

## 02.12 Groundwater Levels of the Main Aquifer and Panke Valley Aquifer (Edition 2018)

### Overview

Exact knowledge of the current groundwater levels, and hence also of the groundwater resources, is crucial for the State of Berlin, since the water for the public water supply of Berlin (217 million m<sup>3</sup> in the year 2017) is provided from groundwater. The groundwater is pumped at nine waterworks, almost entirely within the city area, with the exception of the waterworks Stolpe. It is located on the northern outskirts of the city and pumps water from wells that are located in Brandenburg (approx. 9 % of the total annual pumping volume) (Fig. 1).



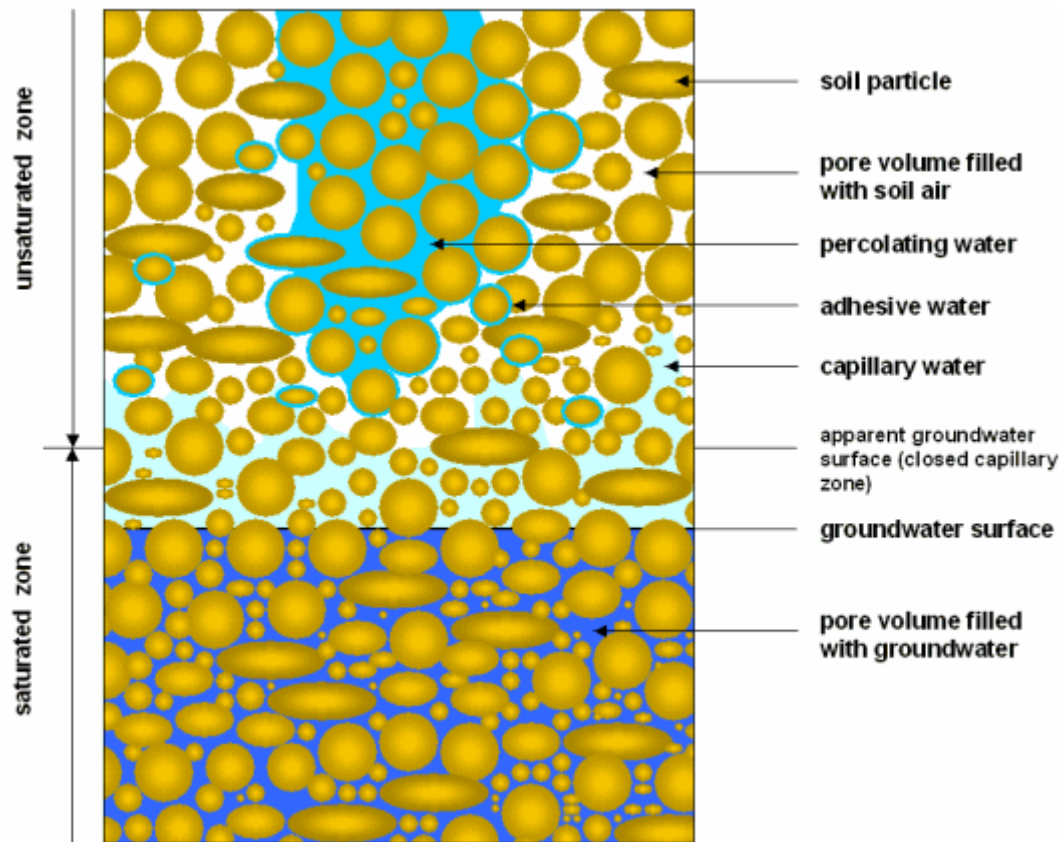
*Fig. 1: Location of the waterworks which supply Berlin with drinking water, as of May 2018*

Additionally, groundwater is pumped from individual wells (like garden wells) and for industrial use, but also in the context of construction sites, groundwater remediation projects and for geothermal usage. In Berlin, numerous cases of soil and groundwater contaminations are known and the information about the hydraulic situation is fundamental for their remediation.

The map of the groundwater levels for the month of May, with the highest groundwater levels throughout the year 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: Types of appearance of subsurface water (modified after Hölting 1996)*

**Aquifers** consist of sands and gravels, and, as incoherent material, make the storage and movement of groundwater possible.

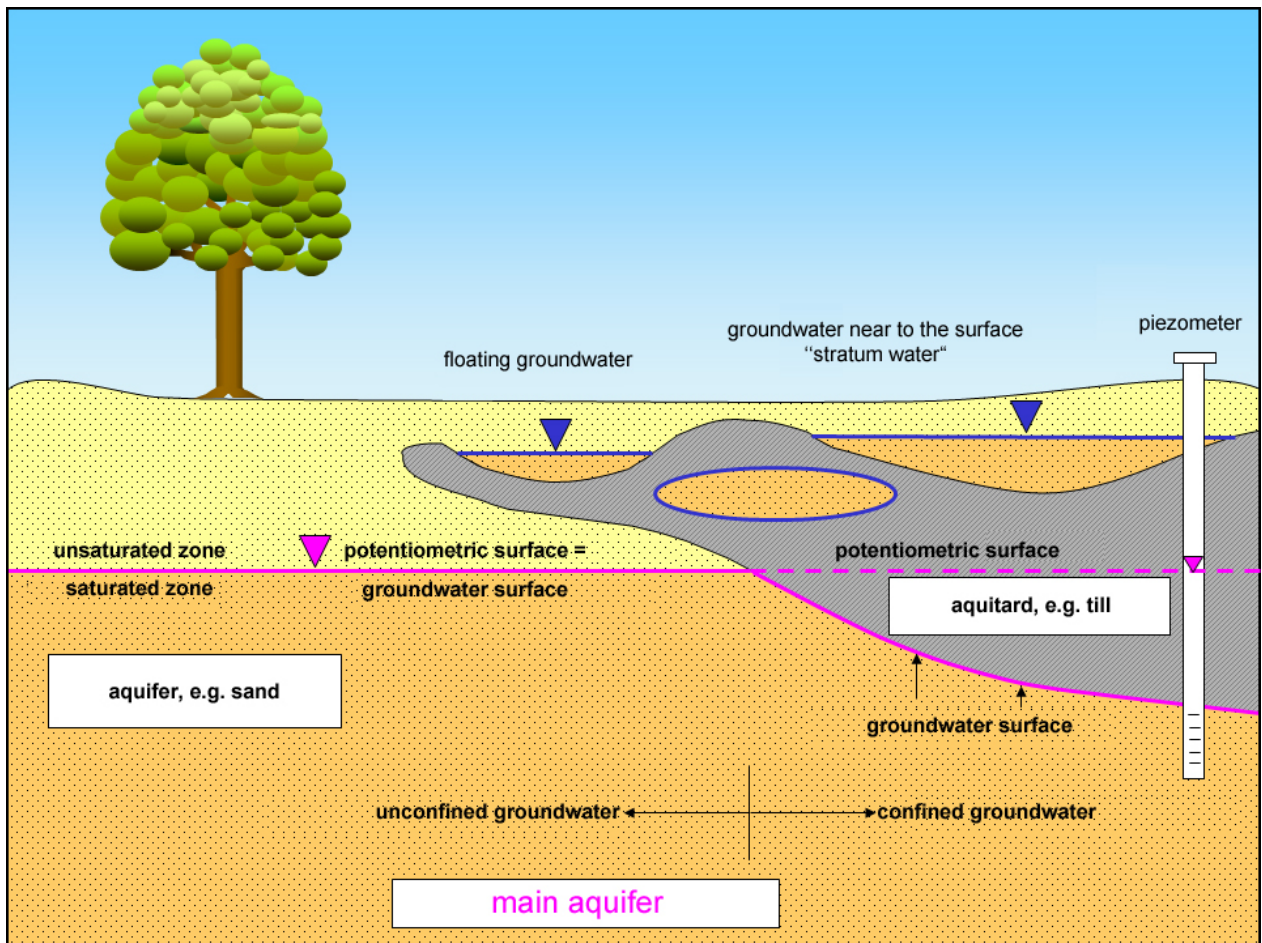
**Aquitards** consist of clay, silt, peat clay and glacial till and, as cohesive material, hinder water movement.

