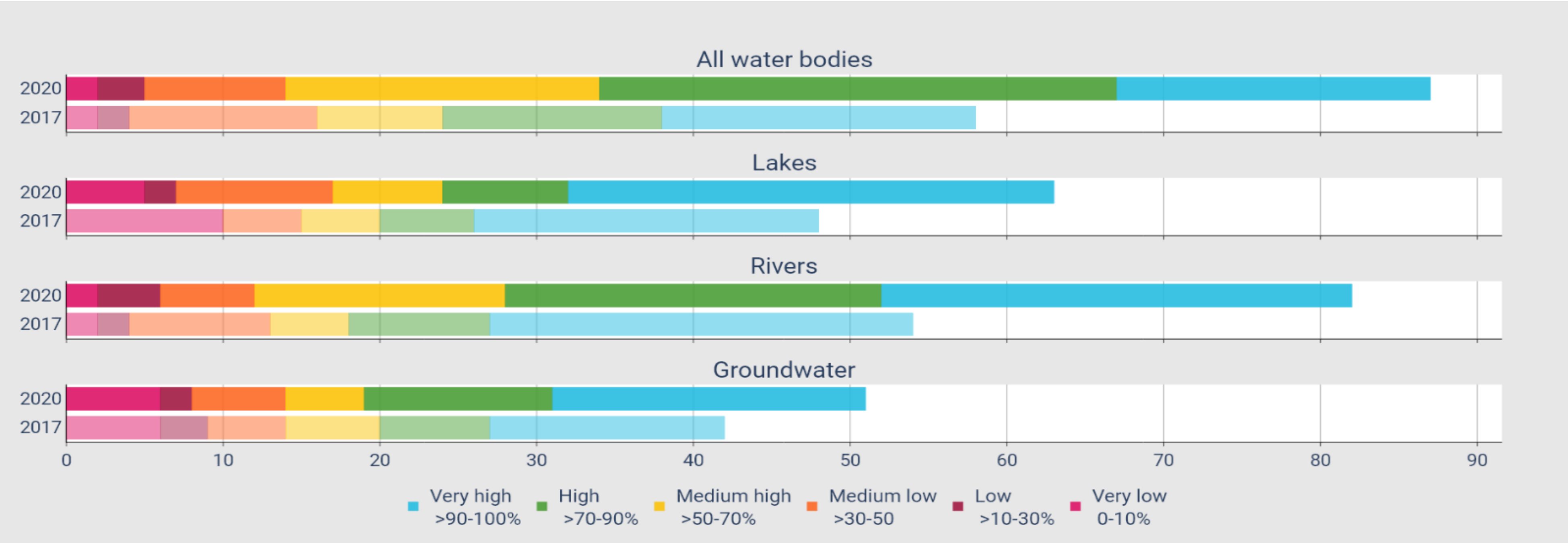
- Discusses why monitoring groundwater is more difficult?
- Provides guidance on identifying aquifers and defining bodies of groundwater.
- Reviews options for groundwater sampling.
- Discusses parameter choice and Level 1 and Level 2 reporting for groundwater quality.
- It briefly looks at field operations
- The suitability of different water quality parameters
- Looks at target setting for groundwater

Introduction

The monitoring data collected for SDG indicator 6.3.2 should:

- provide sufficient information about ambient water quality status, and
- allow long term trends to be identified.

This requires data for the core parameter groups from sites across the country, and measurements to be taken in a standardised and consistent way.



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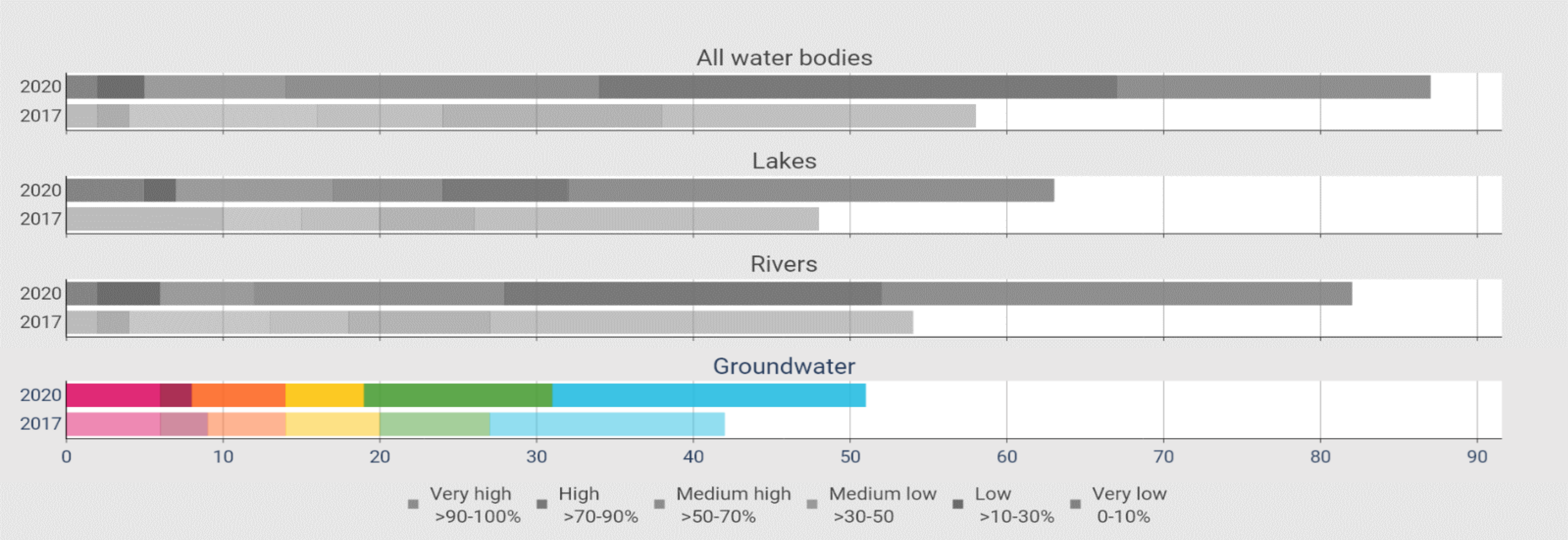
During the both global data drives (2017 and 2020) fewer countries reported on the quality of their groundwater than they did for surface waters.

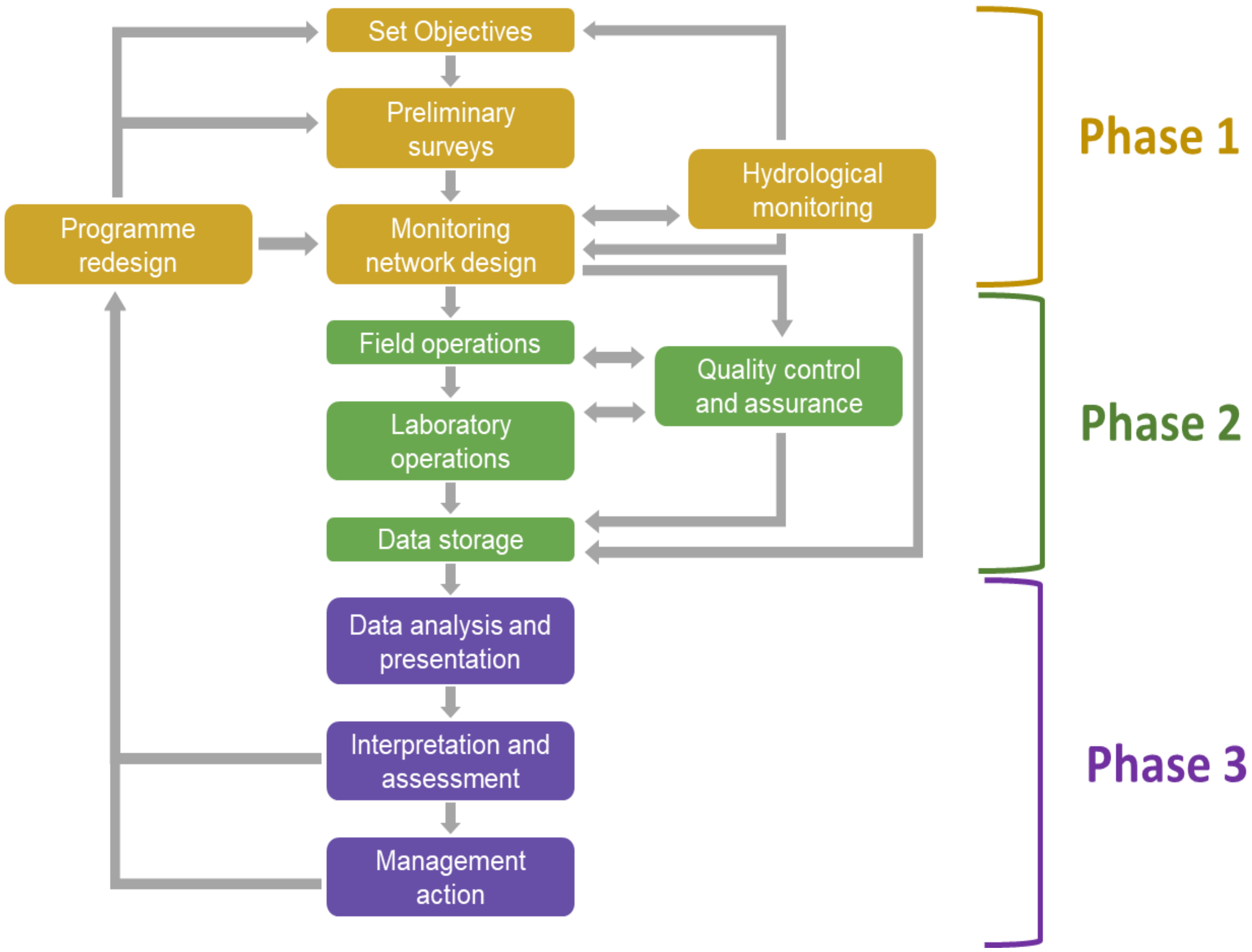


Why is monitoring groundwater more difficult?

There are many reasons why water quality monitoring programmes do not provide the information they should.

To avoid these failures :

- information needs and objectives need to be clearly defined;
- the physical network design needs to be adequately accounted for;
- sample collection, handling, storage and analysis must be well planned;
- quality control and assurance must be included;
- management and interpretation of the resulting data must be understood;
- review, feedback and modification of the design must be undertaken.



Why is monitoring groundwater more difficult?

