Plate 8.5 Observation of Groundwater Level and Spring Discharge

Introduction

Groundwater level and spring discharge are easily measured parameters that quantitatively reflect conditions in an aquifer. At a given point and time, groundwater level is defined as the height that water in an aquifer will rise to when a piezometer is installed in it [3]. The groundwater level reflects the degree to which an aquifer system has been filled up, while spring flow represents the quantity of water that freely discharges from such a system. Moreover, groundwater levels and spring discharge reflect complex processes involving aquifer recharge (precipitation and surface water infiltration) and discharge on the one hand, and on the other hand, the geometry, thickness and nature of the aquifer material [2].

Groundwater makes up over 80 % of potable water supplies in Switzerland. Responsibility for the observation and monitoring of this important resource is shared between the Confederation, the cantons, third level institutions and private organisations. The objective of these activities is to follow quantitative variations in groundwater resources in the short term and to appreciate long term changes sufficiently early, be they linked to natural or anthropogenic influences. To achieve these objectives the institutions involved rely on local, regional and national networks. The data is collected from these networks in a consistent manner thus ensuring a sound source of essential monitoring data that can be used for interpreting of long term trends. This information is an important tool that may be employed for the sustainable management of groundwater.

This plate incorporates more than 900 measuring stations (wells, piezometers and springs) currently operating in Switzerland, as well as another 150 points which have been abandoned. For obvious reasons, these monitoring stations are concentrated in areas where the availability and need of water is greatest, namely in the porous unconsolidated deposits in large alluvial river valleys that are often heavily urbanised (cf. plate 8.6). The stations all meet the following criteria:

- operational on 1st January 2003
- part of a long term monitoring network
- providing processed data that are available to the public.
- Defunct observation stations integrated into the plate have been used for monitoring for more than 10 years.

Measurement principles and data acquisition

Groundwater levels are measured by means of installations that provide access to the underground, such as piezometers (vertical tubes in the subsurface having a blank upper part and a screened lower part), pumping wells, or even manometers in the case of artesian aquifers. These measurements can be carried out in a number of ways. Groundwater levels may be measured manually by lowering a water level probe down inside the piezometer/well casing. A meter is connected to the probe by a graduated measuring tape. The meter makes a noise or illuminates a light once contact is made with the water. The graduated tape allows the difference between the water level and a fixed reference point (top of a pumping well or piezometer) to be measured. For mechanical measurements, a float is connected to an analogue recording drum (groundwater level recorder). More sophisticated monitoring stations are equipped with a pressure transducer connected to a digital data logger.

Piezometers normally measure the natural condition of the aquifer. However, this is not the case where the groundwater is affected by pumping wells and its level is disturbed. In fact, when pumping an aquifer, an artificial drawdown in the piezometric surface can be observed around the pumping well. Groundwater hydrographs and the data series generated by them are regularly collected and either digitised or recorded in numerical format. All relative groundwater depth values are subsequently converted to altitudes (m a.m.s.l.) by subtraction from a fixed reference point, before being checked, possibly being corrected, archived and made available to the public.

Spring discharge measurement methods rely strongly on calculations used to determine the flow rate in a water course. In fact, water levels are measured using weirs or flumes of a known cross sectional area at the spring, or in the nearby water course. Water level data collected using floats or pressure transducers are subsequently converted into flow rates using rating curves (plate 5.1[2]).

Factors influencing groundwater quantity – case studies

Due to the complexity of the hydrological cycle, many different factors, which are often interrelated, influence groundwater behaviour.

In a general manner, rainfall entering the aquifer by infiltration is the principal cause of groundwater fluctuation particularly when there is no connection to surface water. This is observed in the Jens, Moos groundwater hydrograph [4], where for precipitation events of a given intensity, the effects on the water table are more attenuated during warm months, associated with strong evapotranspiration, than during cooler months.

In alluvial aquifers, the water table is often intimately linked with the adjacent water course, as is frequently the case in Switzerland. Moreover, compared to the variations observed in the Rhine, levels in the unconfined aquifer as measured at the Felsberg piezometer (N. 6504) [5], consistently follow the changes occurring in the river, while displaying a certain inertia. This results in groundwater fluctuating in a more subdued manner, which is slightly delayed and diffuse in time relative to those in the river.

