Plate 8.6 Groundwater Resources

Introduction

The «Groundwater Resources» map (1:500 000) is a further development of the 1967 edition of the Hydrogeological Map of Switzerland [6]. The principal contents of this map have been established from numerous data [3,4,7] creating a nationwide representation of near surface groundwater resources and their yields. The current map with its associated geographic information system (GIS) has the same database as the Geological Map of Switzerland [1,2]. This map will form the foundation for a further map depicting the vulnerability of groundwater resources and reflecting their susceptibility to pollution.

Hydrogeology Fundamentals

The rate of water movement through a rock or soil (permeability) depends on its lithology and tectonic setting (plates 8.2 and 8.3). A high permeability is one of the prerequisites for the development of a productive groundwater supply. The recharge of groundwater resources occurs through the seepage of precipitation and infiltration of surface water. In regions of karst and rock fall debris, streams can even completely disappear through sinkholes or large voids. From such infiltration zones, groundwater flows through the sub-surface to discharge zones where it is often manifest as springs and feeds surface waters (plate 8.3). Groundwater recharge is seasonally influenced. In regions affected by alpine runoff, maximum recharge to aquifers occurs principally in spring and summer, which is also enhanced by snowmelt. These processes lead to fluctuations in the water table and in spring discharge rates. In addition to controlling factors of recharge such as precipitation, air temperature and vegetation patterns, topographic relief, geologic conditions (geometry, lithology, thickness and permeability of the conductive and confining layers), interaction with surface waters plays an important role.

Groundwater Regions and Use

More than 80 percent of Swiss drinking water requirements are met by groundwater (pumped wells and springs) with the remainder provided from lakes. Half of the groundwater resources are derived from the «very productive» resources of thick gravels in extensive river valleys (about 6 % of the land surface of Switzerland). These groundwater resources are fed to a large extent by infiltrating river water. Since such alluvial gravels possess a high capacity for purification of many pollutants, they constitute the most important drinking water resources of Switzerland. In some extensive valleys (e.g. between the Walensee and Obersee), the gravels are loamy or sandy so that the groundwater resource can be only categorised as «productive». This applies also to raised gravel deposits (i.e. terrace gravels), where there is reduced groundwater recharge (e.g. «Deckenschotter», often moraine-covered).

Carbonate regions with significant underground drainage systems (about 16 % of the Swiss land surface) dominate in the Jura region as well as in the alpine calcareous regions (principally Helvetic Nappes). The karst uplands are characterised as water poor but have water use from springs that are often productive. Such systems are highly susceptible to all types of pollution.

Rock types having less productive groundwater resources generally include the areas of the Swiss Plateau (Molasse sandstones, conglomerates of the Tertiary and gravelly moraines) and the alpine regions (e.g. crystalline rocks of the Central Massifs and Penninic Nappes as well as flysch). Here, groundwater extraction is limited to smaller but locally significant springs, which typify these aquifers.

Rock types having negligible groundwater resources are widespread throughout Switzerland. They serve mostly as aquicludes. In the Jura they are characterised by clay-rich strata, in the Swiss Plateau by marly Molasse deposits and Quaternary clayey silts. Aquicludes of alpine regions are represented by sedimentary and metamorphic rock sequences. In almost all locations there are thin layers of permeable unconsolidated materials (e.g. talus deposits). Small- and moderate-sized springs emanate from these aquifers, which are underlain by sediments of lower permeability.

Groundwater Resources in Unconsolidated Sediments

The most productive groundwater resources are in the coarse-grained unconsolidated porous deposits. Within this «very productive» category of groundwater resources (principally valley gravels, plate 8.4), the productivity or yield is differentiated principally based on the thickness of the saturated zone (usable saturated thickness). The permeability, lithology and hydraulic connection to surface waters are other factors which are taken into account. Coarse-grained scree deposits as well as loam-poor gravels both at the periphery and outside of the valley bottom areas may also exhibit a high permeability and substantial thickness. However, these deposits are often drained to a great extent. As a result, they are only classified as «productive». Groundwater resources in moraine deposits and in fine- to medium-grained scree deposits are in the «low productivity» category. Locations without any productive groundwater resources are associated with clay, silt, fine sands and loamy moraine deposits or areas with protective covers of relatively low permeability.

