Water system description

A58 Low-Tech Campus area

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Contents

1 Introduction

Rijkswaterstaat is exploring opportunities for more effective and sustainable water management in a more holistic approach. Water management is one of the starting points for creating a more integrated system in which the infrastructure of Rijkswaterstaat is an integral part of the environment and the community.

This report describes the water system around the Low-Tech Campus of Rijkswaterstaat that is situated around the rest area Kloosters along the A58. The description is focussed on the main infrastructures of RWS that are present in the area:

- Section of highway A58 between exit Best and exit Oirschot
- Deepened section of highway A2 near Best
- Wilhelminakanaal and in particular the section: Het Grote Pand

The aim of this report is to provide a water system description that can serve as a baseline description to be used for further development of holistic water management opportunities. This description of the water system provides the basis for use specifically in the approved INTERREG Rural Roadwater Rescue (RRR) Project (INTERREG Call 3) and the proposal submission of Stereo Roads in 2024 (INTERREG Call 4).

First a description of the surface water system with a focus on the Wilhelminakanaal is provided in Chapter 2. Next the groundwater system in relation to the Wilhelminakanaal, the deepened section of Highway A2 near Best and the A58 between exit Best (no 7) and exit Oirschot (no 8) is described in Chapter 3. The water systems of the highway sections are described in Chapter 4. Finally, Chapter 5 provides a summary and overview of potential next steps in the analysis.

2 Surface water system

Note: This paragraph on Wilhelminakanaal is largely based on the report 'Stedelijk waterbeheer kanalen, 2017' complemented with information from other sources.

The main surface water in the project area is The Wilhelminakanaal that connects to the Zuid-Willemsvaart in the east and Amer north of Sluis 1 in the west (Figure 1). The total length of the canal is approximately 70 km. The canal is divided into four sections, each with a different target water level. The target water level drops from east to west at sluices and is kept at a constant level between two sluices.

The part of the canal that is situated in the project area is called "Het Grote Pand", which is located between Sluis IV (since June 2023 called Sluice 24) in the west and the Zuid Willemsvaart in the east. The part of the Zuid-Willemsvaart between Sluis 6 in the north and Sluis Helmond in the south, also belongs to Het Grote Pand. Other surface water bodies that are directly connected to Het Grote Pand are the former Zuid Willemsvaart north of Sluis 7 and the Beatrixkanaal, east of Eindhoven, up to the river Dommel. In the west water is discharged from the Wilhelminakanaal at the discharge structure in Oosterhout, next to sluice I.

