02.12 Groundwater Levels of the Main Aquifer and Panke Valley Aquifer (Edition 2017)

Overview

Exact knowledge of the current groundwater levels, and hence also of groundwater stocks, is imperative for the State of Berlin, since the water for the public water supply of Berlin (221 million cu.m. in 2016) 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 waterworks which supply Berlin with drinking water, as of May 2017

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 State Geology Working Group produces a map of ground-water levels every month, for internal use. The map for 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 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 sediment 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).

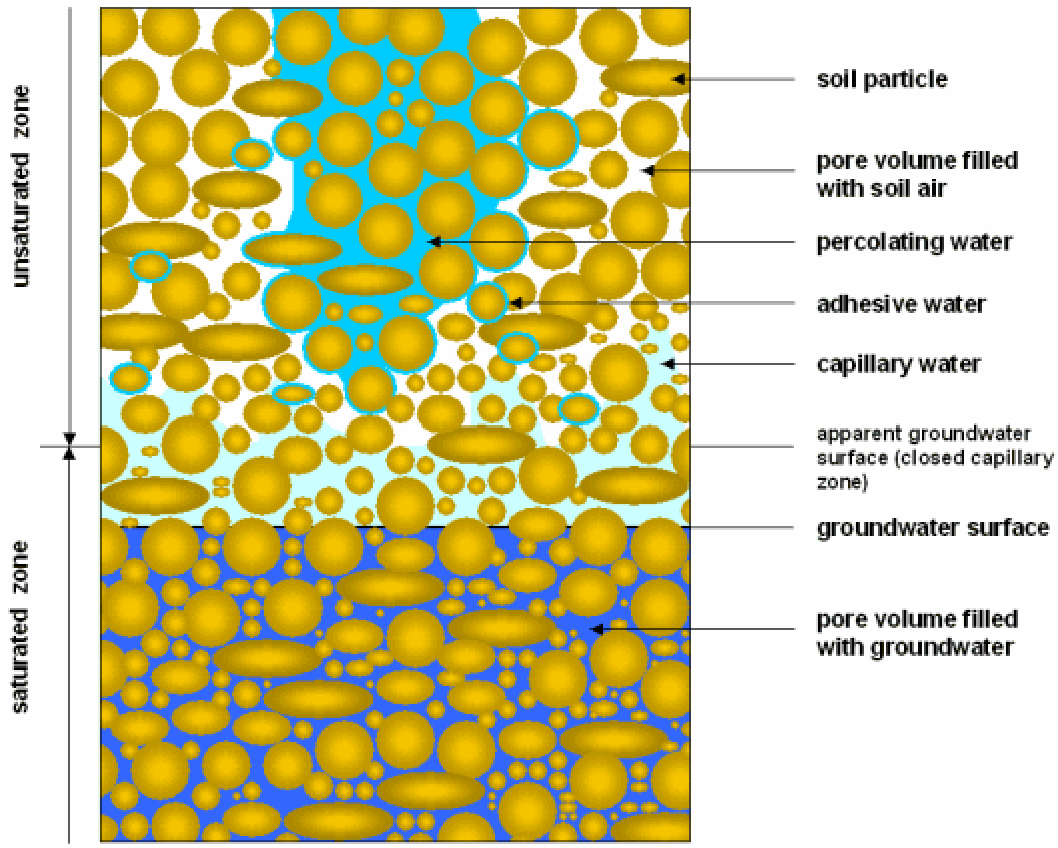

Fig. 2: Phenomenology of Underground Water (from Hölting 1996)

Aquifers consist 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 consist of clay which is virtually impermeable to water.

If the potentiometric surface lies within an aquifer it is known as **free** or **unconfined groundwater**, i.e., the phreatic and potentiometric 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 potentiometric surface is above the phreatic surface (Fig. 3).

If an aquitard, such as a layer of 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).

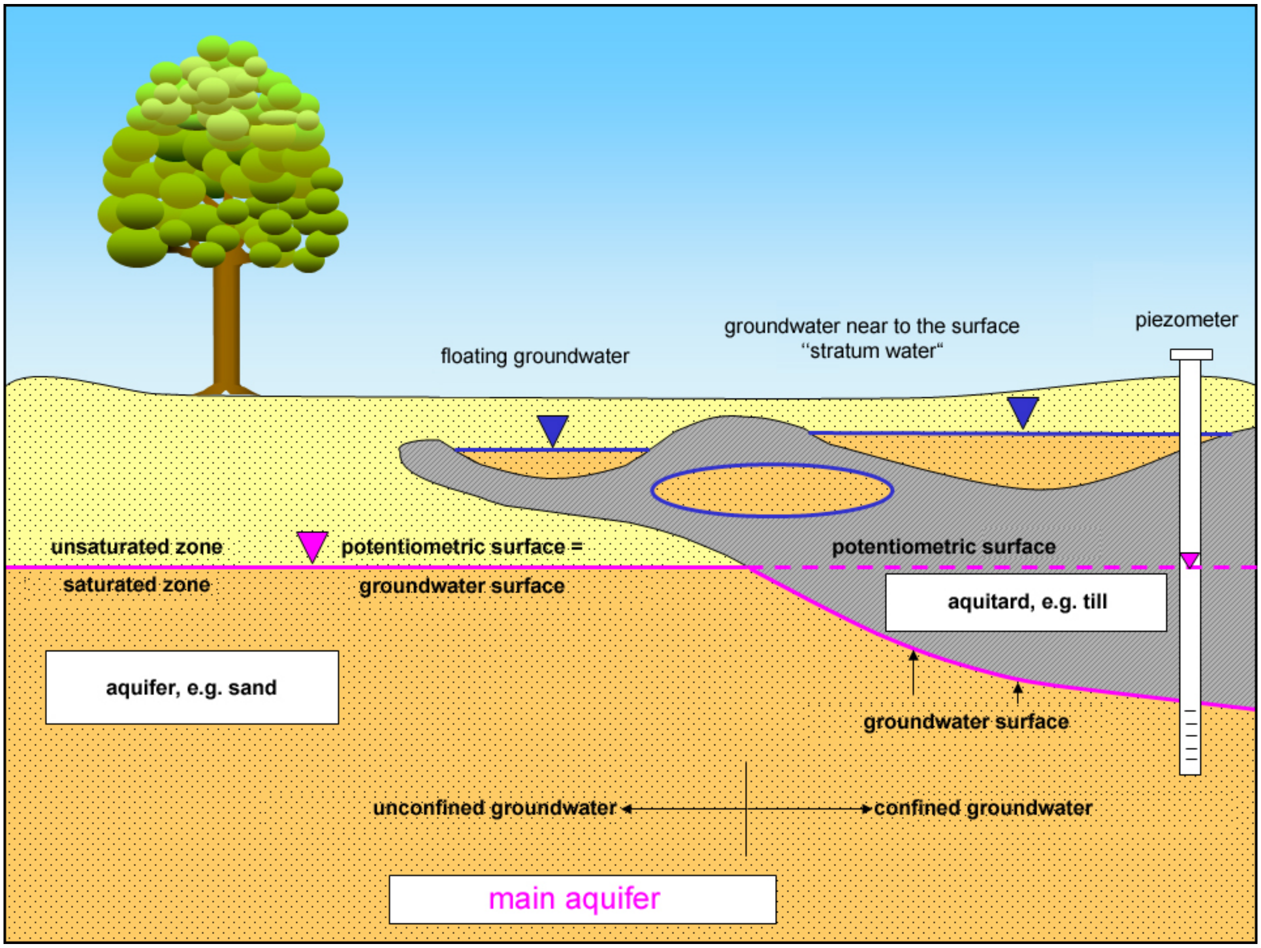

Fig. 3: Hydrogeological Terms

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).