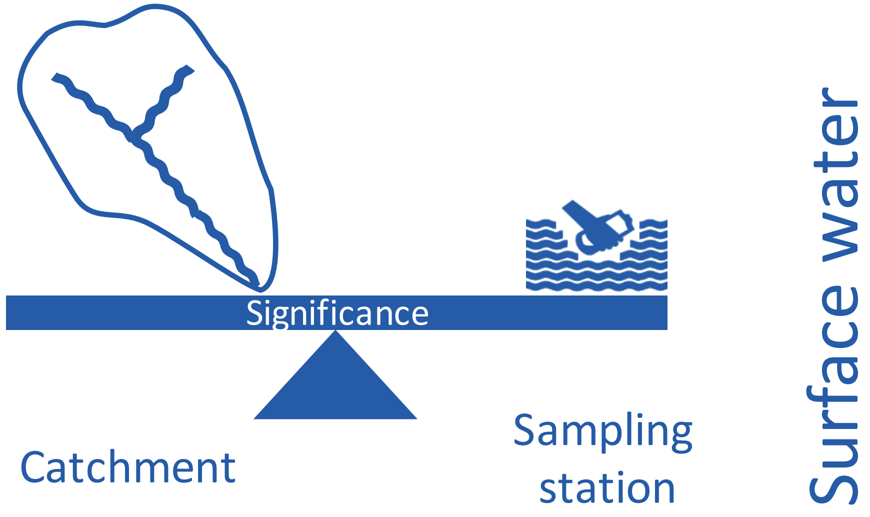
The challenge of groundwater quality monitoring is fundamentally different from that for surface waters.

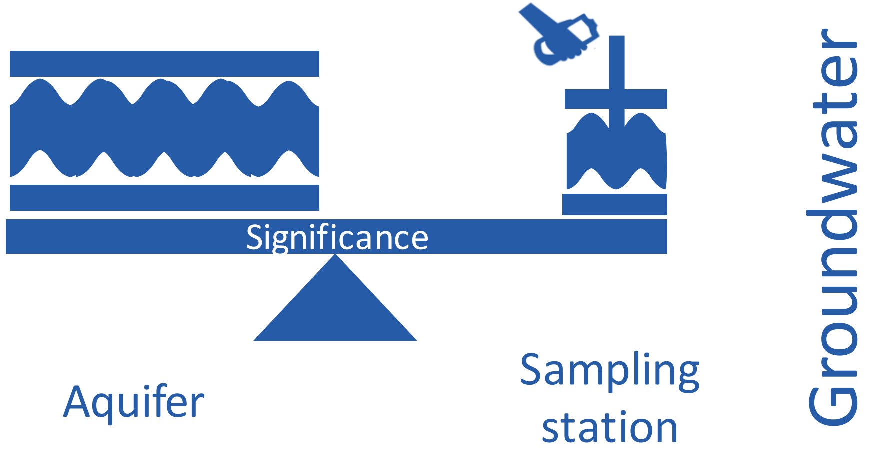
River monitoring provides a composite picture for an extensive catchment, buffering-out the effect of factors local to the sampling station.

The reverse is generally true for groundwater! The influence of very local factors, such as:

- wellhead contamination,
- well depths,
- pumping rates,
- the immediate catchment and
- sampling protocols, can dominate.

This can distort the broader picture for the aquifer, and needs to be understood and taken into account.





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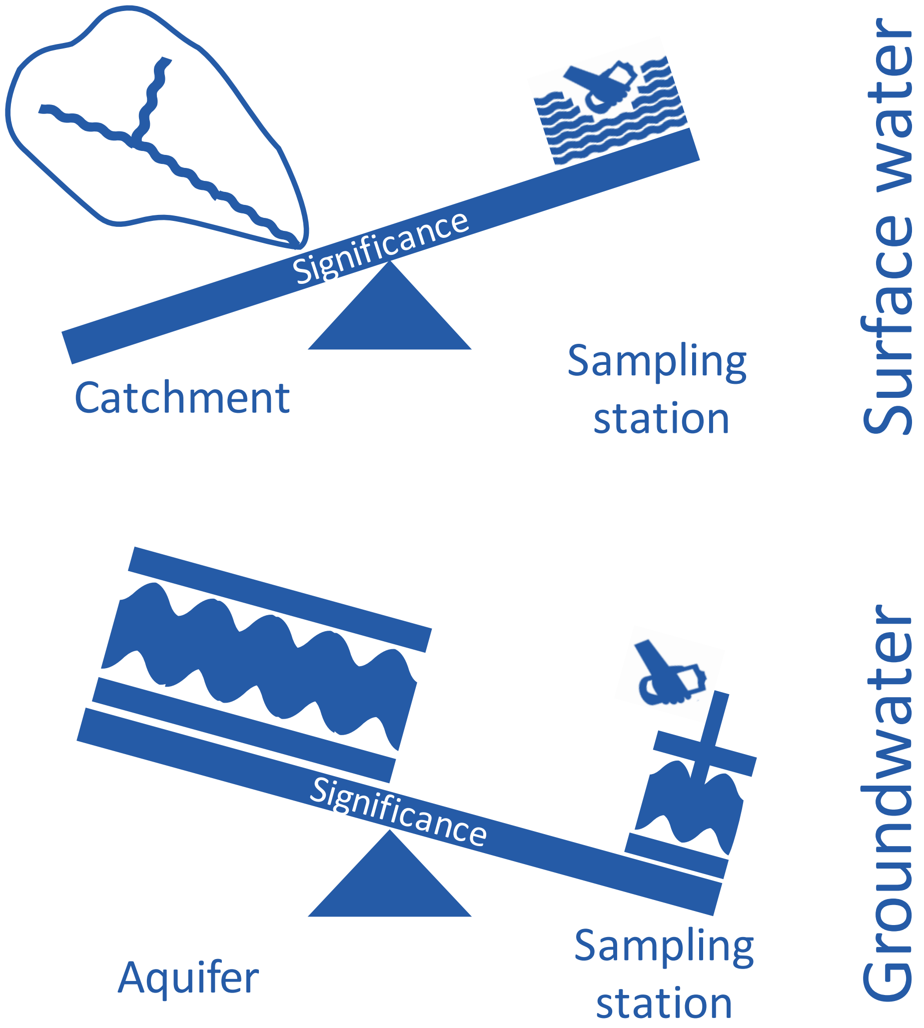


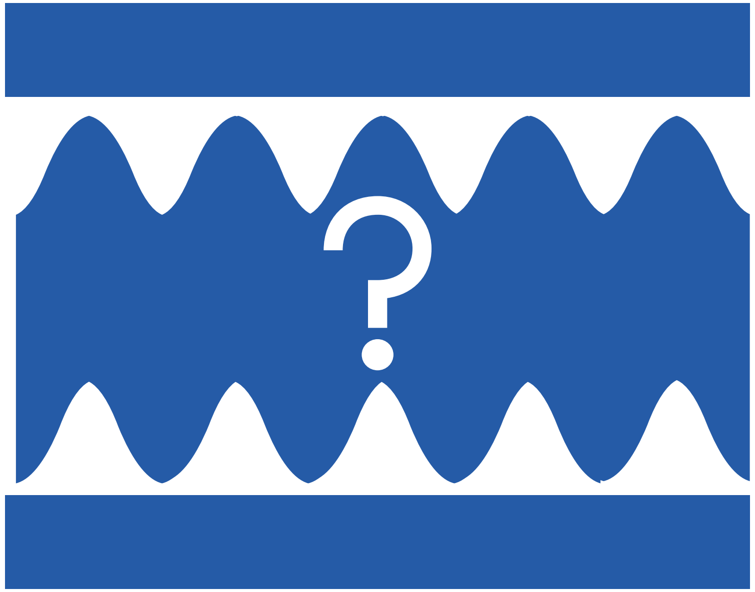
Why is monitoring groundwater more difficult?

For groundwater, the general constraints outlined above are often supplemented by a **lack of hydrogeological knowledge.**

This can weaken

- the **design of the monitoring network** and
- **interpretation** of the results.

This is important because aquifers, and the groundwater bodies they contain, are **usually more complex** than surface waters and much less **accessible** for sampling.



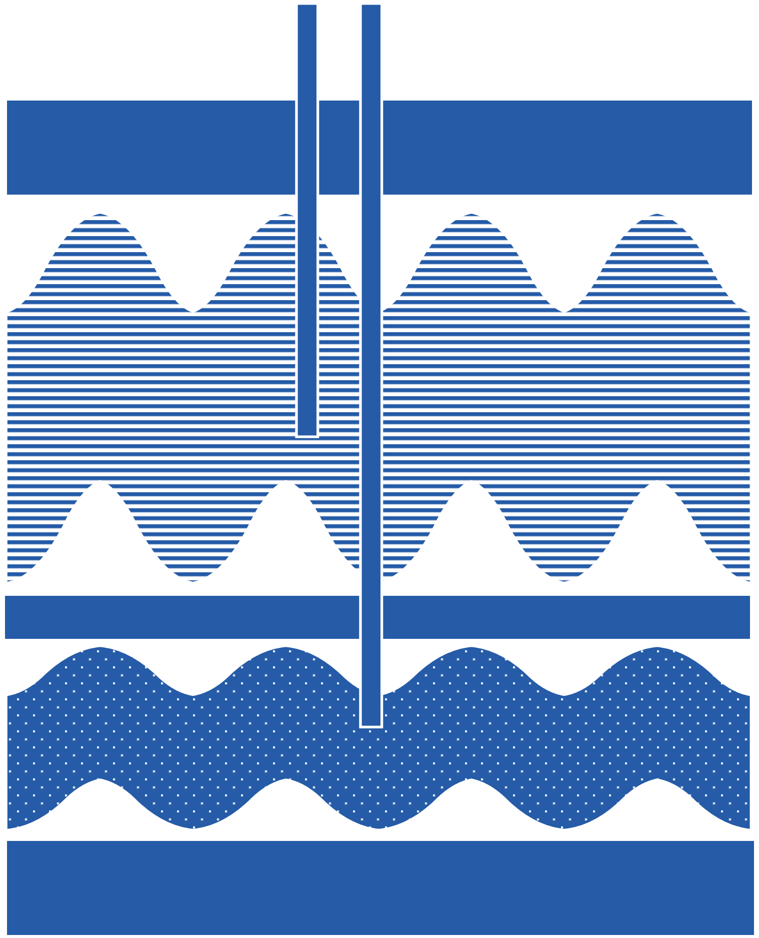
Why is monitoring groundwater more difficult?

Most groundwaters have much longer residence times than surface waters.

This means that groundwaters need to be sampled less frequently than surface waters, but obtaining a representative picture of groundwater quality may require a greater density of sampling.

The depth and subsurface complexity of aquifers has a major bearing on the choice of sampling point.

Samples taken from wells in close proximity can produce very different results, especially if they draw water from different depths in the aquifer or even from different aquifers.