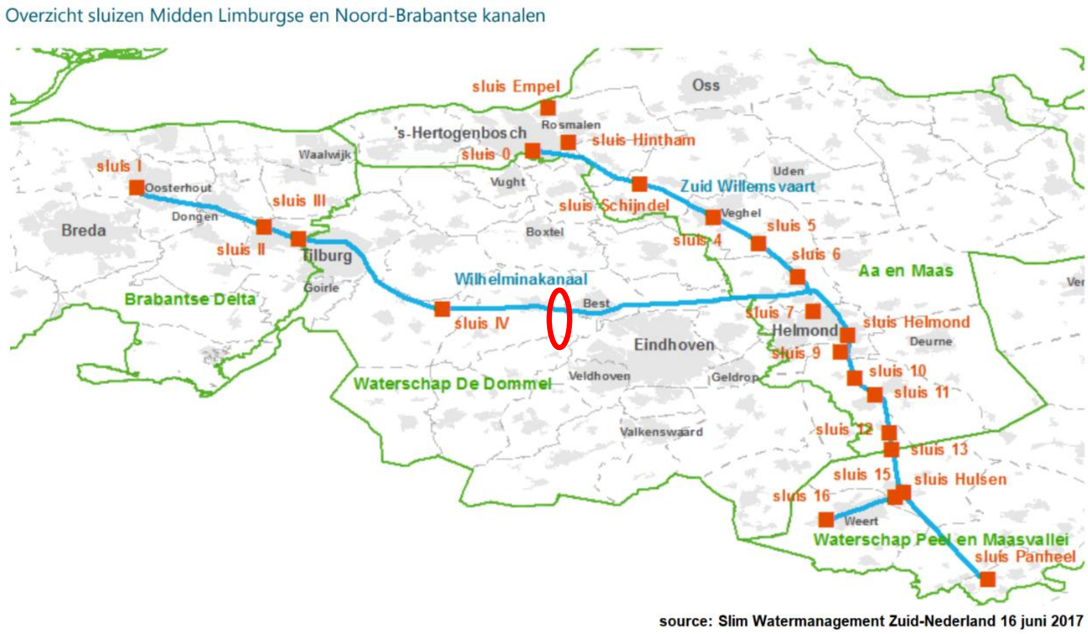


Figure 1 Overview of sluices in Middle Limburg and North Brabant canals. The red circle indicates the position of the Low-Tech Campus.

Figure 2 Replacement of sheet piles along the Wilhelminakanaal. Extraction of a sheet pile (May 26, 2020).

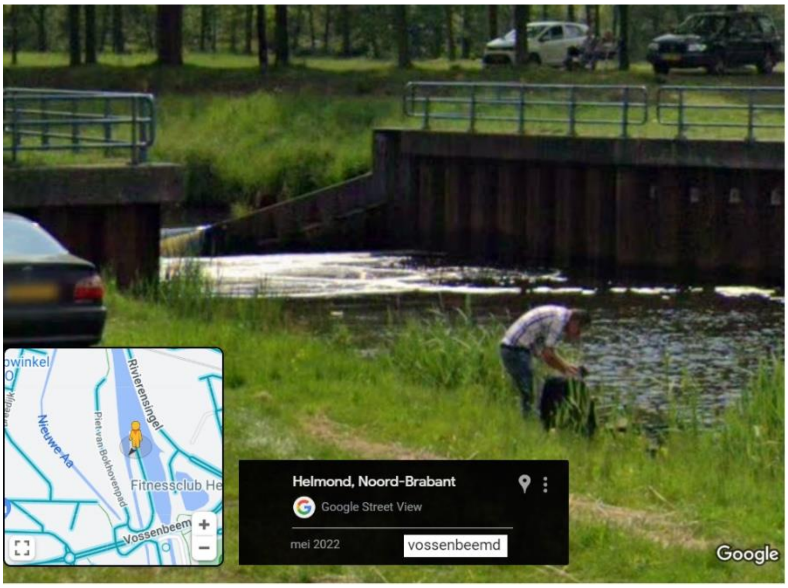


Figure 3 Discharge of Nieuwe Aa over a weir into the Zuid-Willemsvaart.

2.1 Zuid-Willemsvaart

The Wilhelminakanaal receives water from the Zuid-Willemsvaart in the east. The most relevant water inflows (> 4 m^3/s) into the Zuid-Willemsvaart are (Figure 6):

- From Belgium (Lozen) water inlet into the Zuid-Willemsvaart is controlled with a maximum flow rate of 10 m^3/s.
- Water inlet from the river Meuse is possible at pumping station Panheel, up to a rate of 6 m^3/s.
- Water inlet under gravity conditions from the Bakelse Aa (waterboard Aa en Maas) and by structure Vossenbeemd (Aa, RWS).

A draft version of a study for RWS states that the amount of water that can be supplied from the Meuse to the Zuid-Willemsvaart will become limited during summer. This is caused by the low water levels and discharge of the Meuse during the summer season.
Water is discharged from the Zuid-Willemsvaart at sluice 0 in ‘s-Hertogenbosch, at sluice Berlicum into the Maximakanaal and through the Wilhelminakanaal.

