02.12 Groundwater Levels of the Main Aquifer and Panke Valley Aquifer (2009 Edition)

Overview

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. 205 million cu.m. in 2008) is obtained from groundwater. This groundwater is pumped at nine waterworks, almost entirely within the territory of the city. Only the Stolpe Waterworks on the northern outskirts obtains water from Brandenburg, but also supplies Berlin with approx. 9 % of the city's total intake (Fig. 1).

Fig. 1: Location of the nine waterworks which supply Berlin with drinking water, as of May 2009

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

For this reason the Geology and Groundwater Management Working Group produces a map of ground-water levels every month. The map from may, the month with normally the highest groundwater level, is published in the Environmental Atlas.

Definitions Regarding Groundwater

Groundwater is underground water (DIN 4049, Part 3, 1994) which coherently fills out the cavities in the lithosphere, and 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 percolates (infiltrates) into the ground first fills these pores. Only that part of the percolating water which is not bound as adhesive water in the non-water-saturated soil, nor used up by evaporation, can percolate to the **phreatic surface** and form groundwater. Above the phreatic surface, capillary water is present within the unsaturated soil zone; it can rise to various heights, depending on the type of soil (Fig. 2).

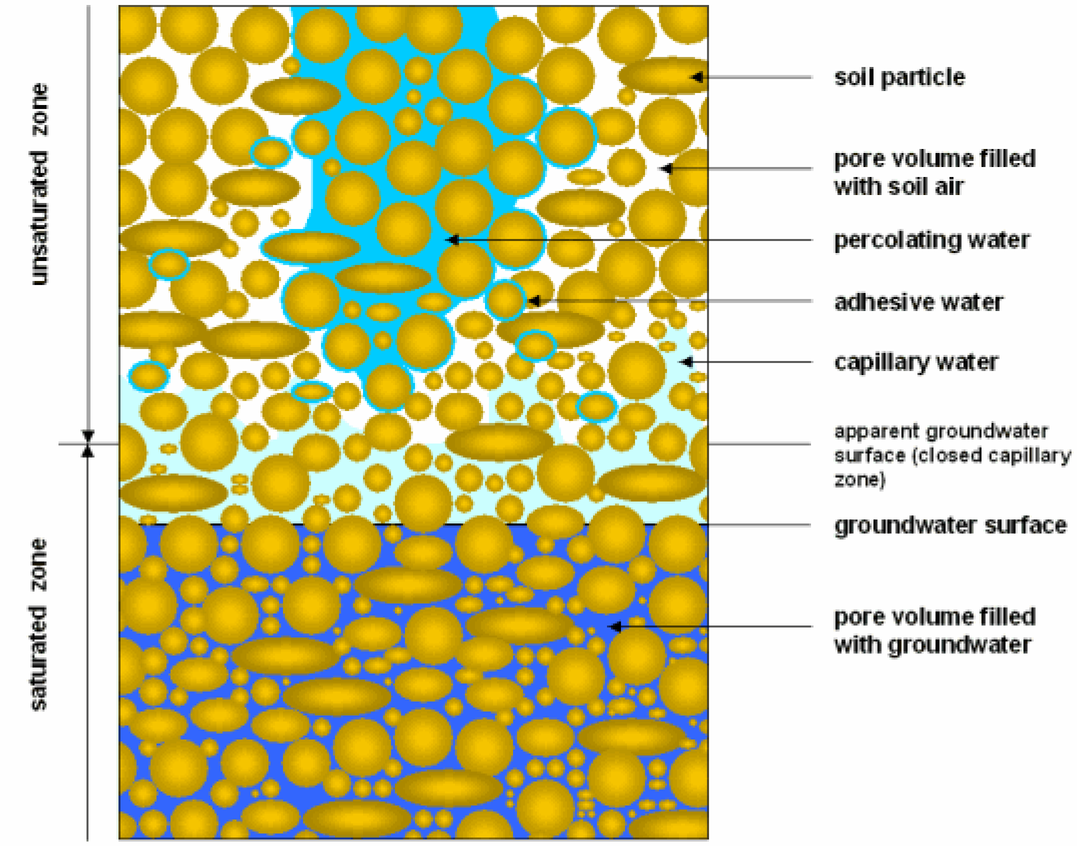

Fig. 2: Phenomenology of Underground Water (from Hölting 1996)

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 is known as **free** or **unconfined groundwater**, i.e., the phreatic and piezometric surfaces coincide. In cases of **confined groundwater** however, an aquifer is covered by an aquitard so that 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 (Fig. 3).

If an aquitard, such as a glacial till, is located above a large coherent aquifer (main aquifer), surface-proximate groundwater may develop in sandy segments above the aquitard and in islands within it, as a result of precipitation. This is unconnected with the main aquifer, and is often called **stratum water**. If an unsaturated zone is located below the glacial till, it is called **floating groundwater** (Fig. 3).