**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**. The phreatic and the 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 located above the phreatic surface (Fig. 3).

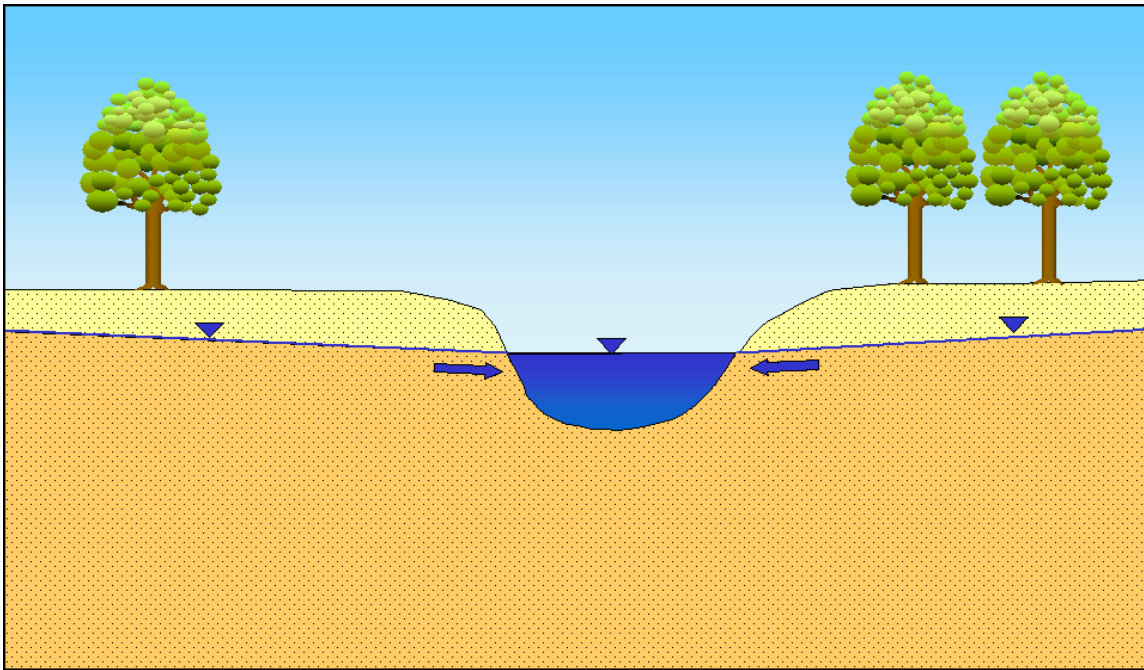
If an aquitard (e.g. a layer of glacial till) is located above a large coherent aquifer (Main aquifer), shallow groundwater may develop in sandy segments above the aquitard and in islands within it, as a result of

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).



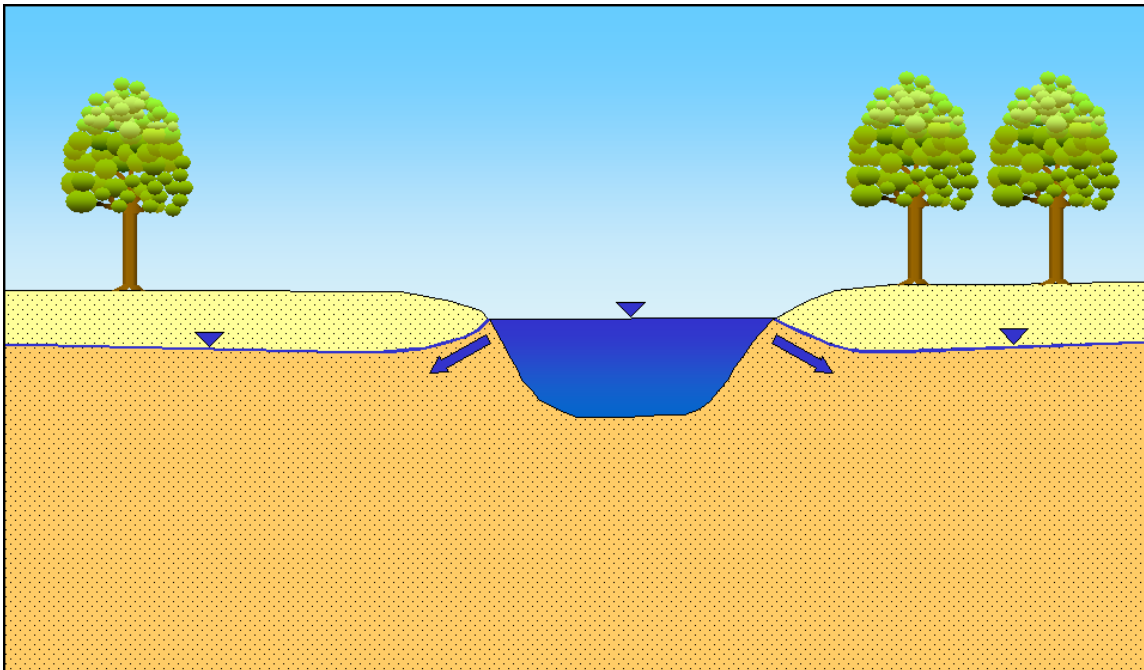
*Fig. 3: Hydrogeological terms*

Typically, groundwater flows with a small gradient into rivers and lakes ("receiving channel") and infiltrates into them (effluent conditions; Fig. 4a).



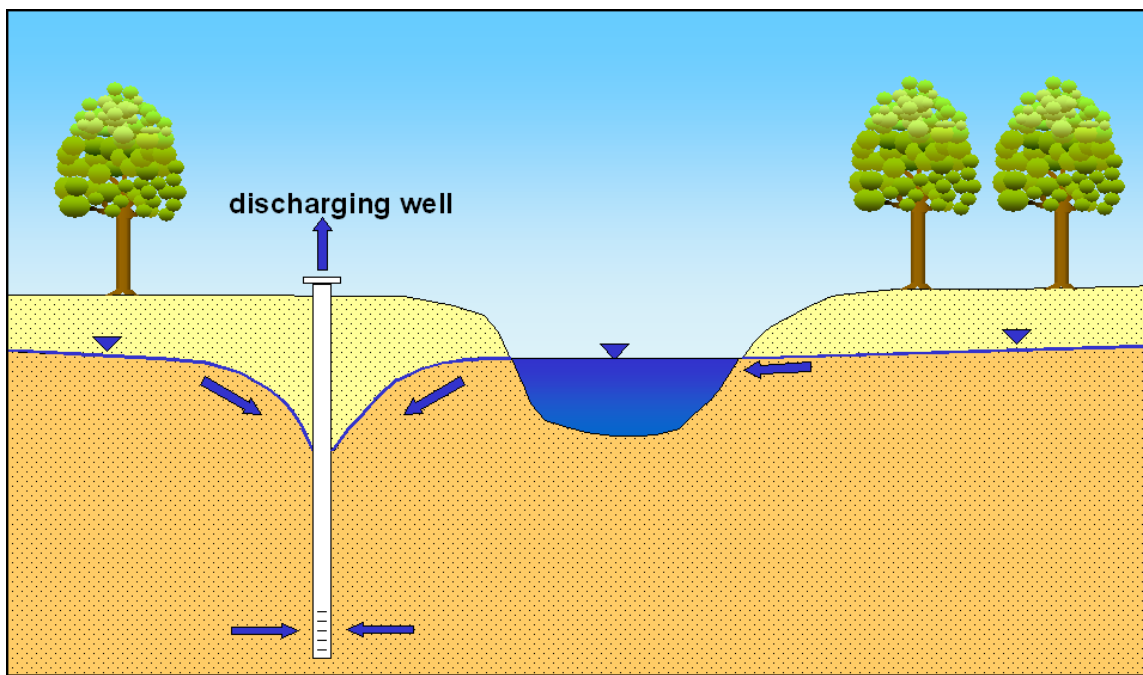
*Fig. 4a: Groundwater infiltrates into the surface waters (effluent conditions)*

In times of flooding, the water surface is higher than the groundwater surface and surface water infiltrates into the groundwater (influent conditions). This is known as **bank infiltration** (Fig. 4b).