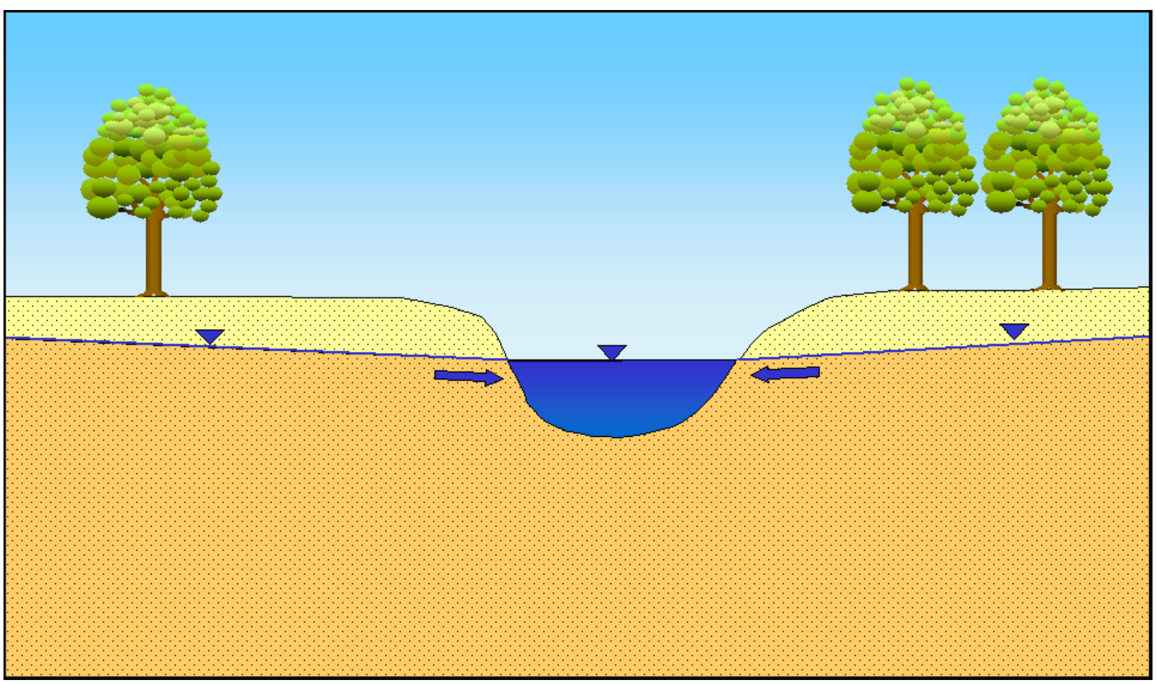

Fig. 4a: Groundwater infiltrates into bodies of water (effluent conditions)

In times of flooding, the water surface is 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).

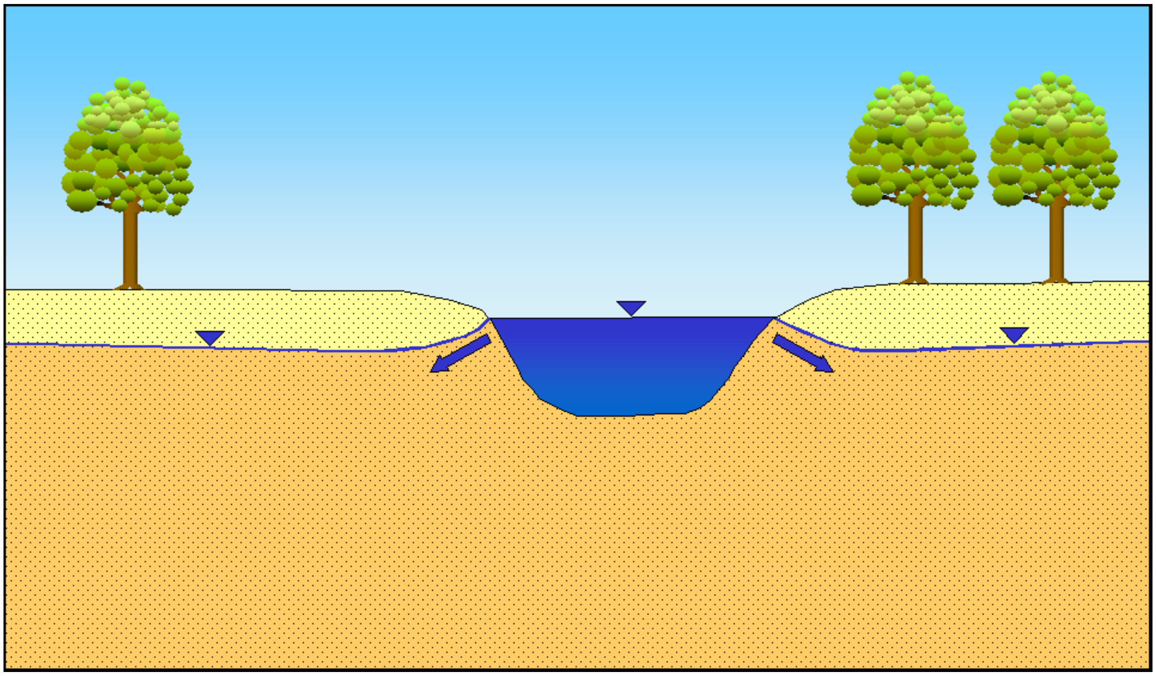

Fig. 4b: Bank-filtered water caused by flooding: Surface water infiltrates into the groundwater (influent conditions)

If in the neighbourhood of these surface waters, groundwater is discharged via 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). The amount of bank filtration is between 50 and 80 % of the total water obtained in Berlin, depending on the location of the wells.

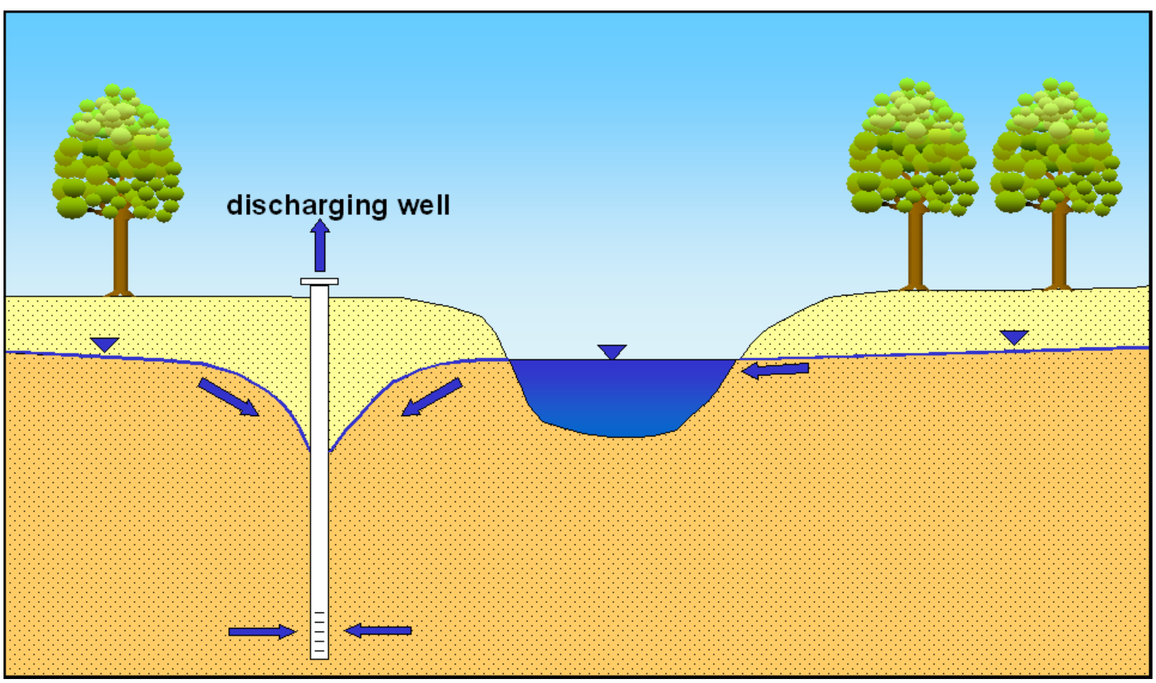

Fig. 4c: Bank-filtered water caused by discharge of groundwater: due to the drop in the groundwater caused by wells, surface water infiltrates into the groundwater