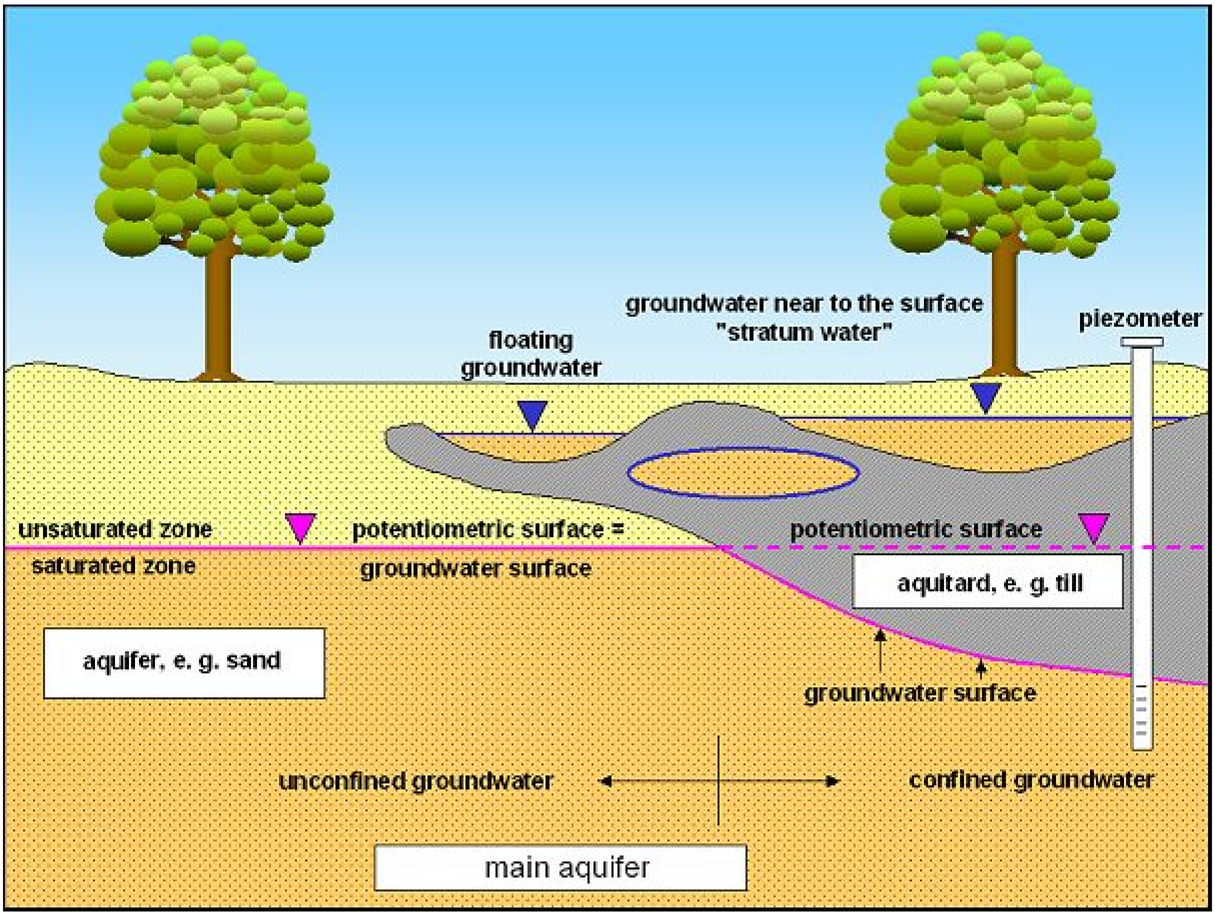

Fig. 3: Hydrogeological Terms

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

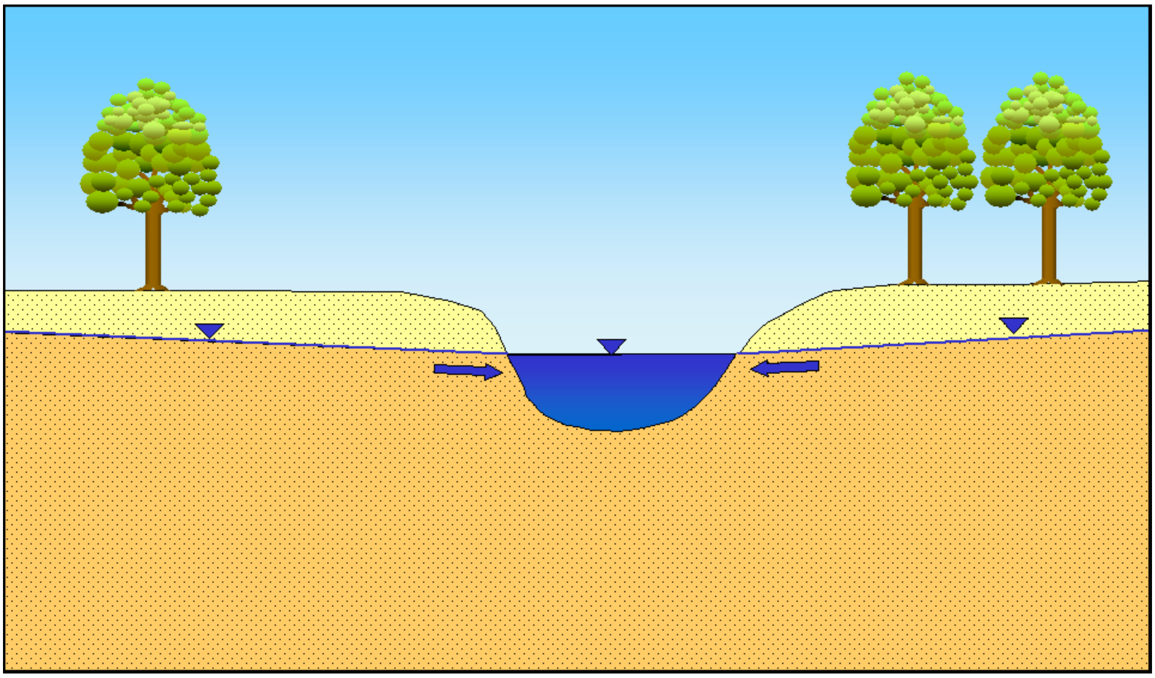

Fig. 4a: Groundwater infiltrates into bodies of water

In times of flood, the water surface is situated higher than the groundwater surface. During such periods, surface water infiltrates into the groundwater (**influent condition**). This is known as **bank-filtered water** (Fig. 4b).

