Geophysical Research Abstracts
Vol. 20, EGU2018-8303, 2018
EGU General Assembly 2018

Session HS1.8: History of Hydrology

Physically based modelling: historical hydrology for future water management Drentsche Aa

Erik Querner[1], Erik Meijles[2,3], Harry Jager[4], Paul Hendriks[4], Theo Spek[3]

1 Querner Consult, C.J. Blaauwstraat 38, 6709 DA Wageningen, The Netherlands (erik@querner.eu)
2 Faculty of Spatial Sciences, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands
3 Centre for Landscape Studies, University of Groningen, PO Box 716, 9700 AS Groningen, The Netherlands
4 Water Board Hunze and Aa's, P.O. Box 195, 9640 AD Veendam, The Netherlands

Introduction

One way to assess future hydrological regimes is to find evidence from corresponding periods in the past. A problem often exists in describing the historical water system quantitatively. Although substantial variations in historical floods have been identified in Europe since medieval times, quantitative analyses were only carried out from the 1950s onwards. This is partly due to the fact that landscape historical disciplines lacks sufficient serial archives and generally tends to describe landscape changes in a qualitative way, whereas the hydrological discipline prefers a quantitative approach. We therefore need to develop an interdisciplinary historical hydrological literacy. Hydrological models can provide good results for current situations, but a lack of historical datasets or reference conditions often prevent a robust analysis. Such so-called retrospective-modelling or a physical based model can be useful tools to create reference conditions for historical situations and is the bases on the premise that future hydrological systems will behave more or less in similar ways. This is important to evaluate measures for future climate-robust water management.

This study focuses on the functioning of the historical hydrological system in the Drentsche Aa catchment one hundred years ago. The past hydrological system could be valuable for the required management plan of the Natura 2000 areas within the catchment. The work will focus on the modelling of the Drentsche Aa catchment and it's surrounding using the hydrological model SIMGRO.

Study area and SIMGRO model schematisation

The modelling area covers 1200 km^2 and is located in the northern part of the Netherlands (see **Fig. 1**). The area of main interest is approximately 310 km^2 and covers the basin of the river Drentsche Aa (Querner and Rakhorst, 2006). The ground surface slopes from about 24 m+MSL in the south to about –1 m in the north. The area consists of sandy soils in the upper parts with clay and peat in the stream valleys and the lower part.

SIMGRO is a distributed physically-based model that simulates regional transient saturated groundwater flow, unsaturated flow, actual evapotranspiration, sprinkler irrigation, stream flow, groundwater and surface water levels as a response to rainfall, reference evapotranspiration, and groundwater abstraction (see Fig. 2). The model is used within a GIS environment and gives the possibility of using digital data, such as a soil map, land use, watercourses, etc., to serve as input data for the model and to show results. It is also a tool for analysis and discussion, because interactively data and results can be presented. The groundwater system is schematized by means of a finite element network: 49 050 nodes, spaced at about 200 m in the interest area and in the stream valleys spaced at 75 m. The surface water is subdivided in 5625 sub-basins. The geology of the area is quite complex, due to influences from the Pleistocene period, permafrost, tectonic movements, and influences from wind and water. A major influence on the groundwater flow patterns are the resistant layers formed by glacial till that cause large areas with perched water tables.

Major landscape and hydrological changes 1900-1950

Until 1900 more than 80 percent of the Drentsche Aa study area consisted of wet heathlands with shallow water tables, resulting in soil filled up to their storage capacity (Spek et al., 2015). The general lack of a natural superficial drainage network caused a very slow and stable runoff to the stream valleys. Stimulated by the introduction of artificial fertilizers and the emergence of agrarian economy since the 1890's large parts of these heathlands were drained and reclaimed in the first half of the 20th century. The reclamations resulted in a dense network of new ditches which accelerated the run-off to the stream valleys, causing frequent periods of flooding in the 1920s and 1930s. These problems were solved in the subsequent decades by the construction of new straight channels parallel to the meandering streams as well as water regulation by new weirs (Meijles & Williams, 2012).

Objective of the study from a perspective of a Water board

One way to assess future hydrological regimes is to find evidence from corresponding reference periods in the past. It will make it possible to relate the effect of hydrological measures to the changes in land use in the twentieth century. Such insight is needed for the Natura 2000 site covering the valley of the Drentsche Aa. Current measures that are formulated aim to decrease peak discharges, since high discharges are considered harmful for aquatic life in the streams. Water managers also expect high discharges to have an impact on erosion and sedimentation patterns within the stream and may result in a continuing deepening of the stream, which will consequently results in lowering of groundwater levels with desiccation of adjacent meadows and marshes. The Natura2000 plan also requires to restore several rare habitats and vegetation compositions in the stream valley. Therefore, knowledge on flooding frequency and the hydrological regime in general in the past and future.

Required data

For the time horizon around 1900 the following data has been used for the Simgro model:

- The first map of the surface water system in the Netherlands published by the Dutch Water Authority Rijkswaterstaat (see parts of map in **Fig. 3**). Derived from this map are the presence of water courses around 1900;
- Historical land use 1900 (HGN1900) as given in **Table 1** for 1900 and 2000;
- Dimensions of the main streams around 1900 based on the report of De Jonge (1924);
- Peat layers in the stream valleys of the Drentsche Aa to derive the ground level for 1900 (de Vries et al., 2008);

- Potential evapotranspiration of the land-use at 1900 (a percentage of the present values)
- Groundwater levels for the model boundary dependent on the groundwater fluctuation class (higher levels than now a days).

