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"Arteser Aktionsprogramm" for sustainable deep groundwater resources management, example of the municipality of Grafendorf bei Hartberg

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Abstract

The department for Water Management, Resources and Sustainability of the Styrian Government, conducted the "Arteser Aktionsprogramm" to decommission or redevelop old artesian drillings and/or wells. The activities should ideally lead to an increase in the water levels and flow rate in the redeveloped state of the art artesian wells.

The regeneration of deep groundwater systems can primarily be proved in regions where as many wells as possible are professionally deconstructed or redeveloped. This is documented at the municipality of Grafendorf bei Hartberg, where observation data of the water level and flow rate are available and show impressive results: After the deconstruction of 59 artesian wells in Grafendorf the water levels rose considerably and flow rates in the state of the art wells increased by a factor of 20. So the sustainable application of the "Arteser Aktionsprogramm" could be verified.

Die Abteilung 14, Wasserwirtschaft, Ressourcen und Nachhaltigkeit, des Amtes der Steiermärkischen Landesregierung führte das „Arteser Aktionsprogrammes" durch, um alte artesische Bohrungen und/oder Brunnenanlagen zu sanieren oder rückzubauen. Die getätigten Maßnahmen sollten im Idealfall einen Anstieg der Druckspiegel hervorrufen und die Schüttung der dem Stand der Technik entsprechenden, artesischen Brunnenanlagen erhöhen.

Natürlich ist die nachhaltige Verbesserung der Tiefengrundwasserverhältnisse in erster Linie dort nachzuweisen, wo möglichst viele Brunnen saniert oder rückgebaut werden. Zur Dokumentation bietet sich daher die Marktgemeinde Grafendorf bei Hartberg an, da hier auch diverse Messungen hinsichtlich Druckspiegel und Schüttungsmengen durchgeführt werden konnten.

Die Ergebnisse sind beeindruckend: Nach dem fachgerechten Rückbau von 59 artesischen Brunnenanlagen in Grafendorf stieg der Druckwasserspiegel signifikant und flächendeckend an, die Schüttung bei dem Stand der Technik entsprechenden Brunnen erhöhte sich bis auf das Zwanzigfache. Der nachhaltige Nutzen des Arteser Aktionsprogrammes konnte somit nachgewiesen werden.

1. Introduction

Deep groundwater with an age of 50 years and more is used for the drinking water supply in many regions on earth. An appropriate chemical and physical quality as well as a sufficient yield are the necessary prerequisites. The regeneration of deep groundwater depends on a sustainable production and use.

Shallow aquifers are often highly vulnerable and the sustainable use is endangered by the negative impacts of droughts and threshold exceedance of quality targets related to contaminants such as nitrate or pesticides or even nuclear hazards. Thus, deep groundwater is increasingly important for sustainable drinking water supplies. Only water with a residence time of several decades guarantees a proper supply of unpolluted water in sufficient quality in case of emergency. Therefore, deep groundwater should not be wasted.

Low precipitation, high evapotranspiration and poorly productive shallow aquifers forced the inhabitants of Eastern Styria to use deep groundwater systems. This was the reason why the artesian groundwater exploration began at the end of the 19th century and increased in the first half of the 20th century. Most of the artesian wells were drilled by hand using standpipes with a length of only ten to twenty meters. The pipes are not necessarily completely developed as potential borehole collapses might occur along incomplete casing or open-hole sections with instable sediments. Therefore, such insufficient well developments enable uncontrolled groundwater flow and lead to groundwater waste. Furthermore, it can be observed that different layers of multi layered aquifer systems are hydraulically connected and thus influence each other quantitatively and qualitatively.

The deconstruction process of these older wells with a diameter of less than 2 inches and distorted and corroded pipes was normally avoided because of too many unknown factors and risks. In addition, these older artesian wells are often situated at locations that are not accessible for standard drilling equipment.

In Eastern Styria about 200 l/s of high-quality drinking water are wasted as a result of its uncontrolled overflow (Joanneum Research et al., 2005). It was high time to establish a program for saving deep groundwater sustainably, which was done with the "Arteser Aktionsprogramm". This program provides funding to cover 70 % of the costs by the Federal Government

of Styria, if artesian wells are decommissioned and professionally deconstructed (Ferstl, 2014).

2. Geographical overview and hydrogeology

Grafendorf bei Hartberg and the surrounding areas are located about 50 km northeast of Graz at the northern margin of the Styrian basin (Figure 1), a deep sedimentary basin in the southeast of the Eastern Alps. The Middle Styrian Swell separates the shallow Western from the deeper Eastern Styrian Basin (Figure 2).

The basement of the Styrian basin is made up of crystalline rocks dipping steeply into depth in the west and northwest of Grafendorf bei Hartberg. The basin is filled with neogene sediments reaching a thickness of up to 3.000 meters near Fürstenfeld (Figure 2).

