Does groundwater pose a risk to underground structures, or do underground structures pose a risk to potential groundwater resources?

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Abstract: Groundwater not only poses a risk to underground structures, but such structures also pose a risk to groundwater resources. These risks have to be recognized, assessed and minimised in order to provide for the greatest possible protection of the groundwater resources. This paper presents results from two tunnels constructed in the Lower Inn Valley, Austria and their impact on the groundwater systems.

Key words: groundwater resources, tunnelling, monitoring, risk assessment, Austria

INTRODUCTION

Groundwater constitutes a dominant factor during the construction of tunnels. It may slow down the construction progress, necessitate more costly excavation concepts or even lead to an abandoning of the tunnelling. However, it is clear that tunnels may also have significant effects on the environment. The effects manifest themselves on the one hand as quantitative impacts and on the other hand as qualitative consequences. These changes to the groundwater system have to be monitored and minimised in order for a tunnelling project to gain acceptance and to ensure the greatest possible protection of the groundwater.
This paper using examples from two reconnaissance tunnels which have recently been excavated using mining techniques (NATM), in the Lower Inn Valley, Tyrol, Austria, for the Munich-Verona High Speed Railway Project - see also Schwarz[3] in this edition.

THE INGRESS OF KARST WATER DURING TUNNEL ADVANCE IN STABLE HARD ROCK

Overview

During the construction of the Vomp East Reconnaissance Tunnel in the year 2000, four sudden and large discrete water ingresses (approx. 50 l/s) occurred in karstified Wetterstein limestone, which was partially linked to each other over an intercommunicating chute system. An impact on the groundwater system could not be ruled out. In the stable hard rock the construction of the tunnel was not effected significantly.

Monitoring programme

In order to ascertain the extent of the draw-down due to these ingresses, the existing above ground hydrological monitoring programme was intensified and additionally coupled with measurements of the water ingresses in the tunnel.
The interval of measurements was increased from a 14 days (as required by the public authorities) to daily measurements. At the ingress points, in the monitoring wells (boreholes

to tunnel level) and at the springs the parameters water level/discharge, temperature and electrical conductivity were recorded. In addition, chemical and isotope sampling ($\delta^{18}O$, $\delta^{3}H$) at 4 week intervals was carried out.

Weather-specific annual variations and assessment of impact

Downstream of the reconnaissance tunnel a water supply (spring) is located. The water of this spring and the water ingress in tunnel show a similar hydrochemical and isotopic composition (see Fig. 1).

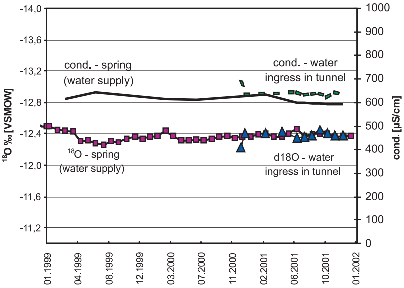

Figure 1. $\delta^{18}O$-Values and electrical conductivity from the spring and the water ingress in tunnel

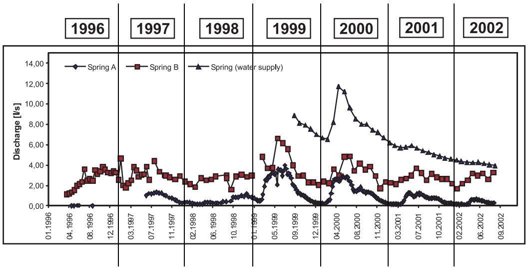

Figure 2. Long-term spring discharge hydrographs from the Lower Inn Valley, Austria

At that time (2000/2001) it appeared that there was no impact on the water supply, as the discharge of this spring showed no sudden decrease. Therefore an approach was adopted which involved assessing the weather-specific annual variation of other springs and making comparisons using discharge hydrographs. The springs selected for this are located in differing geological formations from within the entire project area, however they show comparable discharge characteristics (see Fig. 2).

Conclusions

Using this comparative approach, it seemed unlikely in 2001 that the water supply was affected. However, as a result of the continued long-term monitoring it has become apparent that the water supply has been affected (2002/2003).

The examples show that impacts resulting from tunnelling, which cannot be directly deduced from the hydrographs of the measuring points, are difficult to interpret when the monitoring period is too short. Especially extreme hydrological variations make an interpretation more difficult and may result in a misjudgement of the situation. The most important prerequisite is long-term collection of data and a multimethodical approach for an extensive data basis, which allows a distinction between weather specific, and anthropogenic impacts.

TUNNEL ADVANCE IN HARD ROCK CONTAINING FAULT ZONES

Overview

In the Brixlegg East Reconnaissance Tunnel, a water ingress (25 l/s) coupled with the flushing out of a large amount of material occurred during drilling works for anchors in dolomite. In the course of a lithostructural and hydrogeological investigation programme a water-saturated fault zone containing unconsolidated material was detected ahead of the face and to the side of the tunnel (SAUSGRUBER[4]). Due to the geomechanical conditions of this fault zone, and the high water pressures (up to 5 bar), further tunnelling using conventional methods was not feasible without a reduction of the groundwater pressure, so the tunnel advance had to be temporarily discontinued. With regards to the construction problems refer to SCHWARZ[3]. At the time, hydrological monitoring indicated a possible connection to a health spa, which is located at a distance of app. 600m from the site of the water ingresses. After an unsuccessful large-scale injection test (REICHL[2]), a draw-down test was conducted which was officially approved by the public authorities.

