02.12 Groundwater Levels of the Main Aquifer and Panke Valley Aquifer (Edition 2006)

Overview

The exact knowledge of the current ground-water levels, and hence also of groundwater stocks, is imperative for the State of Berlin, since 100% of the drinking-water supply (approx. 212 million m³ in 2005) is obtained from groundwater. This groundwater is pumped at nine waterworks, almost entirely from the city's own area. Only the Stolpe Waterworks on the northern outskirts obtain water from Brandenburg, but also supply Berlin (Fig. 1).

Fig. 1: Location of the nine waterworks supplying Berlin with drinking-water in May 2006

Moreover, groundwater reserves are tapped for in-house and industrial use, as well as for major construction projects and heating-related purposes. Numerous instances of soil and groundwater contamination are known in Berlin, which can only be rehabilitated on the basis of exact knowledge of groundwater conditions.

Definitions Regarding Groundwater

Groundwater is underground water (DIN 4049, Part 3, 1994) which coherently fills out the cavities in the lithosphere, the movement of which is caused exclusively by gravity. In Berlin, as in the entire North German Plain, the cavities are the pores between the soil particles in the loose sediments. Precipitation water which seeps (infiltrates) into the ground first of fills out these pores. Only that part of the infiltrating seepage water which is not bound as adhesive water in the non-water-saturated soil, or used up by evaporation, can seep to the **phreatic surface** and form groundwater. Capillary water within the unsaturated soil zone is situated above the groundwater surface which is able to arise to different hight, due to the type of soil (Fig. 2).

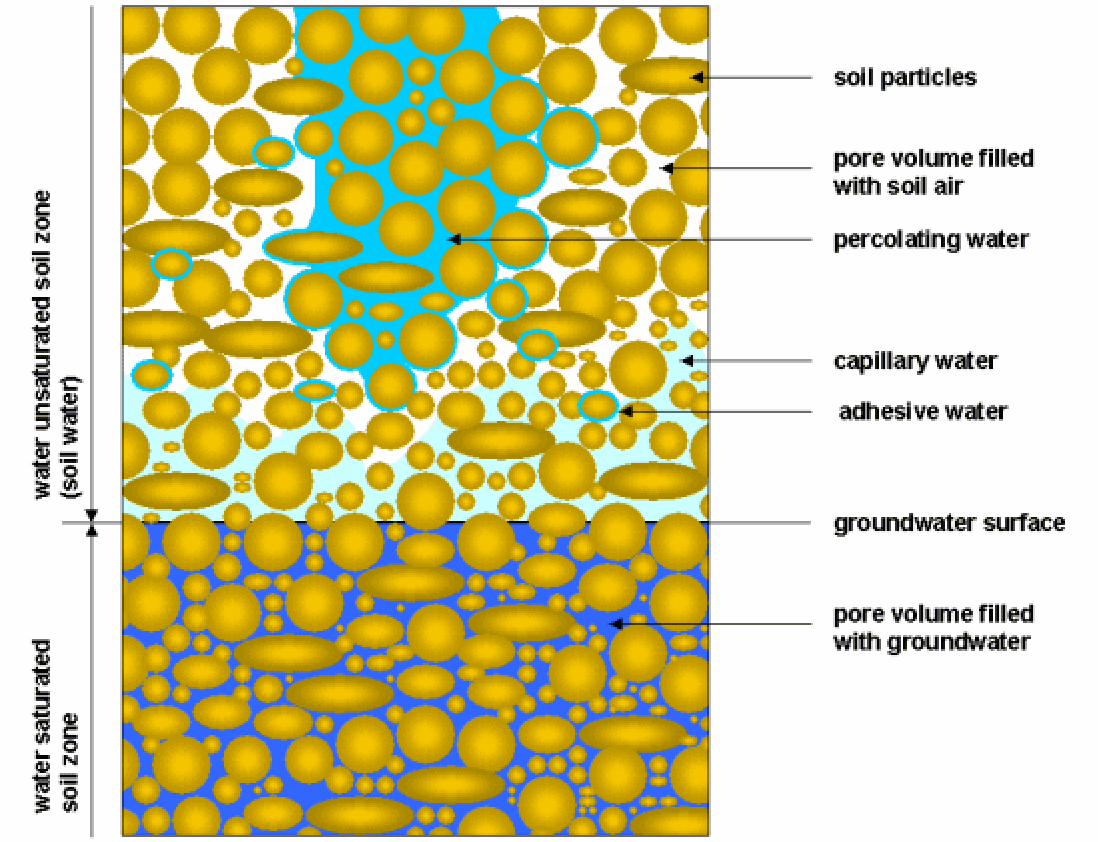

Fig. 2: Phenomenology of Underground Water (from Hölting 1996)

Aquifers are made of sands and gravels, and, as incoherent material, make the storage and movement of groundwater possible.
Aquitards consist of clay, silt, gyttja and glacial till and, as cohesive material, hinder water movement.
Aquicludes are made of clay which is virtually impermeable to water.