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

If pumping of groundwater in the vicinity of surface water bodies is leading to a drop of the phreatic surface drops below the water table of the surface water body, 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.



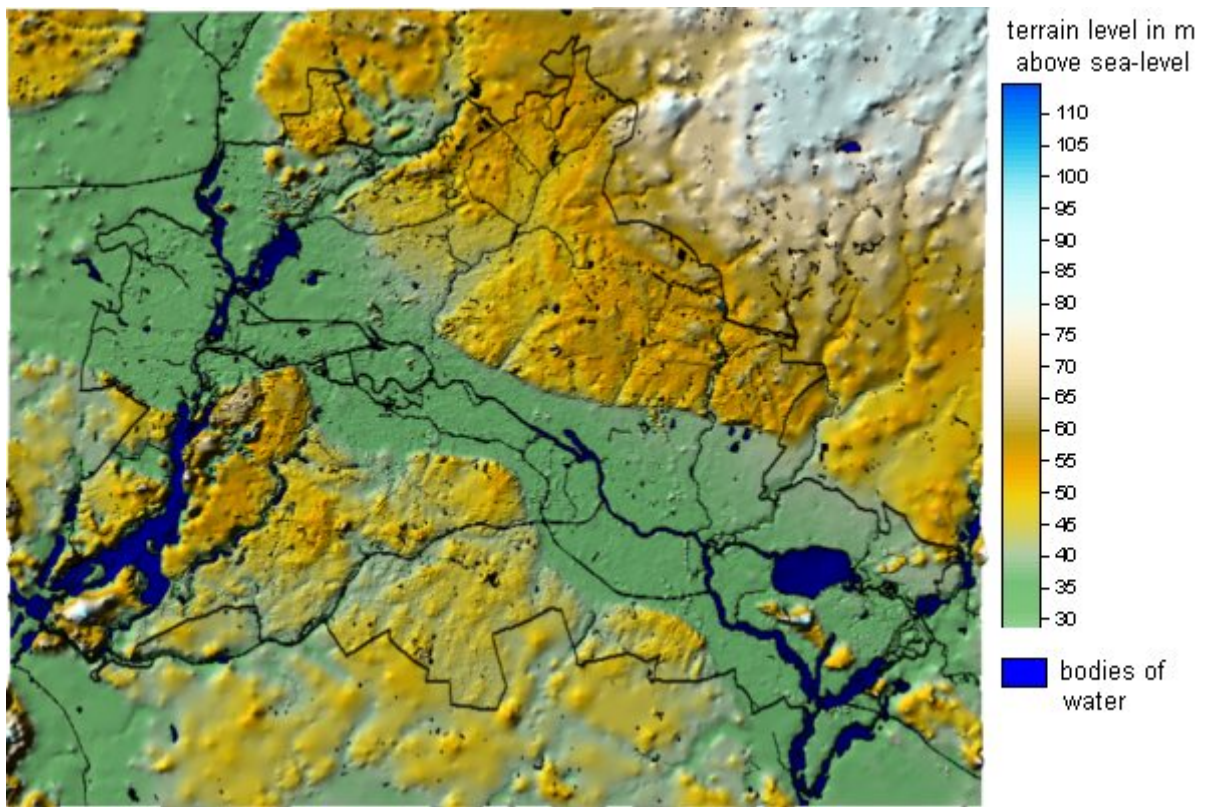
*Fig. 4c: Bank-filtered water caused by discharge of groundwater: due to the drop in the groundwater caused by wells, surface water infiltrates into the groundwater*

The **groundwater flow velocity** in Berlin is approx. 10 to 500 m per year, depending on the hydraulic gradient and the transmissivity of the aquifer. However, in the surrounding flow field of the well galleries, these low-flow velocities can increase significantly.

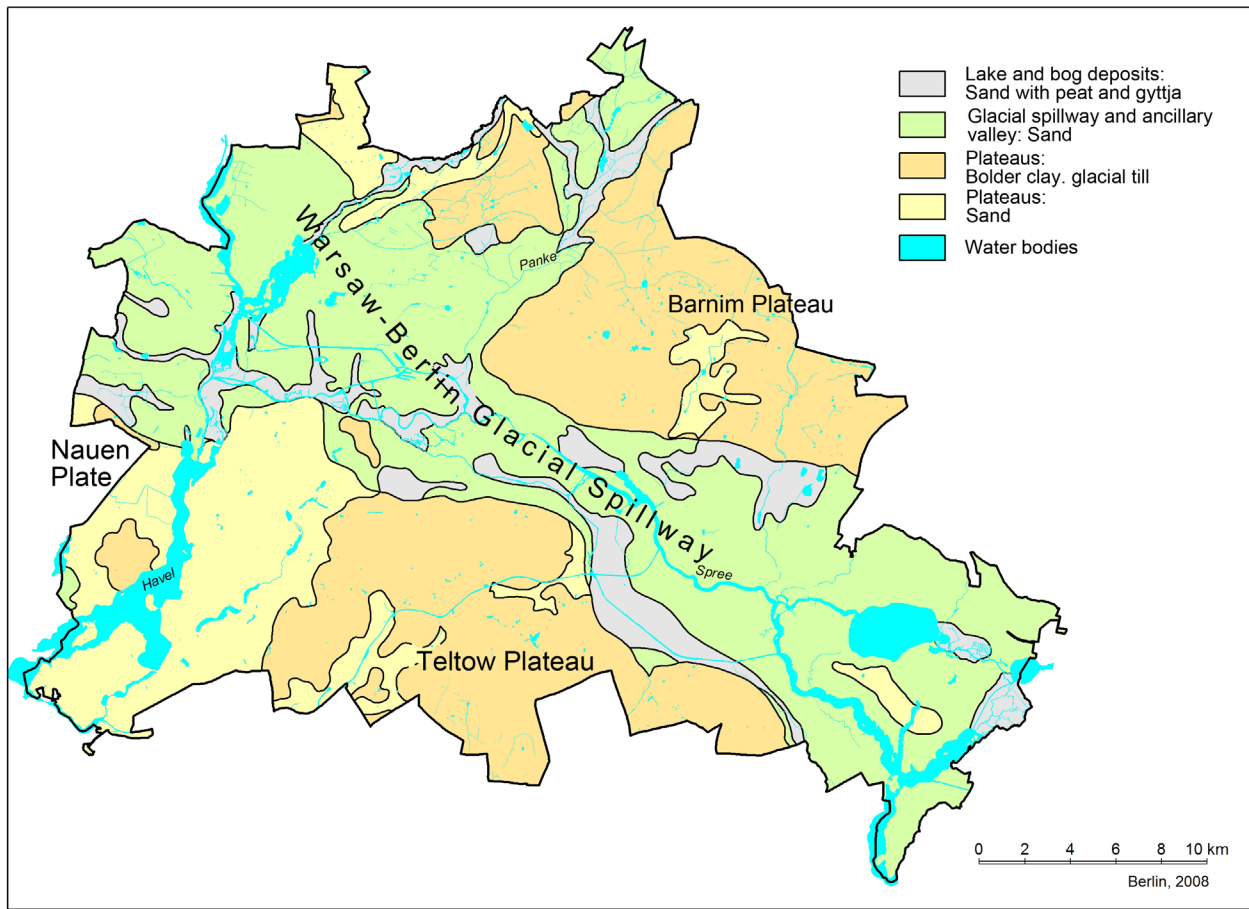
## Morphology, Geology and Hydrogeology

The present surface of Berlin is mainly a result of the Weichselian glaciation, the most recent of the three major quaternary inland glaciations. It has determined the morphology of the city (Fig. 5): the low-lying Warsaw-Berlin glacial spillway and its side valley, the Panke Valley, which consists predominantly of sandy and gravelly sediments; 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 (Fig. 5 and Fig. 6). For more information on the geology, see LIMBERG & SONNTAG (2013) and the [Geological Outline \(Map 01.17\)](#).





