02.17 New Groundwater Formation (Edition 2019)

Overview

The term new groundwater formation (groundwater recharge) as used here refers to the process by which groundwater is formed from the percolation of precipitation. The amount of new groundwater formation differs from the amount of percolation water. Compared with the percolation water rate, it is reduced by the proportion of interflow, i.e., the portion of the runoff that flows into the receiving waters from the near-surface layers of soil. For these reasons, a **New Groundwater Formation** map (Map 02.17, Edition 2019), has been drafted in addition to the Percolation (Map 02.13.2, Edition 2019) and the Total Runoff (Map 02.13.3, Edition 2019) maps.

Given the expected change in water balance due to climate change, knowledge of the level of new groundwater formation is particularly important. Not only for long-term and sustainable use of groundwater resources, but also for estimating the potential risk of the transport of pollutants from the unsaturated zone into the groundwater (Verleger und Limberg 2013, Löschner 2008). The amount of new groundwater formation shown in Map 02.17 as the new groundwater formation rates (mm/year) differentiated by area, is an important initial parameter for deriving the dwell time of the percolation water in the groundwater overburden (Map 02.16, Edition 2004).

Statistical Base

The runoff formation and percolation rates in Maps 02.13.3 and 02.13.2, respectively, of the Environmental Atlas (Edition 2019) constitute the essential basis for the calculation of new groundwater formation rates differentiated by area. A detailed description of the databases for these maps can be found in the text for Map 02.13. In addition, data on runoff measurements to receiving waters as well as data from the literature were used for the calculation.

Methodology

The amount of new groundwater formation was calculated from the percolation rates using the method suggested by Glugla (Glugla and Fürtig, 1997, Glugla and Müller, 1997, Glugla and Eyrich, 1993, Glugla and König, 1989, Glugla et al., 1999).

According to Glugla (see above), for **unconfined aquifers**, such as the glacial spillways and outwash plains of northern Germany, the new groundwater formation corresponds to the percolation water; there, the following applies:

GWNB = Ri = P – Eta – Row

where

GWNB =	new groundwater formation,
Ri =	percolation water,
P =	long-term mean annual precipitation totals,
Eta =	long-term mean actual evapotranspiration,
Row =	long-term mean surface runoff.

However, in areas with confined aquifers, e.g. the ground moraines with glacial till or loam, only part of the percolating water reaches the groundwater. In these areas, part of the percolating water is carried away as near-surface interflow into bodies of water (receiving waters). Surface runoff and interflow together constitute the mean runoff MQ to the receiving waters. In areas with **confined aquifers**, the new groundwater formation can therefore be derived from the difference between the calculated total runoff formation (R = P - Eta) and the real runoff MQ of the receiving water which drains the area. In these areas, the following applies:

GWNB = Ri - Rzw

GWNB = P – Eta – Row - Rzw

GWNB = P – Eta – MQ

where

GWNB =	new groundwater formation,
Ri =	percolation water,
P =	long-term mean annual precipitation totals,
Eta =	long-term actual mean evapotranspiration,
Row =	long-term mean surface runoff,
Rzw =	long-term mean interflow,
MQ =	mean runoff to the receiving water (= Row + Rzw).

Data on mean runoff to receiving waters in the (sub-)catchment areas are an important basis for the calculation of new groundwater formation in areas with confined aquifers. These data are, however, only partially available. The data situation for the application of this method to the area of the State of Berlin it to be considered difficult. Nevertheless, overall, the method suggested by Glugla enables plausible new groundwater formation rates to be calculated from the runoff and percolation water data.

For the determination of new groundwater formation rates, areas with confined and unconfined aquifers were distinguished first, because the new groundwater formation only differs from the percolation water in the areas with confined aquifers. The areas with confined aquifers were essentially derived from the Digital Map for the Characterization of Overburden, according to the WFD (SenStadt, 2002). Moreover, all mapped areas with confined groundwater (see Map 02.07, Edition 2010) which extend beyond the areas shown as confined on the above-mentioned "groundwater overburden" map, were designated as confined. Fig. 1 shows the areas for the determination of new groundwater formation rates, with differentiation between unconfined and confined aquifers.