It can be noted that the change in land use over the last 100 years was considerable. Large area in 1900 were covered with Erica, small scrubs and sand dunes (see **Table 1**). In 1900 only 7% was forested, in the beginning of the 20th century large areas were forested resulting in the 20% now a days.

Results

For three time windows results are presented: the hydrological situation 1900 and the present situation. Both using the present meteorological data. For the future situation at 2050 the climate scenario 'extreme warm' was chosen (temperature rise 2 degrees and warmer air circulation).
Calculations were carried out for 8 years (2000-2007) to calculate the groundwater fluctuation classes, such as average highest (GhG) and average lowest (GlG). These levels generally represent conditions at the end of winter resp. summer.

<u>Stream discharges</u>

Figure 4 shows the discharge of the Drentsche Aa at the catchment outlet near de Punt, for the situation 1900 and present. Based on model results, the discharge peaks of the catchment are higher in 1900 as present. This is because in 1900 there was less evapotranspiration and no groundwater extractions were present at that time (**Table 3**).
Table 2 shows the discharges for all three time horizons and show different exceedance levels What is most striking, is that difference in stream discharge between 1900 and present are much higher than for the anticipated climate in 2050. This could imply that in the last 100 years we have seen larger changes in the hydrological regime than that is foreseen for future decades.

Groundwater levels

Figure 5 shows the groundwater levels calculated for situation 1900 and present using the meteorological data for 2000-2007. Because the depth of the water courses in 1900 was shallower the present ground water and surface water levels are lower.

The change in groundwater levels, average highest GhG and lowest GlG are shown in **Figure 6**. The present levels are lower than in 1900. The change in the GlG levels is much more than for the GhG levels. This general trend is sometime reversed because of the occurrence of perched water tables and peat subsidence in the stream valleys. In **Figure 7** these differences are shown for a cross-section across the basin. Also shown in Figure 7 are the differences in highest and lowest ground levels for the climate scenario 2050.

Water balance

Table 3 shows the water balance for the groundwater. The actual evapotranspiration was in 1900 about 17% higher than now a days and thus the groundwater recharge in 1900 was higher. In 1900 the extractions for drinking water were not present and the drainage to the surface water was about 24% higher. These figures are based on the present rainfall data used for the modelling of the situation in 1900. It is known that in 1900 the yearly rainfall was about 18% lower than today.

Discussion and conclusions

The change in groundwater levels between hundred years ago and now has been much more than the changes which will occur over 50 years assuming the anticipated climate change.

Using the same rainfall data for 1900 reveals a decrease of 17% in evapotranspiration for 1900 and therefore an increase in groundwater recharge of the same amount.

Suggested improvements of the hydrological modelling for 1900:

- Rainfall data for 1900 and as well to include the aspect of snow hydrology in the model;

- The use of a more sophisticated hydraulic surface water model and refinement of the dimensions water courses for 1900.

Literature:

De Jonge, W.M., 1924. Plannen tot verbetering van de kleine rivieren in Drenthe: Drentsche Aa. Prov. Drenthe, Van Gorcum & Comp., Assen

Meijles, EW & A.G. Williams, 2012). Observation of regional hydrological response during time periods of shifting policy. Journal of Applied Geography 34 (456-470). DOI: 10.1016/j.apgeog.2012.02.002.

Querner, E.P. & M. Rakhorst, 2006. Impact assessment of measures in the upstream part of Dutch basins to reduce flooding. In: Climate Variability and Change – Hydrological Impacts (Ed. S. Demuth, A. Gustard, E. Planos, F. Scatema and E. Servat). Proc Fifth FRIEND World Conference, Havana, Cuba, Nov. 2006. IAHS Publ. 308, IAHS Press, Wallingford, UK, pp.180-186.

Spek, T., H. Elerie, J.P. Bakker, I. Noordhoff, 2015. Landschapsbiografie van de Drentsche Aa. Koninklijke Van Gorcum, 520 pp., ISBN 9789023252719.

Vries, F. de; Hendriks, R.F.A.; Kemmers, R.H.; Wolleswinkel, R.J., 2008. Het veen verdwijnt uit Drenthe: omvang, oorzaken en gevolgen. Wageningen, Alterra, Alterra-rapport 1661. 70 blz.