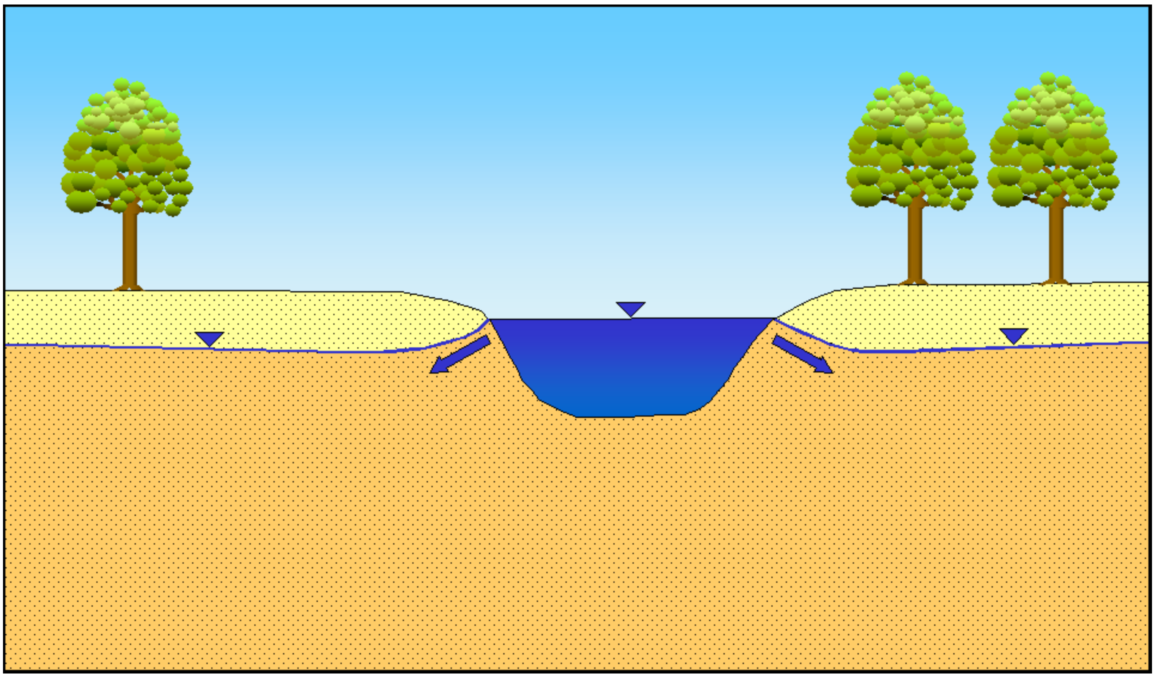

Fig. 4b: Bank-filtered water caused by flood water: surface water infiltrates into groundwater

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 body of water will also feed bank-filtered water into the groundwater (Fig. 4c).

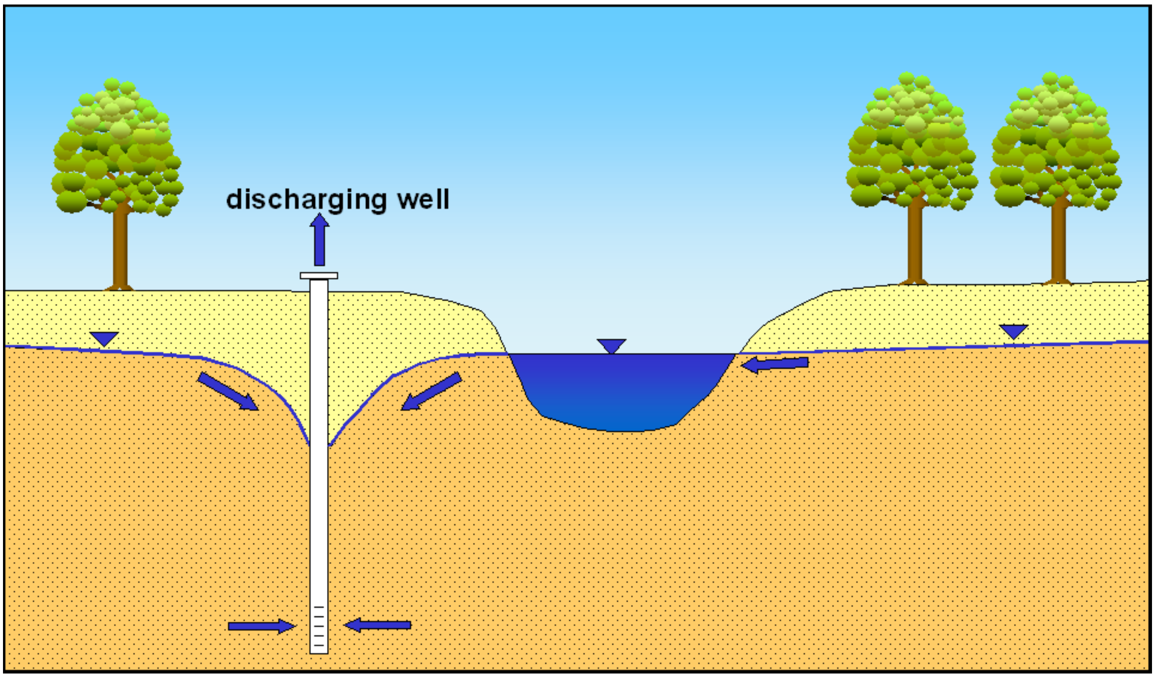

Fig. 4c: Bank-filtered water caused by discharge of groundwater: due to the drop in the groundwater caused by wells, surface water infiltrates into the groundwater

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

Morphology, 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 its Panke Valley branch, consisting predominantly of sandy and gravel deposits; the neighboring Barnim Plateau to the north; and the Teltow Plateau with the Nauen Plate to the south, which are covered in large part by the thick glacial till and boulder clay of the ground moraines (Fig. 5 and 6).

