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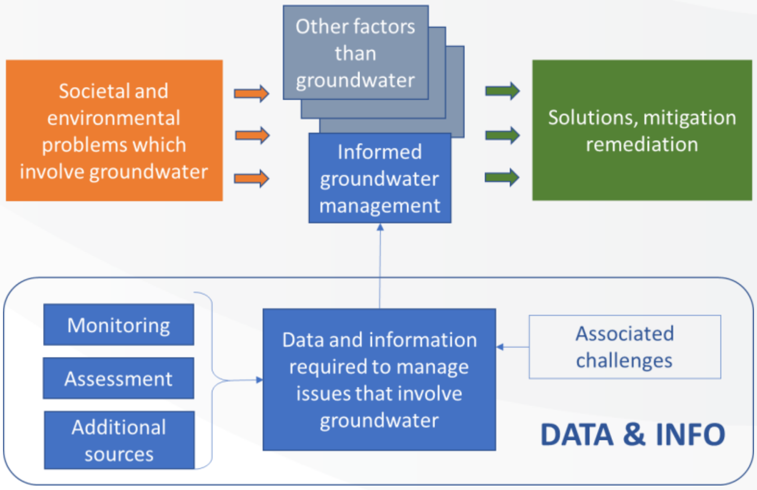
DATA AND INFORMATION

Data and information required for informed groundwater management

Rationale

Many societal and environmental problems involve groundwater. A recent overview reveals that more than 40 United Nations agencies, programmes and affiliated organisations deal with about 65 groundwater-related topics or issues, from food production to sanitation, from climate change to water supply and biodiversity. However, due to the diversity and complexity of issues and hidden character of groundwater, it is often challenging to adequately incorporate it into the water management process. To understand properly the role (provisional, regulatory, societal, supporting) of this important resource within the problem under consideration, and to choose the right management measures, data and information are required.

Most of the data and information necessary for informed management are obtained through groundwater monitoring and assessment. Groundwater management measures may ask for additional data and information, depending on the problem under consideration and the role of groundwater in it. These main sources of data and information are briefly addressed in this overview, along with related challenges.



Data and information needs and sources

Groundwater monitoring and assessment are carried out at various scales (local, state or international) and by various organisations (e.g. governmental, non-governmental and private). The first place to look for existing groundwater data and information are national institutions, such as ministries, geological surveys, hydrometeorological services and water agencies. In some parts of the world, especially those with scarce data, monitoring and assessment outcomes could be available at UN agencies and programmes. Universities and other academic and research institutions may also hold datasets. These organisations also provide regional and global overviews.

Groundwater monitoring is the systematic measurement/observation and recording of the state of an aquifer, which is usually changing due to natural (e.g., change in precipitation pattern) and human (e.g., water abstraction) impacts. Despite the importance of groundwater, the UN Summary Progress Update 2021 on SDG 6 raised the issue of the lack of groundwater data and groundwater monitoring initiatives, emphasizing that groundwater monitoring is a 'neglected area'.

Groundwater monitoring programmes can have various purposes; the most common one is the reference/baseline or ambient monitoring, to identify timely possible unwanted changes such as over-abstraction and pollution. Other purposes include monitoring compliance with regulation standards, contributing to scientific studies, and monitoring the long-term effects of climate and other global changes.

Groundwater needs to be monitored over time in terms of quantity and quality. The most common parameters to monitor groundwater quantity are groundwater levels, spring flow and abstraction. Groundwater recharge is usually estimated rather than directly measured.

Groundwater quality is more complex. It is recommended to include basic parameters (electrical conductivity, pH, temperature, nitrate and chloride), supplementary at lower frequency (major cations and ions, total dissolved solids), microbiological (e.g., faecal coliforms, Escherichia coli), supplementary in specific settings (fluoride, arsenic, phosphorus, and more) and supplementary if specific pressures, often of anthropogenic origin, are identified (specific pesticides, heavy metals and more).

Depending on the purpose, monitoring networks are set up at various scales and with various density and frequency of observations. The frequency of observation depends also on the parameter, but in general (for reference or ambient networks), it is advised to monitor groundwater levels every two weeks to capture trends and seasonality, and groundwater quality parameters at least twice a year (e.g. during the dry and wet season). Highly vulnerable aquifers that provide services to people and the environment need to be monitored more frequently. For some basic parameters, continuous automatic monitoring devices are available.