The **groundwater velocity of flow** in Berlin is approx. 10 to 500 m per year, 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 relief of the earth's surface in Berlin was predominantly the result of the Weichselian glaciation, the most recent of the three great quaternary inland glaciations, which has determined the morphology of the city (Fig. 5): the low-lying Warsaw-Berlin Glacial Spillway with its Panke Valley branch, which consists predominantly of sandy and gravelly deposits; the neighbouring Barnim Plateau to the north; and the Teltow Plateau with the Nauen Plate to the south. Both plateaus are covered in large parts by the thick glacial till and boulder clay of the ground moraines (Fig. 6). The morphological appearance is supplemented by the depression of the Havel chain of lakes (Figs. 5 and 6). For more on the geology, see LIMBERG & SONNTAG (2013) and the Geological Outline (Map 01.17).

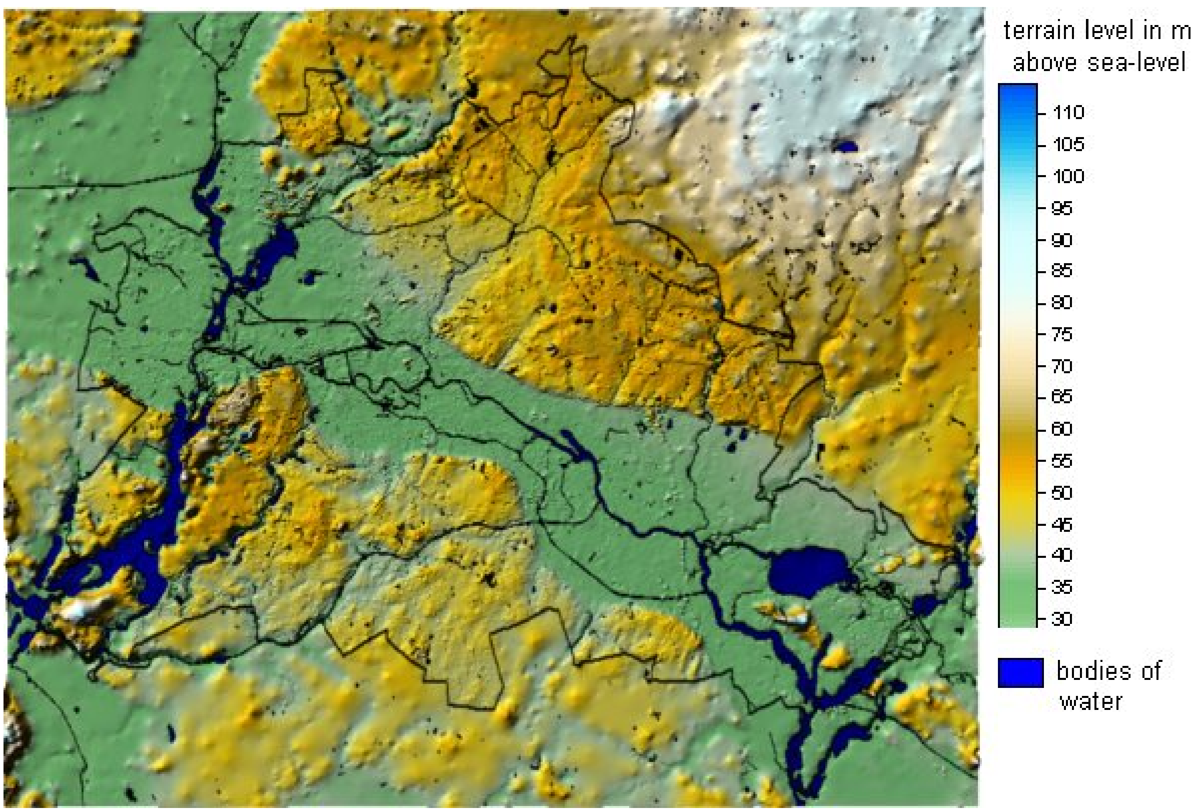

Fig. 5: Morphological Outline Map of Berlin

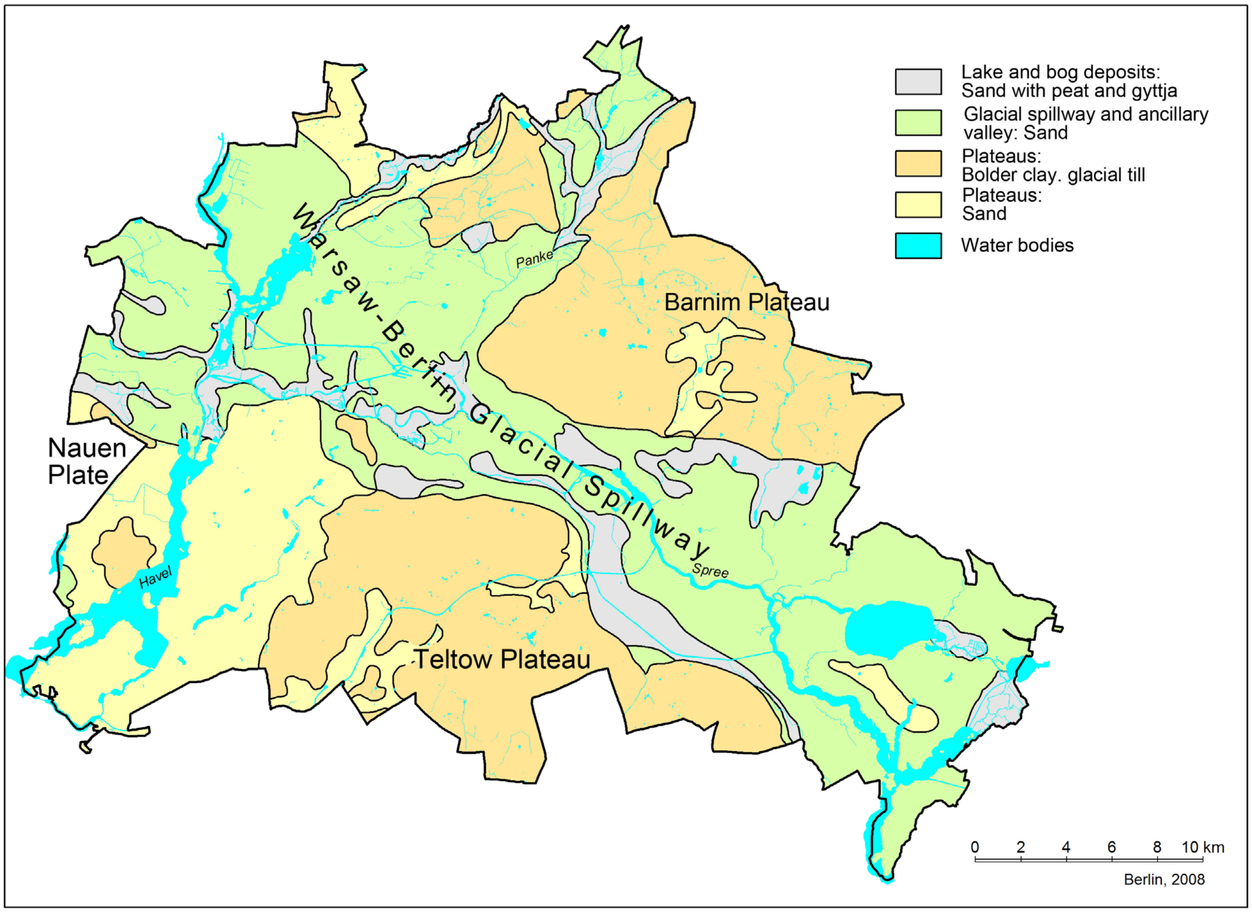

Fig. 6: Geological Outline Map of Berlin

The loose sediments dating from the quaternary and tertiary and averaging approx. 150 m in thickness, whose pore space is often filled with groundwater almost up to the terrain surface, are of special significance for the water supply and for the foundations of buildings. They form the freshwater stock from which Berlin draws all the water for the public water supply. Numerous waterworks and other pumping facilities have lowered the groundwater in Berlin, for more than 100 years in some areas.