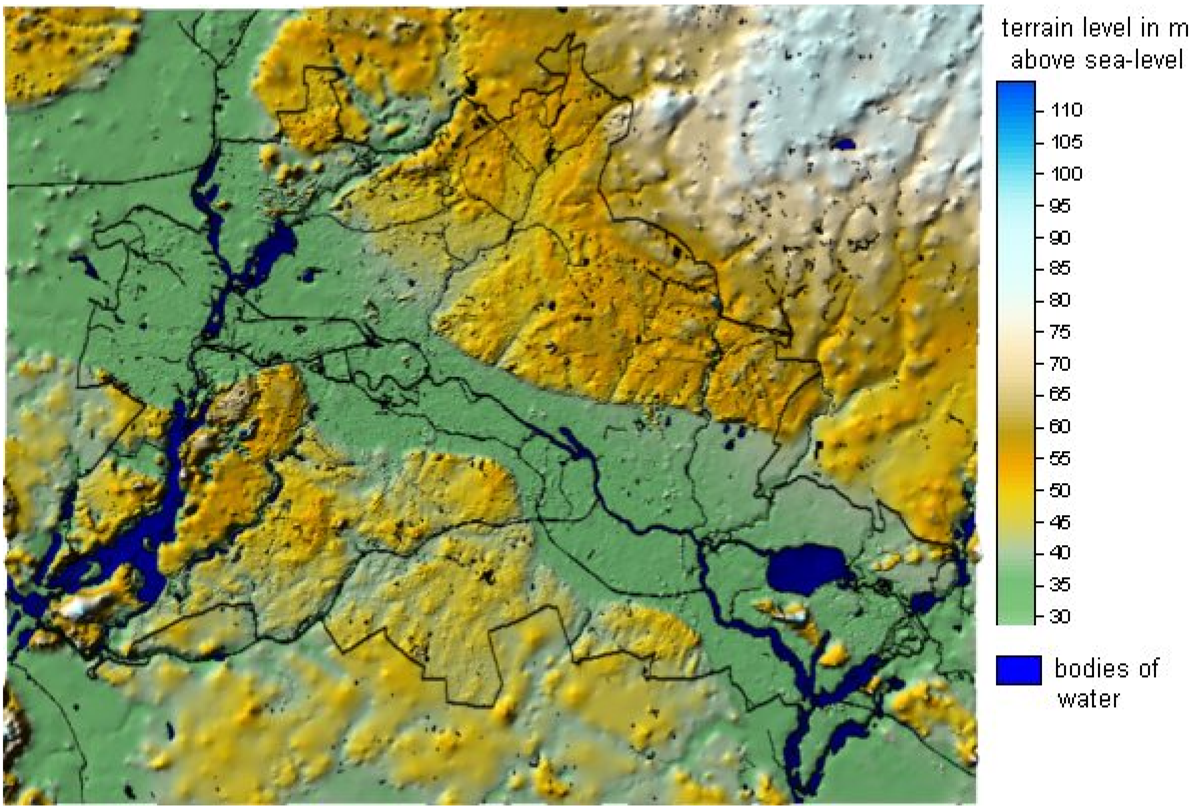

Fig. 5: Morphological Outline Map of Berlin

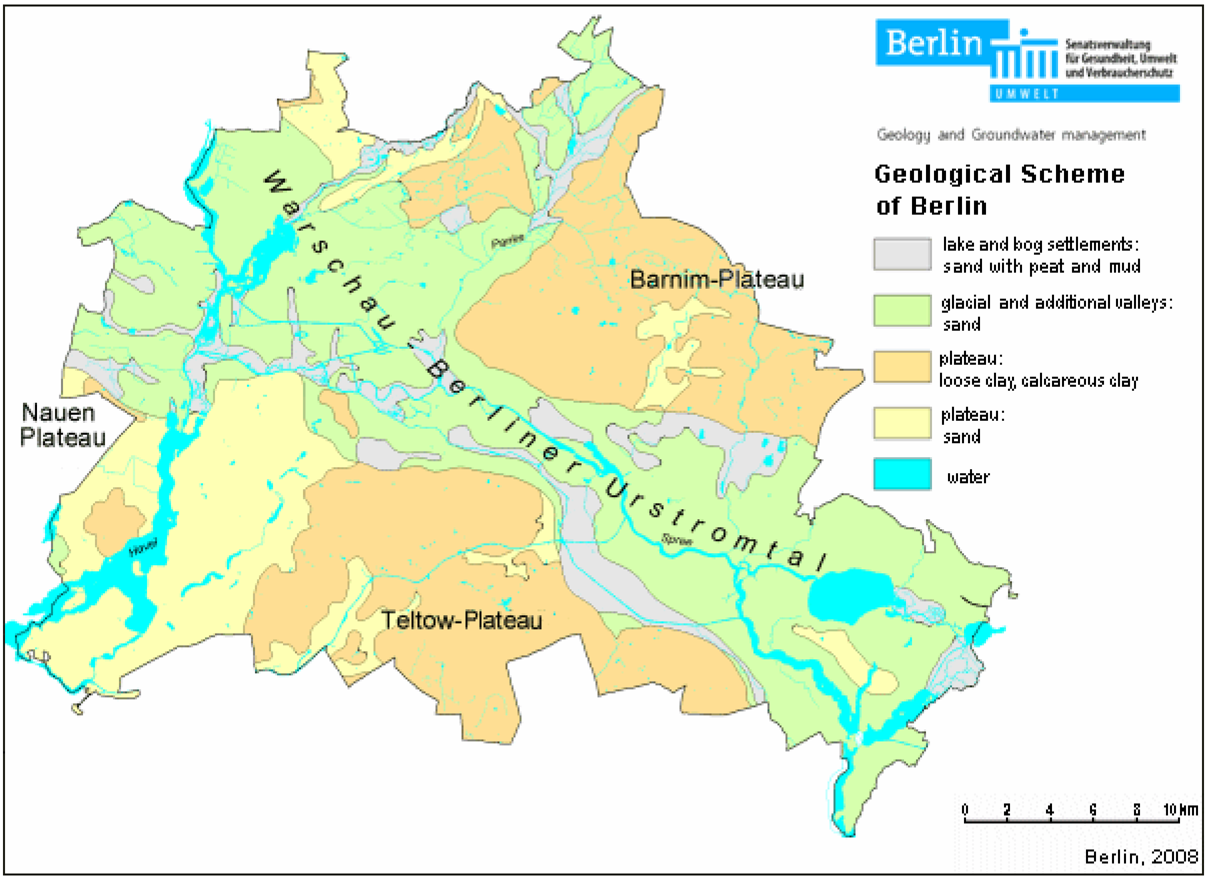

Fig. 6: Geological Outline Map of Berlin

The loose sediments dating from the quaternary and tertiary, and averaging approx. 150 m in thickness, are of special significance for the water supply and for foundation of buildings. They form the freshwater stock from which Berlin draws all the drinking water and a large part of the process water. Numerous waterworks an other pumping facilities have lowered the groundwater in Berlin partly since more than 100 years.