Groundwater is monitored through terrestrial, in-situ groundwater monitoring networks, sometimes assisted by remote sensing and citizen participation. These relatively new approaches are important to consider, especially in places where conventional data is scarce. Remote sensing techniques have been used by the scientific community to improve

monitoring and estimation of quantitative groundwater resources. Broader stakeholders' participation or "citizen science" initiatives can promote the integration of local knowledge into hydrogeological characterization and groundwater system assessments. These include not only individual citizens but also user associations.

Quality assurance and control measures need to be in place to guarantee that the data collected is reliable, which means that it could be used further for broader scale assessment or decision - making. Once checked, data should be stored, processed and disseminated accordingly (see also "Challenges" below).

Groundwater assessments use monitoring outcomes together with all other relevant information to evaluate the status of the groundwater resource (at that point in time), its usage, possible developments as well as threats to the resource, generally with the purpose of supporting decision-making and planning processes.

For a groundwater assessment, mainly two types of data and information should be considered: time-independent groundwater data/metrics, and non-groundwater data. Examples in the first category are: all data needed for a hydrogeological characterisation (e.g. delineation of hydrogeological units, well and borehole data, etc.), and special data such as zones of groundwater-surface water exchange, zones prone to land subsidence, and others (if relevant). Non-groundwater data encompasses data on physiography and climate (e.g. temperature, precipitation), environmental aspects (e.g. water quality, wastewater control), socio-economic aspects (population, water use, gender aspects), and legal and institutional aspects (e.g. regulations, authorizations).

Additional data and information needs

Measures, tools and instruments (shortly measures) are possible management solutions for groundwater issues. Measures can be about supply, such as securing current supply or increasing it. Other measures target demand for water, in order to decrease it or at least stabilise it. Regarding groundwater quality, many measures on groundwater protection come in the form of regulations. Regulations are elaborated from the groundwater law and/or similar policy documents which determine groundwater governance at national and international level. Any management measures required stakeholders' participation, at various levels and in various forms.

Most of the data and information required for implementation of measures comes from "regular" groundwater monitoring and assessment. However, sometimes additional and/or specific data and information are needed, often related to the applicability of the measure. For example:

- Water recycling via aquifers may be used to sustainably increase supply in urban areas. However, urban water recycling is often conditioned by advanced treatment of reclaimed water as well as social acceptance. Related data should be collected and processed prior to any investment.

- Water metering has many advantages. However, before (further) investment, a proper assessment of the historical water metering data and the socio-economical situation should be made, followed by a benefit- and scenario analysis.
- Groundwater zoning is used regularly to protect groundwater sources from nearby human activities that may compromise its quality. Among others, the zoning asks for specific data on land-use planning, besides detailed data about groundwater quality monitoring in terms of network density and frequency of observations as well as number of measured & analysed variables i.e. possible pollutants. Likewise, delineation of the zones requires extensive knowledge on the groundwater flow regime.

Examples of measures implemented in other areas with similar hydrogeological, environmental and socioeconomic characteristics and statistics are always useful to collect, although some less visible boundary conditions (e.g. acceptance and enforcement) can substantially differ from country to country. Sometimes a combination of methods is needed to deal with an issue. Most measures are not mutually exclusive, on the contrary they are reinforcing or synergistic. The fact that different issues occur simultaneously makes possible interventions even more complex. All these factors should be borne in mind while collecting and processing data and information, avoiding duplication and enabling harmonization across types, sources and sectors.

Challenges

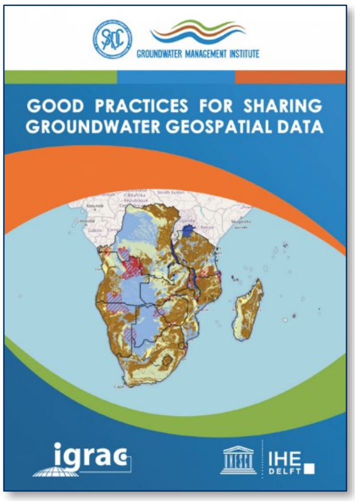
There are a series of challenges to be faced when obtaining and using data and information. The main challenges can be summarised as: duplicated, contradictory and/or non-existent mandates to collect groundwater data; lack of resources; general lack of sharing of data and information; poor data management without proper quality control and assurance; and that data collected is not transformed into useful information.