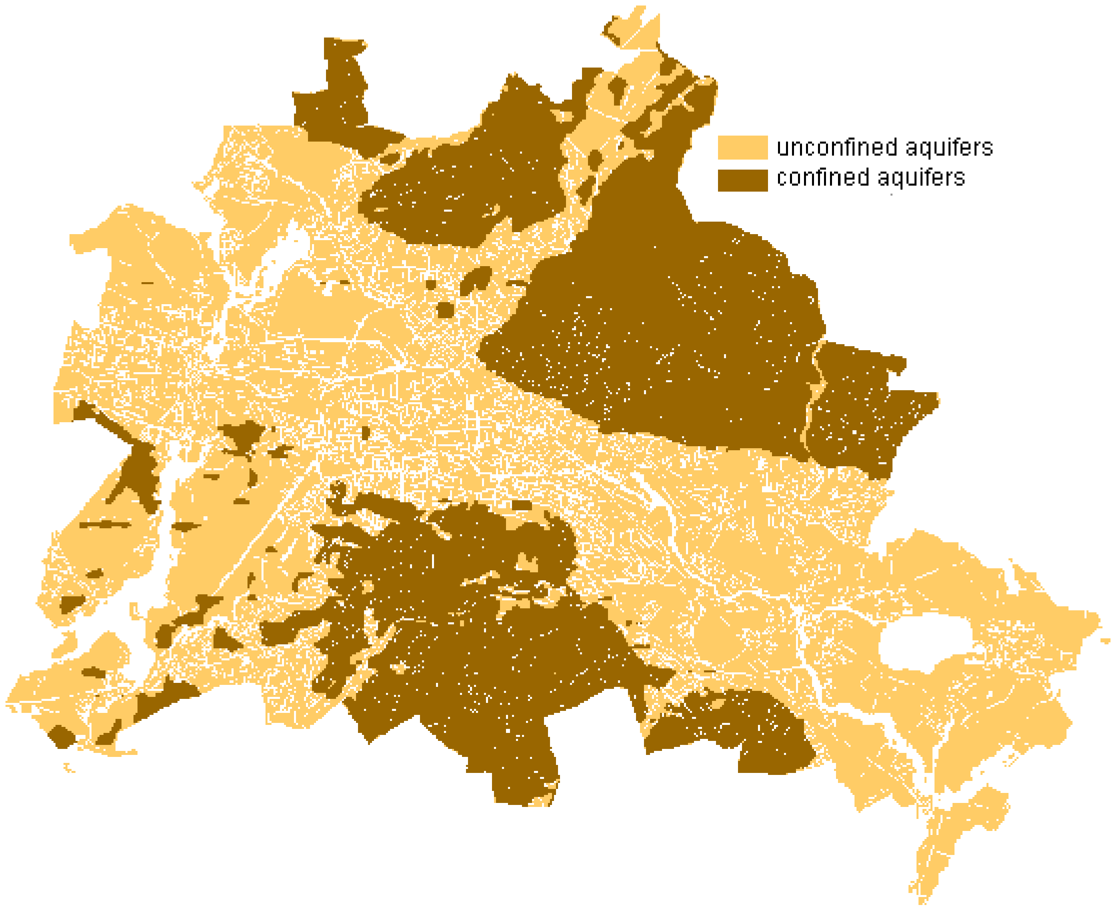

Fig. 1: Areas with confined and unconfined aquifers

The contiguous, confined areas identified here are essentially the Barnim and Teltow ground moraines. The Warsaw-Berlin glacial spillway and the larger valley lowlands of the Barnim, particularly the Panke Valley, are essentially areas with unconfined aquifers, except for isolated islands with cohesive substrata. Large contiguous areas with unconfined aquifers are also present in the area of the plateau sands of the Teltow Plateau and the Nauen Plate. In terms of the area of the State of Berlin, the area with unconfined groundwater (518 sq. km) exceeds that with confined aquifers (335 sq. km).