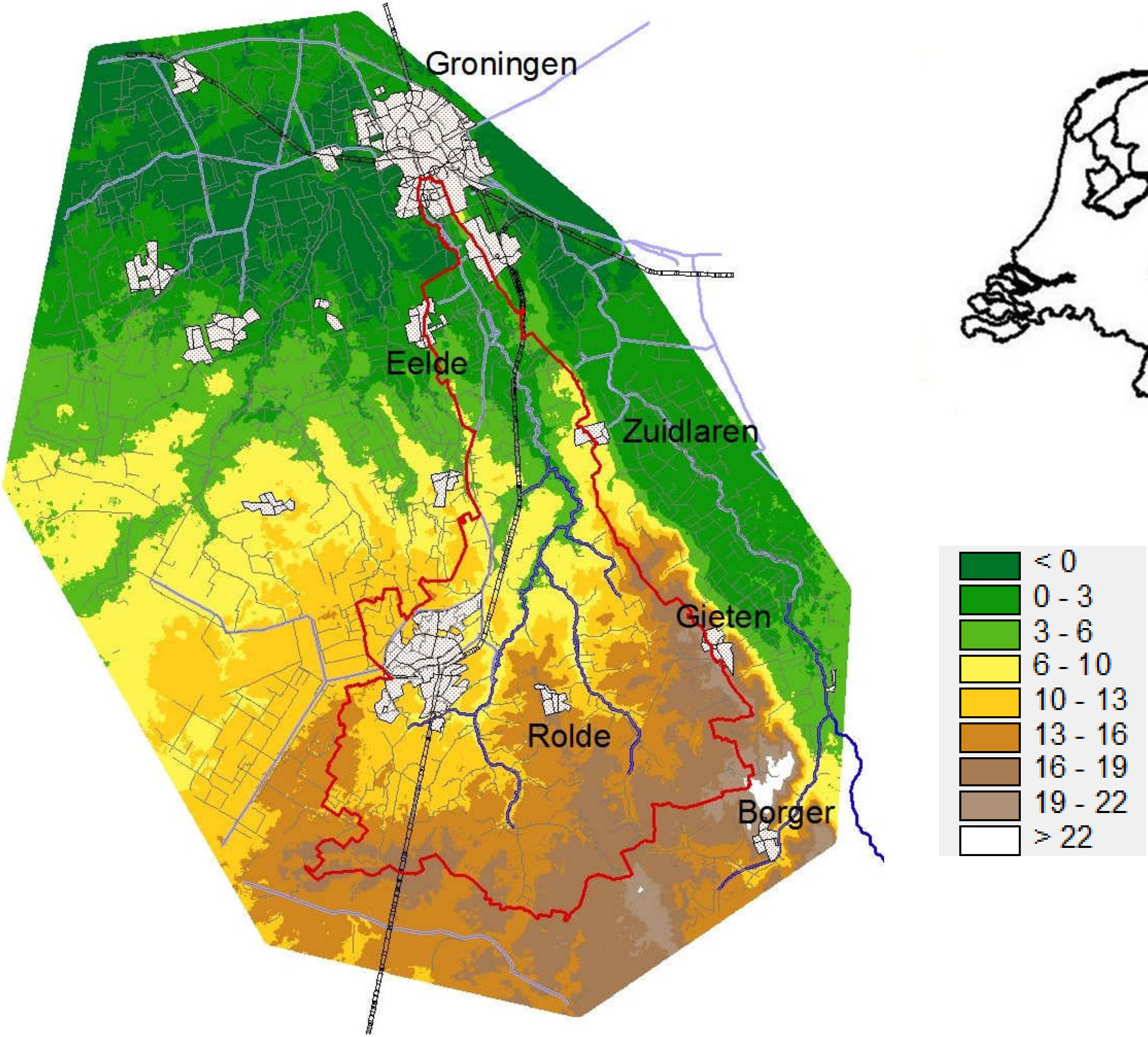


Figure 1 Extend of the model area around the Drentsche Aa catchment (shown in red) and the ground level elevation (m+MSL).