In settled areas, wells extract large quantities of water and aquifer pumping may draw the piezometric surface down sharply, albeit locally and temporarily, before it gradually recovers to its initial state once extraction ceases (see the Dietikon hydrograph).

In the case of springs, even if meteorological conditions play an equally important role, it is rather the nature and type of aquifer (see plate 8.4) that controls the discharge rate. Three examples illustrate the principal discharge regimes:

The case of Schlichenden Brünnen [5] represents a spring in a karstic setting with most of its catchment at over 1000 m in altitude and having a poorly developed soil cover. Precipitation events result in strong increases in flow rate due to preferential infiltration and rapid circulation in the large conduits of the karst network (caves), followed by a gradual decline resulting from more diffuse drainage through finely fissured rock.

The spring at Pierre Ozaire in Savigny [1] is an outflow from a fissured Molasse aquifer without links to surface water. Its groundwater hydrograph displays a less dramatic behaviour due to the network of fine fissures and the buffering effect of the overlying molassic rock cover that has altered to a sandy silt composition. The influence of meteorological events is minimal, except during prolonged precipitation events which give rise to significant recharge.

The source of the Chalet at Dizy [1] discharges from unconsolidated rocks and has an even more stable behaviour, typical of porous aquifers. Scattered intense spring and summer showers have practically no influence on groundwater level, whereas autumnal rainfall generates more notable responses.

Treatment of long term data

Treatment of long series of data permit trends that are difficult to detect over short periods of time to be recognised, and detailed analyses of the state of water resources to be completed.

The behaviour of groundwater levels at Nebikon, Winkel [5] is simultaneously represented by average water levels for each month and by the mean monthly water levels determined for a number of years (averages are calculated over a 15 year period). On the one hand, this graph of the groundwater balance permits periods when recharge is greater than normal (blue areas) to be highlighted; on the other hand, those periods when recharge is less than normal (grey areas) can be identified. Two phases of low recharge (in 1997–1998, and in 2003) correspond to periods of pronounced drought and associated aquifer drainage, whereas the blue areas represent wetter years with more aquifer recharge.

In order to illustrate long-term spring discharge behaviour, the Source of the Areuse at St-Sulpice [5] has been selected. The contrast between daily mean spring discharge rates for 2002 with the long-term monthly means, and the maxima and minima recorded over a 20 year period, permits trends to be discerned, and by the same process, important information concerning the use of the resource to be derived. Moreover, minimal values are used to define critical and residual flow rates that may be used as a basis to determine a sustainable use of groundwater resources. Similarly, the maxima provide very useful historical information, notably concerning the size of the infrastructure to be installed around springs and the risks associated with flooding.

Schematic hydrogeological models

The gravel aquifer at Felsberg, on the Rhine upstream of Chur, represents a typical example of an aquifer associated with a large river. This type of aquifer consists of well defined unconsolidated deposits found on valley bottoms, often containing alternating beds of partially silty and sandy gravels, characterised by high permeabilities, from which an important proportion of all drinking water is obtained (see plate 8.6). In this type of aquifer, observation of groundwater behaviour is made using piezometers and pumping wells, which act as measurement points that provide access to the water table. Interpolation of data from these points permits groundwater equipotential maps to be developed, whose trend indicates the direction of groundwater flow, which generally occurs perpendicular to the contours. Depending on its location, the aquifer may be recharged by surface water (see situation A), whereas elsewhere groundwater discharges to surface water (see situation B). These trends can reverse depending on the hydraulic regime.

Approximately one fifth of the country’s area is directly underlain by karstified bedrock. The Muotatal aquifer is a typical example of this type of system. Karst aquifers are characterised by double porosity in which water circulation is, at the same time, very rapid through large conduits and a good deal slower through more diffuse finely fissured rock. In this type of aquifer quantitative groundwater observation can be carried out using data collected from springs.

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