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

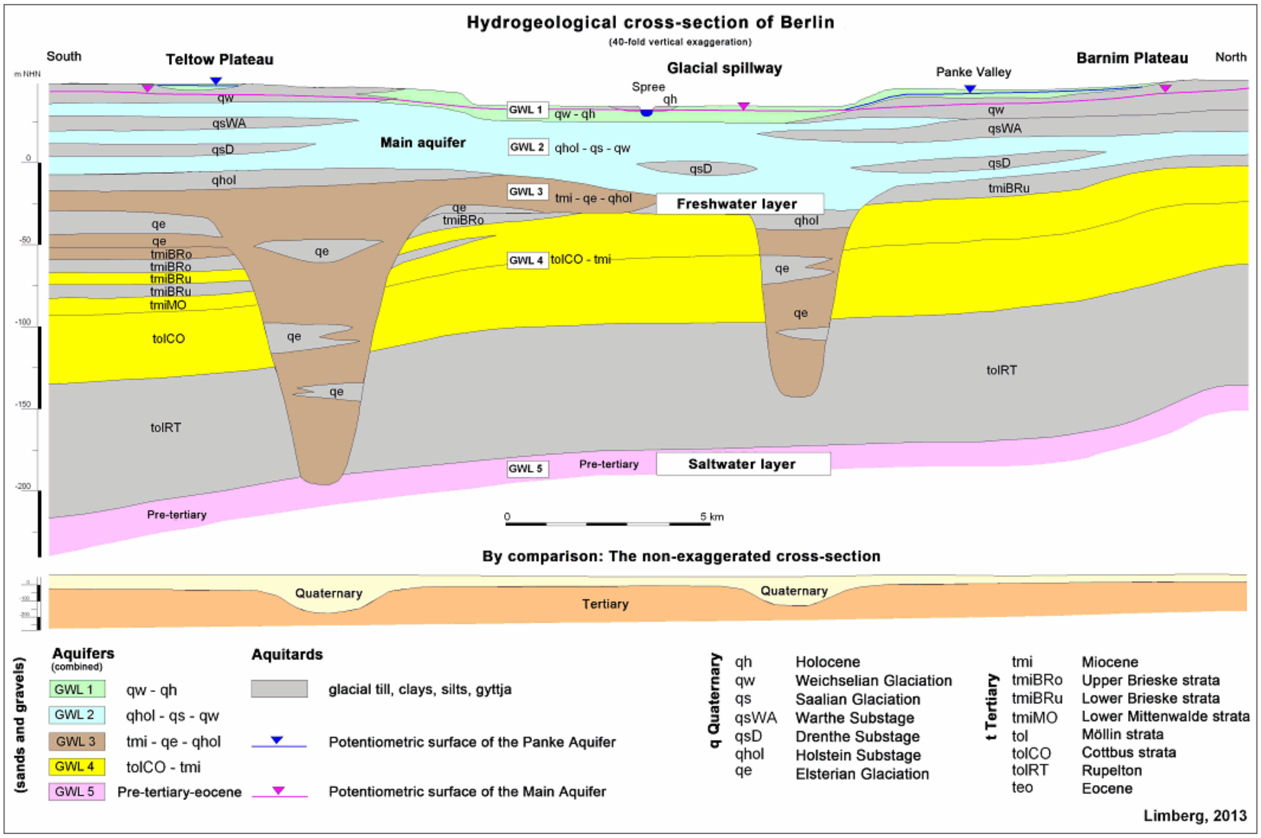

Fig. 7: Schematic hydrogeological cross-section of Berlin, from south to north

Due to the alternation of aquifers (green, blue, brown 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 – largely a Saale-Glaciation-era aquifer – is known as the **Main Aquifer**, since it supplies the predominant share of the public water supply. 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 north-western 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 (Figs. 7 and 8).

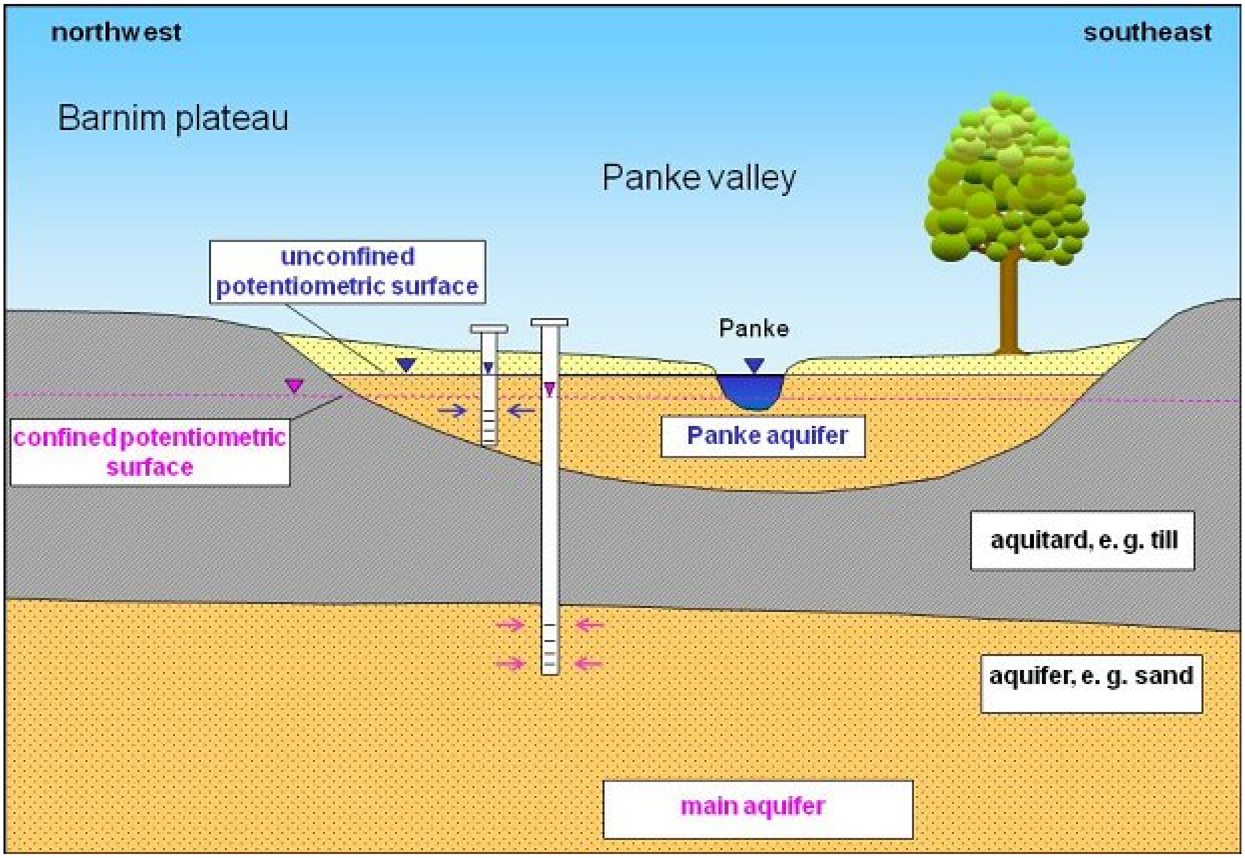

Fig. 8 The unconfined Panke Valley Aquifer (Aquifer 1) in the north-western area of the Barnim Plateau is situated above the Main Aquifer (Aquifer 2), which is confined in this area

In the north-western 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 parts 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 State Geology Working Group of the Senate Department for the Environment, Transport and Climate Protection, by the Berlin Waterworks and the federal state of Brandenburg.