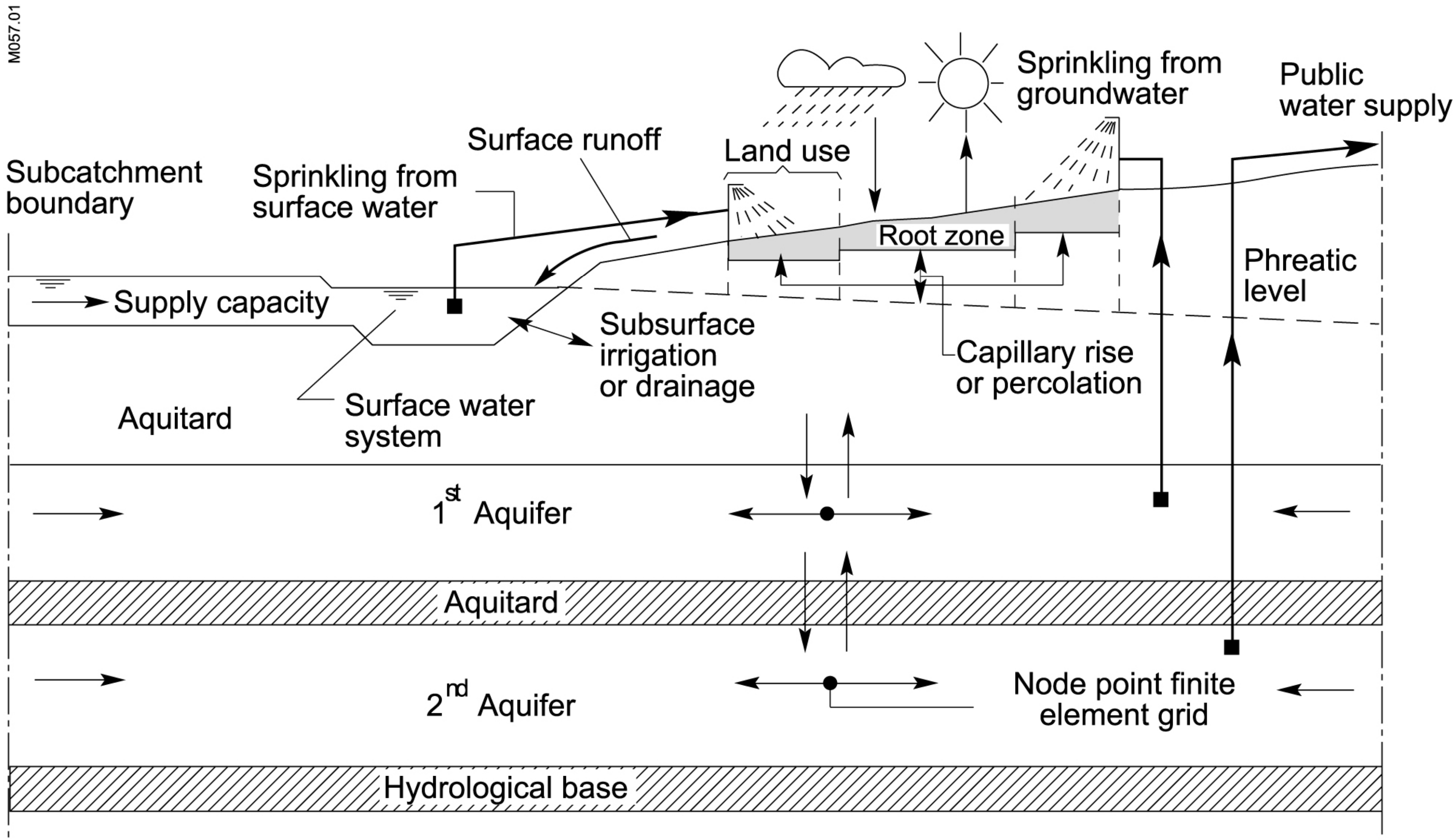


Figure 2 Schematisation of water flows in the SIMGRO model.