Groundwater the **phreatic surface** of which lies within an aquifer, i.e., whose phreatic and piezometric surfaces coincide, is known as **free** or **unconfined groundwater**. If however, an aquifer is covered by an aquitard, the groundwater cannot rise as high as it might in response to its hydrostatic pressure. Under these conditions, the **piezometric surface** is above the phreatic surface of the groundwater, which is then referred to as confined (Fig. 3).

If an aquitard is located over a large coherent aquifer (main aquifer), such as a glacial till, above that glacial till **floating groundwater** may develop temporarily. If there is groundwater in sandy segments inside an aquitard it is called **perched groundwater** (Fig. 3).

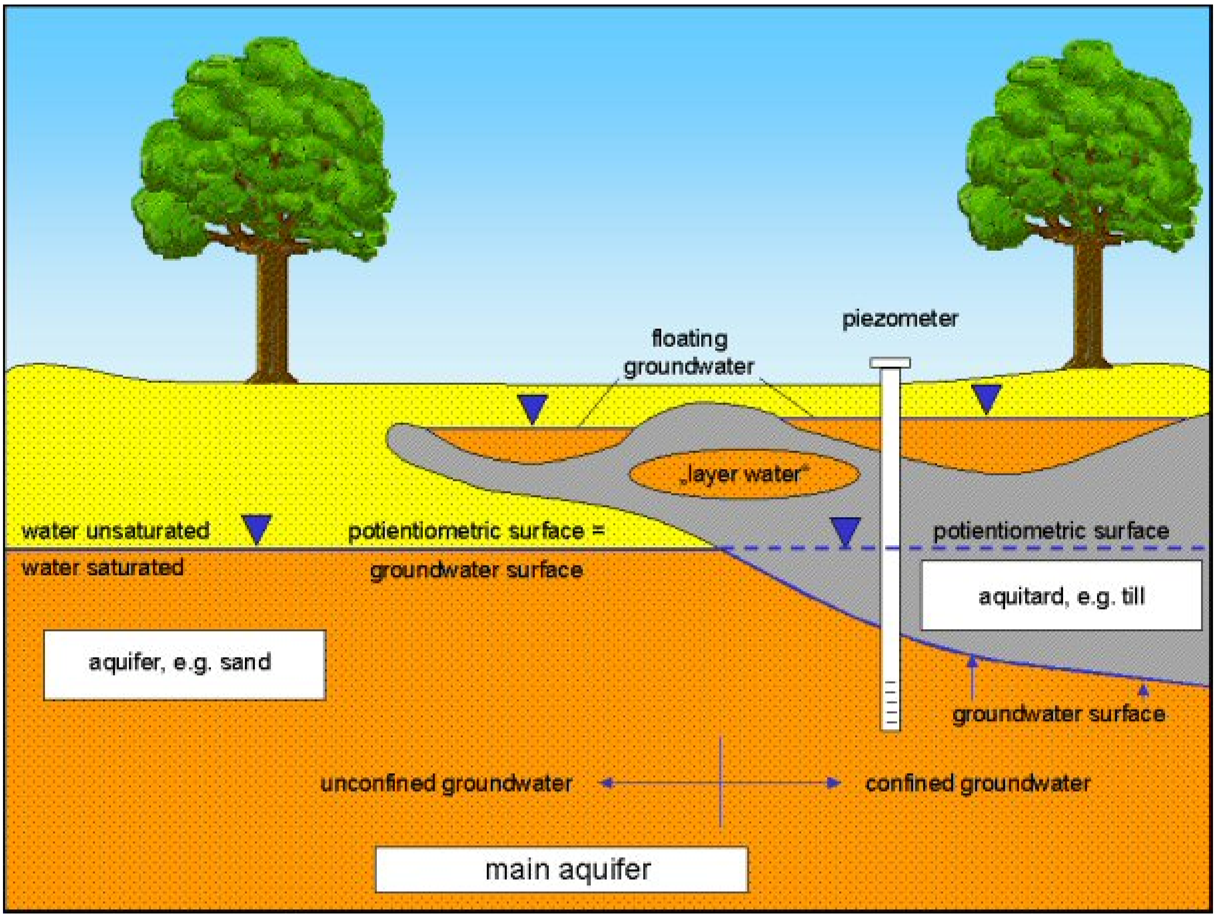

Fig. 3: Hydrogeological Terms

As a rule, groundwater flows at a low incline into the rivers and lakes (receiving bodies of water) and infiltrates into them (**effluent conditions**; Fig. 4a).