In many cases, groundwater data are scattered among various organisations, in hardly interoperable formats and poorly processed, and there is rarely an overview of what type of data this is and where it can be found. At the same time, certain types of data are not collected, since there is a lack of guidance on which data should be collected and for what purpose.

There is a lack of resources, both human and financial, in many areas of the world, especially in low- and middle-income countries. Here, hydrogeological capacity is missing, even when groundwater makes up the largest part of the (managed) water resources. When there is no technical capacity, groundwater data cannot be collected and managed in a proper way, and cannot be transformed into useful information and knowledge. In the absence of institutional capacity, groundwater issues are not considered as a priority in the agenda.

A lack of human resources goes hand in hand with a lack of financial resources. If there is not enough funding, it is not possible to hire professionals or to train staff to be in charge of collecting, processing and managing groundwater data, or to design and implement a groundwater monitoring network. Although often relatively expensive, monitoring is a wise investment: identifying problems at an early stage can be highly cost-effective, allowing mitigation measures to be introduced before serious deterioration of the resource takes place.

Access to and sharing of data and information is often deficient, especially in low-income countries. Data and metadata (i.e. information about the data) is commonly not discoverable or shared among the national institutions that need it, and to an even lesser extent this is done internationally. Although it would be highly advantageous if groundwater data collected with public funds were freely accessible, and private companies disclosed relevant data and information concerning subsurface water-related parameters that would improve the assessment and management of groundwater, this is rarely the case. For example, geophysical and borehole data acquired during oil and gas exploration could improve knowledge of aquifer extent and parameters, but is generally not available in the public sphere.



Poor data management gives rise to a series of unnecessary and avoidable problems. For instance, missing metadata (such as georeferencing) that can be easily gathered when collecting data, makes the latter unusable. In addition, when data is not stored in a systemic way, and there are no protocols on how to share it (on what format or frequency), it makes it almost impossible to make use of the data gathered.

When data is not processed and reported, when the reports are not understandable by their target audience (e.g. policy makers, general public) or their objective is not clear, data cannot be transformed into useful information.

Not addressing these challenges may have negative consequences since they cast doubt on the reliability of the data and makes questionable any decision made based on them. A lack of reliable data may result in a poor groundwater assessment, that translates to uninformed (poor) management of the resources. This will inevitably lead to groundwater depletion and/or pollution, resulting in not enough water for all users, degradation of ecosystems, disease, and more. Valuable financial resources and time are wasted when they are spent in collecting data that is unusable, creating reports with no influence/impact, and investing in equipment/software that is not used.

Finally, not addressing these challenges means that data may not be there when urgently needed. For instance, if there is a public health crisis that could have been avoided if the rise of certain contaminants had been identified via groundwater quality monitoring campaigns, or if there is no historical data to understand why an aquifer is depleting and what can be done to reverse this situation.

Take home messages

- Current scientific knowledge in hydrogeology and the methods and tools available are sufficient to address most groundwater management issues. The challenge lies more with their concrete implementation and the scarcity of reliable data for area-specific groundwater assessments and scenario analyses.

- Since all aquifers and their boundary conditions are unique, it is crucial to have groundwater assessments at field level to enable informed policies and management of groundwater resources.
- No groundwater assessment is complete and no reliable prediction can be made without an in-depth analysis of historical data.
- Ensuring that data are findable, accessible, interoperable and reusable (FAIR concept) will support transforming data into useable information for decision making.
- Specific data and information are needed to manage societal and environmental issues that involve groundwater.
- Multiple challenges need to be addressed to ensure informed (ground)water management, such as ownership, financing, data availability, accessibility and quality, etc.
- Raising awareness, increasing citizen participation and lobbying for appropriate monitoring and assessment is of paramount importance for groundwater sustainability.