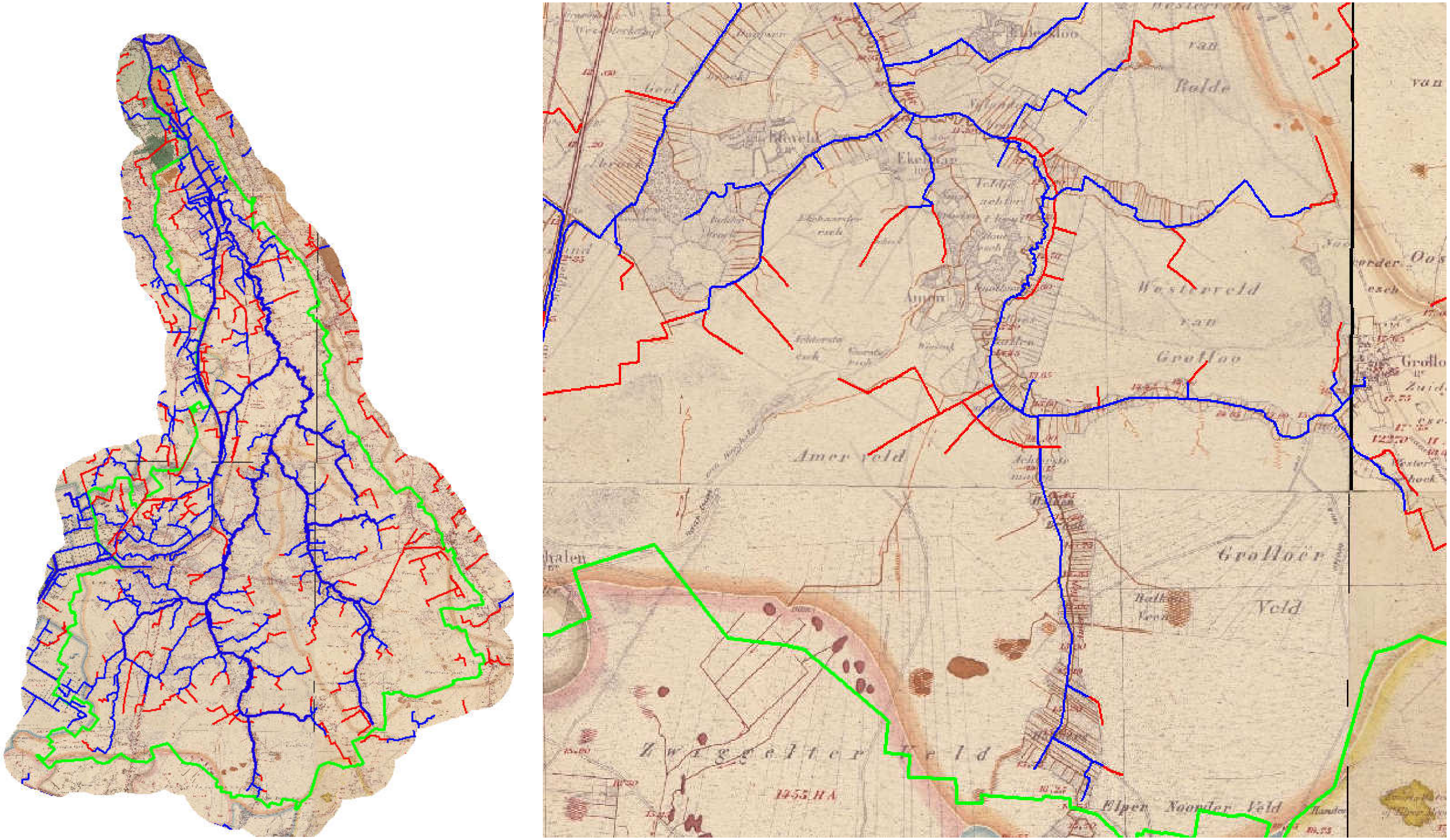


Figure 3 Part of the 1st map of the surface water system in the Netherlands for the study area (Dutch Water Authority Rijkswaterstaat, 1887). Water courses indicated in red are constructed after 1900.

Table 1 Land use in the Drentsche Aa catchment around the year 1900 and 2000.

1900	**(%)**	**2000**	**(%)**
Grassland	25	Grassland	25.1
Agriculture and bare soil	14	Agric. crops, orchards, etc.	19.8
Deciduous forest	3	Deciduous forest	11.4
Pine forest	4	Pine forest	8.9
Urban - built-up area	1	Urban - built-up area	15.0
Natural area (mainly Erica)	53	Nature area	19.8

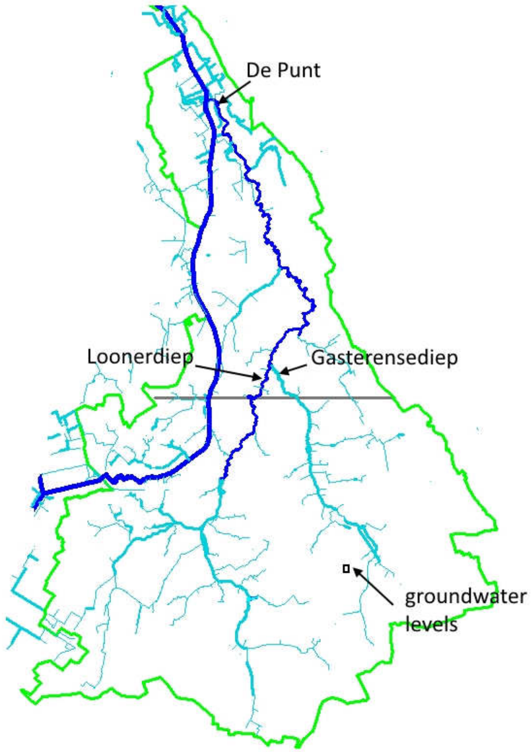


Table 2 Discharges and exceedance levels for three time horizons.

Scenario	Location	Discharge for a given recurrence interval (m^3/s)				
		5 year	1 year	5x/year	15x/year	min 5%
1900	De Punt	20.97	18.40	14.58	11.17	0.67
	Loonerdiep	13.50	10.90	8.36	6.05	0.20
	Gasterensediep	7.85	6.19	4.88	3.27	0.24
2000	De Punt	17.03	13.18	10.18	7.31	0.49
	Loonerdiep	9.16	7.18	5.39	3.82	0.18
	Gasterensediep	8.23	4.05	2.90	1.88	0.17
2050	De Punt	20.27	16.25	12.79	8.72	0.39
	Loonerdiep	10.38	8.67	6.35	4.38	0.13
	Gasterensediep	10.05	6.28	3.56	2.22	0.15

Loonerdiep: 15x/y: 1900 (= 160%); 2000 (=100%); 2050 (= 115%)