In another processing stage (SenStadt Data Base, 2003), the catchment areas of the receiving waters were delineated in those areas with confined aquifers. To the extent available, runoff measurements from water gauges of the receiving waters were assigned to these catchment areas. From the long-term mean runoff MQ and the size of the corresponding catchment, the average annual inflow (sum of surface runoff and interflow runoff) into the respective receiving water was determined. The problems here were on the one hand the frequently insufficient data density (e.g. for the Teltow Plateau), and on the other hand, the fact that measured runoffs are often characterized by discharges from sewage plants and transfers, and by the often very high degree of impervious soil coverage (surfacing), and thus only partially reflect natural runoff behaviour. For these reasons, the runoffs measured in receiving waters generally allow only limited statements to be made.

Due to this very heterogeneous database, three cases had to be distinguished (cf. Table 1) for the runoff data of the receiving waters:

- Case 1: there are runoff values measured at water gauges.
- Case 2: no data are available from measurements; hence, additional data were evaluated from the literature (Glugla and Müller, 1997).
- Case 3: neither measured runoff data nor references from the literature are available. In Case 3, an assumable mean runoff was estimated in the confined catchment areas which have very high surface runoff due to extensive impervious soil coverage. An interflow of 80

mm/a was assumed in these areas. The mean runoff was calculated from the sum of the assumed interflow and the surface runoff according to Map 02.13.1 of the Environmental Atlas for block segments within a catchment area.

Values for Cases 2 and 3 in Table 1 therefore merely show guide values.

Based on the Glugla method (Glugla and Fürtig, 1997, Glugla and Eyrich, 1993), the portion of the runoff formation of each of the delineated catchment areas which was led off as surface runoff and lateral runoff or interflow into the receiving water and therefore does not contribute to new groundwater formation was calculated using this database. Moreover, there is the fundamental problem that parts of the catchment areas drained by the receiving waters are outside the area of the State of Berlin, so that appropriately differentiated runoff data from these areas were not were available. However, since the geological and climatic conditions of the catchment areas considered do not differ significantly inside and outside the state boundary of Berlin, the available runoff data from Berlin have also been taken as being representative for the portions of the catchment areas outside Berlin. A reduction factor for calculating new groundwater formation from the percolation water was then derived for each catchment area from the ratio of runoff or rather percolation water, and the sum of surface runoff and interflow (see Tab. 1).

The calculation process is explained briefly here by way of the example of the Tegel Stream catchment area (as of 2002): The calculated average total runoff formation R in this catchment area is 229 mm/a (area-weighted mean of the total runoff from precipitation of all block segments in this catchment area, according to Map 02.13.3 of the Environmental Atlas). The average percolation water Ri (area-weighted mean of the percolation from precipitation of all block segments in this catchment area according to Map 02.13.2 of the Environmental Atlas) is 192 mm/a. The surface runoff is thus 229 mm/a - 192 mm/a = 37 mm/a. However, the Tegel Stream, which drains this catchment area, has a real mean runoff MQ of 183 mm/a. This mean runoff MQ is formed from the surface runoff (37 mm/a) and the interflow (183 mm/a - 37 mm/a = 146 mm/a). The average new groundwater formation is calculated from the difference between the average total runoff formation R (229 mm/a) and the mean runoff MQ (183 mm/a). It is 46 mm/a in this area, i.e. it is reduced by 76 % compared with the percolation water rate; hence, only 24 % of the percolation water is effective as new groundwater formation. Thus, the new groundwater formation is substantially lower than the average percolation water in this area.