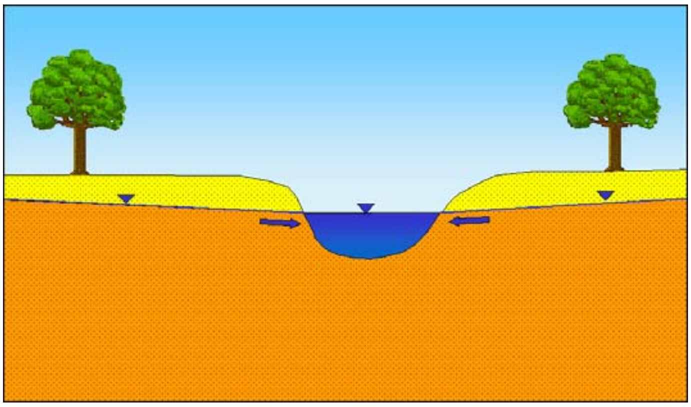

Fig. 4a: Groundwater infiltrates into bodies of water

In times of flood water water surface is situated above the groundwater. During that time bodies of water infiltrate into groundwater (**influent condition**). This is known as **bank-filtered water** (Fig. 4b).

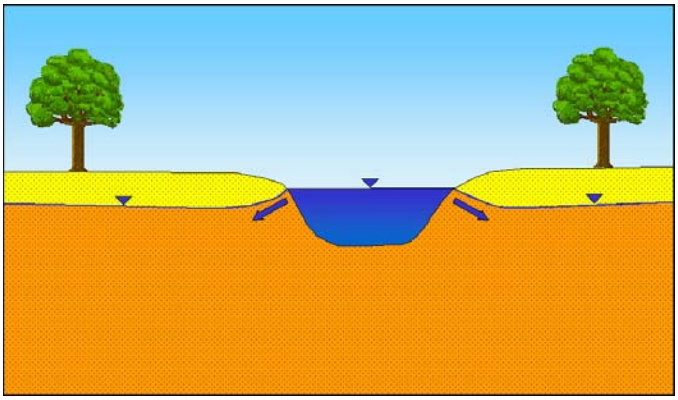

Fig. 4b: Bank-filtered water caused by flood water: bodies of water infiltrate into groundwater

If in the neighborhood of these surface waters groundwater is discharged, e.g. through wells, so that the phreatic surface drops below the level of that body of water, the surface water infiltrates into the groundwater as bank-filtered water, too. (Fig. 4c).

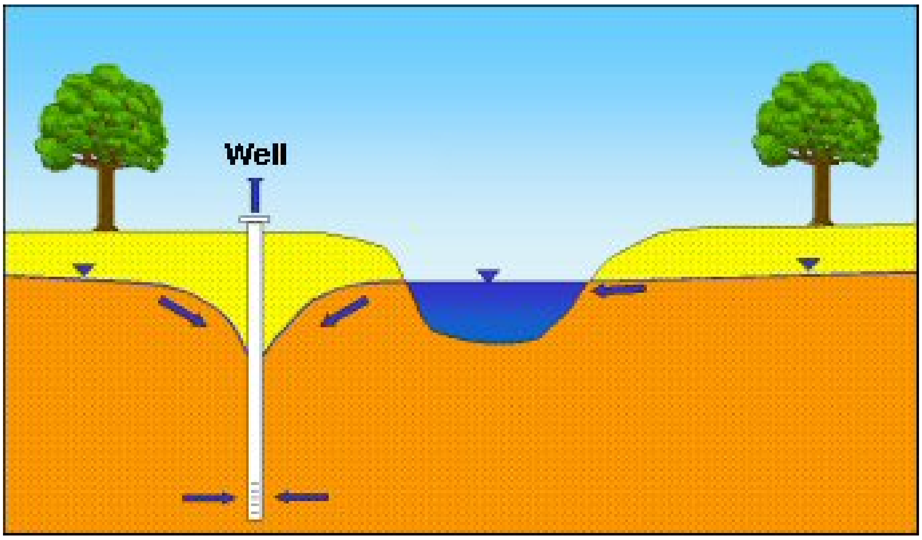

Fig. 4c: Bank-filtered water caused by discharge of groundwater: caused by the lowering of the groundwater by wells, bodies of water infiltrate into groundwater

The **groundwater velocity of flow** in Berlin is about 10 to 500 m p/a, depending on groundwater incline descent and the permeability of the aquifer. However, near well facilities, these low flow velocities can increase significantly.

Geology and Hydrogeology

The present shape of the earth's surface in Berlin was predominantly the result of the Vistula Ice Age, the most recent of the three great quaternary inland glaciations. The most important morphological units are the Warsaw-Berlin Glacial Spillway with the Panke Valley in the neighbourhood with predominantly sandy-gravel deposits, and the Barnim Plateau in the north and the Teltow Plateau with the Nauen Plate in the south, which are covered in large part by the thick glacial till or boulder clay of the ground moraines (Fig. 5).