Monitoring programme during artificial draw-down

In order to exactly monitor the hydrological and water economic effects of the draw-down, an extensive hydrological and geotechnical monitoring programme was carried out, with predetermined criteria for discontinuing the experiment.

In total, 57 above and below ground hydrological and 60 above and below ground geotechnical measuring points were monitored. At the hydrological measuring points the parameters discharge/water level, temperature and electrical conductivity were manually recorded up to 4 times per day (app. 50000 manual measurements in 99 days). Above ground, the monitoring wells and springs in the immediate vicinity of tunnel were equipped with automatic data acquisition systems. In the tunnel, an automatic data acquisition system (Solexperts-GeoMonitor) was installed, which measured water pressure, discharge, water quality and rock deformation. Further, hydrochemical and isotope analyses ($\delta^{18}O$, $\delta^{3}H$ and $\delta^{34}S$) were performed at regular intervals at the above ground and below ground measurement points.

Geohydraulic and geo-chemical analyses

In order to be able to explore better the hydrological and geotechnical properties of the fault zone the following analyses were performed under draw-down conditions in the horizontal cored boreholes drilled from inside the tunnel: Tracer tests, impeller flowmeter tests, electrical conductivity/temperature logs, pressure profiling and depth-oriented sampling.

Results

The feasibility of using drainage to recommence tunnelling was demonstrated during the 10-week long draw-down test. The hydraulic head close to the tunnel face was lowered 40 m under a “steady-state” discharge rate of app. 28 l/s. The draw-down of the regional groundwater table occurred mainly along the fault zone, affecting mainly aquifers bearing sulphate-rich water. One of these aquifers being an economically important spa-water resource, which is located at a distance of app. 600 m west of the actual tunnel face. Here a corresponding head change of 1.8 m was recorded. Temporary changes in the water chemistry were also recorded here and at other locations, even when the induced head change was less than 1 m (see Fig. 3). The data suggests that the perimeter of impact was restricted to the extension of the fault zone.

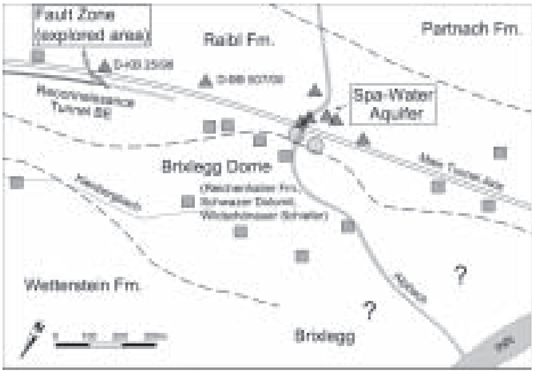

Figure 3. Schematic Map showing known area of fault zone and measuring points locations classified with respect to the response of the draw-down (triangles = reaction water level/discharge and electric conductivity; circles = reaction electric conductivity, squares = no reaction)

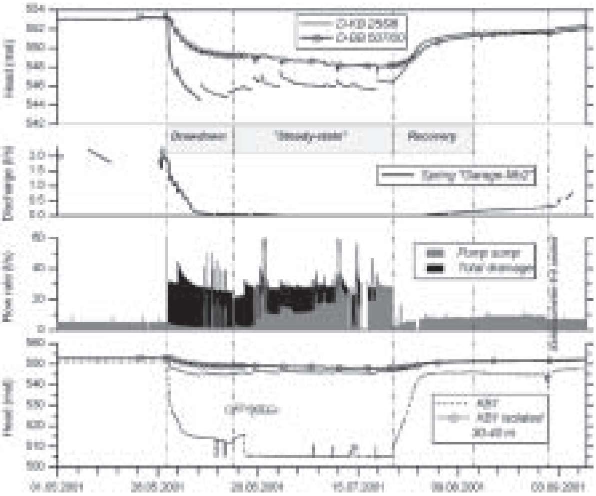

Figure 4. Overview of draw-down curves at selected monitoring locations

The draw-down test also showed that the effects of the temporary change in regional groundwater level are largely reversible (see Fig. 4). This means that under specific boundary conditions further tunnelling is economically feasible if all the relevant supporting measures and a lining, which can sustain the full water pressure, are installed.

Conclusions

Groundwater monitoring and tunnelling requires an interdisciplinary approach on site. Basic and comprehensive collection of data and the carrying out corresponding exploratory tests are needed. When interpreting the data from monitoring wells and springs or water supply facilities (wells), the long-term trend should always be taken into account in order to be able to better assess the variations. Furthermore, long-term collection of chemical and isotopic data also helps considerably in the evaluation of influences. The examples mentioned, point the way towards successful conflict-solving between tunnelling and water economics with regards to methodological and procedural issues as well as the actual excavation methods.

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