This reduction of the percolation water rate for the determination of new groundwater formation was carried out in the same way for the other catchment areas (reduction factor "RDF as percentage of Ri" in Table 1 for the exemplary area of Tegel Stream = 76 %). For the calculation of new groundwater formation rates differentiated by area, the percolation water rates of each individual block segment was reduced by the reduction factor RDF of the catchment area, i.e., in the “Tegel Stream” example, by 76 %.

Subcatchment area	Average total runoff formation R (mm/a) [4]	Average percolation water Ri (mm/a) [4]	Runoff MQ of the catchment area (mm/a)	New GW formation (R – MQ) (mm/a)	RDF as % of Ri
Tegel Stream	229	192	183[2]	46	76
Laake	228	221	80[1]	148	33
Panke	220	191	113[1]	107	44
Kindel Stream	201	196	100[2]	101	48
Neuenhagen Stream	248	238	100[2]	148	38
Wuhle	260	196	100[2]	160	18
Nordgraben	229	196	100[2]	129	41
Selchow	233	219	100[2]	133	39
Spree	339	181	238[3]	101	44
Marzahn-Hohenschönhausen Boundary Ditch (MHG)	327	176	231[3]	96	45
Fürstenbrunnen Ditch	367	179	268[3]	99	45
Teltow Canal	286	182	184[3]	102	44
Grunewald Lakes	254	202	132[3]	122	40

City Ditch	250	180	150[3)]	100	44
Others	234	190	100[2)]	134	29

1) Run-off MQ according to level measurement, 2) Run-off MQ according to literature, 3) Run-off MQ value, estimated, 4) The calculation was carried out in 2003 on the basis of the water balance variables, which were determined from data on land use, impervious soil coverage and the sewage system from 1990 (cf. 02.13 (Edition 1999). The depth to groundwater table was based on information current as of May 2002. The calculation was carried out using ABIMO 2.

Tab. 1: Runoff data, percolation water and new groundwater formation amounts, and reduction factors RDF in the subcatchment areas of Berlin (as of 2002) (Voigt et al. 2003).

For the current edition of the map, the reduction factors determined in this way in 2003 on the basis of the water balance variables from Map 02.13 (Edition 1999, but recalculated with depth to groundwater, as of May 2002) were adopted and applied to the updated percolation water rates in Map 2.13 (as of 2019).

Map Description

In the areas with unconfined aquifers, new groundwater formation rates correspond to the percolation rates shown in Map 02.13.2. The new groundwater formation rates shown in the map are lower than the percolation water rates in the areas with confined aquifers, depending on the conditions and the reduction factors determined. In the areas with confined aquifers, a reduction of at least 18 % (Wuhle) and at most 76 % (Tegel Stream) compared with the percolation water rates occurs; in most areas with confined aquifers, the new groundwater formation rate is approx. 40 % - 50 % lower than the percolation water rate.

The percentage areas of the different percolation water rates according to Map 02.13.2 and the derived new groundwater formation rates (Map 02.17) are shown in Figure 2. The category with >150-200 mm/a predominates. A shift from higher to lower values occurs in the new groundwater formation values compared with the percolation water rate (due to the reduction in confined areas), which is mainly reflected in the mean values. Thus, the percentage areas of category >50-100 mm account for 10.5 % of the percolation water rate, but for only 23.4 % the new groundwater formation rate. On the other hand, the percentage areas for the percolation water rates of the categories above 150 mm are all larger than for new groundwater formation rates.