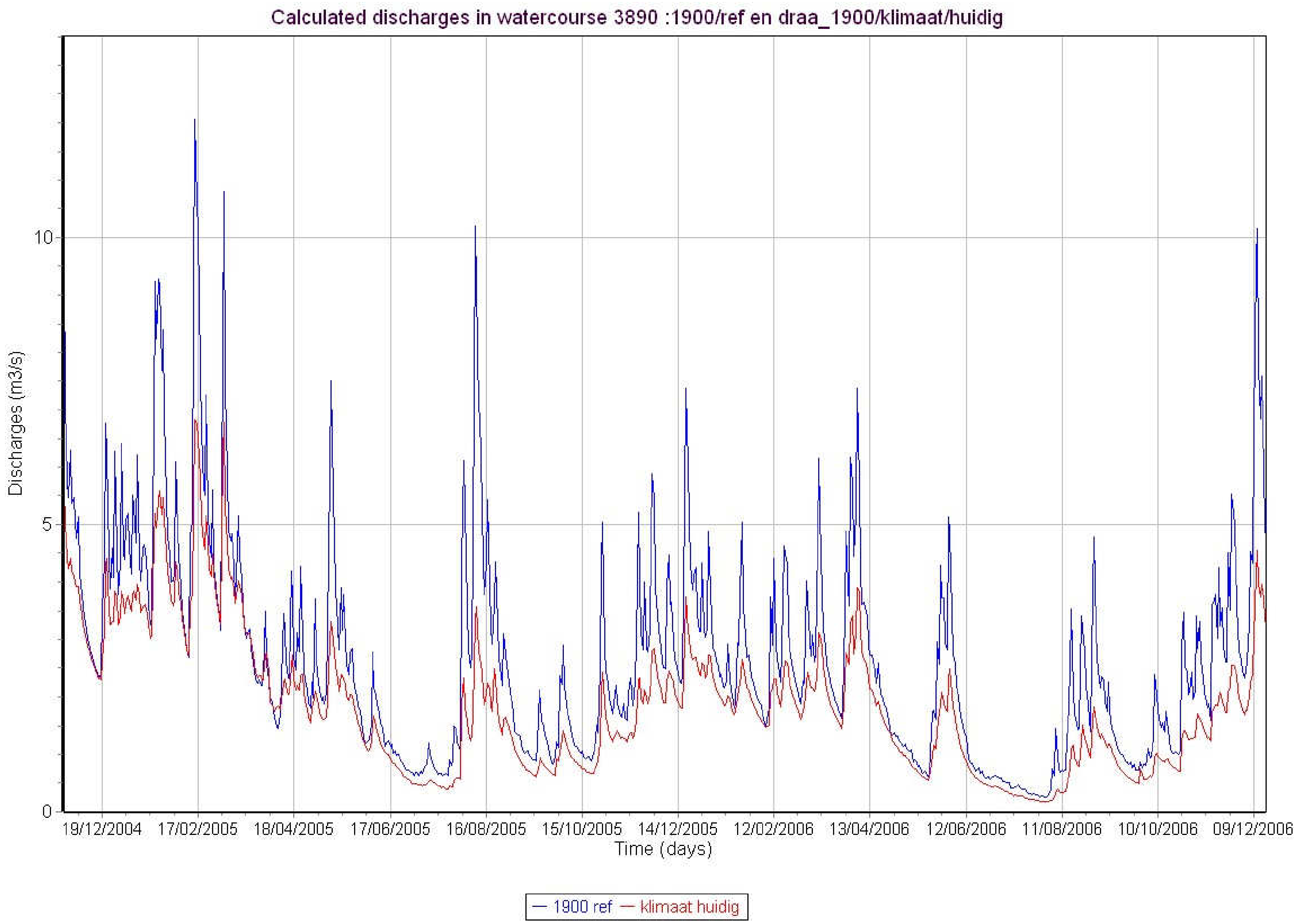


Figure 4 Discharge of Drentsche Aa catchment at De Punt for the 1900 and 2000 time windows.