Figure 1: Geographical overview (source: GIS-Steiermark, 2015)

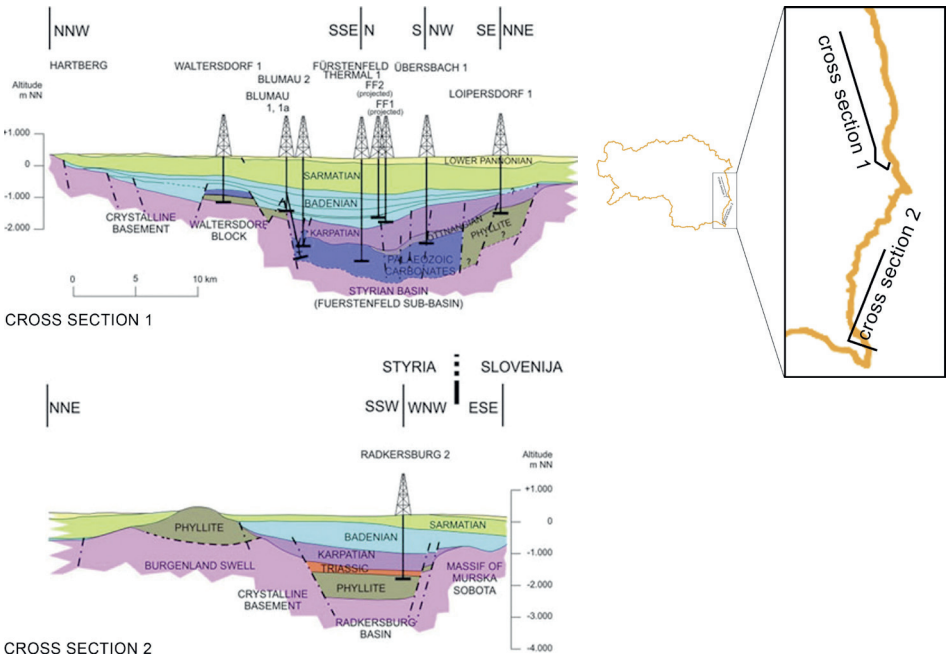

Figure 2: Cross section of the Styrian and Pannonian valley (modified after Goldbrunner, 2013;)

Sedimentation in the central Eastern Styrian Basin started during the Ottnangian with the deposition of basement breccias, red soils and thin coal seams, followed by shales, bituminous marls and coaly layers.

Extension increased during the Karpatian and several hundred meter thick calcareous mudstones and siltstones (Steirischer Schlier) were deposited in the southern part. Synchronous volcanic activity in the Styrian Basin led to the buildup of huge shield volcanoes (Sachsenhofer, 1996).

The northern part was subjected to a strong fluvial input of coarse clastic sediments partly forming polymictic conglomerates.

During the Badenien sedimentation continued with coarse clastic sediments, while magmatic activity continued and shifted northward (Ebner and Sachsenhofer, 1991).

The sediments, which were deposited during the Sarmat, consist of clay, sand and sandstones. Except for the clay layers, these sediments form the most important aquifers for the drinking water supply. The Sarmatian sediments are covered by fine clastic Pannonian layers consisting of clay with some sand and gravel lenses, but there are also some valleys with coarse sediments formed by fluviatile erosion and later buried (Feistritz and Safen valley). The Pannonian clay layers are characterized by a very low hydraulic conductivity. Pleistocene terraces are geographically widespread and represent the top of the deposits.

In Grafendorf bei Hartberg there are 82 artesian wells listed in the database at the Department for Water Management, Resources and Sustainability. An update in 1997 showed that 81 still existed but only eight wells were developed at today's technical standard based on ÖWAV (2015).

There are a lot of publications referring to the location of aquifers, hydrochemistry, isotope analysis, and the age of artesian groundwater observed at test boreholes in Grafendorf (Janschek, 1975; Joanneum Research et al., 2005; Küpper, 1975; Polesny, 1975;

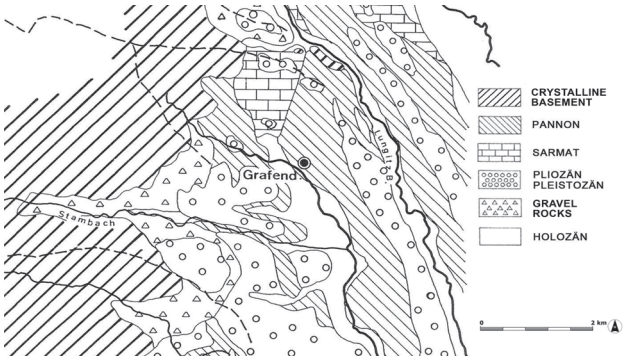

Figure 3: Geological map (modified after Zötl, 1972)