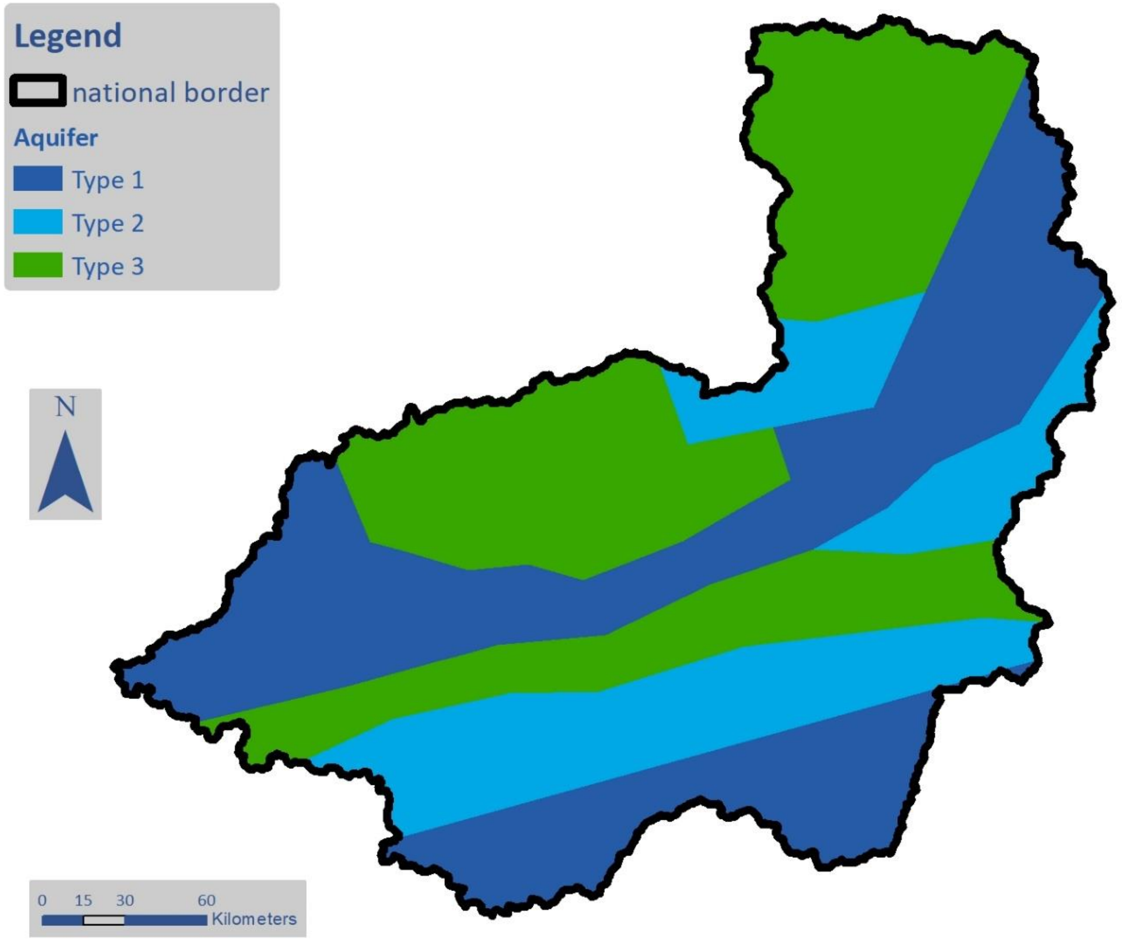


Identifying Aquifers and Defining Groundwater Bodies

The first two steps of indicator 6.3.2 methodology are:

- establish Reporting Basin Districts (RBDs) based on river basins and
- define water bodies within them.

For groundwater, once the RBDs have been defined, this means identifying the location of the productive aquifers and looking how they might be subdivided into groundwater bodies.



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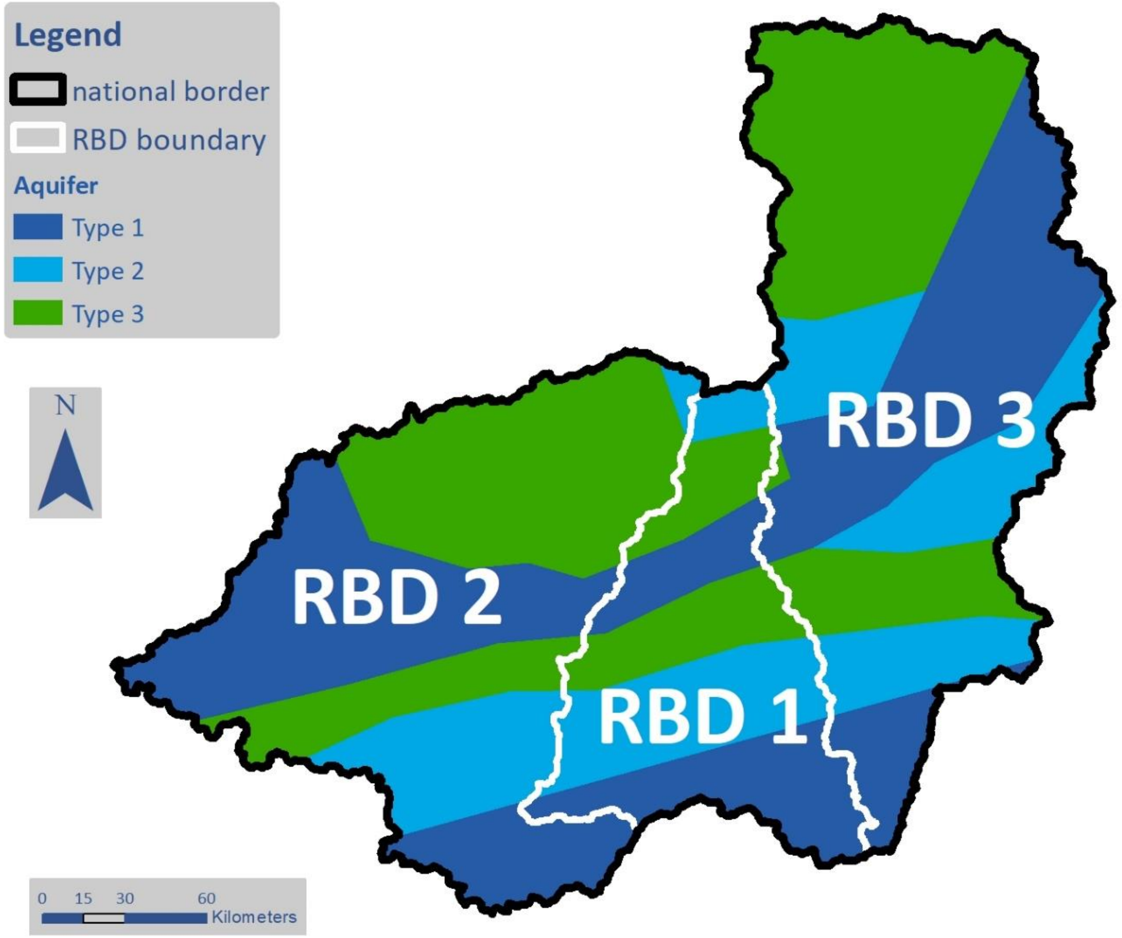


Identifying Aquifers and Defining Groundwater Bodies

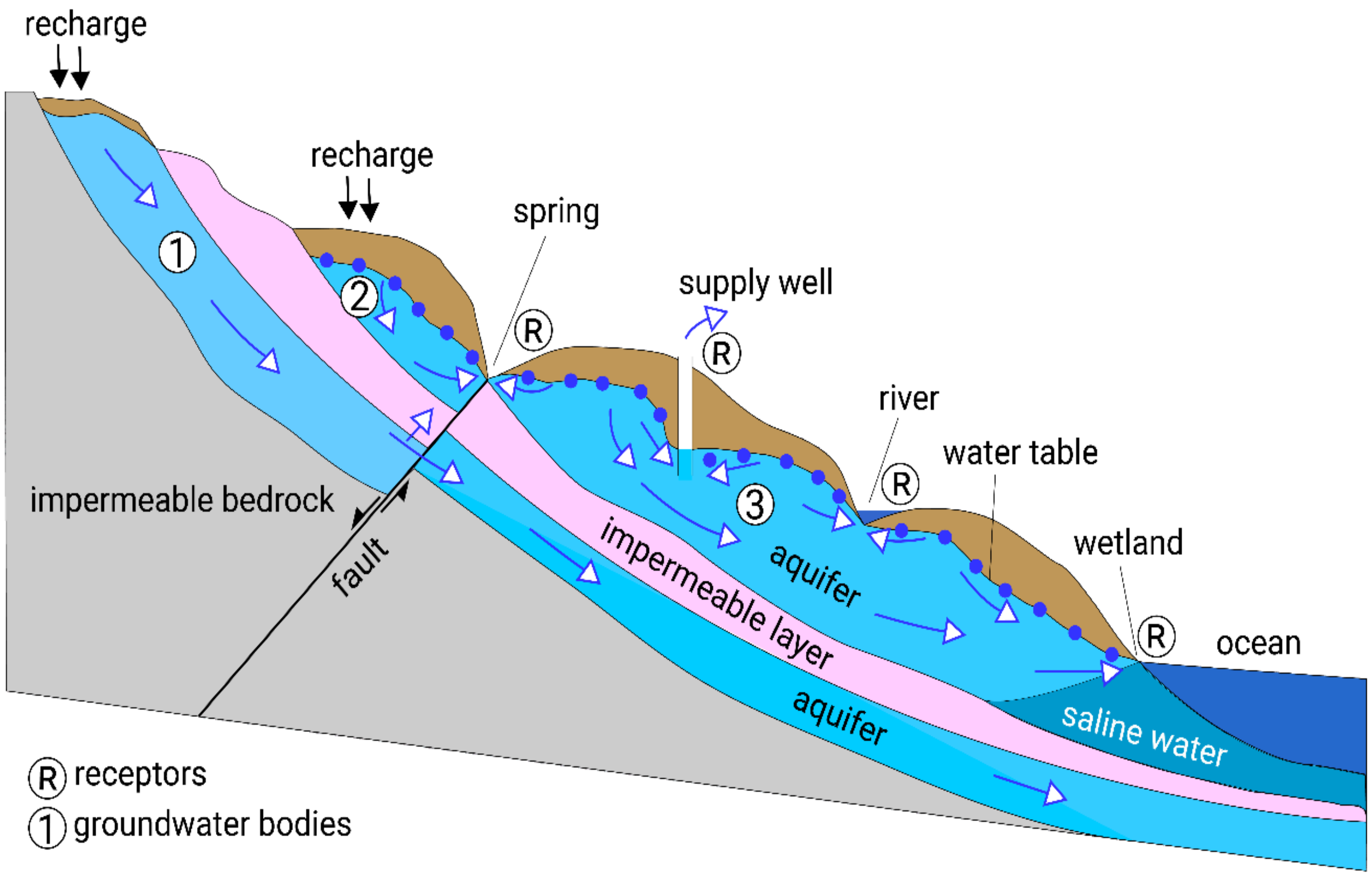
As for surface waters, groundwater bodies form the discrete units which are classified as either “good” or “not good”.

To monitor groundwater it is essential to understand where the water comes from and where it goes to.

Simple conceptual hydrogeological models showing the origins of groundwater, directions of flow and locations of discharge are needed.

This approach helps to identify:

- potential sources of pollution, and
- where poor groundwater impacts on receptors such as springs, supply wells, rivers and wetlands.