The tertiary rupelium layer in a depth of 150 to 200 m is about 80 m thick, and constitutes a hydraulic barrier against the deeper saltwater tier (Fig. 7).

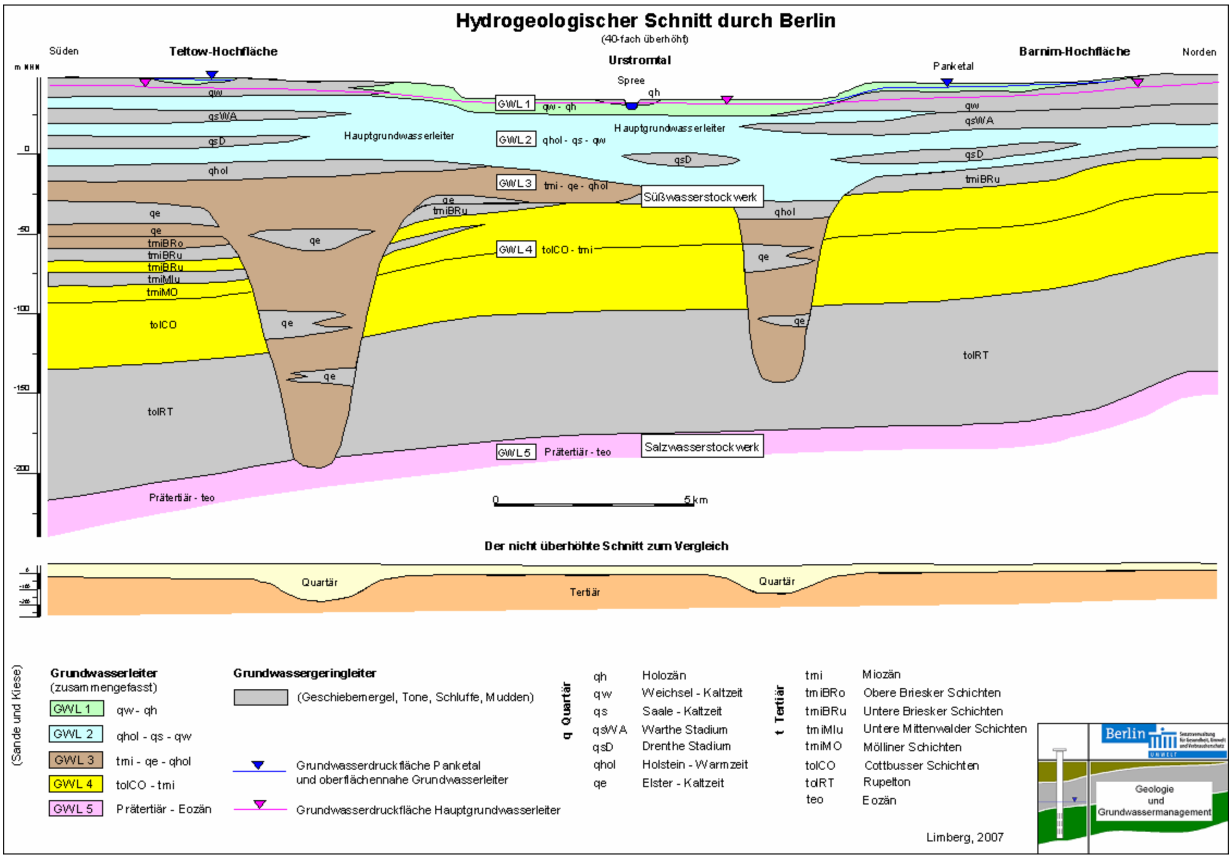

Fig. 7: Schematical Hydrogeological Cross-Section of Berlin from South to North

Due to the alternation of aquifers (green, blue, brownn and yellow in Fig. 7) and aquitards (grey in Fig. 7), 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 and process water. The fifth aquifer is in the saltwater tier under the rupelium.