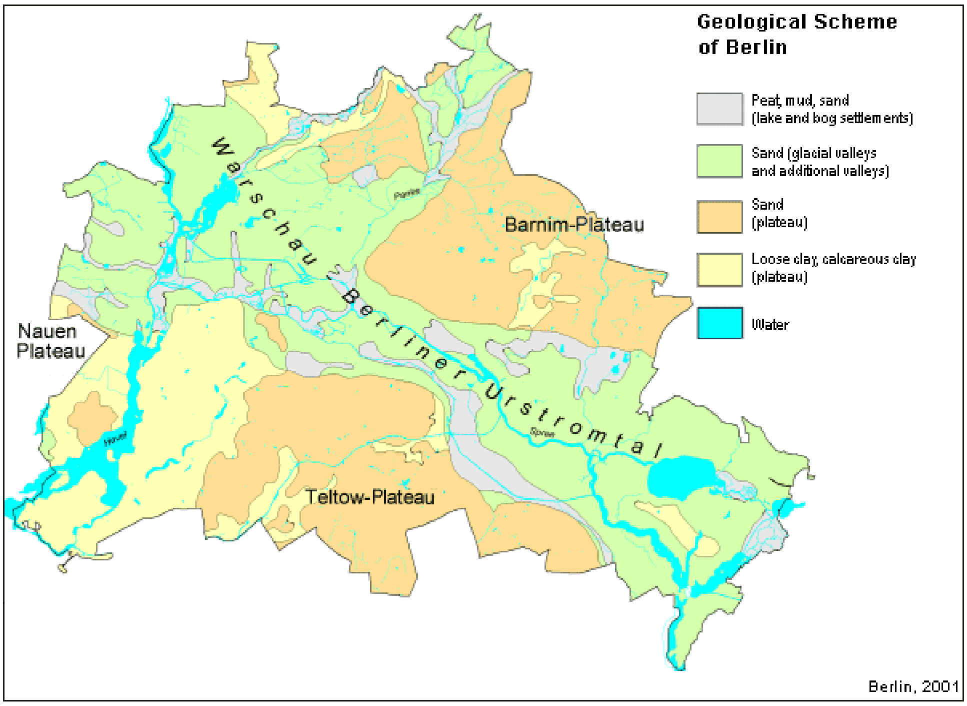

Fig. 5: Geological Outline Map of Berlin

The loose sediments dating from the tertiary and quaternary, and averaging approx. 150 m in thickness, are of special significance for the water supply and for the foundation soil. They form the freshwater stock from which all the drinking water and a large part of the process water of the city is drawn.

The tertiary rupelton clay layer beneath it is about 80 m thick, and constitutes a hydraulic barrier against the deeper saltwater tier (Fig. 6).