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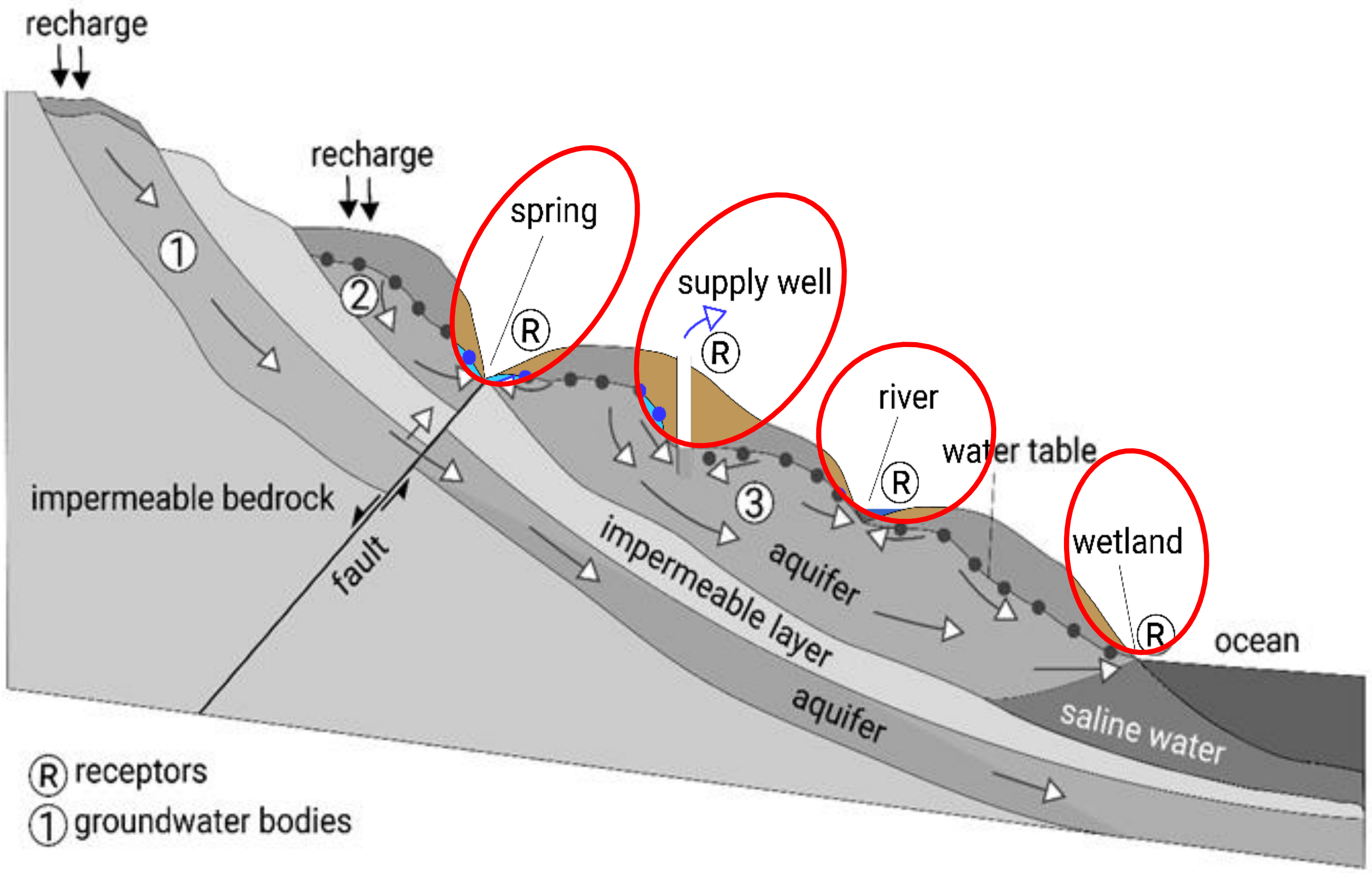

Identifying Aquifers and Defining Groundwater Bodies

Water bodies should be homogeneous in nature, but these units are often complex and require further sub-division.

Criteria for subdivision include:

- by groundwater flow divides,
- where major geological faults bring impermeable material against an aquifer, and where
- small shallow aquifers formed by alluvial or glacio-fluvial sediments overlying less permeable bedrock.

The complexities of aquifers, their vertical dimension in quality variation, and the slow movement, mean that **even relatively small bodies of groundwater are unlikely to be properly represented by one, or even a small number of monitoring points**.

Identifying Aquifers and Defining Groundwater Bodies

In this example, three groundwater bodies have been delineated based on **groundwater flow divides**.

However, the boundaries of groundwater bodies defined in this way may not be static and can move:

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- changes in recharge,
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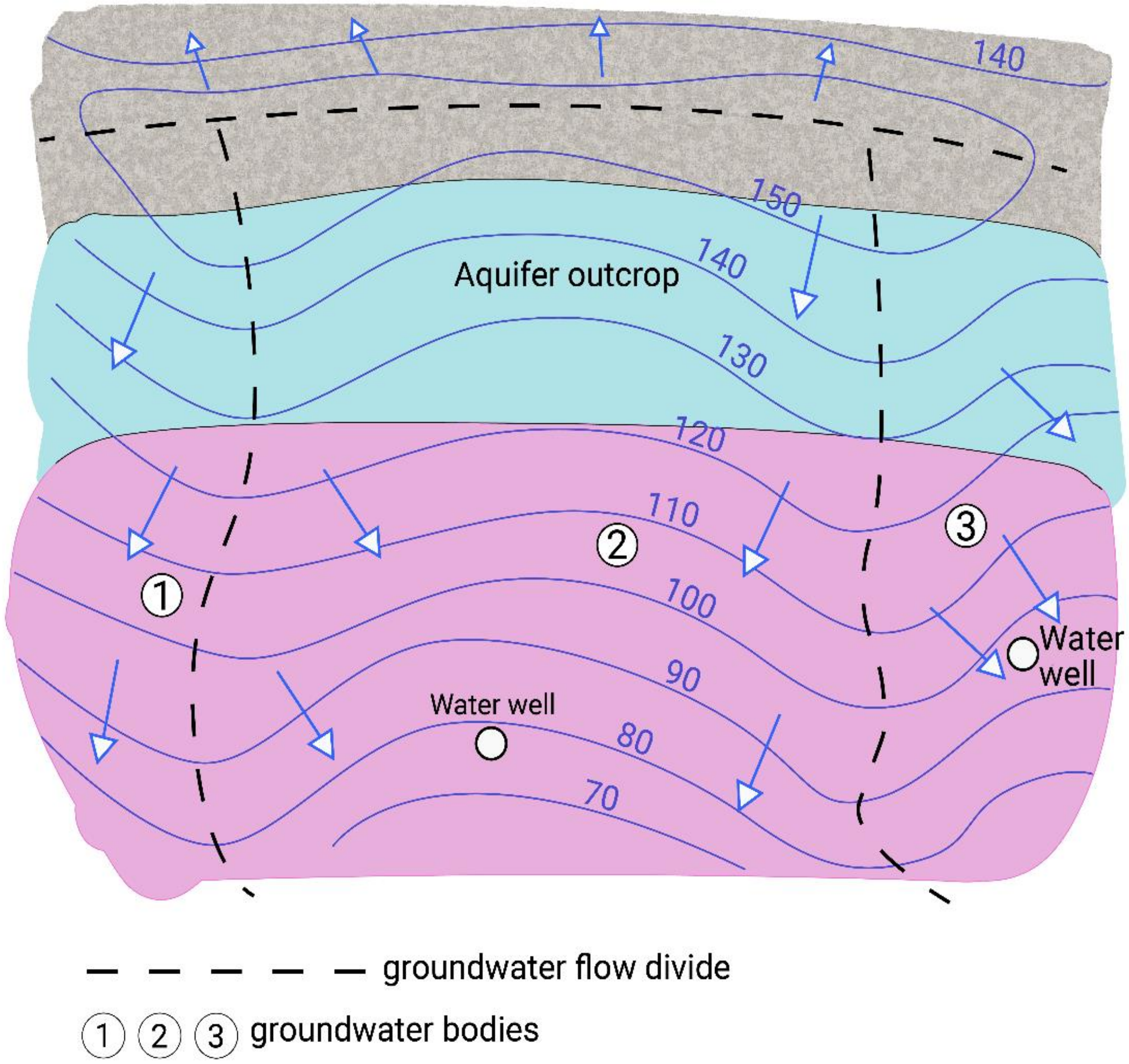

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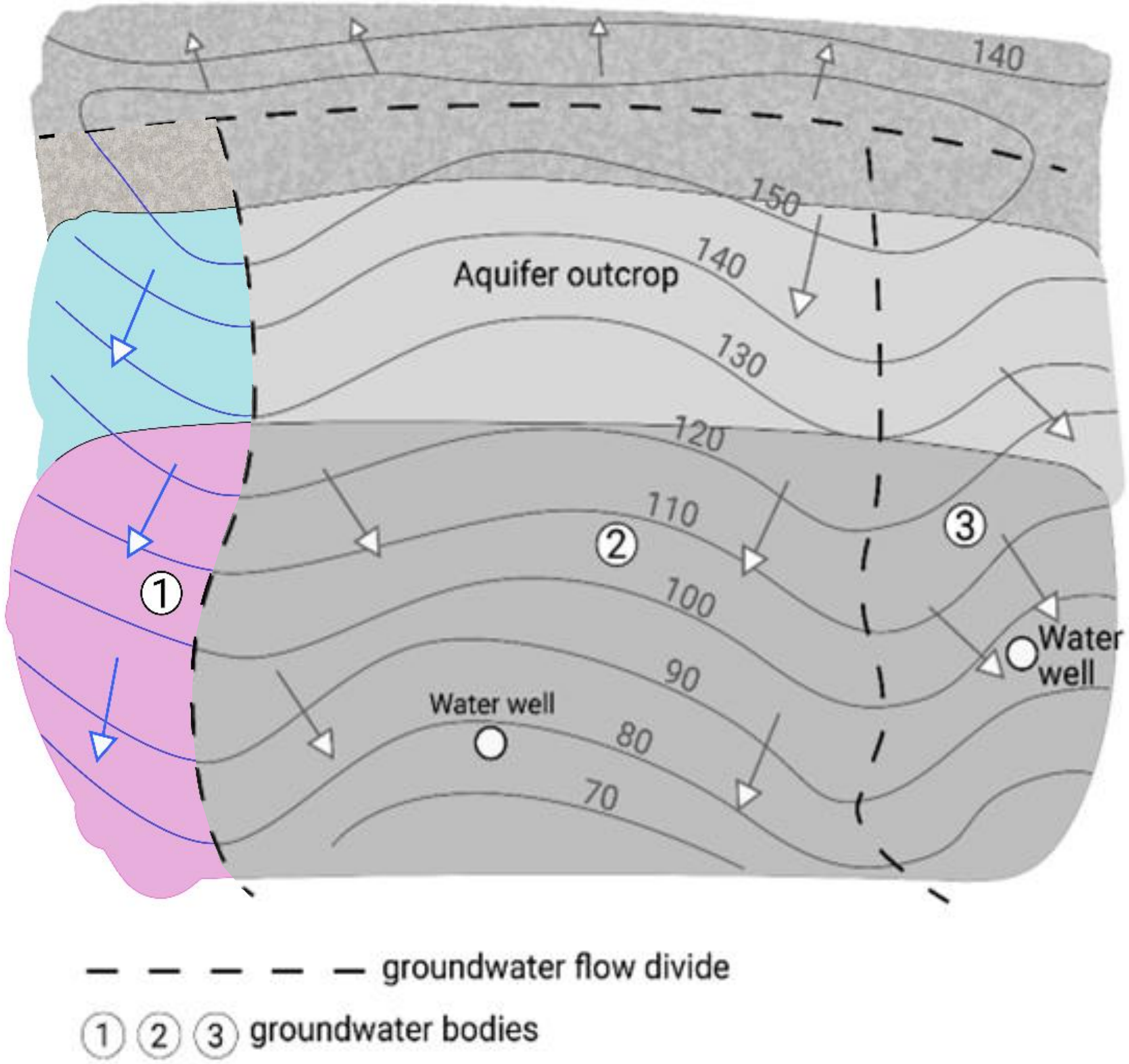