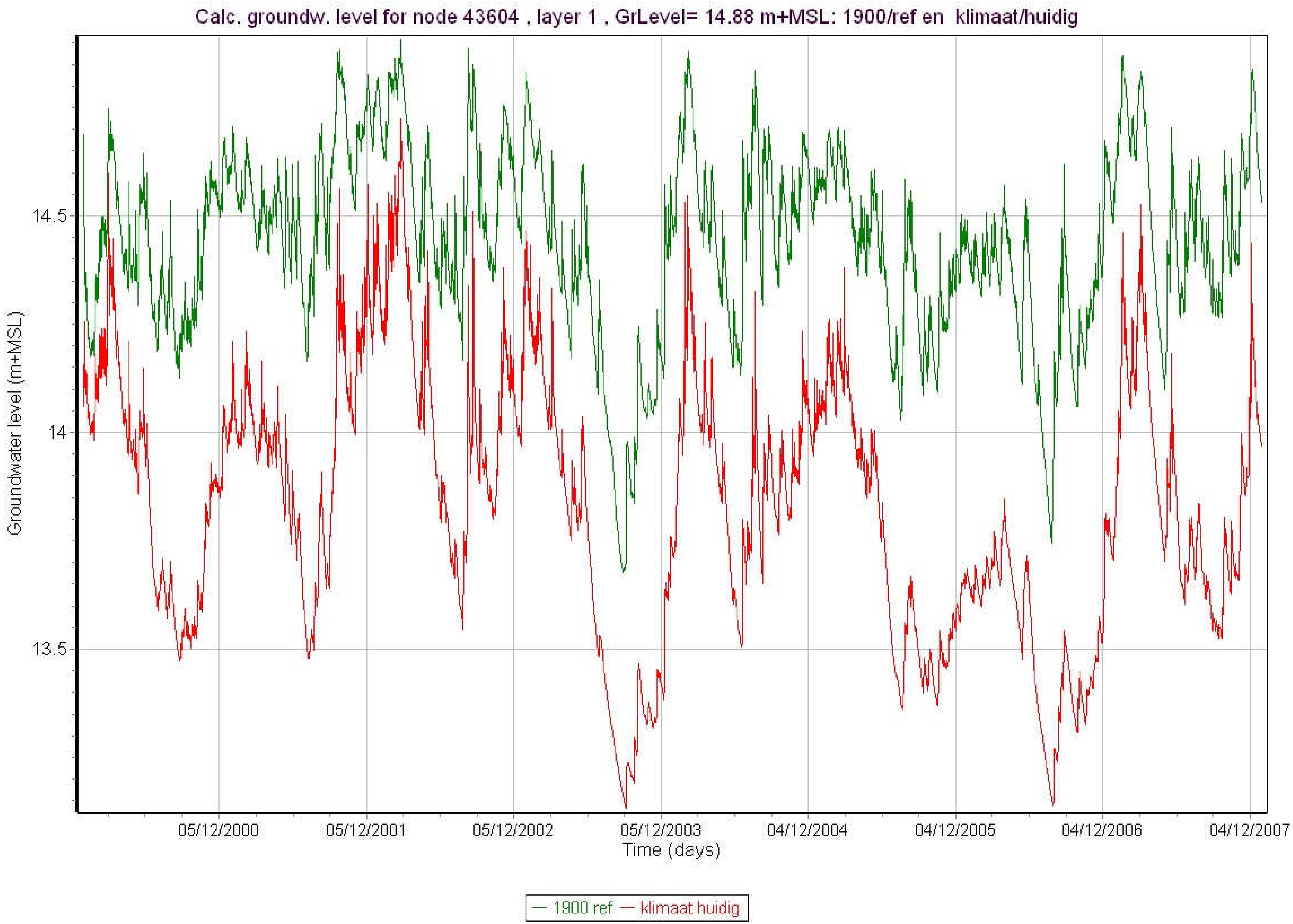
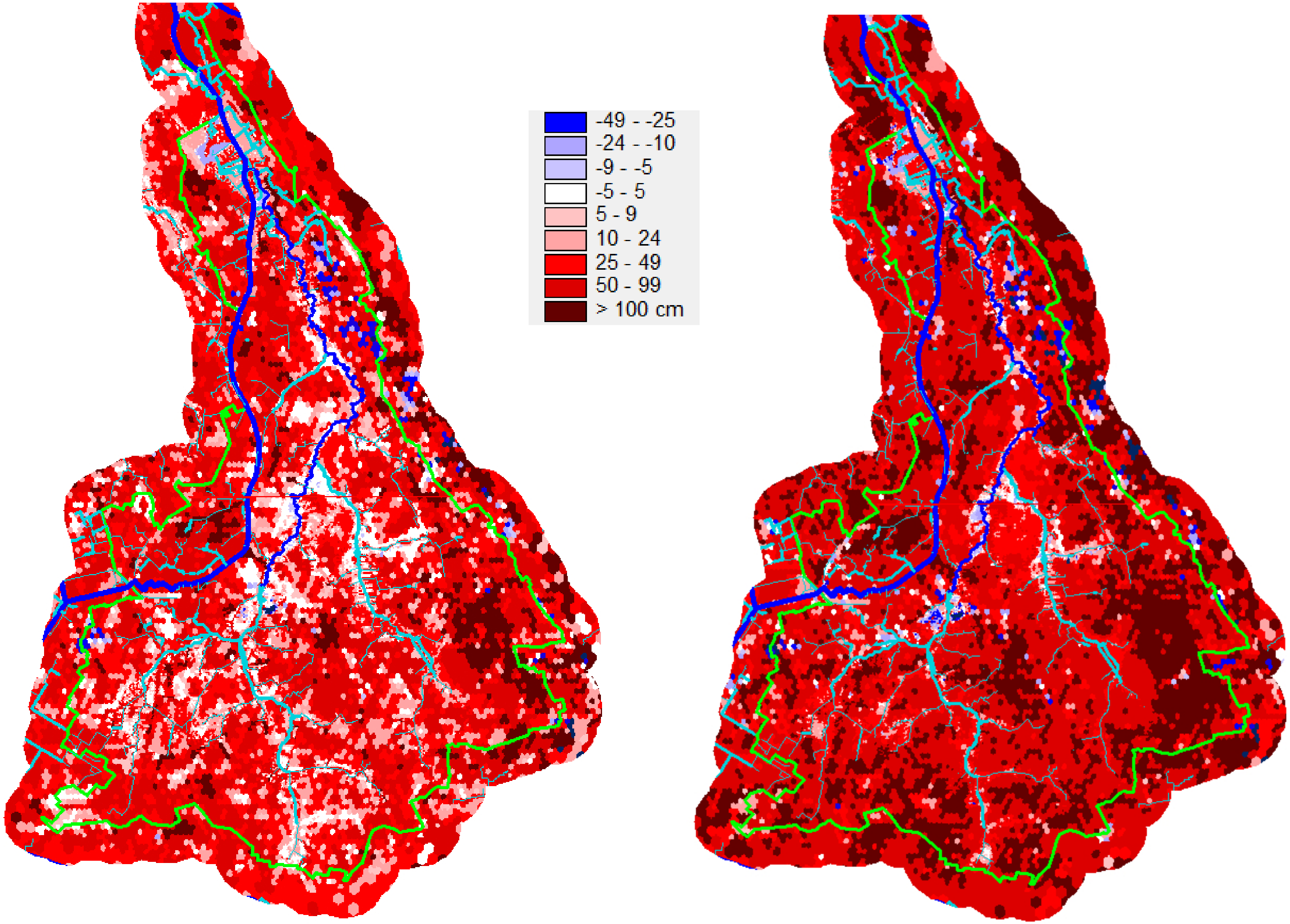


Figure 5 Groundwater levels calculated for the 1900 and 2000 time windows, using meteorological data for 2000 (location shown on map of the Drentsche Aa catchment).