Groundwater Resources in Consolidated Rocks

In some locations, karst-prone areas of limestone- and dolomite-dominated sequences have more productive groundwater resources than those of other hard rock areas (cf. lithologic columns of representative tectonic units). Groundwater commonly circulates quickly in a system of fissures, channels and caverns. These features have been formed by the processes of dissolution acting on joints in the rock (e.g. plate 8.4). However, while there are some high-yield springs present in karst regions, these areas do not have the productivity of the extensive alluvial valley gravels. Similarly, evaporite deposits (sulfate and rock salt) can also exhibit karst morphology but have reduced groundwater resources which are highly mineralised. Fissured, occasionally porous types of hard rock exhibit «variable» and «low productivity» groundwater resources. The latter category includes inter-layered claystone, marl, sandstone and conglomerate rocks, in which the water circulates primarily along fractures and secondarily through pores, resulting in numerous smaller springs that have not been shown on the map. In the massive crystalline rocks (e.g. granite), water circulates preferentially along fractures and discontinuities and in near-surface disturbed and fractured zones. Locations without any productive groundwater occur in marl, claystone and shale. As a rule metamorphic rocks (e.g. shists and gneiss) also fall within the «very low productivity» category. These types of rocks function as «aquicludes» confining more permeable strata.

Low Permeability Protective Cover

Specificly identified are areas where potential «highly productive» groundwater resources are overlain by thick low permeability covers which act to protect them (e.g. loamy moraine deposits). Direct recharge is thus diminished in these regions.

Multi-layered Aquifer Systems

Groundwater systems with multiple layers occur where different aquifers overlie one another. They are separated by confining aquicludes (e.g. in glacially cut valleys) or they may be hydraulically connected with each other (e.g. gravels over limestone). Deep multi-layered groundwater resources of the unconsolidated formations of the Swiss Plateau region are also shown on the map. Until now, they have remained relatively undeveloped, due to their high mineralisation. These resources are better suited for heating purposes rather than for drinking water. Deep multi-layered groundwater circulation systems are illustrated on plate 8.3.

Groundwater Chemistry

The chemical characteristics of groundwater in the major aquifer types are presented in plate 8.4. The current map indicates only areas of groundwater which have high mineralisation and/or oxygen-depletion. The high level of mineralisation results from natural leaching processes which release chlorides and sulfates into the groundwater from readily soluble rocks (i.e. sulfate, rock salt). Reduced levels of oxygen commonly occur in moor, wetland and bog regions as a result of reducing conditions in their peat layers.

Groundwater Management

Data depicting groundwater circulation (e.g. flow direction) are marked in blue, infiltration/recharge zones (e.g. seepage locations) in red and discharge zones (e.g. drainage canals) in green. The selection of important springs and production wells represents groundwater usage. Springs are subdivided according to flow rate (greater or less than 600 l/min). Important thermal (water temperature greater than 20 °C) and mineral springs (mineralisation greater than 1 g/l) are also shown [5]. Practically all groundwater production wells are located in alluvial gravels of large river valleys. They are displayed according to their licensed extraction rate (greater or less than 5000 l/min). In locations of high productivity, adjacent springs and pumping wells are often shown together for ease of display. In areas of low productivity, even smaller springs or production wells are shown as they are indispensable as a drinking water supply. River engineering structures such as weirs and retention basins can increase infiltration along their length, but can also impair groundwater chemistry if the river water quality is poor. Facilities exist to artificially recharge groundwater for drinking water supplies (e.g. Geneva, Basel, Zurich). River water is diverted to recharge the upstream stretches and this water is then produced from groundwater zones further downstream. Drainage ditches serve as discharge zones for cultivated lands being dewatered (agricultural drainage practice) and act to regulate the level of the groundwater table. Only larger facilities of this type are displayed.

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References

[1] **Bundesamt für Wasser und Geologie (in Vorbereitung):** Geologische Karte der Schweiz 1:500 000. Bern.

[2] **Bundesamt für Wasser und Geologie (in Vorbereitung):** Tektonische Karte der Schweiz 1:500 000. Bern.

[3] **Bundesamt für Wasser und Geologie (ab 1862):** Geologische Spezialkarten der Schweiz (verschiedene Massstäbe). Bern.

[4] **Bundesamt für Wasser und Geologie (ab 1930):** Geologischer Atlas der Schweiz 1:25 000. Bern.

[5] **Högl, O. (1980):** Die Mineral- und Heilquellen der Schweiz. Bern.

[6] **Jäckli, H., Kempf, T. (1967):** Hydrogeologische Karte der Schweiz 1:500 000. In: Atlas der Schweiz: Tafel 16, Wabern-Bern.

[7] **Schweizerische Geotechnische Kommission (ab 1972):** Hydrogeologische Karten der Schweiz 1:100 000. Zürich.