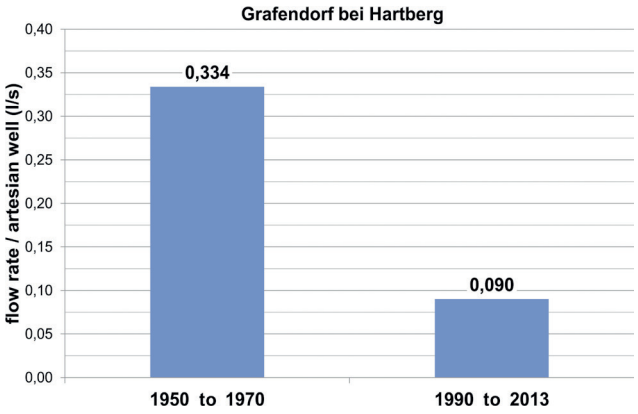

Figure 4: Average flow rate of artesian wells in Grafendorf bei Hartberg (Geologie & Grundwasser GmbH, 2013; modified). Deviations of previous explained values result from well losses; in 1950 only 75 wells were developed.

Zetinigg, 1972, 1982; Zötl, 1972, 1983). To explain all results and explorations in detail would be beyond the scope of this discussion.

In the 1950s these wells showed an artesian pressure of about 3.0 bar and an artesian overflow of about 25 l/s. In the 1970s an artesian pressure of more than 0.5 bar was still documented (Zetinigg, 1972). The artesian overflow decreased gradually to a value of 6.75 l/s in 2013 (Geologie & Grundwasser GmbH, 2013).

According to Zetinigg (1972) the wells in the cadastral municipality Grafendorf reached the crystalline basement at a depth of 182 m below ground surface and were developed with screen sections at five different aquifer layers with varying pressure heads. In the cadastral municipality of Seibersdorf three different aquifers with varying pressure heads were identified down to a depth of 125 m (no basement reached), and in the cadastral municipality of Obersafen four different aquifers were proved with varying pressure heads down to a depth of 170 m (no basement reached).

3. Professional deconstruction of the artesian wells

During April and August 2013 59 artesian wells were deconstructed in a stepwise manner with a standardized procedure described below.

The standardized procedure and workflow (according to ÖWAV, 2015):

- If there is no information about the well a camera inspection is required.
- It's recommended to flush the well down to the final depth. If the final depth can't be reached, it's necessary to reach at least the end of the tubing.
- A locking device (pressure valve or packer) has to be installed on the standpipe to enable an injection from above.
- The flow rate and the hydraulic head of the well have to be measured.
- Inspection of the well by a circulation process with water to prove if the suspension is injectable in the well is required.
- A tube with a diameter of at least 0.5 inches has to be inserted down to the final depth of the borehole.
- Injection equipment with the possibility to measure and record pressure and quantity of the used suspension has to be installed.
- A cement-clay-mineral-suspension with a density of about 1.6 g/cm^3 and a marsh-time of minimum 40 seconds has to be prepared.
- The injection has to be prepared and performed in a batch-wise process to guarantee the optimal quality. Specific density and viscosity have to be ascertained.
- The borehole has to be filled from the bottom up to the ground level with this injection suspension, the tube has to be pulled out successively.
- After the injection process from the bottom up to the ground level and a following consolidation time, a final injection from above is required until the injection pressure increases significantly.

Figure 5: Photo documentation of the standardized procedure

4. Results

59 artesian wells in Grafendorf bei Hartberg were professionally deconstructed by applying the standardized procedure. The injection campaign yielded impressive results. Three reconstructed artesian wells nearby, which were drilled to comparable depths and developed in the same aquifer systems, showed a significant increase of the hydraulic heads. Prior to the injection campaign of the 59 artesian wells, the

pressure heads of these three wells were just over 0 bar and increased to about 0.7 bar after the injection of the 59 artesian wells. Additionally, the total flow rate increased from 15 l/min to 330 l/min. The data were provided by the Bezirkshauptmannschaft Hartberg (2013).

After the adaptation to the technical state of the art one additional reconstructed artesian well in the cadastral municipality of Obersafen showed an increase in the hydraulic pressure from 0.1 bar to 2.2 bar after the injection campaign of the 59 artesian wells. The flow rate of this artesian well increased from 3 l/min to 100 l/min.

The artesian well Grafendorf III (neu) of the Stadtwerke Hartberg is equipped with a pressure sensor (data logger) observing the water level above the sensor in the well every fifteen minutes. Figure 6 shows the time series of the relative water pressure above the data logger, which vary slightly between 5.1 and 5.3 bar. In April 2013 the decommissioning activities of the Arteser Aktionsprogramm began. During this period the water pressure (Figure 7) fluctuated between 5.1 and 5.4 bar as a result of the deconstructing processes. After the decommissioning activities the water pressure increased significantly and reached nearly 6.0 bar. An increase in the water level of roughly 0.8 bar could also be observed in this artesian.