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

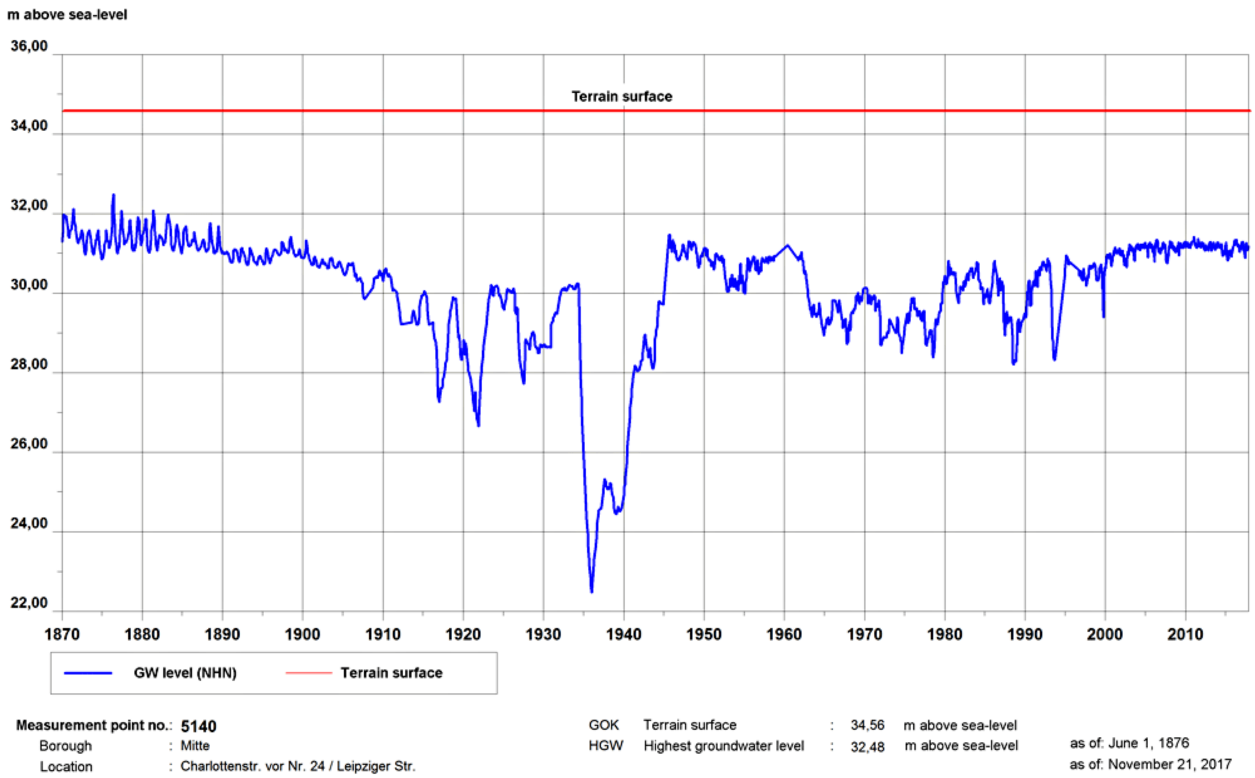

Fig. 9: Hydrographic curve of groundwater levels at a measurement point in the borough of Mitte, since 1870
(The highest groundwater level (HGW) was measured here on June 1, 1876. Since 1905, the groundwater level has been greatly affected by numerous drawdowns.)

The Berlin groundwater measurement network grew rapidly: Thus, 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. 1,000 measurement points which are installed at the five different aquifers.

In the inner-city area too, which is not within the area affected by the waterworks, groundwater conditions have for over 100 years been strongly anthropogenically overformed. This can be shown by way of the example of the hydrographic curve of groundwater levels at Measurement Point 5140 (Figure 9) in the borough of Mitte, as follows:

Until 1890, the largely natural seasonal fluctuations of the groundwater level remained apparent. With the growth of the city, increased impervious coverage, and the construction of small wells for drinking water, the amplitude was reduced, and the groundwater level had, by 1905, been moderately lowered. Thereafter, the large water retention operations connected with major construction sites, e.g. for the underground/ subway and the urban rail lines (S-Bahn), for the construction of the Reichsbank (today, the Foreign Ministry) and for bunkers, etc., with their deep cellars reduced the level of the groundwater by another 10 m over a large area. In 1945, at the time of the collapse of the infrastructure after the Second World War, the groundwater level quickly rose back almost to its original level. During the years of reconstruction, it was then repeatedly lowered again. Since the termination of major construction projects with groundwater retention, the groundwater is now back to a high level, and major precipitation events rapidly lead to a short-term rise in the level. Here, as in other areas of the city, in buildings which have not been sealed against the maximum expected groundwater levels this causes damage from penetrating groundwater.

In around 1,000 groundwater observation wells, data loggers are installed since the late 1980s, which record the groundwater level on a daily basis. About 10 % of these data loggers are equipped with a remote data transmission module so that the data is sent to the Geological Survey of Berlin on a daily basis. The data from the rest of the data loggers is retrieved manually from the logger on a monthly to three-monthly basis and then imported into the database. The measured values of the city state wide groundwater measuring network are published on the website of the ""Wasserportal" and are freely accessible to everyone [available in German only].

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 2,198 groundwater measurement points and 121 surface-water measurement points for the main aquifer (Aquifer 2), and from 100 groundwater measurement points and 13 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, 2017 was used; for the others, the value taken during the month of May which was closest to this date was used.

The distribution of the measurement points is irregular: The measurement network is densest in the city centre 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 Aquifer 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 analysed 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
ETRS89 easting (min./max.)	360685,2/424199,1	388657,5/402242,1
ETRS89 northing (min./max.)	5796007,73/5845998,10	5823424,1/5837402,5
Spacing	about 200 m	about 200 m
Number of grid lines	x = 318 / y = 263	x = 69 / y = 471
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 10.0, 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 north-eastern Berlin with blue isolines. The interval between the groundwater isolines is 0.5 m. These show the potentiometric 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 areas are shown with black dots.

The map is based on the topographical General Map of Berlin, scale of 1 : 50,000, in grid format, and the geological outline for the Berlin state territory, at a scale of 1 : 50,000, which was derived from the geological General Map of Berlin and Surrounding Areas, scale of 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 potentiometric surface of the main aquifer lies within such an aquitard, groundwater conditions are confined. In sandy segments above the till or in islands, near-surface groundwater may be formed, which is also called stratum water (see also Fig. 3). After extreme precipitation, it may rise to the surface. The groundwater levels of these locally highly differentiated areas have not been separately ascertained and portrayed.

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 Figs. 7 & 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:
https://www.berlin.de/senuvk/umwelt/wasser/wasserrecht/grundwasserbroschuere.html (only in German)

Current Situation in May 2017

As a rule, the groundwater incline in Berlin, 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 neighbouring 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 also Fig. 4c).