*Fig. 5: Morphological map of Berlin*



**Fig. 6: Geological map of Berlin**

The unconsolidated quaternary and tertiary sediments show a thickness of approx. 150 m and the pore volume is often filled with groundwater up to ground level. These layers build the freshwater reservoir that is used for the public water supply for the city state of Berlin. Numerous waterworks (see also Fig. 1) and other pumping stations have lowered the groundwater table in Berlin for more than 100 years in some areas.

The clayey Oligocene layer from the Septarienton Formation ("Rupelton") is situated in a depth of 150 to 200 m below ground level and is approx. 80 m thick. It serves as a hydraulic barrier against the underlying saltwater aquifer (Fig. 7).

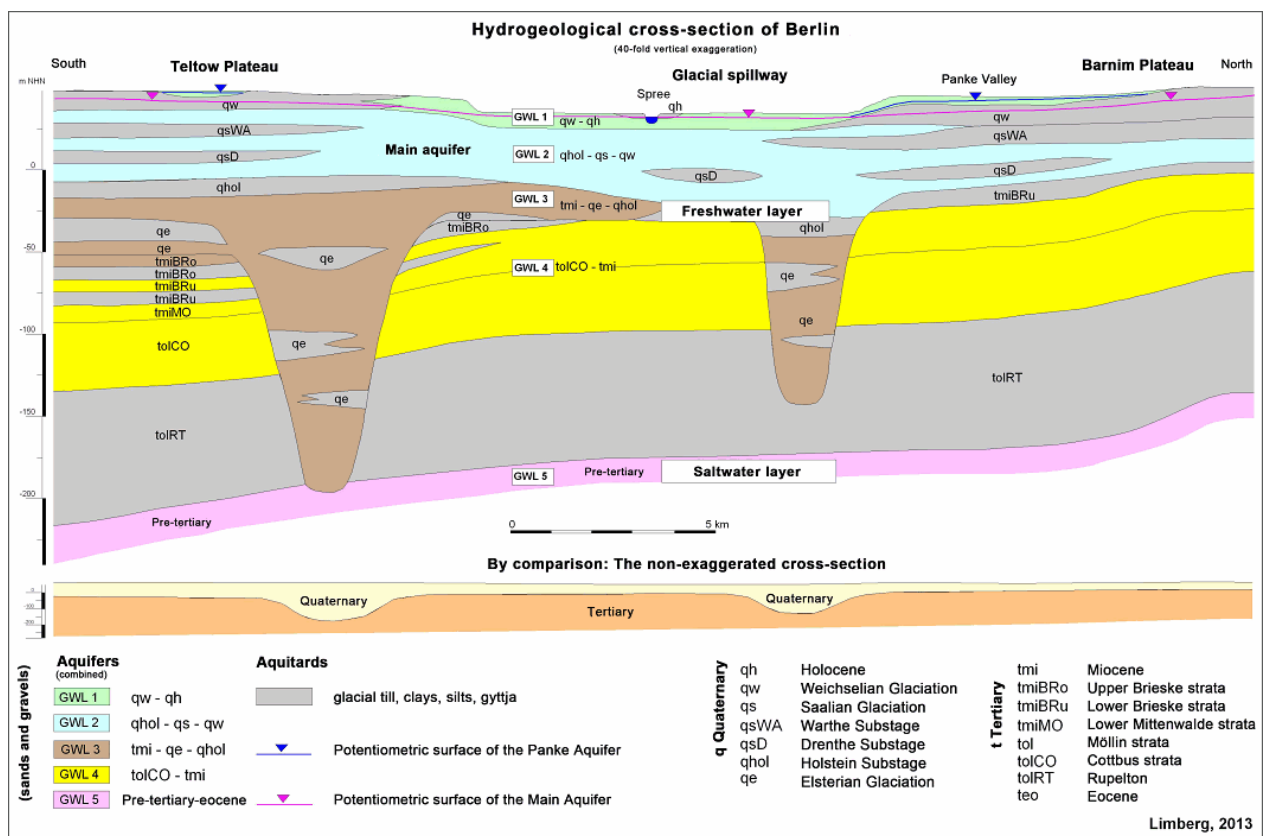
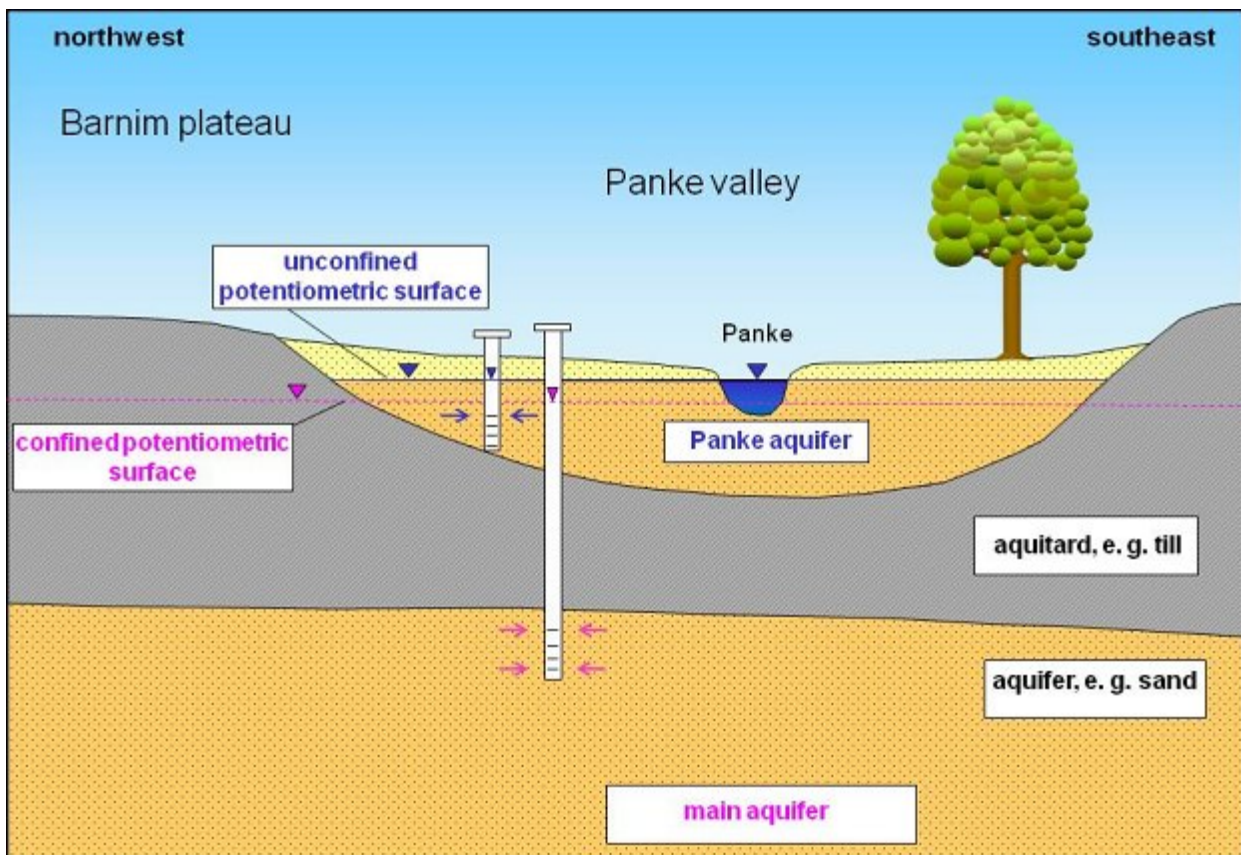


Fig. 7: Schematic hydrogeological cross-section of Berlin, from south to north

Due to the alternation of aquifers (green, blue, brown and yellow in Fig. 7) and aquitards (grey in Fig. 7), the freshwater reservoir in the Berlin area is broken down into four distinguishable hydraulic aquifers (LIMBERG, THIERBACH 2002). The second aquifer is built up predominantly by sediments of the Saalian glaciation and is known as the **Main Aquifer**, since most of the water for the public water supply is pumped from it. The fifth aquifer is found below the Septarienton Formation and is a saltwater aquifer.