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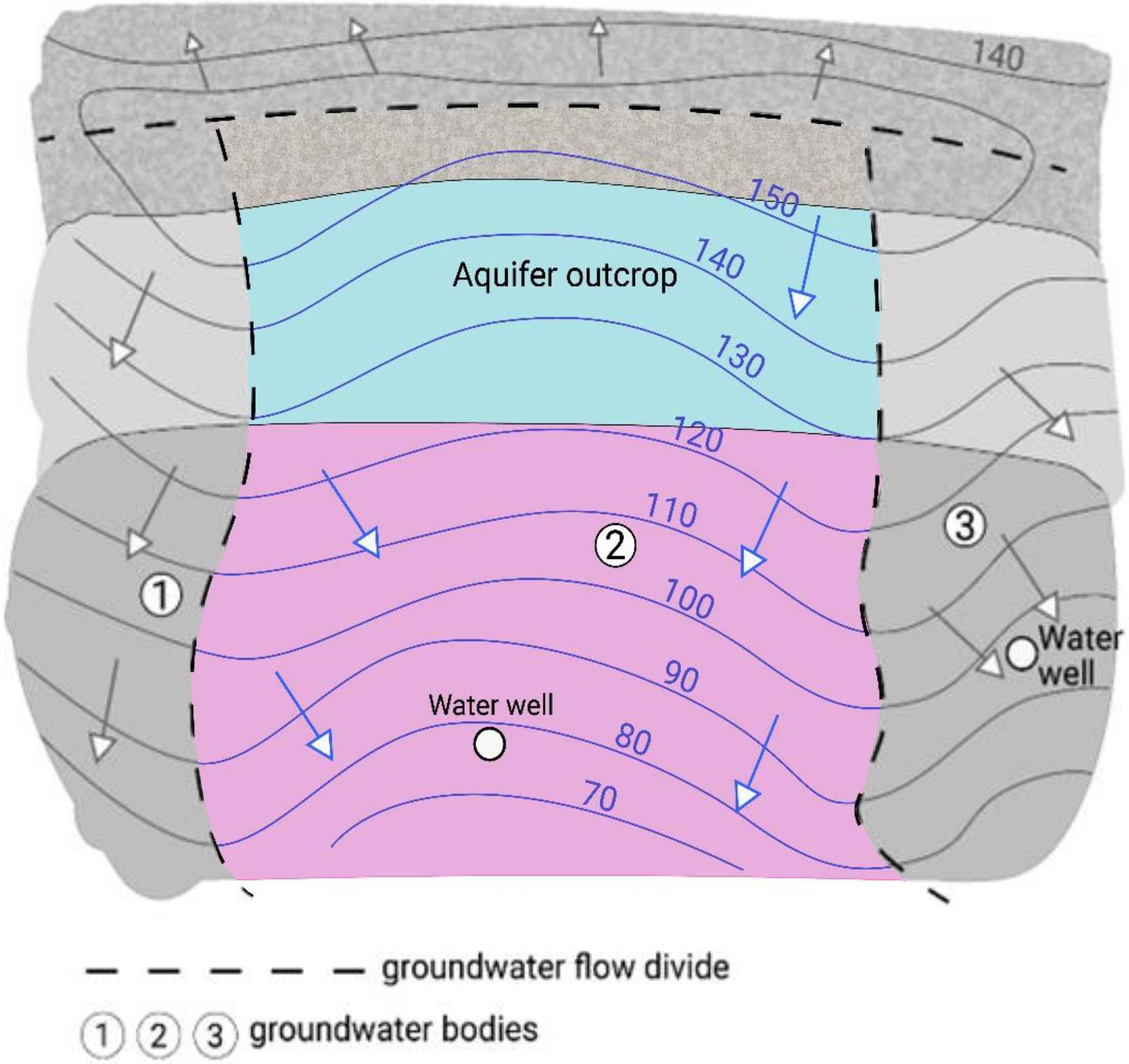

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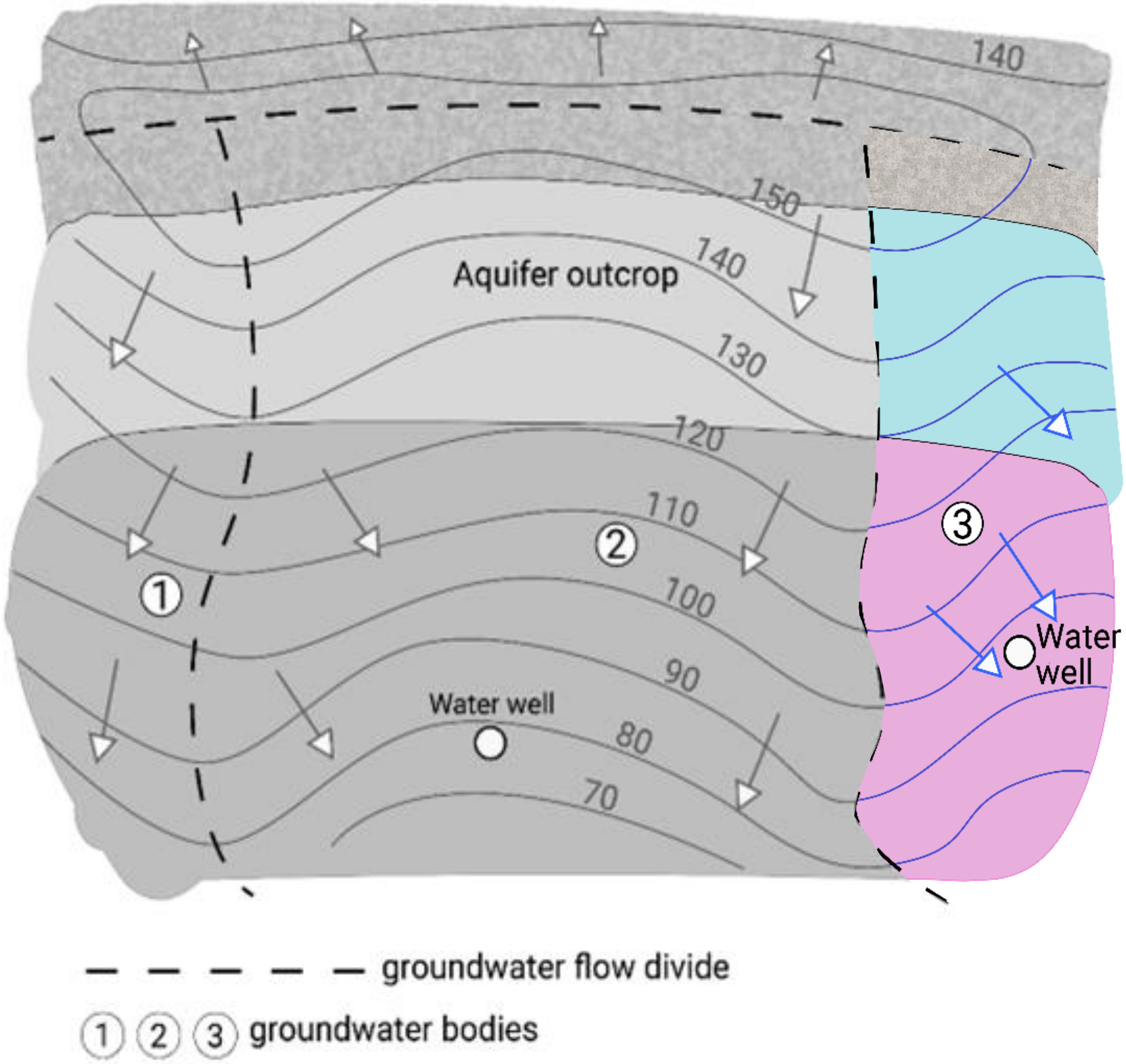

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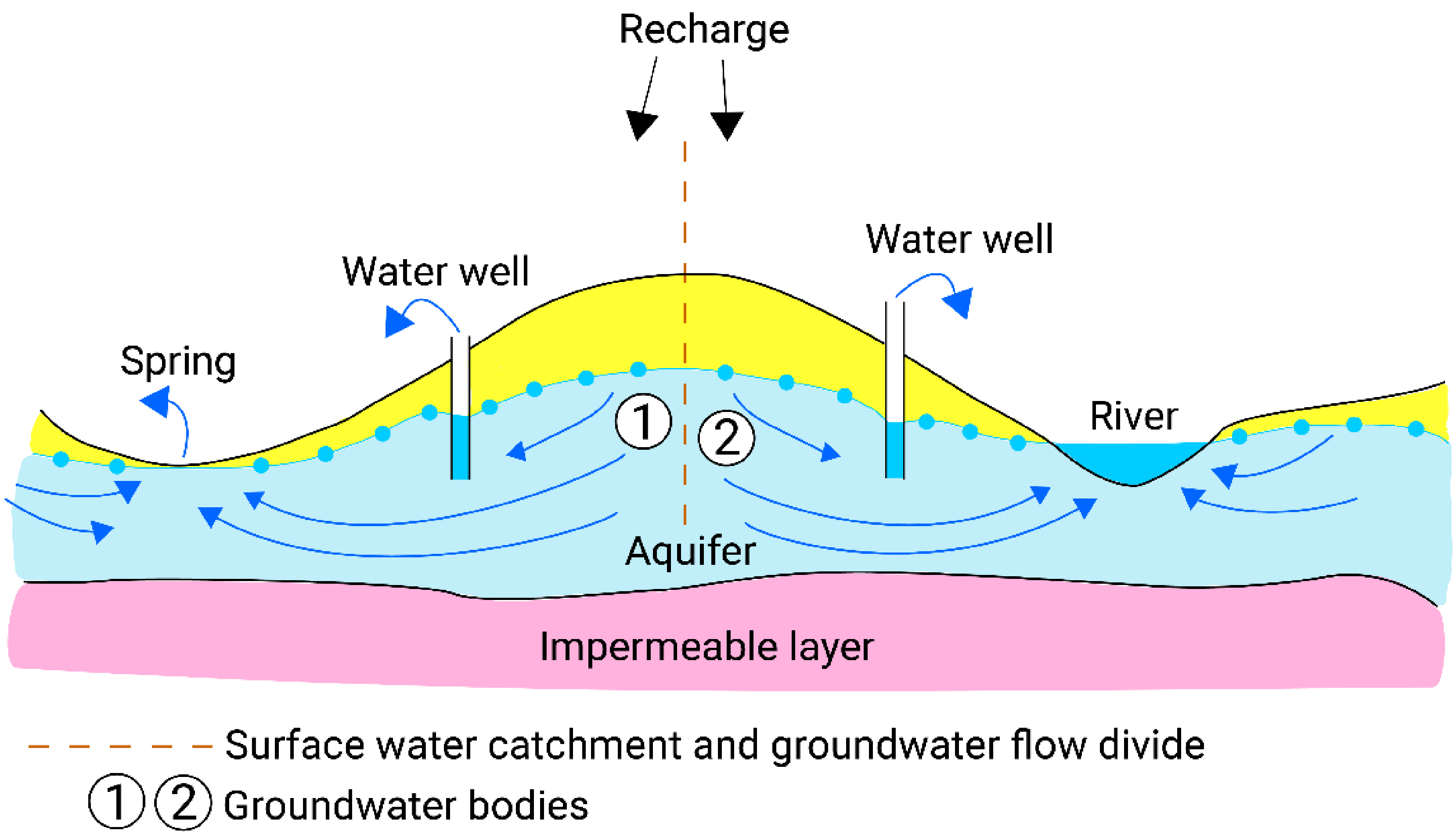