In May 2017, too, the potentiometric 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 ff.). Areas in the Glacial Spillway in which the groundwater rebounded over this period of time by more than half a meter and by more than one meter, respectively, are shown on the difference map 1989-2012 (Fig. 10).

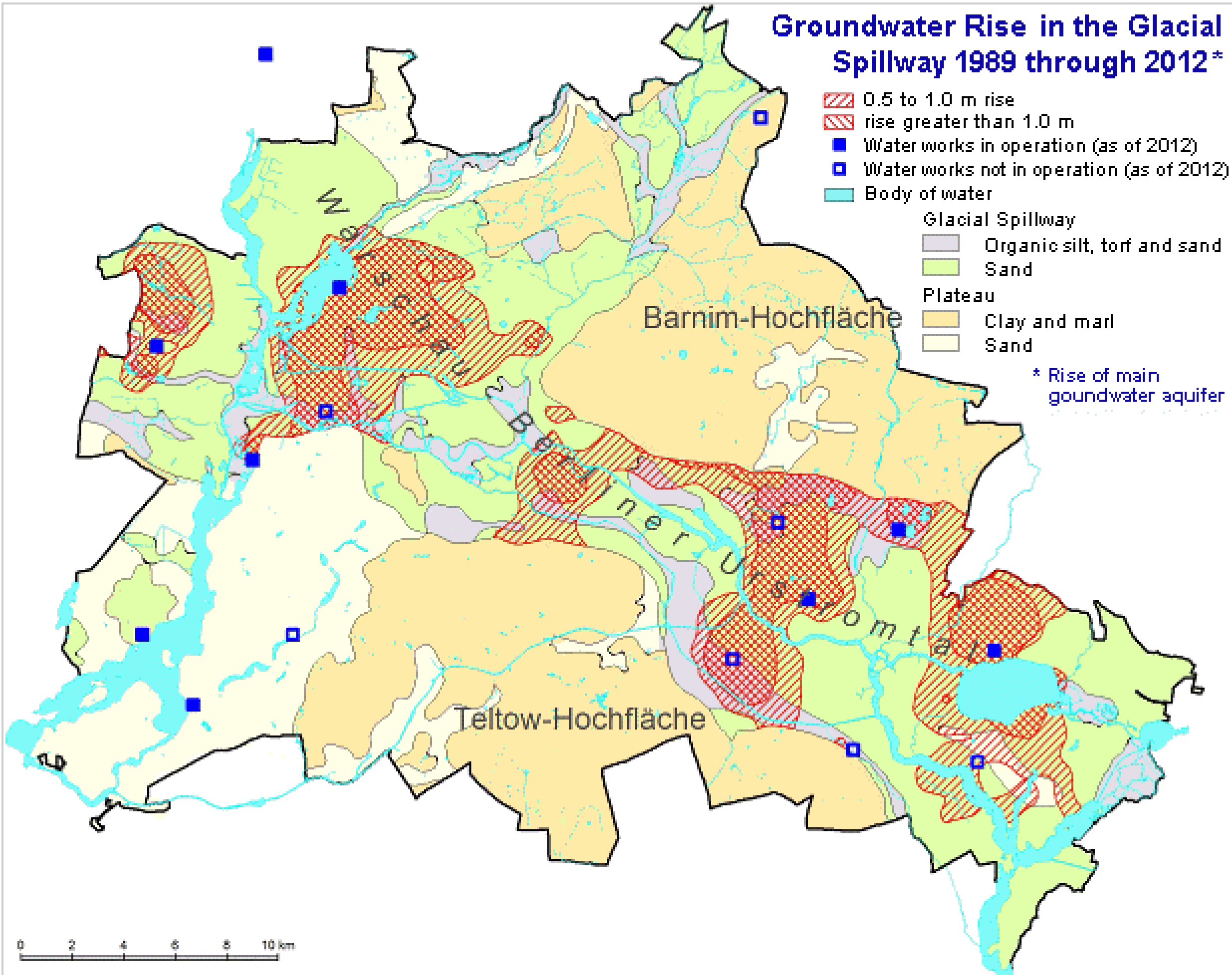

Fig. 10: Groundwater Rebound in the Glacial Spillway between 1989 and 2012

The reduced raw-water discharge by the Berlin Water Utility since 1989 as a result of the decreased need for drinking and industrial water is responsible for the constant rise of the groundwater level. Moreover, five of the smaller Berlin waterworks (Altglienicke, Friedrichsfelde, Köpenick, Riemeisterfenn and Buch) were shut down altogether in the period from 1991 to 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 former Senate Department for Urban Development and the Environment, groundwater is still being discharged at the Johannisthal location in order to support 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 performed the groundwater management there for continuing the dewatering of the cellars.

The Water Conservation Districts of the Buch, Jungfernheide and Altglienicke waterworks were abolished in April 2009.

The overall discharge of raw water by the Berlin Water Utility for public water supply dropped by almost half (42 %) in Berlin over a period of 28 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. After a further phase of decline, the discharge increased again to 221million cu.m. in the past years (Fig. 11).

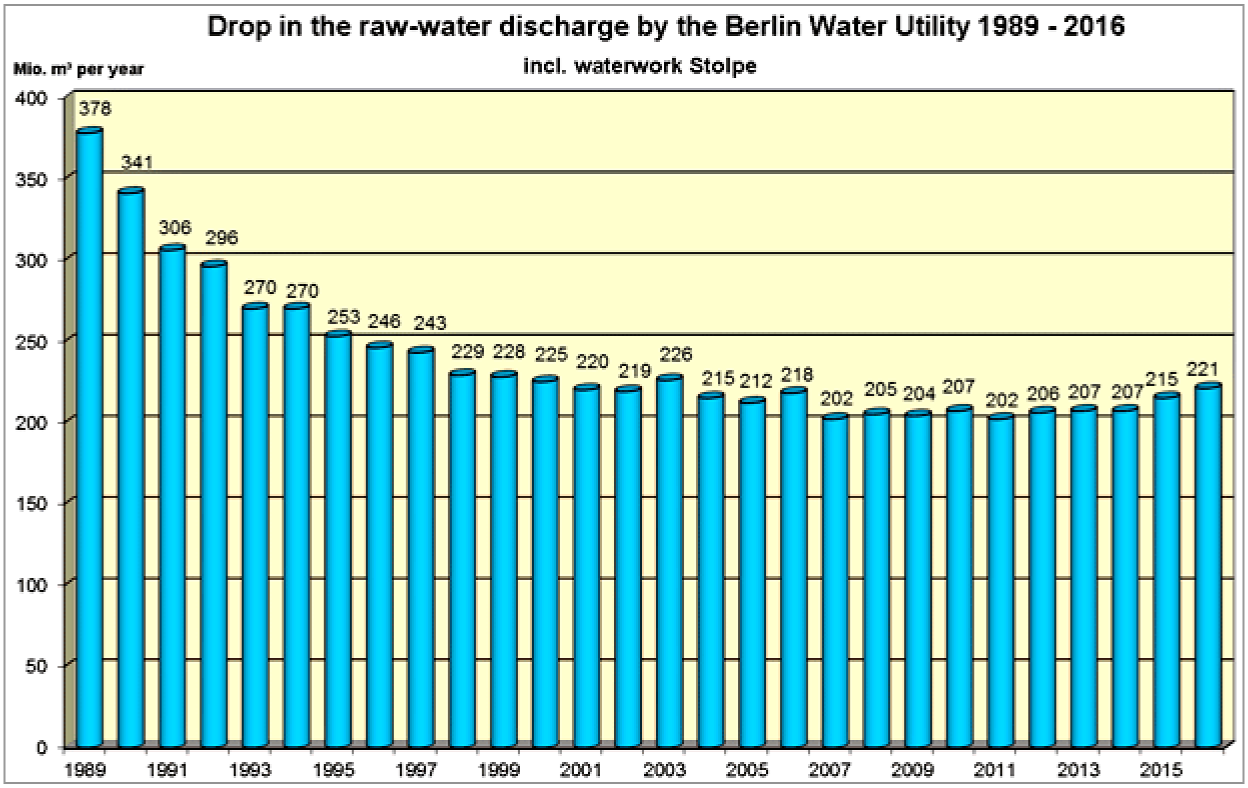

Fig. 11: Drop in the raw-water discharge by the Berlin Water Utility over a 28-year period

The development of the groundwater levels from May 2016 through May 2017 is exemplified at four measurement points which are largely unaffected by the withdrawal of water by the waterworks (Fig. 12).