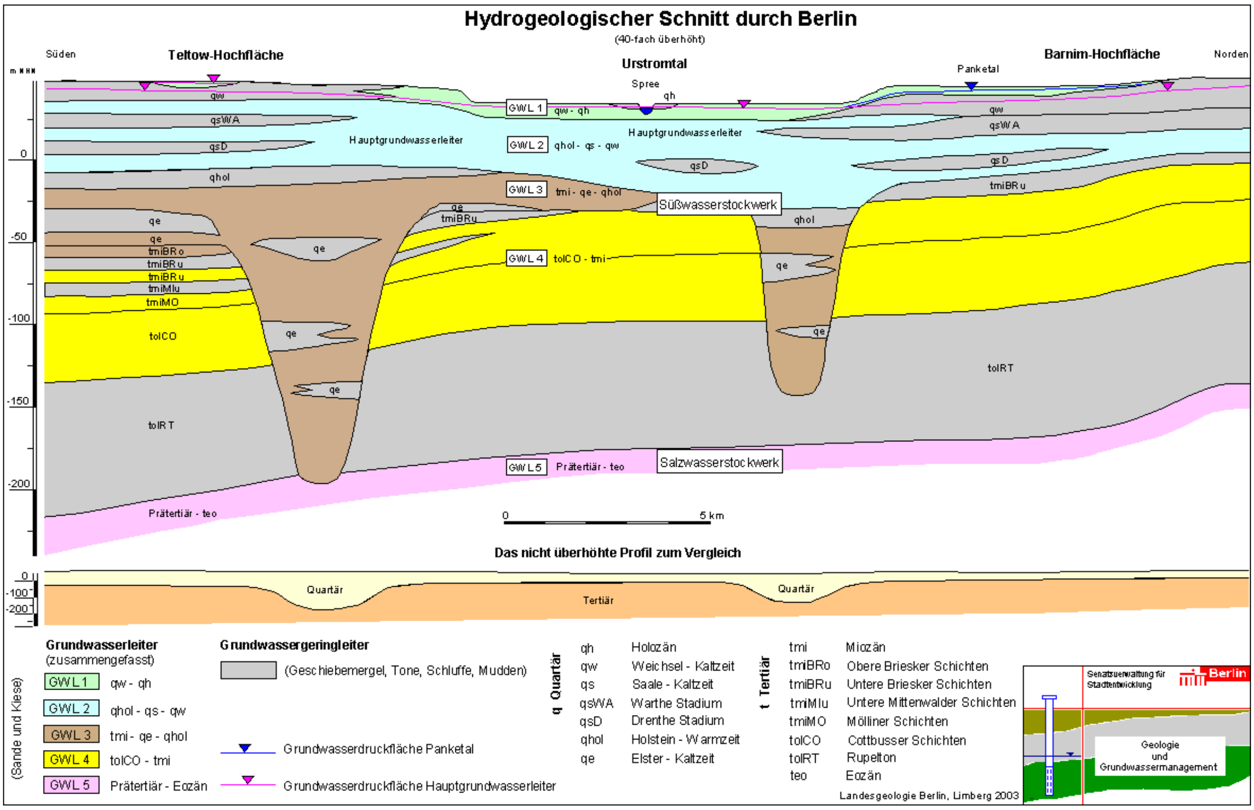

Fig. 6: Hydrogeological Cross-Section of Berlin

Due to the alternation of aquifers and aquitards, the freshwater stock in the Berlin area is broken down into four separate hydraulic aquifers (Limberg, Thierbach 2002). The second aquifer, which is largely a Saale-glaciation-era aquifer, is known as the **main aquifer**, since it supplies the predominant share of the drinking water. The fifth aquifer is already in the saltwater tier under the saltwater stock.

The groundwater conditions in the main aquifer (aquifer 2) are shown in the groundwater isoline map in violet, as well as the Panke Valley aquifer (aquifer 1) in the north-western area of the Barnim Plateau in blue. Here the Panke Valley aquifer situated above the main groundwater aquifer, separated by the clay-layer of the ground moraine (Fig. 6 and 7).

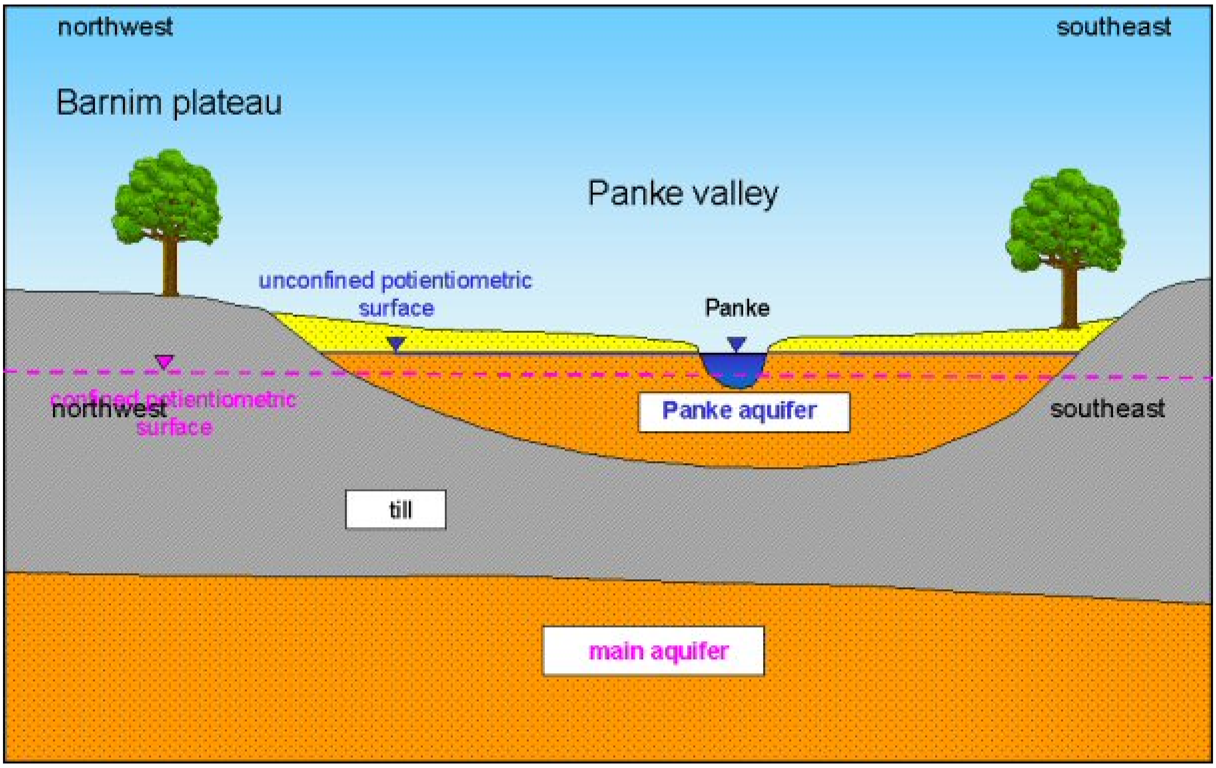

Fig. 7 The unconfined Panke Valley aquifer (aquifer 1) in the northwest of Berlin is situated above the main aquifer (aquifer 2), that is confined in this area

In the north-western area of the Barnim Plateau the ground moraines are that mighty that no main groundwater aquifer exists or the main groundwater aquifer occures only in a thickness of a few meters. For those areas of the Berlin city groundwater isolines are not displayed.