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. The Panke Valley aquifer is situated above the main aquifer and is separated from it by the glacial till of the ground moraine (Fig. 7 and Fig. 8).





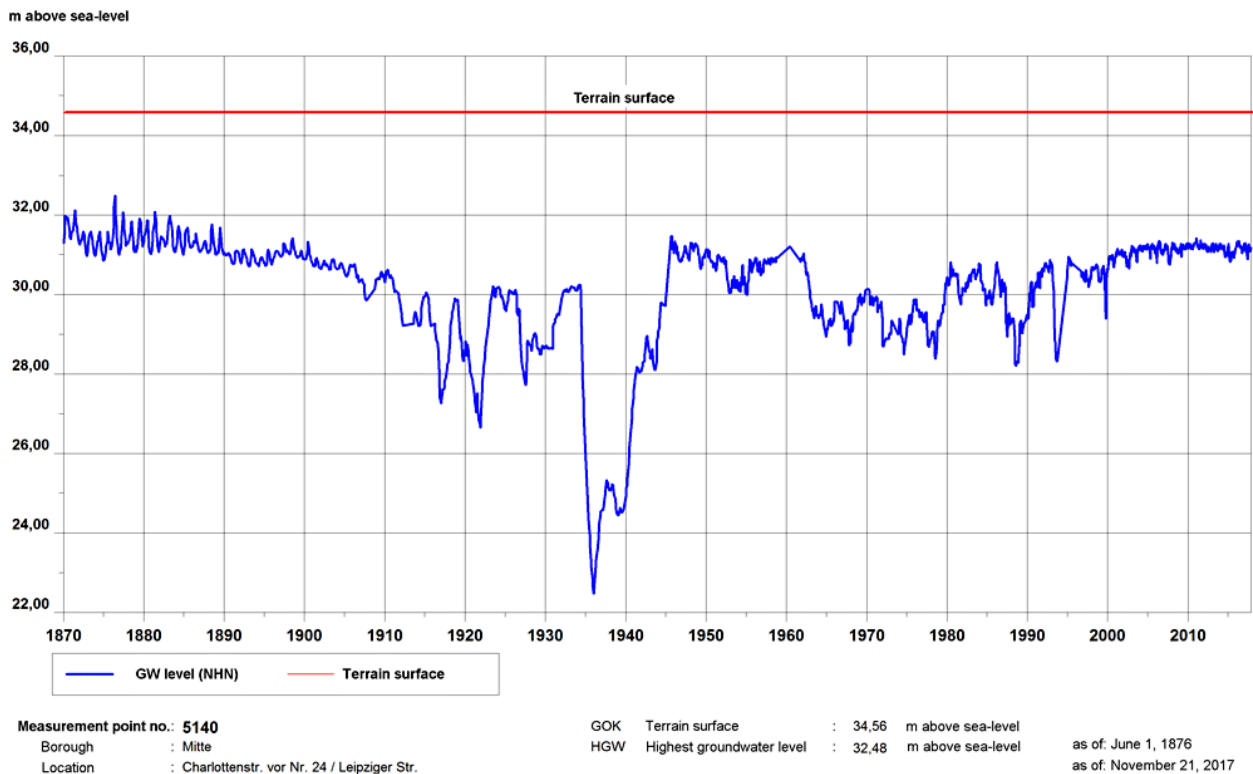
*Fig. 8 The unconfined Panke Valley Aquifer (Aquifer 1) in the north-western area of the Barnim Plateau is situated above the Main Aquifer (Aquifer 2), which is confined in this area*

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 that is needed for the preparation of the groundwater contour map is provided by the State Geology workgroup of the Senate Department for the Environment, Transport and Climate Protection, by the Berlin Waterworks [*Berliner Wasserbetriebe*] and by the federal state of Brandenburg.

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



*Fig. 9: Hydrograph of the groundwater level at an observation well 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 highly affected by numerous drawdowns.*

The Berlin groundwater monitoring network grew rapidly. By 1937, there were already more than 2000 observation wells. After an optimization of the monitoring network in the city area, the State Geology workgroup operates approx. 1,000 observation wells that are installed in five different aquifers.

In the inner-city area too, which is not within the area affected by the waterworks, groundwater conditions have been influenced strongly by anthropogenic processes for over 100 years now. This can be shown by way of the example of the hydrographic curve of groundwater level at the observation well 5140 (Fig. 9) in the borough of Mitte, as following:

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 Berliner Wasserbetriebe 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 with an at least monthly measurement frequency. If the groundwater has a direct connection to surface water (effluent situation, Fig. 4a), additional level data from surface-water measurement points are used.

For the present map, the water level data of 1866 groundwater observation wells within Berlin, of 337 groundwater observation wells from Brandenburg and of 47 surface-water measurement points is used for the main aquifer (Aquifer 2). For the groundwater level map of the Panke Valley aquifer (Aquifer 1) on the Barnim plateau, the water level data of 80 groundwater observation wells and 13 surface-water measurement points is used. In groundwater observation wells with daily measurements, the value of May 15th, 2018 was used, while for the other cases, the value was taken from the day that was closest to May 15th, 2018.

The distribution of the groundwater observation wells is irregular: The monitoring network is densest in the city centre and in the immediate intake areas of the water-works, 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 gain information about the correlation of the spatial distribution and the groundwater level of the measurement points a variogram analysis was performed. For the groundwater level map of May 2018, for the first time, active wells of the Berliner Wasserbetriebe that pump from the main aquifer were taken into account. The status of the wells was set to active based on the recorded pumping volume. The water levels in the wells were derived from the surrounding observation wells.

The geostatistical parameters as a result of the variogram analysis for the main aquifer the Panke Valley aquifer are shown in Tab. 1.

| Geostatistical parameter             | Main aquifer          | Panke Valley aquifer        |
|--------------------------------------|-----------------------|-----------------------------|
| ETRS89 easting (min. / max.)         | 360685.2 / 424199.1   | 388657.5 / 402242.1         |
| ETRS89 northing (min./max.)          | 5794825.1 / 5845998.1 | 5823424,1 / 5837402.5       |
| Spacing                              | about 50 m            | about 200 m                 |
| Number of grid lines                 | x = 1200 / y = 1000   | x = 69 / y = 71             |
| Variogram model type                 | linear                | linear                      |
| Slope                                | 0.0011                | 0.001615                    |
| Anisotropy ratio                     | 1                     | 2                           |
| Anisotropy angle                     | -°                    | 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          | 24                    | no search (use of all data) |
| Min. number of data in search radius | 8                     | 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=10,000 | no search (use of all data) |
| Search ellipse, angle       | 136.7°                | no search (use of all data) |
| Smoothing                   | 3                     |                             |

**Tab. 1: Input data for the interpolation with the Kriging method**

A program for calculating and plotting surfaces (Software: Surfer 13 by Golden Software Inc.) was used to convert the spatially irregular distributed groundwater and surface water level data into an equidistant data grid with a spacing of approx. 50 m. This was conducted by an interpolation according to the point kriging method. The groundwater contours are shown with the basis of this grid after smoothing with the factor 3.

Especially for the Panke Valley aquifer it was necessary to adjust the geostatistical calculated surface to the hydrogeological situation manually in order to display the effect of the surface water bodies such as the “Panke”, the “Buchholzer Graben” and the “Nordgraben” realistically. Additionally it was crucial to adjust the hydraulic flow conditions of the boundaries of the Panke Valley manually and with a scientific.

## 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 used groundwater observation wells, as well as the individual waterworks are indicated, with their active wells and the water protection 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 isolated sand lenses, 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 determined 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. The glacial till is thinning out toward the Warsaw-Berlin glacial valley and the Panke Valley aquifer is interlocking with the main aquifer.