The groundwater conditions of the main aquifer (Aquifer 2) are shown in the groundwater contour map in violet; in the Panke Valley aquifer (Aquifer 1) in the northwestern area of the Barnim Plateau, they are shown in blue. Here, the Panke Valley aquifer is situated above the main groundwater aquifer, separated from it by the glacial till of the ground moraine (Fig. 7 and 8).

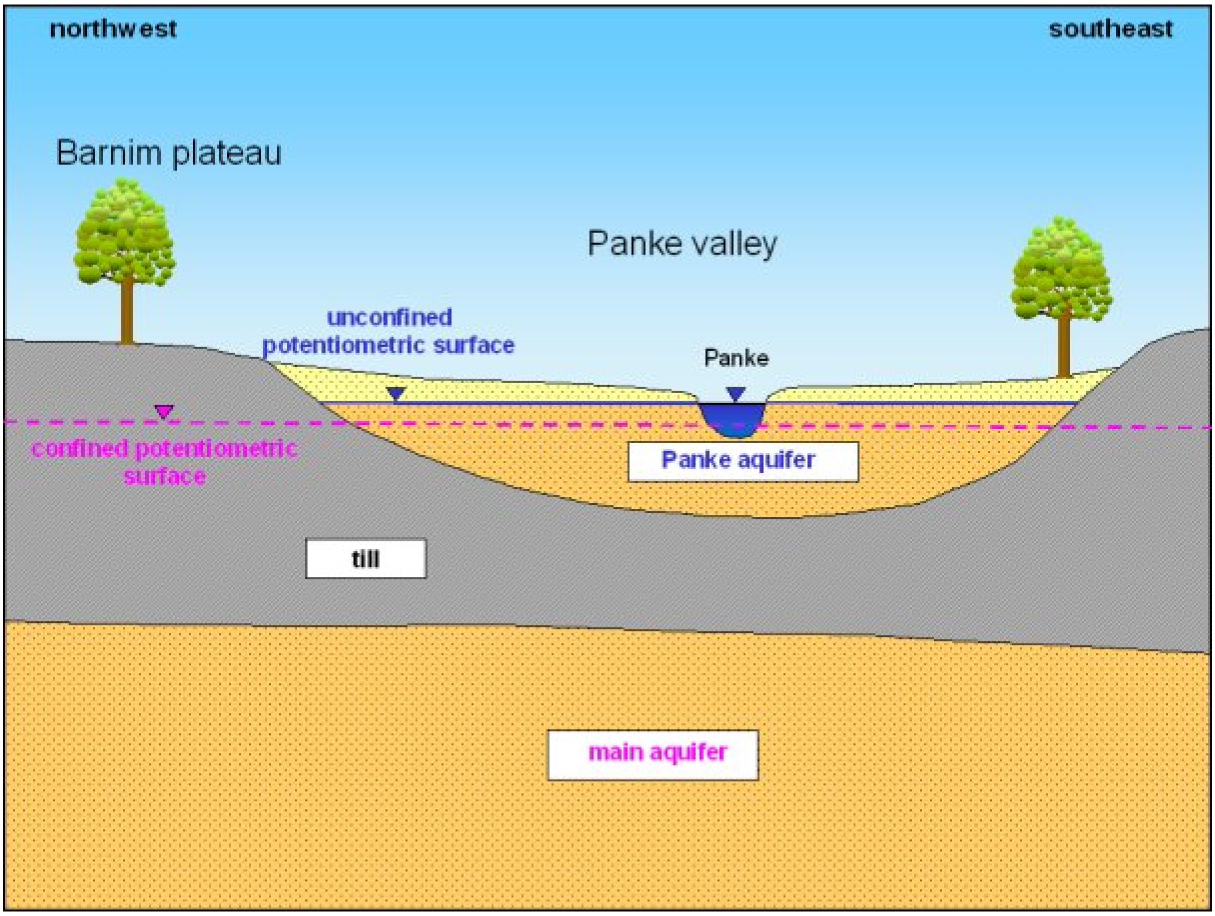

Fig. 8 The unconfined Panke Valley aquifer (Aquifer 1) in the northwestern area of the Barnim Plateau is situated above the main aquifer (Aquifer 2), which is confined in this area

In the northwestern area of the Barnim Plateau, the ground moraines are so thick that no main groundwater aquifer exists, or occurs only in isolated places, with a thickness of a few meters. For those areas of the Berlin city area, no groundwater contours can be shown.

Statistical Base

The basic data for the preparation of the groundwater contour map are provided by the Geology and Groundwater Management Working Group of the Senate Department for Health, the Environment and Consumer Protection.

The first regular recording of phreatic levels and their development was initiated in Berlin as early as in the year 1869, at 27 groundwater measurement points (Fig. 9).