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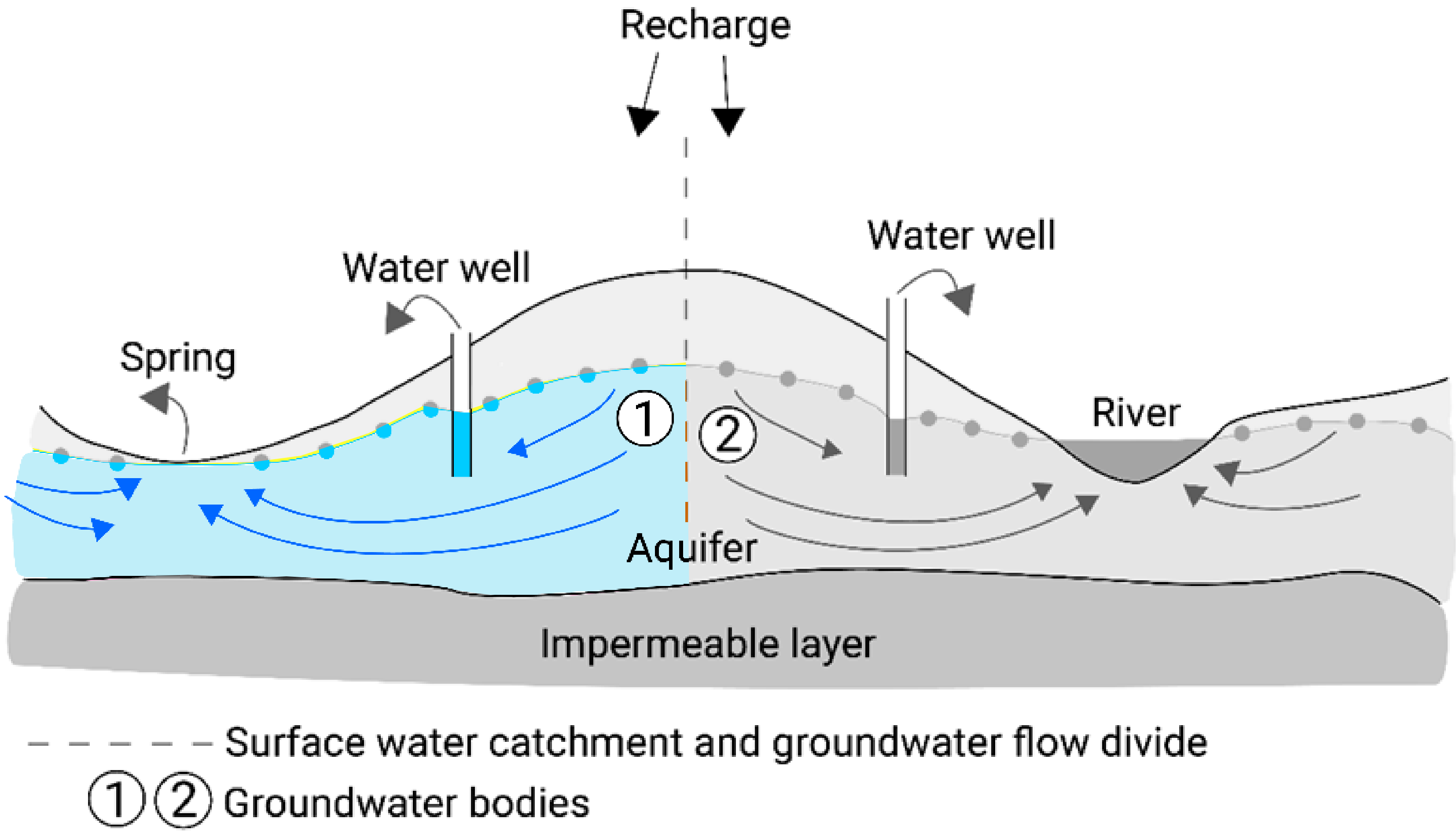

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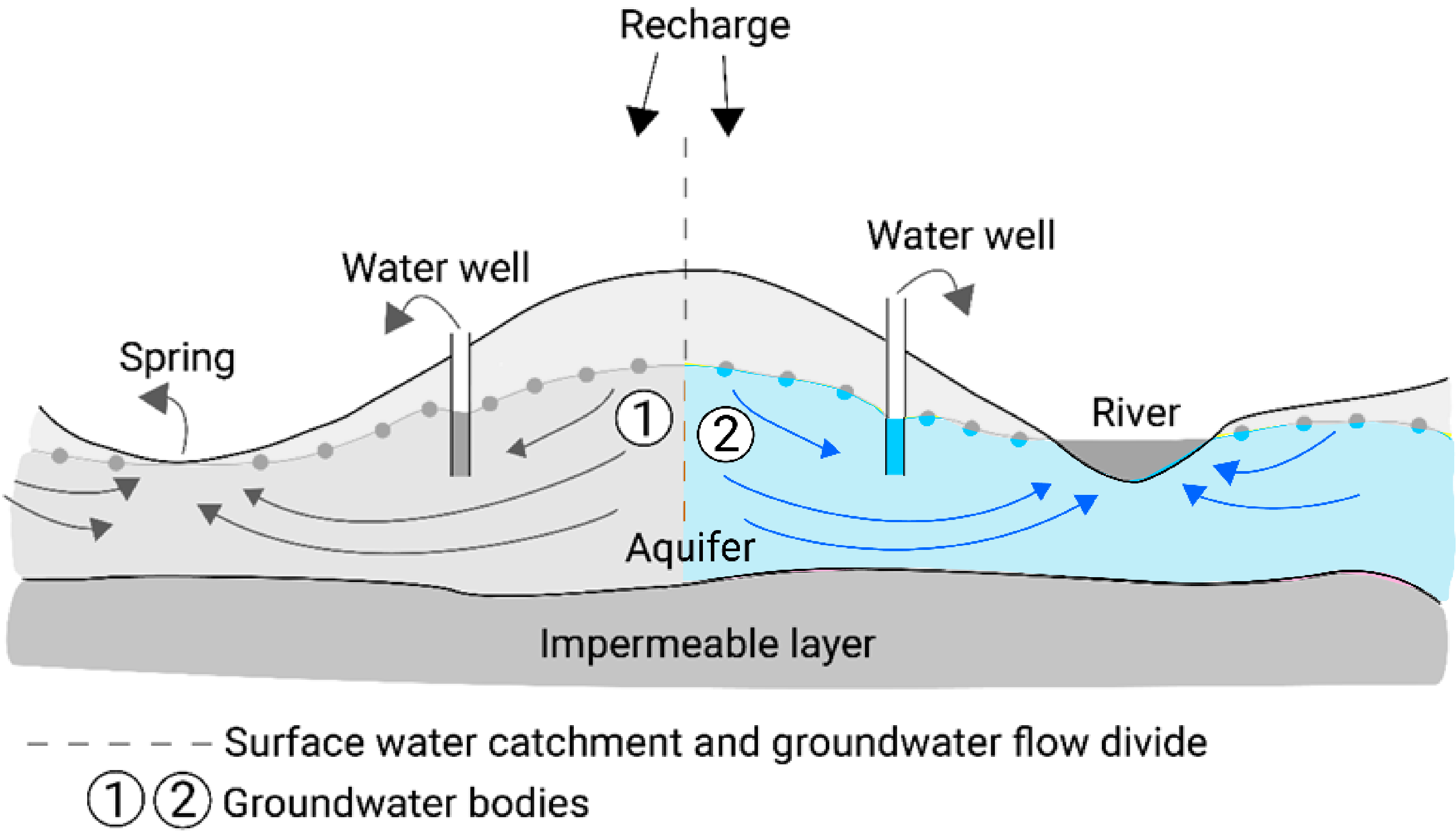