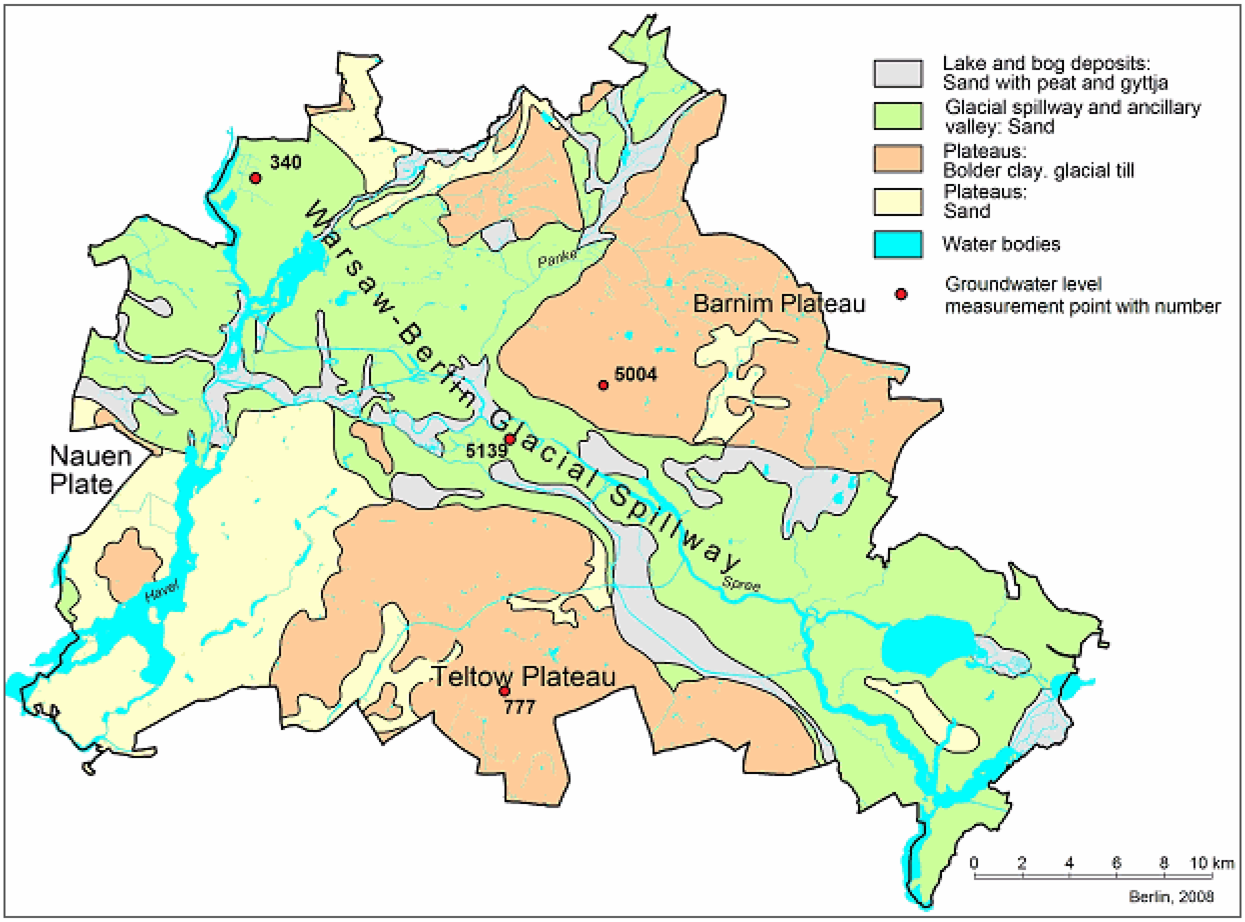

Fig. 12: Four exemplary measurement points: 340 and 5139 in the Glacial Spillway, 777 on the Teltow Plateau, and 5004 on the Barnim Plateau

The groundwater levels at the two measurement points in the unconfined aquifer of the Glacial Spillway exhibit nearly the natural annual variation with low groundwater levels in autumn and high ones in spring. The amplitude of the hydrographic curve of the groundwater level of Measurement Point 340, which is situated on the outskirts of the city, is pronounced, while that of the inner-city Measurement Point 5139 exhibits an attenuated annual variation. The short-term fluctuations in groundwater levels here in December and January are rather connected to construction projects involving both lowering of the level as well as adding to the level. Due to a very “dry” year, the groundwater level at Measurement Point 340 was more than one decimetre lower on 15 May 2017 than in the year before (Fig. 13 and 15).

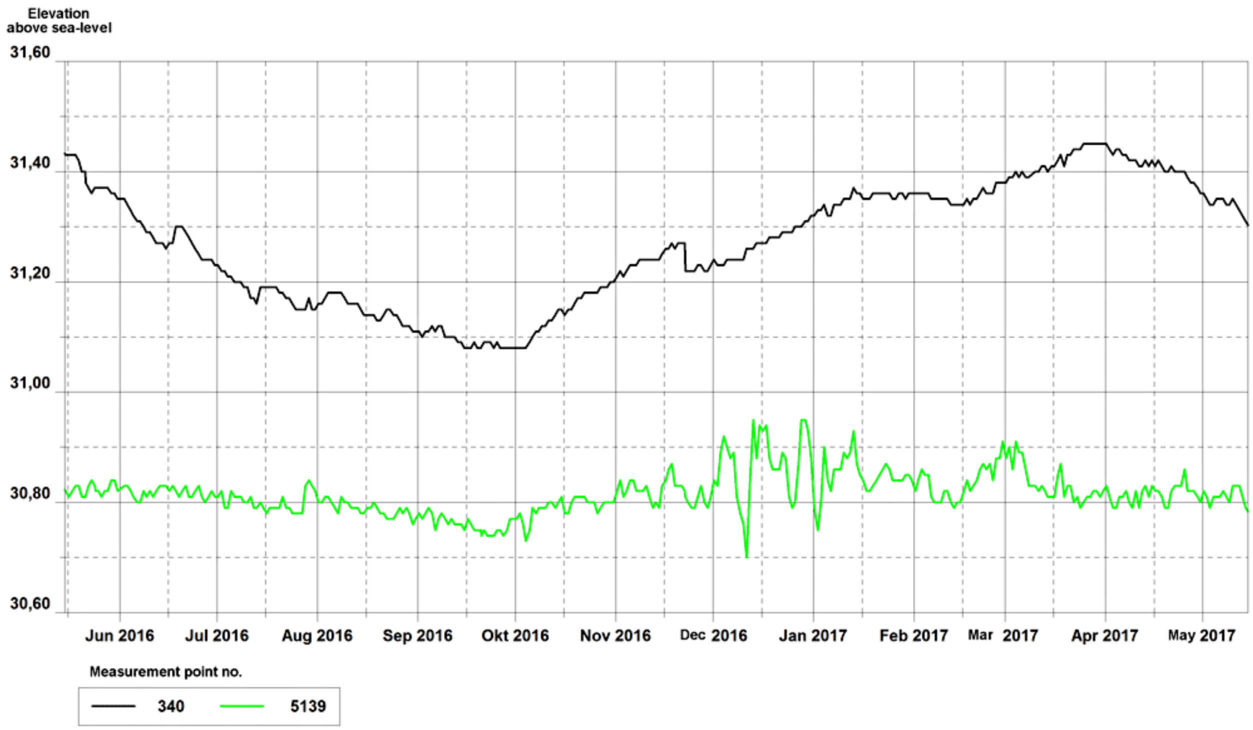

Fig. 13: Hydrographic curves of groundwater levels at two measurement stations in the Glacial Spillway, May 15, 2016 to May 15, 2017

By contrast, on the Teltow Plateau and on the Barnim Plateau, the development of the groundwater level at Measurement Points 777 and 5004 in the covered, confined aquifer was similar to the one in the Glacial Spillway during the same period (Fig. 14). However, here the annual variation with the natural fluctuations is not as pronounced as at Measurement Point 340. Due to a very "dry" year, the groundwater levels at both measuring points were more than one decimetre lower on 15 May 2017 than in the year before (Figs. 14 and 15).