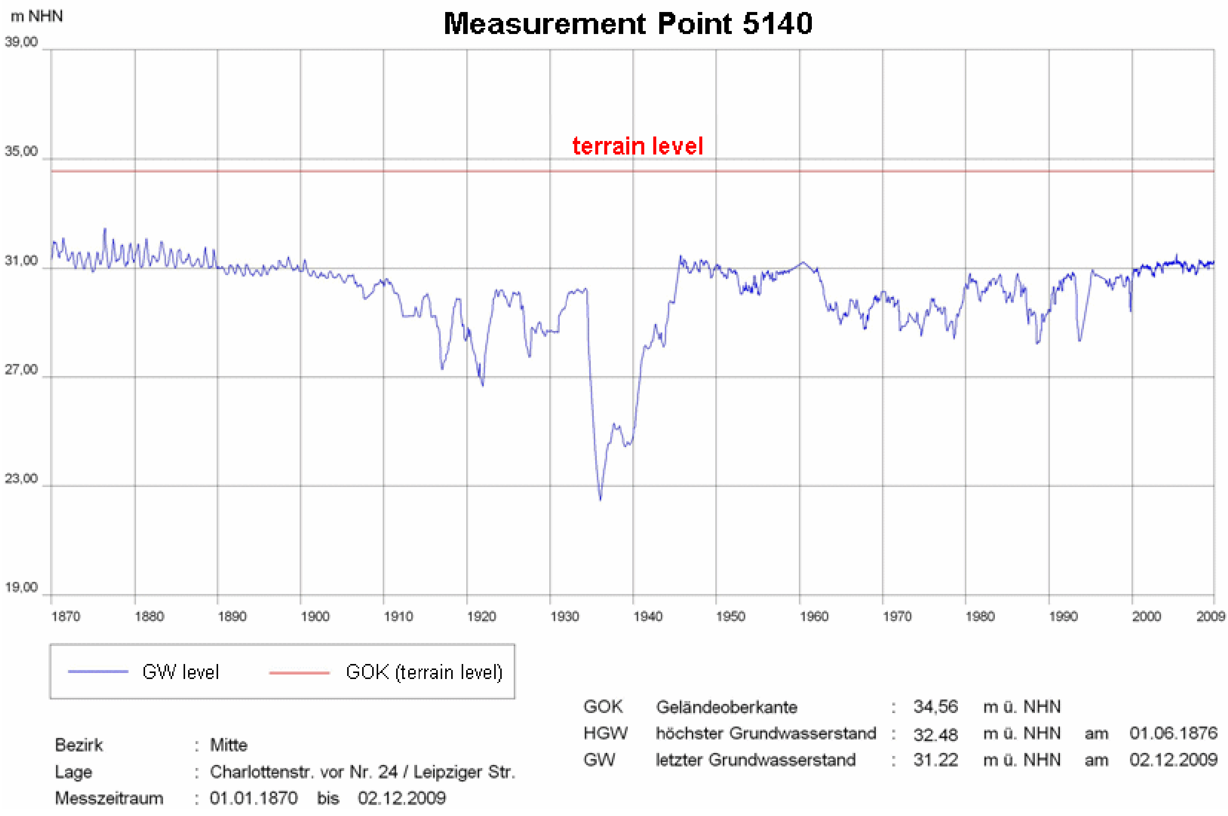

Fig. 9: Hydrographic Curve of Groundwater Levels at a Measurement Point in the Borough of Mitte, since 1870
(The highest groundwater level(HGW) was here measured on Juny 1st, 1876. Since 1905 the groundwater level temporary is heavily affected by numerous drawdowns.)

The Berlin groundwater measurement network grew rapidly: By 1937, there were already more than 2000 measurement points. At present, following an optimization of the measurement network in the city, the State Groundwater Service operates approx. 1000 measurement points which are installed into the five different aquifers. The measurement points are equipped with automatic data loggers, and provide daily measurements. Meantime the data base contains more than six million measured values.

In addition, the Berlin Water Utility and the Brandenburg state Environmental Agency as well as other waterworks operators in Brandenburg provide groundwater level measurement data for the Berlin area and the surrounding areas, for the most part monthly. If the groundwater has a direct connection to surface water (effluent situation, Fig. 4a), additional level data from surface-water measurement points are used.

The present map incorporates measurements from 1771 groundwater measurement points and 33 surface-water measurement points for the main aquifer (Aquifer 2), and from 42 groundwater measurement points and seven surface-water measurement points for the Panke Valley groundwater aquifer (Aquifer 1) on the Barnim plateau. At the measurement points which are measured daily, the value of May 15, 2009 was used; for the others, the value taken during the month of May which was closest to this date.

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 less dense at the outskirts of the city, especially in the surrounding areas in Brandenburg.

Methodology

The groundwater contours of the main aquifer as well as the Panke Valley aquifers were calculated using an interpolation method (point-kriging). In order to obtain information about the interrelation between the measuring points, concerning their spatial distribution and groundwater level, data were first analyzed by variogram analysis.

The geo-statistical parameters ascertained by variogram 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

The irregularly distributed groundwater and surface measurement data were transformed into an equidistant grid with a spacing of 400 m, with the aid of a program for the calculation and graphic representation of surfaces (Surfer 8.0, by Golden Software). This was accomplished by interpolation according to the Kriging method. The groundwater contours were represented on the basis of this grid, after smoothing.

An groundwater contour map with a grid width of 200 m, updated monthly, has been prepared for internal official use (Hannappel & et al. 2007).

Map Description

The present groundwater contour map describes the groundwater situation of the main aquifer with violet groundwater isolines and the Panke Valley aquifer in northeastern Berlin with blue isolines. These show the piezometric surface area of the unconfined and confined groundwater, respectively (see also Fig. 3). In areas of the main aquifer with confined groundwater, the groundwater contours 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 updated new edited and enlarged areas are shown with dots.

The map is based on the topographical General Map of Berlin, 1:50,000, in grid format, and the geological outline for the Berlin state area 1:50,000 (2007), that was derived from the geological General Map of Berlin and Surrounding Areas, 1:100,000. In addition, the appropriate support points (groundwater measurement points and surface-water levels) as well as the individual waterworks are indicated, with their active wells and water conservation areas.

Hydrogeological 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. In sandy segments above the till, the periodic formation of perched groundwater is possible, which can, after extreme precipitation, rise to the surface. The groundwater levels of these locally highly differentiated areas have not been separately ascertained. Within the till, sandy islands may become filled with groundwater, or so-called stratum water (see also Fig. 3).