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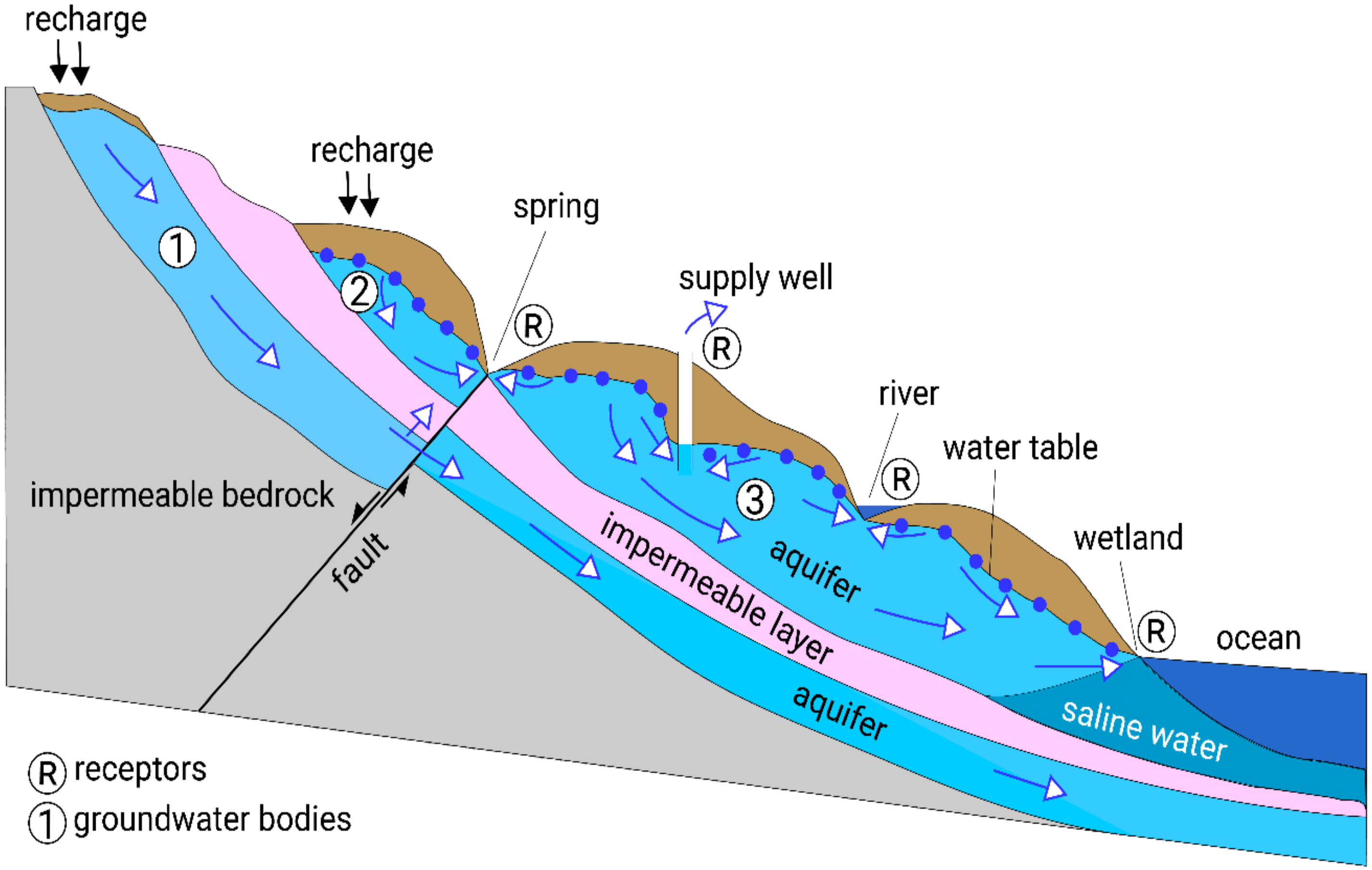
The complexities of aquifers, their vertical dimension in quality variation, and the slow movement, mean that **even relatively small bodies of groundwater are unlikely to be properly represented by one, or even a small number of monitoring points**.

Identifying Aquifers and Defining Groundwater Bodies

In this example, a major fault brings impermeable material against an aquifer, restricting groundwater flow, to form a suitable boundary.



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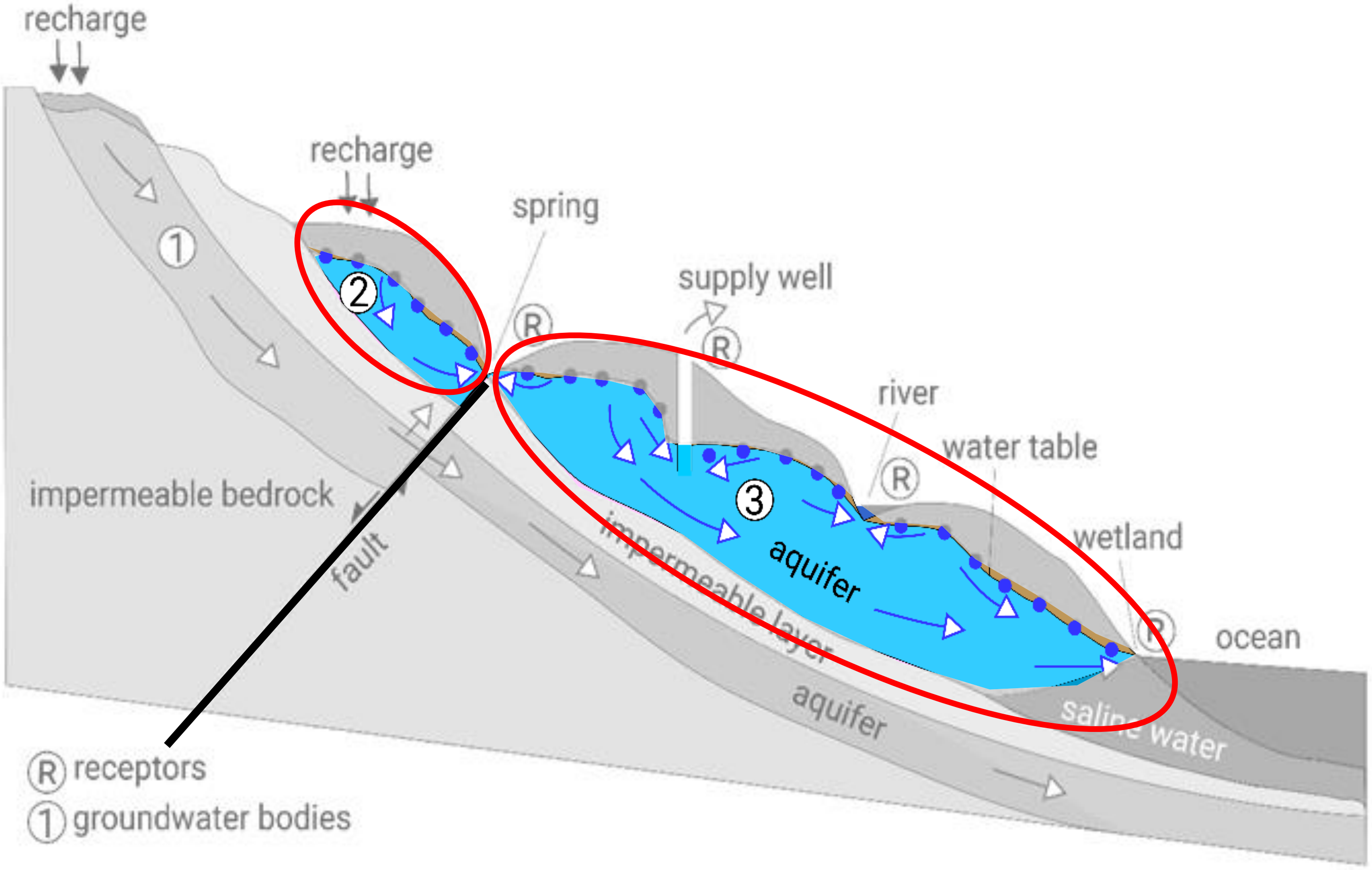
- The upper single **unconfined** aquifer is divided into **two groundwater bodies** (one of which is quite small) by a large fault.



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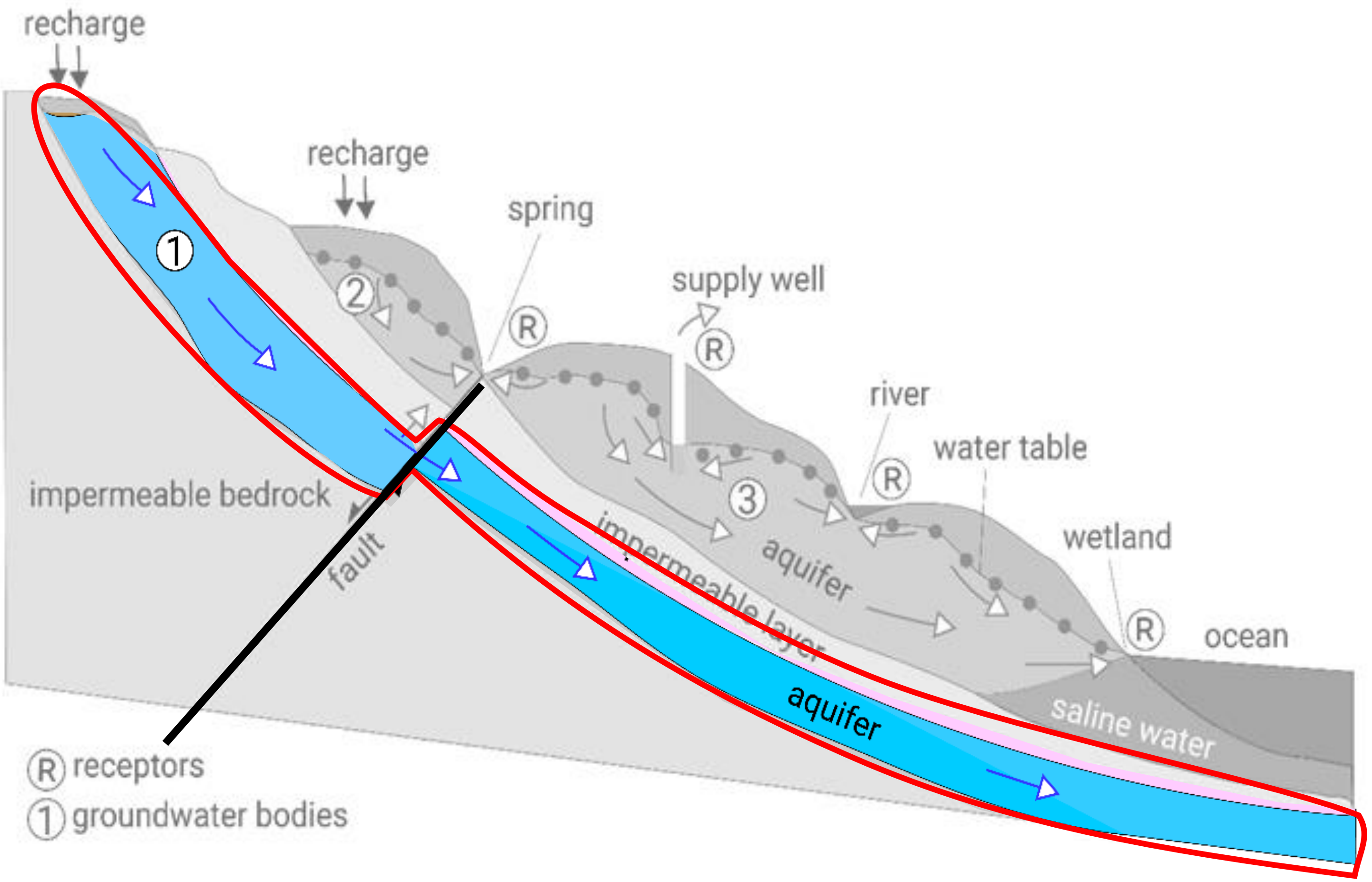
- The upper single **unconfined** aquifer is divided into **two groundwater bodies** (one of which is quite small) by a large fault.
- But for the underlying **confined** aquifer, the displacement of the fault is not sufficient to impede groundwater flow so this remains as a **single water body.**



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As a general rule due to the complexities of aquifers, their vertical dimension in quality variation, and the slow movement, mean that **even relatively small bodies of groundwater are unlikely to be properly represented by one, or even a small number of monitoring points!**

Identifying Aquifers and Defining Groundwater Bodies

Arid and semi-arid countries that have extensive groundwater but little or no surface water can choose to report by **aquifer-based units** in place of RBDs if they prefer.

These aquifers are often:

- deep, thick, flat-lying with low groundwater gradients,
- groundwater residence times measured in centuries rather than decades
- do not receive significant groundwater recharge under current climatic conditions.
- are often heavily exploited, with water quantity management challenges
- well protected against possible quality impacts from land activities
- examples of bodies of groundwater which can be characterised by a small number of sampling points.