Statistical Base

The basic data for the preparation of the groundwater isoline map are provided by the Working Group Geology and Groundwater Management of the Senate Department of Urban Development.
The regular recording of groundwater levels and their development started already in 1870 at 29 groundwater measurement points (Fig. 8).

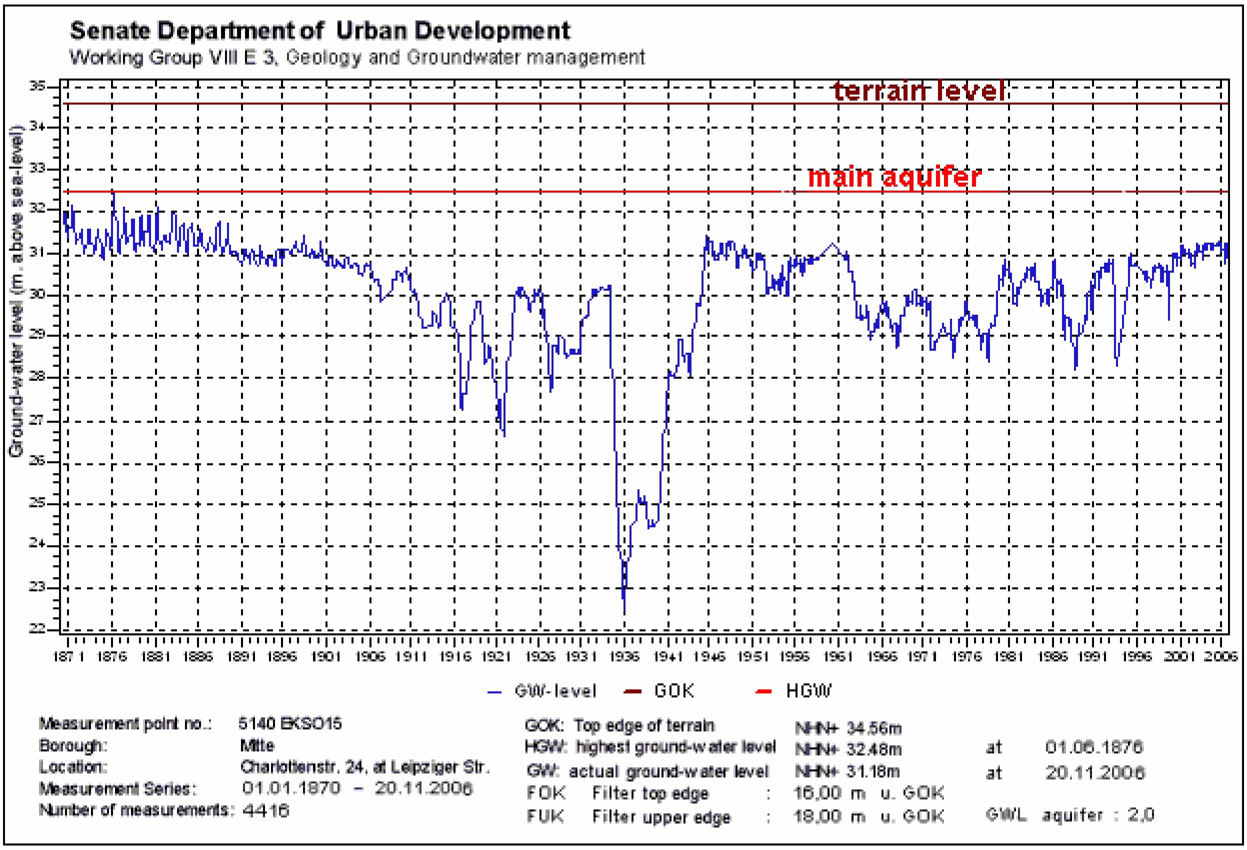

Fig. 8: Hydrographic Curve of Groundwater Levels at a Measurement Point in the Borough of Mitte, from 1870 to the Present

The Berlin groundwater measurement network grew rapidly: By 1937, measurements were already being taken at more than 2,000 measurement points). At present, following a measurement network optimization in the city area, the State Groundwater Service operates approx. 1,000 measurement points which are screened into the five different aquifers. The measurement points are equipped with automatic data loggers, and provide daily measurements, some of them wireless.

Additional the Berlin Water Utility and the Brandenburg state authority for environment as well as other Brandenburg operators of waterworks provide groundwater measurement data for the Berlin area and the surrounding / hinterland, for the most part monthly taken. If groundwater has a direct connection to surface water (effluent situation) additional level data from surface water measurement points are used.