In the Panke Valley, on the northern side of the spillway, the Barnim Plateau, a major independent coherent aquifer has developed. It is located above the main aquifer, which is covered by the glacial till of the ground moraine (see also fig. 7 and 8). On the present map, this aquifer is indicated by separate blue groundwater isolines. 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.

For more information, see the Groundwater Brochure:

http://www.berlin.de/sen/umwelt/wasser/wasserrecht/grundwasserbroschuere.html (only in German)

Current Hydraulic Situation in May 2009

As a rule in Berlin, the groundwater incline, and hence, too, the flow direction, is 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 those waterworks in operation during the measurement period, and have sunk the phreatic 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 surface waters (see Fig. 4c).

In May 2009, the phreatic surface, which has been lowered in Berlin by drinking-water discharge over the past hundred years, was at a relatively high level compared to 1989 (Limberg et al. 2007: pp. 76 et seq.).

The since 1989 reduced raw-water discharge by the Berlin Water Utility as a result of the falling needs of drinking and industrial water is responsible for the constant increase of groundwater. Five of the smaller Berlin waterworks (Altglienicke, Friedrichsfelde, Köpenick, Riemeisterfenn and Buch) were shut down altogether between 1991 and 1997. In addition, drinking water production at the two waterworks Johannisthal and Jungfernheide has been discontinued temporarily since September 2001; at the latter, the same has been true for artificial groundwater recharging. However, under the immediate water management measures of the Senate Department for Health, the Environment and Consumer Protection, groundwater is still being discharged at the Johannisthal location, so as not to endanger current local waste disposal and construction measures. Likewise at the Jungfernheide location, groundwater was discharged by the Department through the end of 2005. Since January 2006, a private company has continued this work temporarily.

The Water Conservation Districts of the waterworks Buch, Jungfernheide und Altglienicke were canceled april 2009.

The overall discharge of raw water by the Berlin Water Utility for drinking water purposes dropped by almost half in Berlin during a period of 19 years. In 1989, 378 million cu.m. were discharged, as opposed to 219 million cu.m. in 2002. In 2003, the discharge briefly increased slightly to 226 million cu.m. due to the extremely dry summer, but then dropped again by 2008, reaching 205 million cu.m. (Fig. 10).

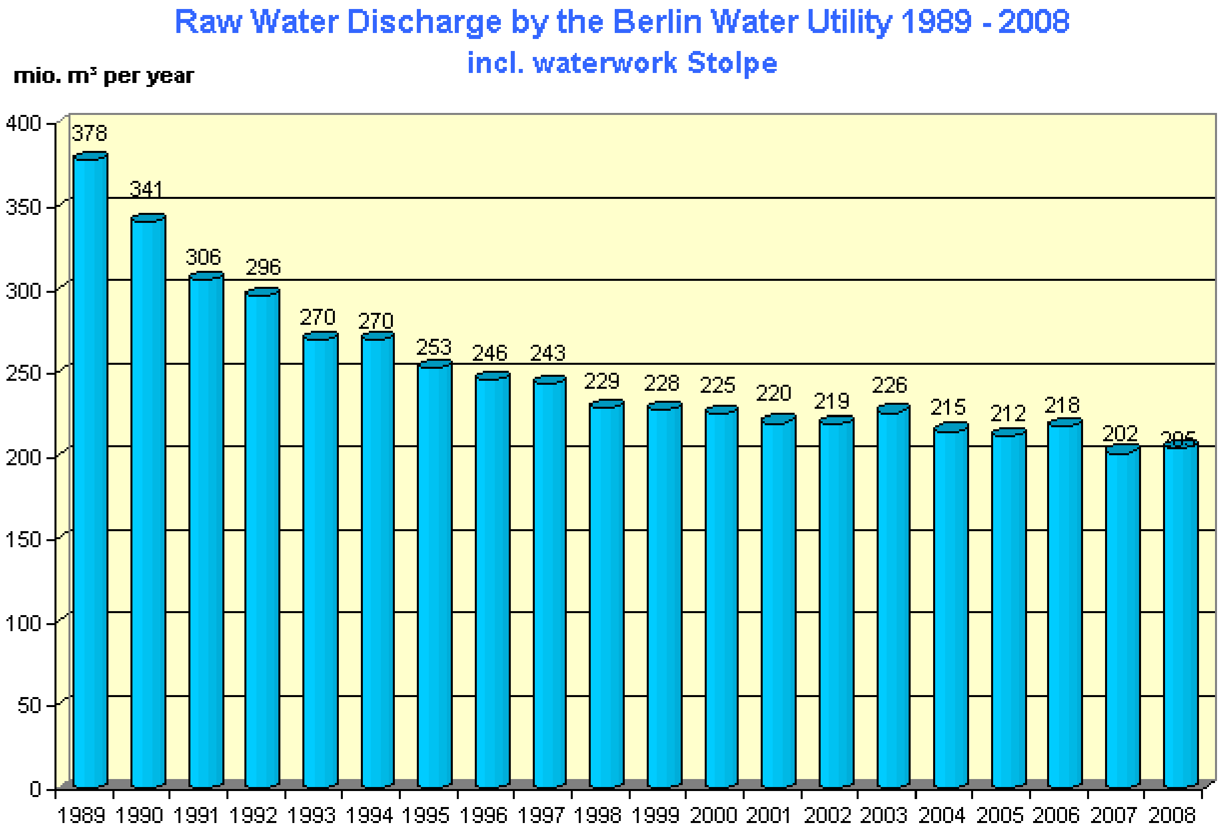

Fig. 10: Drop in raw-water discharge by the Berlin Water Utility over a twenty-year period

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