For more information, see the Groundwater Brochure:

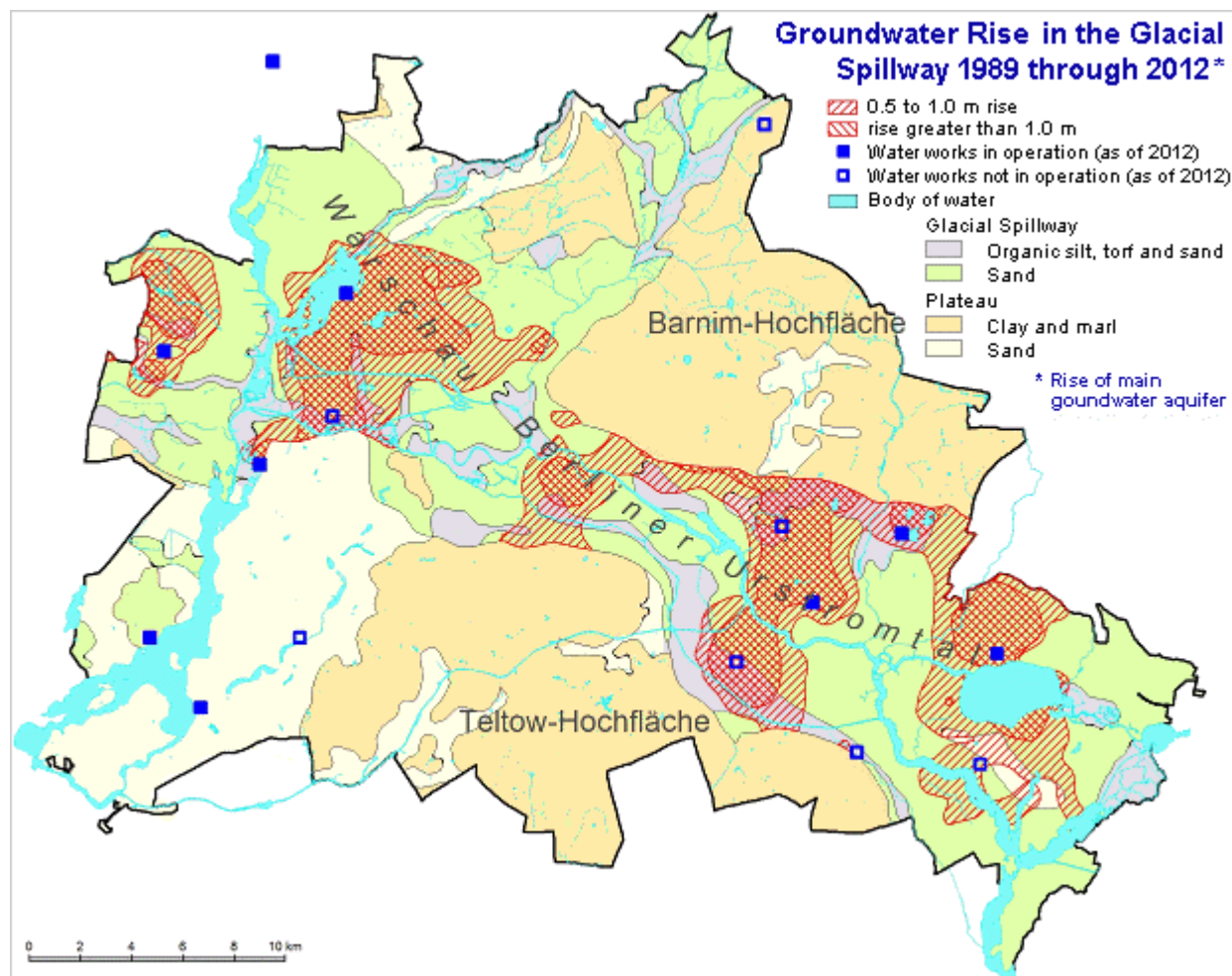
<https://www.berlin.de/senuvk/umwelt/wasser/wasserrecht/grundwasserbroschuere.html> (only in German)

## Current Situation in May 2018

As a rule, the hydraulic gradient 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 that were active during the measurement period, and

have lowered 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 2018, 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 re-rose 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). Since 2012, the long-term mean of the groundwater level is stable in most parts of the city area.



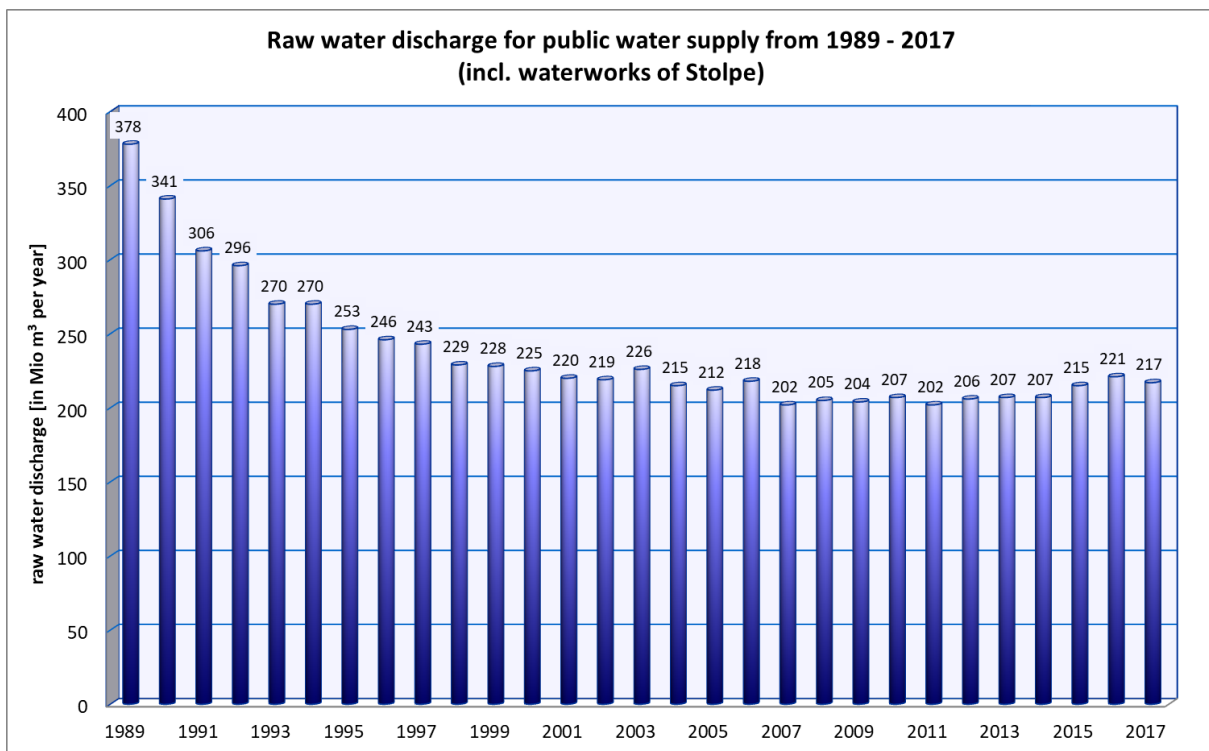
**Fig. 10: Groundwater rise in the glacial spillway between 1989 and 2012**

The reduced raw-water discharge by the Berliner Wasserbetriebe 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, Riemkefenn 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, also artificial groundwater recharge was put on hold. 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 Senate 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.