The present map incorporates measurements from 1,872 groundwater measurement points and 25 surface water levels, which are screened exclusively into the main aquifer (2nd GWL), for the Panke Valley groundwater aquifer (first GWL) on the Barnim plateau 32 groundwater measurement points and 6 surface water levels. At the measurement points which are measured daily, the value of May 15th 2006 was used; at the others, the nearest monthly value to this day was used.

The distribution of the measurement points is irregular: The measurement network is densest in the city center and in the immediate intake areas of the waterworks, and is thinner at the outskirts of the city, especially for the Brandenburg hinterland.

Methodology

The groundwater isolines of the main aquifer as well as the Panke Valley aquifers were calculated using a interpolation method (point-Kriging). To get informations about the interrelation between the measuring points, concerning their spacial distribution and groundwater level, first data were analysed by Variogramm-analysis.

The geo-statistical parameter determined by the Variogramm-analysis for the main groundwater aquifer and the Panke Valley aquifer are listed in Table 1.

Geostatistical parameter	Main aquifer	Panke Valley aquifer
Soldner easting (min./ max.)	-5600 / 56,800	22,000 / 35,000
Soldner northing (min./ max.)	-3200 / 48,000	25,000 / 38,000
Spacing	400 m	400 m
Number of grid lines	x = 157 / y = 129	x = 34 / y = 34
Variogram model	linear	linear
Slope	0.00109	0.001615
Anisotropic ratio	2	2
Anisotropic angle	141.4°	128.6°
Kriging type	point	point
Drift type	none	none
Interpolation type	linear	linear
Number of sectors	4	no search (use of all data)
Max. no. of data in all sectors	128	no search (use of all data)
Max. no. of data per sector	32	no search (use of all data)
Min. number of data in research area	2	no search (use of all data)
Number of max. free sectors	3	no search (use of all data)
Search ellipse, radius	R1=10,000 / R2=5000	no search (use of all data)
Search ellipse, angle	141.4°	no search (use of all data)

Tab. 1: Interpolation inputs for the Kriging method

For the calculation of the groundwater isolines of the main aquifer, the irregularly distributed groundwater measurement data (base points) were transformed into an equidistant grid with the aid of a program for the calculation and graphic representation of surfaces (Surfers 8.0, by Golden Software). This was accomplished by interpolation according to the Kriging method. The groundwater isolines were represented on the basis of this grid, after smoothing.

Map Description

The present groundwater isoline map describes the groundwater situation of the main aquifer by means of the violet coloured groundwater isolines and the blue coloured of the Panke Valley aquifer in the North East of Berlin. These show the piezometric surface area of the unconfined and confined groundwater (see also Fig. 3). In areas of the main aquifer with confined groundwater the groundwater isolines are displayed in broken lines. In areas with no main groundwater aquifer or with an isolated main groundwater aquifer of low thickness no groundwater isolines are displayed. Those areas are defined with dots.

The map basis is the topographical General Map of Berlin, 1:50,000, in grid format, and the new geological outline for the Berlin state area, that was derived from the geological General Map of Berlin and surrounding, 1:100,000. In addition, the appropriate supporting points (groundwater measuring points, surface water levels) as well as the individual waterworks are indicated, with their wells and water conservation areas.

Hydrogeologic Situation

On the plateaus, the main aquifer is extensively covered by the glacial till and bolder clay (aquitards) of the ground moraines. Wherever the piezometric surface of the main aquifer lies within this aquitard, groundwater conditions are confined. This may at times result in the formation of floating groundwater in sandy areas above the glacial till . It may ascend to the surface after extreme precipitation. The ground-water levels of these high differentiated areas are not detected. Inside the the glacial till sandy segments can be filled with groundwater, the so called perched groundwater (see also Fig. 3).

On the Barnim Plateau to the north, an independent coherent bigger aquifer has developed in the Panke Valley. It is located over the main aquifer, which is covered by the glacial till of the ground moraine (see also fig. 7). In the present map, this aquifer is indicated by own groundwater isolines (blue). A spur of the glacial till toward the Warsaw-Berlin Glacial Spillway creates an interlock of the Panke Valley aquifer with the main aquifer there.

Hydraulic Situation

As a rule, the groundwater incline such as the floating direction in Berlin is oriented from the Barnim and Teltow Plateaus and the Nauen Plate toward the receiving bodies, the Spree and Havel Rivers.

Depression cones have formed around the wells at the waterworks; during the measurement period, they have sunk the groundwater surface below the level of the neighboring surface waters: Thus, in addition to inflowing groundwater from the shore side, the water pumped here also includes groundwater formed by infiltration (bank-filtered water) from these aboveground waters (see also Fig. 4).