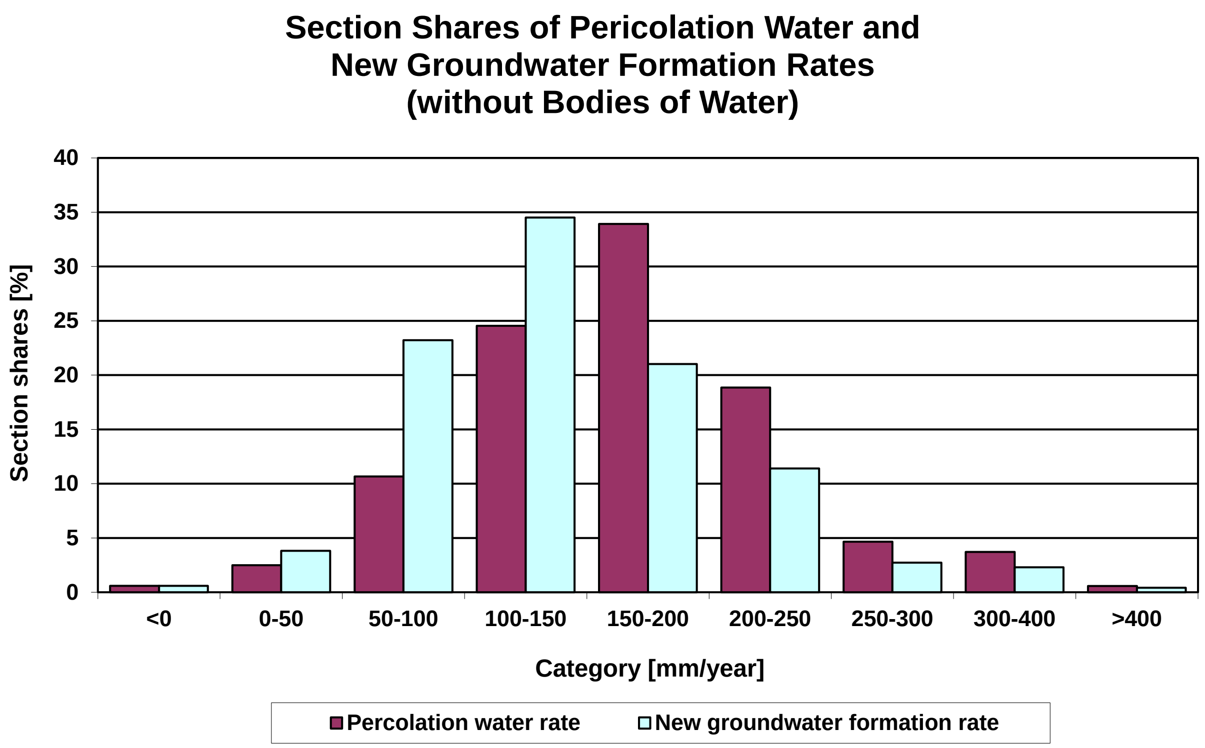

Fig. 2: Percentage areas of percolation and water new groundwater formation rates (without bodies of water) (as of 2017)

Taking into account the area sizes, total figures can be derived for the area the State of Berlin from the new groundwater formation rates. In Tab. 2, these values are compared with the corresponding values calculated from the total runoff formation and the percolation water:

Tab. 2: Water balance and new groundwater formation in Berlin

	Total runoff formation	**Percolation water**	**New groundwater formation**
Area-weighted mean average value (mm/a)	255	169	141
Absolute value in million cu.m/a	213	142	118
Absolute value in l/s* sq. km	8.1	5.4	4.5

Remarks:
All values not including bodies of water. The shares of bank filtrate (which e.g. are pumped into the Berlin waterworks from the Havel and Spree Rivers) are not taken into account in the percolation water or new groundwater formation.

Tab. 2: Water balance and new groundwater formation in Berlin, as of 2017

It must be noted that the calculations for percolation water rates were carried out **taking into consideration impervious soil coverage**. This means that the values given for new groundwater formation represent a mean value across the hard surfaced (impervious) and unsurfaced (pervious) areas of a block segment shown, including the road space surrounding them. Since the impervious surface cover and the different degrees of sewer availability affect the water balance considerably, the values given are not transferable to the pervious parts of the respective areas.

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