Therefore, the success and the sustainable use of the "Arteser Aktionsprogramm" could be verified impressively.

5. Conclusions

The deconstruction of (artesian) wells with the assistance of packers and sleeve pipes is a well-known standard procedure for wells which were developed in the last decades with a diameter of 2 inches or more as it is state of the art. But the deconstruction of older wells with a diameter of less than 2 inches and distorted and corroded pipes was normally avoided because of too many unknown factors and risks. In addition, these older artesian wells are often situated at locations that are not accessible for standard drilling equipment.

175 artesian wells were deconstructed since the "Arteser Aktionsprogramm" was launched in 2008. The now standardized procedure and workflow guarantees a decommissioning process without underground damage or leakage while eliminating the uncontrolled use and waste of artesian groundwater at the surface. In addition, the redeveloped wells avoid the hydraulic short circuiting of different layers of multi layered aquifer systems influencing each other quantitatively and qualitatively.

The standardized procedure and workflow operate effectively, so they were implemented in the guidelines of the ÖWAV (2015).

One main goal of the office of the Styrian Government, department for water management, resources and sustainability is to provide an appropriate chemical and physical drinking water quality and a sufficient yield while covering the water demand even in times of negative impacts such as during droughts and the threshold exceedance of quality targets related to contaminants such as nitrate or pesticides or even nuclear hazards.

With the "Arteser Aktionsprogramm" in the regional ground water system of the Styrian basin a state of equilibrium might be reached again. Nevertheless, it will take several years, joined forces and financial resources, but a first step is done.

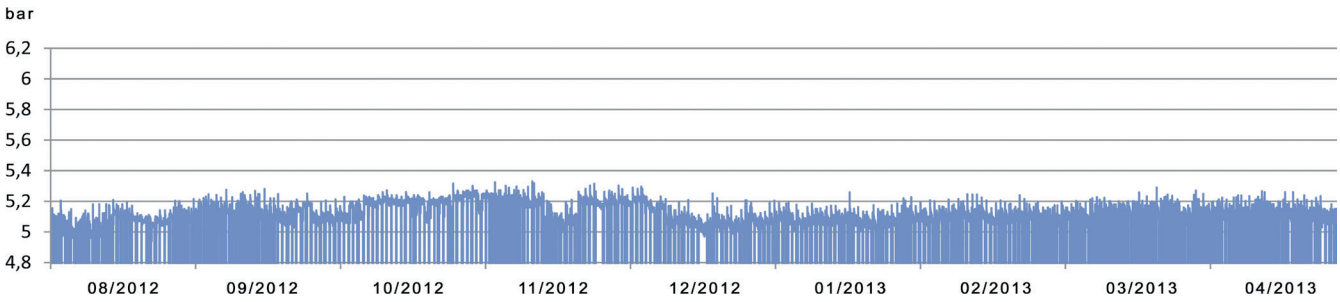

Figure 6: Water pressure above data logger sensor of the main aquifer in the artesian well Grafendorf III (neu) of the Stadtwerke Hartberg before the decommissioning process

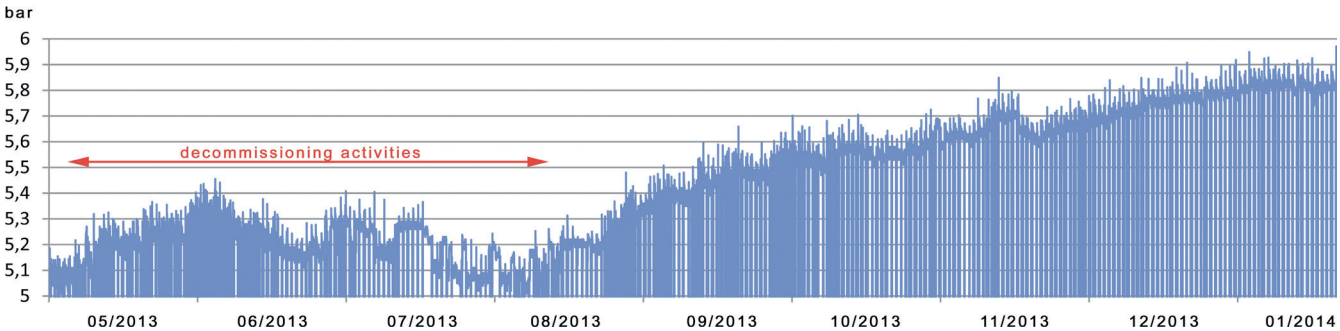

Figure 7: Water pressure above data logger sensor of the artesian well Grafendorf III (neu) of the Stadtwerke Hartberg during and after the decommissioning process

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