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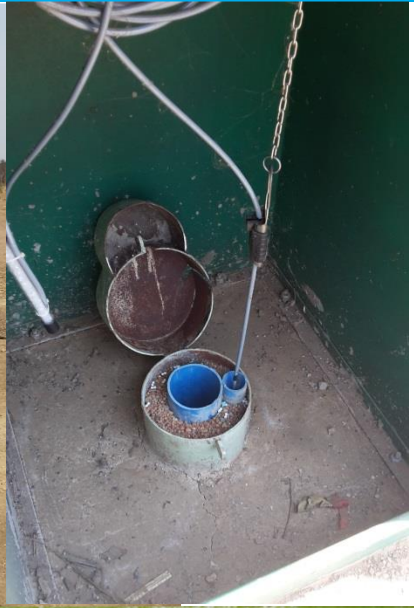
Selecting Sampling Points

If there are a several sampling options, the general location should be chosen to reflect the whole groundwater body, especially the source – pathway – receptor groundwater flow system outlined above.

The network may need to take account of **population** and **land use**, with greater monitoring effort where agricultural, urban and industrial pressures are most prevalent.

Choice may also need to take account of very localised factors around the monitoring point which could influence groundwater quality and the reliability of sampling. Any monitoring points that are seriously compromised in this way should **not be used**.



Selecting Sampling Points

The choice of sampling point type also influences the reliability and representivity.

Samples of groundwater can be taken from existing wells supplying water for **domestic**, **municipal**, **irrigation** or **industrial** uses, from **springs** or from **purpose-built monitoring wells**.

Each has advantages and disadvantages with respect to practicality, cost and technical aspects.

Photo credit: Bruce Misstear

Selecting Sampling Points – Supply Wells

Sampling point Type	Advantages	Disadvantages
Municipal Supply Well	• cheap and easy to sample • repeat sampling, regular visits • high discharge, representative of quality in the aquifer • pumps usually operating • may have existing time series data	• possible uncertain construction and sample source, mixed water from several depths • possible long time-lag after pollution has occurred • locations fixed by population distribution, skews spatial coverage • municipality/water company may not allow sampling

Selecting Sampling Points – Supply Wells

Sampling Point	Advantages	Disadvantages
Irrigation well	• as first three above, but less likely to have existing time series	• as first two above, but less likely to have construction data • spatial coverage skewed to agricultural areas • may operate seasonally only
Industrial well	• as for irrigation well above	• as for municipal well, but less likely to have construction data
Domestic well	• cheap and easy to sample • repeat sampling, regular visits	• low, intermittent discharge, especially with a handpump • may need purging to remove stagnant water from within the well • may be broken down and not pumping • may be shallow and less representative of the aquifer • vulnerable to very local pollution

Where possible, the monitoring wells should be selected from those for which construction data are available!

Selecting Sampling Points – Monitoring Wells

Sampling Point	Advantages	Disadvantages
Shallow monitoring borehole	• may provide early warning of pollutants arriving at the water table • repeat, regular sampling • construction likely to be fully known • inert materials can be used	• moderate construction costs • needs pump to collect sample • care needed to remove stagnant water • not very representative of the aquifer
Multi-level piezometers	• construction should be fully known • inert materials can be used • early warning of pollutants at water table • may indicate vertical stratification of groundwater quality • may indicate vertical head differences and up or down movement of water	• high construction costs • needs specialist contractor and materials • may be difficult to install correctly with good seals between sampling intervals • requires special sampling devices and skilled operator

Selecting Sampling Points – Springs

Sampling Point	Advantages	Disadvantages
Springs	• cheap and easy to sample • repeat sampling and regular visits • large springs may be representative of significant bodies of groundwater • springs used for public supply may have existing time series data	• vulnerable to local pollution sources • may be vulnerable to direct rainfall • small springs may represent superficial flow

Sampling Frequency

The absolute minimum for groundwater sampling should be **once** per year.

Higher frequencies of at least **twice** per year are needed for shallow groundwaters which are sensitive to seasonal influences from rainfall, recharge, pumping and from irrigation, and also those susceptible to urban impacts.

Samples should be taken before and after the rainy season and/or at the times of high and low groundwater levels.

Higher frequencies of at least four times per year are needed for karstic limestones.

Field Operations

Many aspects of field operations for groundwater are the same as those for surface waters:

- **Health and safety** considerations
- standard operating procedure (**SOPs**) to ensure consistency and reliability.
- Quality assurance (**QA**) and Quality Control (**QC**) apply to all steps in the monitoring programme.
- **Field notes** to support interpretation and reporting, and should include the:
  - estimated discharge rate and
  - the length of time the pump has been working, together with
  - observations of conditions around the groundwater sampling point, such as any evidence of very localised pollution impacts.

Photo Credit: USGS/Shelley Niesen.
The photo is in the public domain

Parameter Groups – Level 1 parameters

Reporting is done initially at Level 1

Parameter Group	Parameter	Comments and Reason for Inclusion
Salinity	electrical conductivity	Measure of salinization and helps to characterise the water body
Acidification	pH	Measure of acidification and helps to characterise the groundwater body
Nitrogen	nitrate	Ubiquitous contaminant, stable in oxic conditions, health concern for human consumption
Temperature (T) Should be measured and recorded at the same time as other parameters,		

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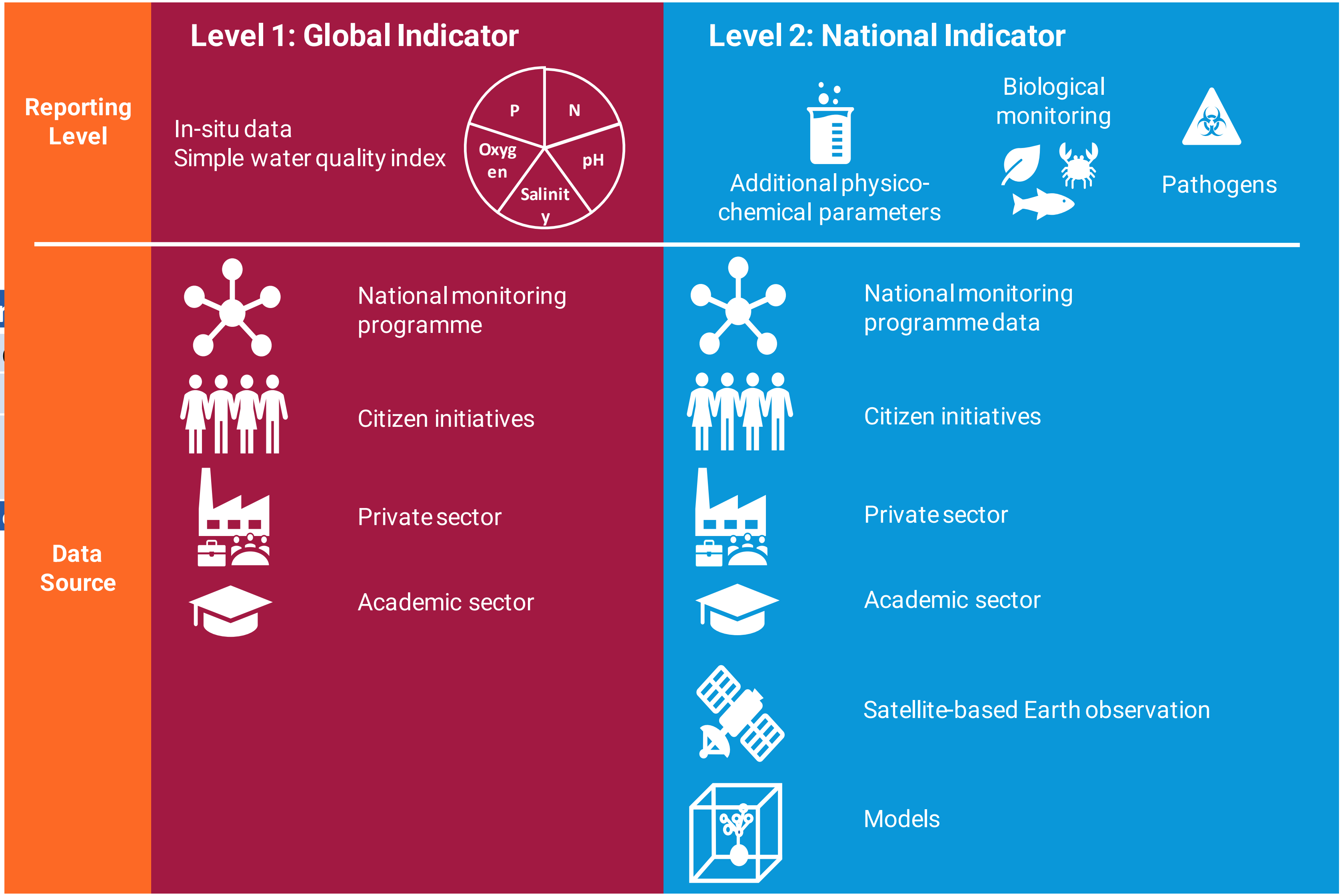
There is the option to report at Level 2



Parameter Groups – Level 2 Parameters

Parameters	
Ca, Mg, Na, K	major cations
Cl, HCO_3 SO_4	major anions
TDS	total dissolved solids
Microbiological Monitoring of Drinking Water Sources sources designated at risk by sanitary inspection	
FC	faecal coliforms
FS	faecal streptococci
E Coli	Escherichia coli
	emerging contaminants

Parameters	
F	fluoride
As	soluble arsenic
U	soluble uranium
NH_4	ammonium
Fe	soluble iron
Mn	soluble manganese
P	orthophosphate
Supplementary Parameters indicative of pollution where specific agricultural, urban or industrial pressures have been identified	specific pesticides
	selected volatile organics
	selected hydrocarbons
	heavy metals
	emerging contaminants

Target Setting

Knowledge of natural background conditions is essential when setting target values for groundwater.

Groundwater quality can be highly variable between aquifers, and higher EC values in a certain groundwater body compared to another may not necessarily represent pollution of groundwater, but simply relate to the hydrological and hydrogeological conditions.

For **EC** targets aquifer or even water body-specific target may be preferable to national targets using a “**deviation from normal**” approach.

For **nitrate** and the associated potential human health impacts, **national** targets are likely to be appropriate.

Summary

- This presentation provides specific technical guidance on monitoring the ambient quality of groundwater in the context of SDG indicator 6.3.2, but greater detail is available from the technical document available on the **Indicator 6.3.2 Support Platform**.
- Monitoring groundwater is more complex than surface water monitoring for several reasons, and as a result fewer countries report on this water body type.
- Aquifers should be identified and groundwater bodies defined using simple conceptual hydrogeological models based on available data.
- The advantages and disadvantages of using existing supply wells, new monitoring wells or springs for groundwater sampling were discussed.
- A proposed framework of parameter groups for groundwater monitoring can be used to identify potential Level 2 parameter groups and to support the establishment or improvement of national groundwater quality monitoring.

Thank you

Indicator 6.3.2 Support Platform

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