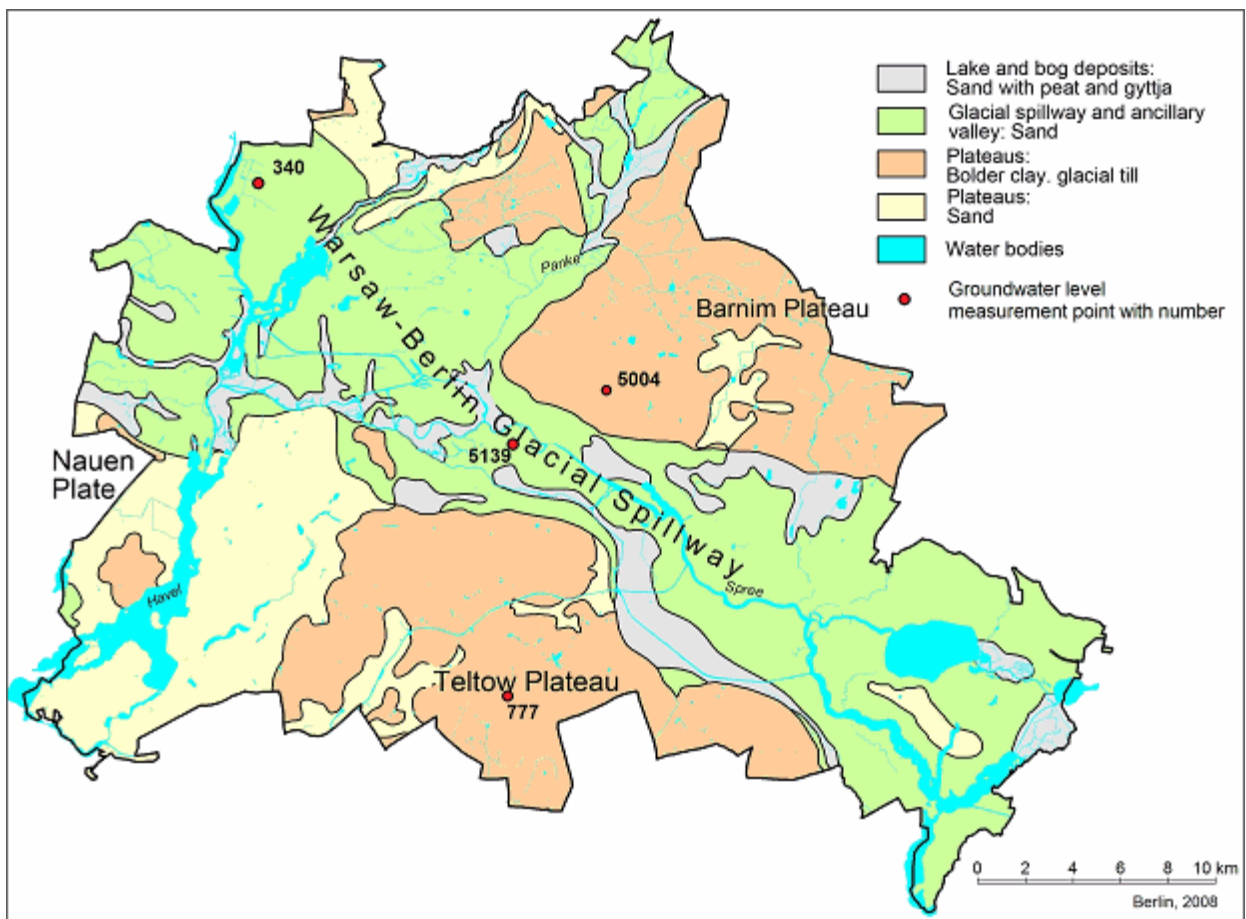
The water protection area of the waterworks of Buch, Jungfernheide and Altglienicke were abolished in April 2009.

The overall discharge of raw water by the Berliner Wasserbetriebe for public water supply dropped by almost half (42 %) in Berlin over a period of 28 years. In 1989, 378 million m<sup>3</sup> were discharged, as opposed to 219 million m<sup>3</sup> in 2002. In 2003, the discharge briefly increased slightly to 226 million m<sup>3</sup> due to the extremely dry summer. After a further phase of decline until 2014, the discharge increased again in the past years to 217 million m<sup>3</sup> at present and is at the same level as during the years of 2000 to 2006 (Fig. 11).



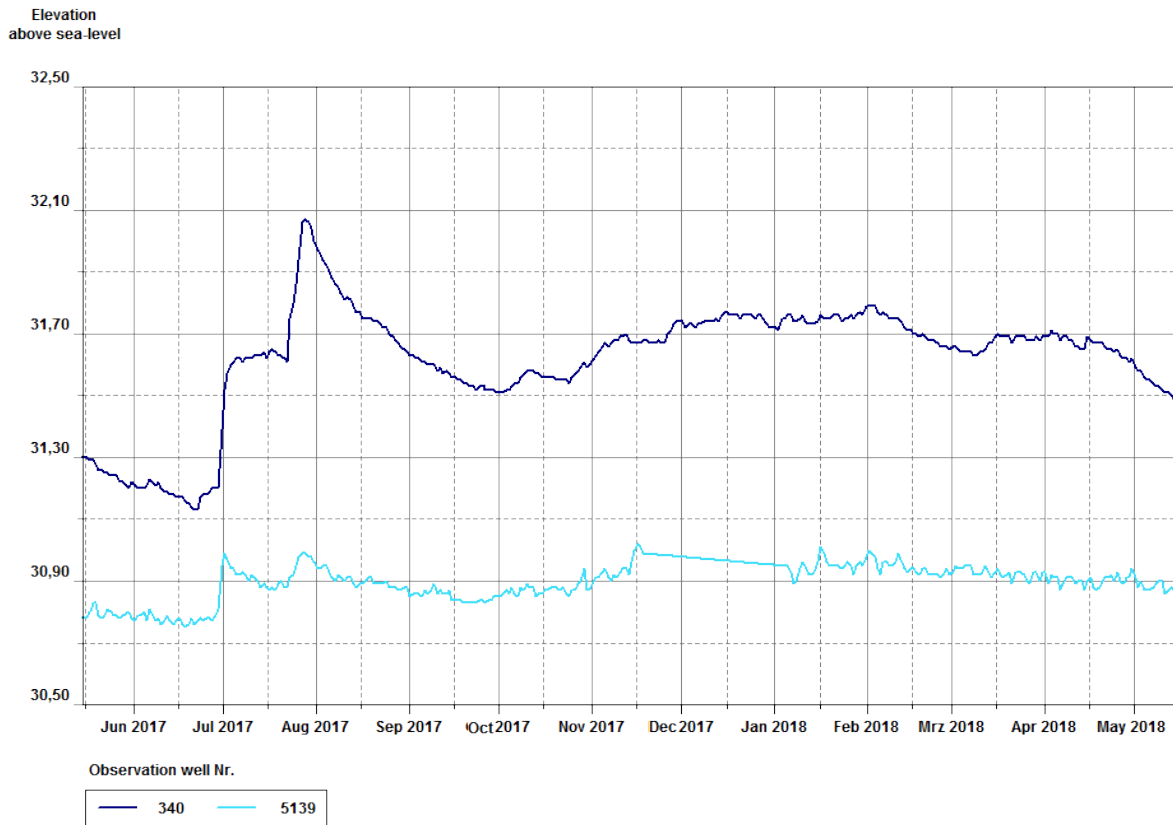
*Fig. 11: Development of the raw water discharge in the last 29 years*

The development of the groundwater levels from May 2017 through May 2018 is exemplified at four groundwater observation wells which are largely unaffected by the withdrawal of water by the waterworks (Fig. 12).