Table 3 Simplified water balance of the Drentsche Aa catchment for the meteorological data 2000-2007. Average inflow in a system is positive and in mm/d.

System		1900	2000
Unsaturated zone	Rainfall	2.64	2.64
	Actual evapotranspiration	-1.27	-1.49
	Groundwater recharge	-1.37	-1.15
Groundwater	From unsaturated zone	1.37	1.15
	Drainage to surface water	-1.16	-0.88
	Extractions	0.0	-0.08
	Regional groundwater flow	-0.21	-0.19



GhG: 2000 - 1900 GlG: 2000 - 1900

Figure 6 Change in groundwater levels, highest GhG (occurring in general March each year) and lowest GlG (occurring in Sept each year). The levels today are generally lower than in 1900.

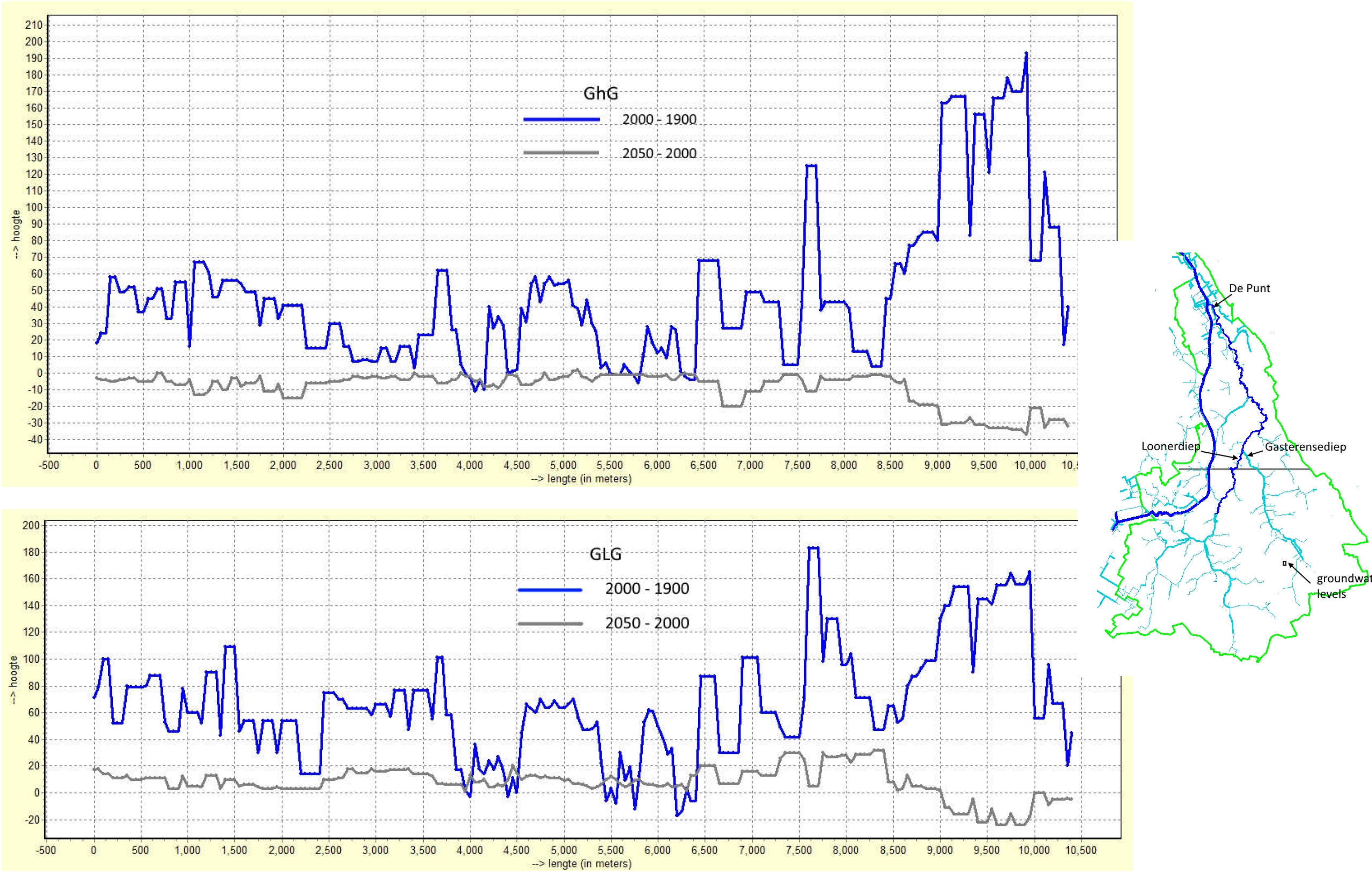


Figure 7 Difference in highest winter and summer lowest groundwater levels for a cross-section of the catchment.