However, in May 2006, the phreatic surface, which has been lowered in Berlin by drinking-water discharge over the past hundred years, was, all in all, compared to 1989 at a relatively high level, as it had been during the previous nine years. The reason for this is the reduced raw-water discharge by the Berlin Water Utility as a result of the falling needs of drinking and industrial water. Five smaller Berlin waterworks (Altglienicke, Friedrichsfelde, Köpenick, Riemeisterfenn und Buch) discontinued their production altogether during the period between 1991 and 1997 were closed during the period between 1991 and 1997: Altglienicke, Friedrichsfelde, Köpenick, Riemeisterfenn and Buch. In addition, drinking water production at the two waterworks Johannisthal and Jungfernheide was discontinued temporarily since September 2001; at the latter, the same was true for artificial groundwater recharging. In the context of immediate measures of water management by the Senate Department for Urban Development, groundwater is, however still discharged at the location Johannisthal, so as not to endanger current local waste disposal and construction measures. Likewise at the location Jungfernheide groundwater has been discharged by the Senate Department for Urban Development until the end of 2005. Since January 2006 a private concern continues this work.

The overall discharge of the waterworks for drinking water purposes has dropped by over 44 % in Berlin during the past 17 years (Fig. 9). In 1989, 378 million m³ were discharged, as opposed to 219 million m³ in 2002. In 2003 the discharge increased lightly to 226 million m³ because of the dry summer, to fall again in 2005 to 212 million m³.

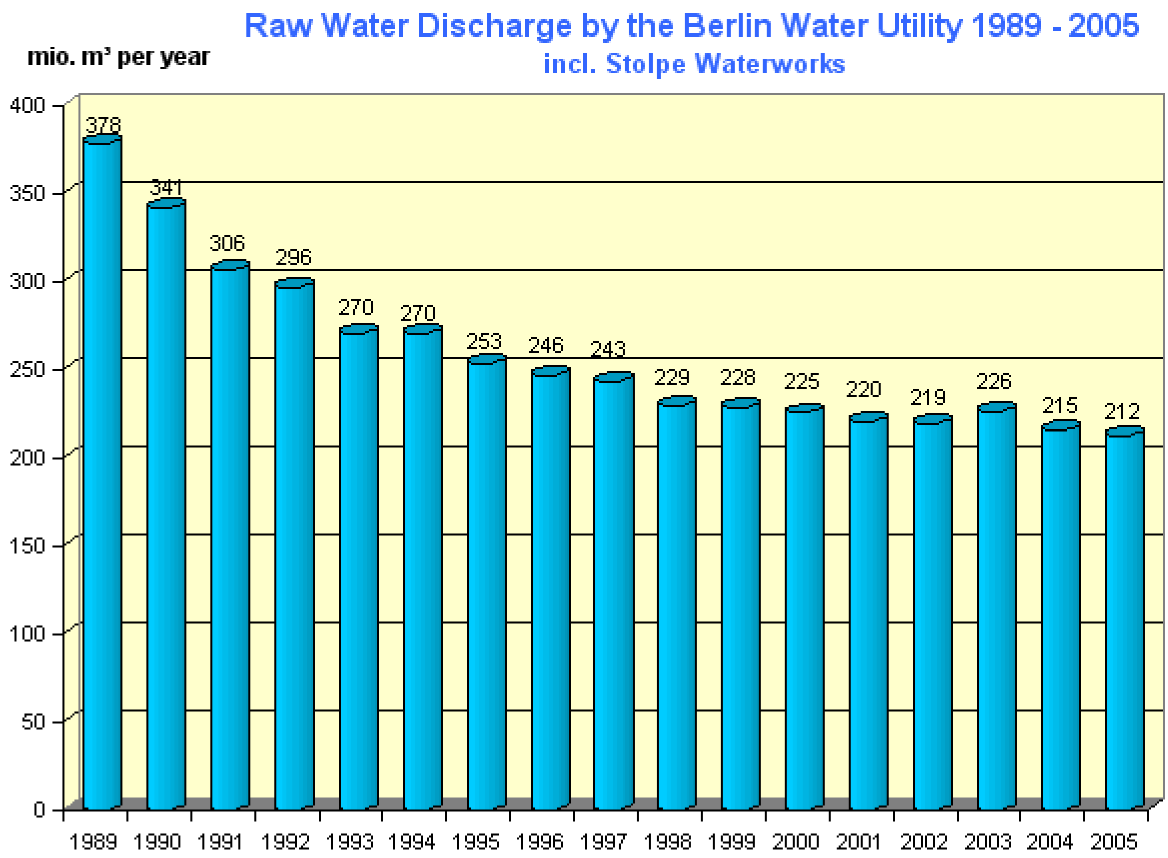

Fig. 9: Drop in Raw-Water Discharge by the Berlin Water Utility during the Past 17 Years

Literature

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[3] **Limberg, A., Thierbach, J. 2002:**
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