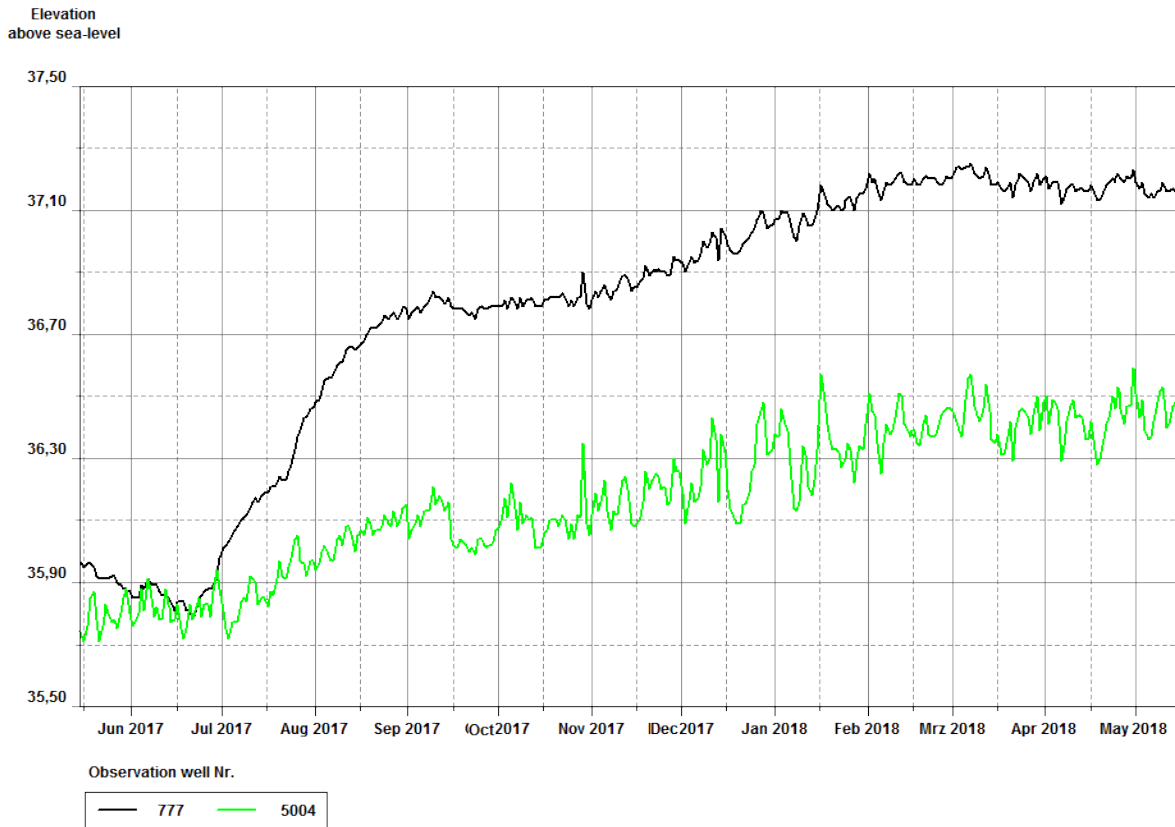
*Fig. 12: Position of the four largely unaffected groundwater observation wells: 340 and 5139 in the glacial spillway, 777 on the Teltow plateau, and 5004 on the Barnim plateau*

The groundwater levels at the two observation wells (340 and 5139) in the unconfined aquifer of the glacial valley show a very fast and immediate reaction to the extreme precipitation events in the end of June and in the middle of July 2017. At the observation well 340 which is located at the outskirts of the city next to farmlands, the groundwater level rose from middle of July to beginning of October about around 1 m. The observation well 5139 which is located in the inner city area with a high soil sealing shows a less strong reaction to the described precipitation events (rise of around 0.2 m). From October 2017 on, the groundwater levels follow the annual longterm trend. Because of the very high total precipitation during the considered period, the groundwater level rose in the glacial valley about around 10 cm from May 2017 to May 2018 (Fig. 13 and Fig. 15).



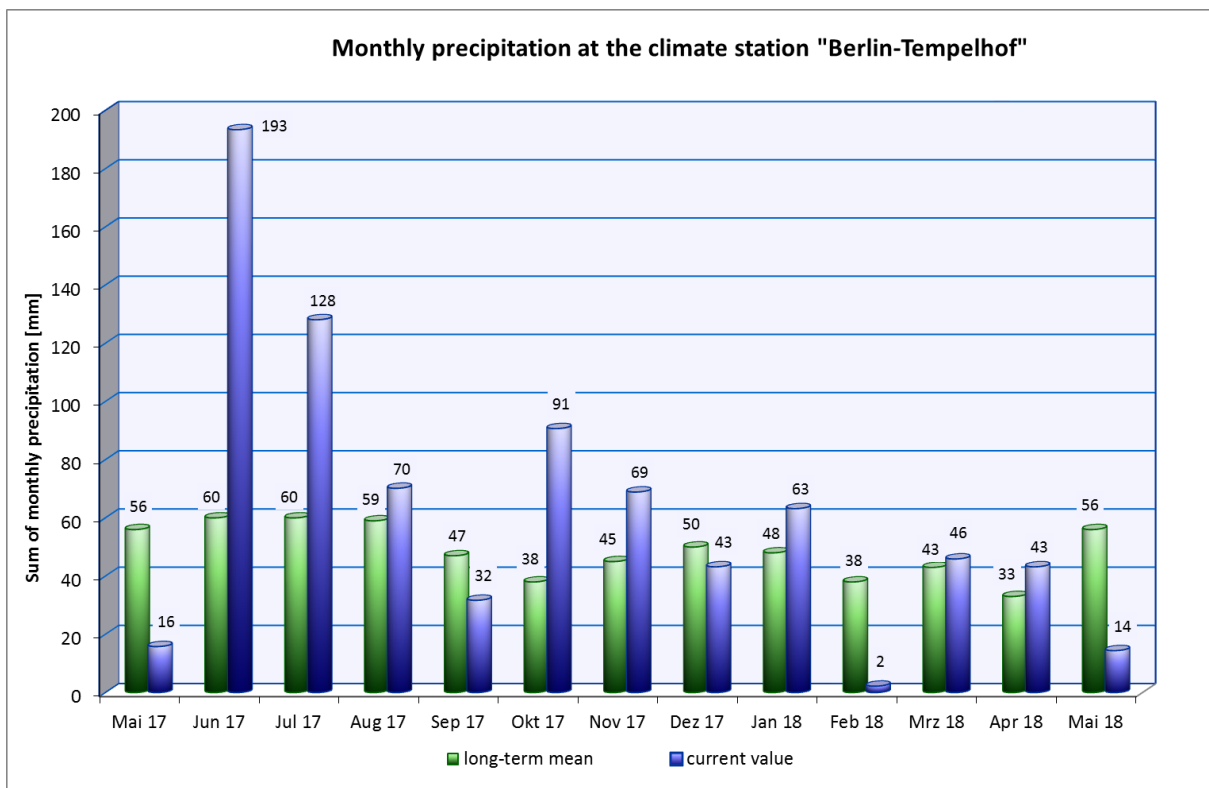
*Fig. 13: Hydrograph of the groundwater level at two groundwater observation wells in the glacial valley from May 15, 2017 to May 15, 2018*

For a contrast, the development of the groundwater levels of the covered confined aquifer on the Teltow plateau and on the Barnim plateau are shown by way of example on the observation wells 777 and 5004 in Fig. 14. The shape of the hydrograph of the groundwater level shows an atypical behavior that again can be explained by the extreme precipitation event of the high summer. Instead of a decrease of the groundwater level in summer, the water level is raising significantly from end of June. Compared to the groundwater level in the glacial valley, the rise is lagging but more long-lasting. The decrease of the groundwater level in late summer is notable in the glacial valley, while shaped as a plateau between September and October in the area of the Teltow and the Barnim plateau. Afterwards, the groundwater levels are rising due to the seasonal nature. In May 2018, the groundwater level is about 1.2 m above the level of May 2017 on the Teltow plateau (Observation well 777) and 0.6 m above the level of May 2017 on the Barnim plateau (Observation well 5004).



*Fig. 14: Hydrograph of groundwater level of two groundwater observation wells on the plateau areas from May 15, 2017 to May 15, 2018*

In the period of June 2017 to May 2018, the precipitation amount at the climate station "Berlin-Tempelhof" with 795 mm was significantly higher than that of the long-term mean (1981-2010) with 577 mm. The high annual precipitation amount is due to the extreme precipitation events in June and July 2017. Also in October 2017, the monthly precipitation amount was higher than that of the long-term mean. In February, as contrast, low precipitation amounts were registered (Fig. 15).



*Fig. 15: Monthly precipitation between May 2017 and May 2018 at the climate station "Berlin-Tempelhof", 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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