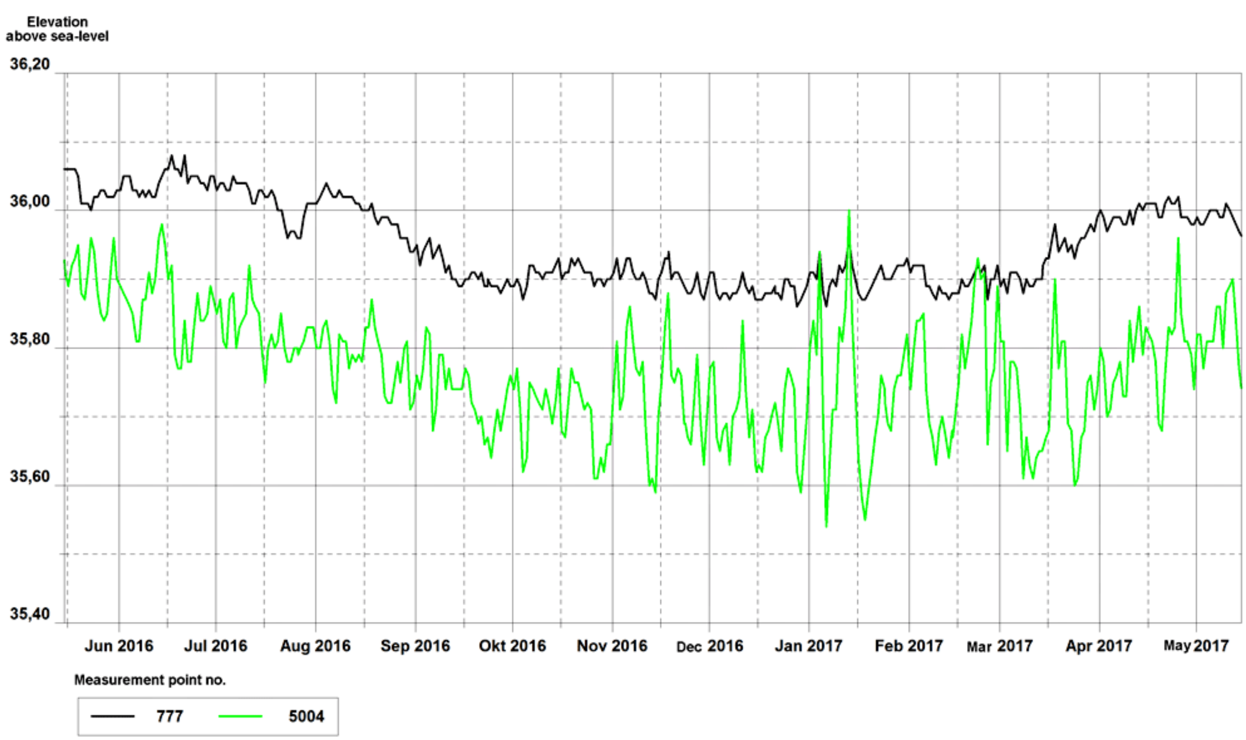

Fig. 14: Hydrographic curves of groundwater levels at two exemplary measurement points on the plateaus, May 15, 2016 to May 15, 2017

In the period from June 2016 to May 2017, the precipitation amount at the Berlin-Tempelhof Measurement Point, with 183 mm, was significantly below that of the long-term mean (1981-2010). Only three of these months displayed a monthly mean respectively that was slightly higher than the long-term monthly mean (Fig. 15). As a result, groundwater levels were up to one decimetre lower in May 2017, than in May 2016 (Figs. 13 and 14).

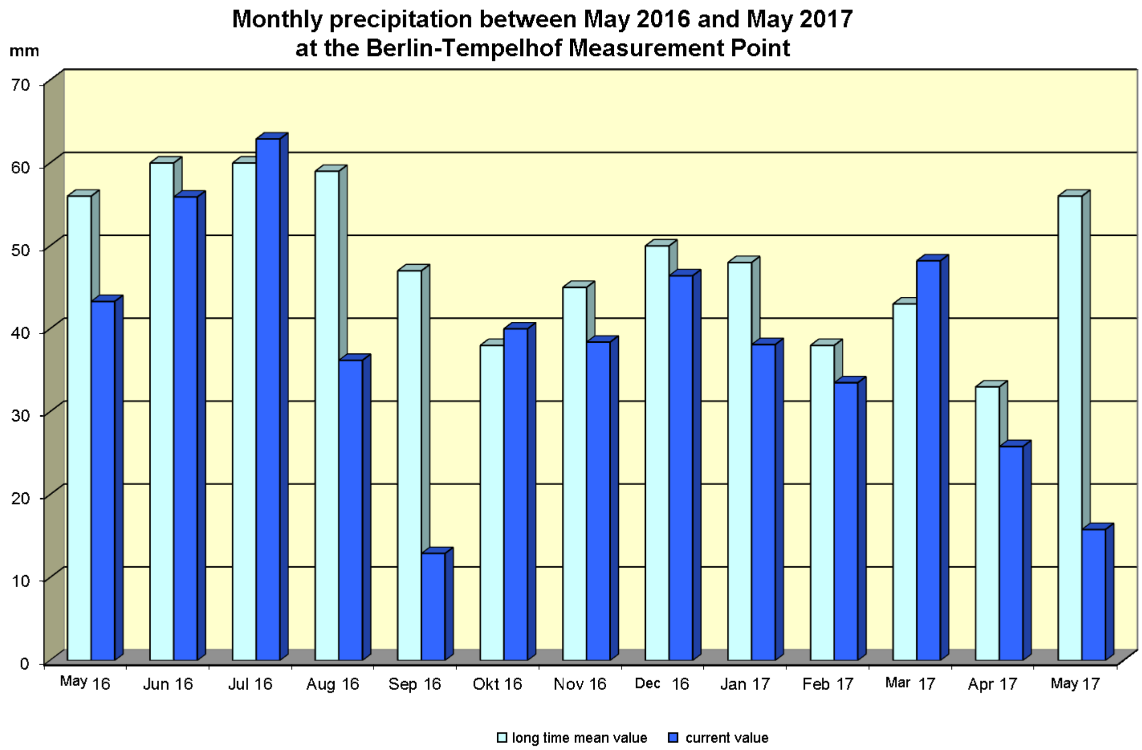

Fig. 15: Monthly precipitation between May 2016 and May 2017 at the Berlin-Tempelhof Measurement Point, compared with the long-term mean, 1981 through 2010.

Information on the expected highest groundwater level (EHGL), which is an important basis for planning the design of buildings, can be found in the Environmental Atlas under: https://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ei219.htm (Limberg et al. 2015).

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