2.2 Wilhelminakanaal – Het Grote Pand

The Wilhelminakanaal is the main water body that crosses the Low-Tech Campus area. The canal receives regional discharges from:

- Inlet Blaarthem (river Dommel, Water board De Dommel), through the Afwateringskanaal and the Beatrixkanaal.
- Inlet Boven Donge (river Donge, Water board Brabantse Delta)

The average depth of the Wilhelminakanaal is 2.3 m (below canal water level) with a minimum depth of 1.9 m. The width of the canal in the area around Oirschot is 25 – 30 m. The banks of the canal are constructed with sheet piles with a length of 6 – 8 m. Figure 2 provides an impression of the length of such a sheet pile. The sheet piles are mainly used for canal bank stability. The sheet piling hasn't been driven deep enough to prevent groundwater flow below the sheet piles.

Het Grote Pand is the section of the Wilhelminakanaal that is located in the area of the Low-Tech Campus. Het Grote Pand of het Wilhelminakanaal and the Low-Tech Campus are situated north-west of Eindhoven (Figure 4). The Grote Pand is easternmost section of the Wilhelminakanaal. Therefore, the sluices in the east of the Wilhelminakanaal and Grote pand are the same. The water level in Het Grote Pand is kept at a fixed level at approximately NAP + 15.0 m. The water level upstream of Sluis Helmond in the Zuid Willemsvaart is more than 5 meter higher than the water level in Het Grote Pand. The water levels downstream of Sluis 6 in the Zuid Willemsvaart and downstream of Sluis IV in the Wilhelminakanaal are more than 2 meter lower than the water level in Het Grote Pand (Figure 5).

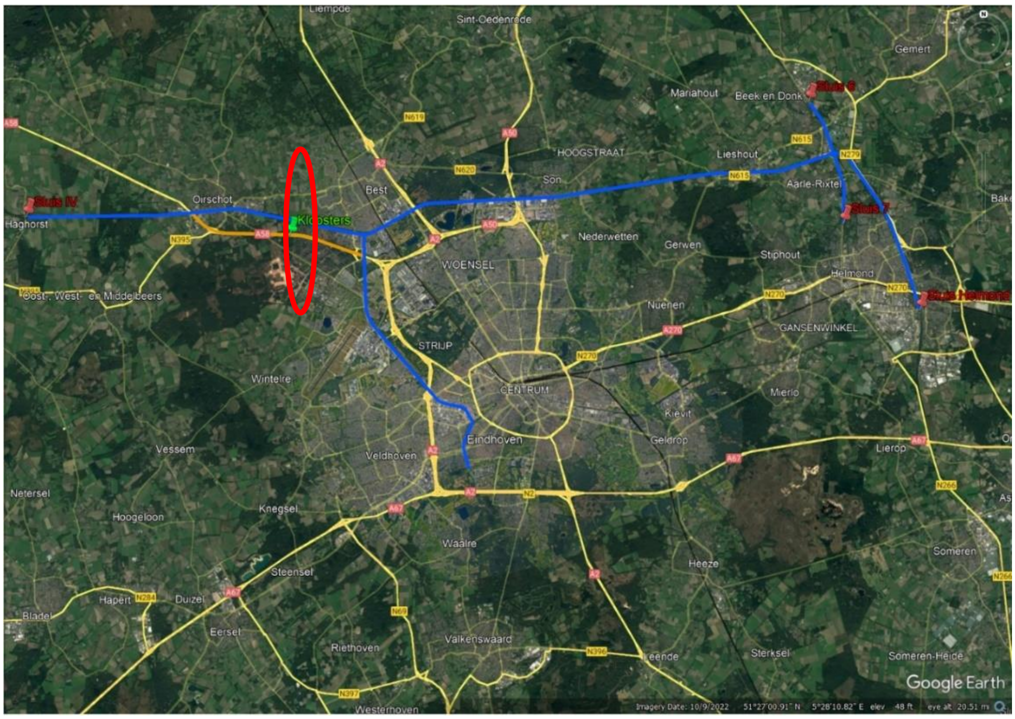


Figure 4 Overview of sections of Het Grote Pand (Source: Google Earth). The red circle is the Low-Tech Campus.

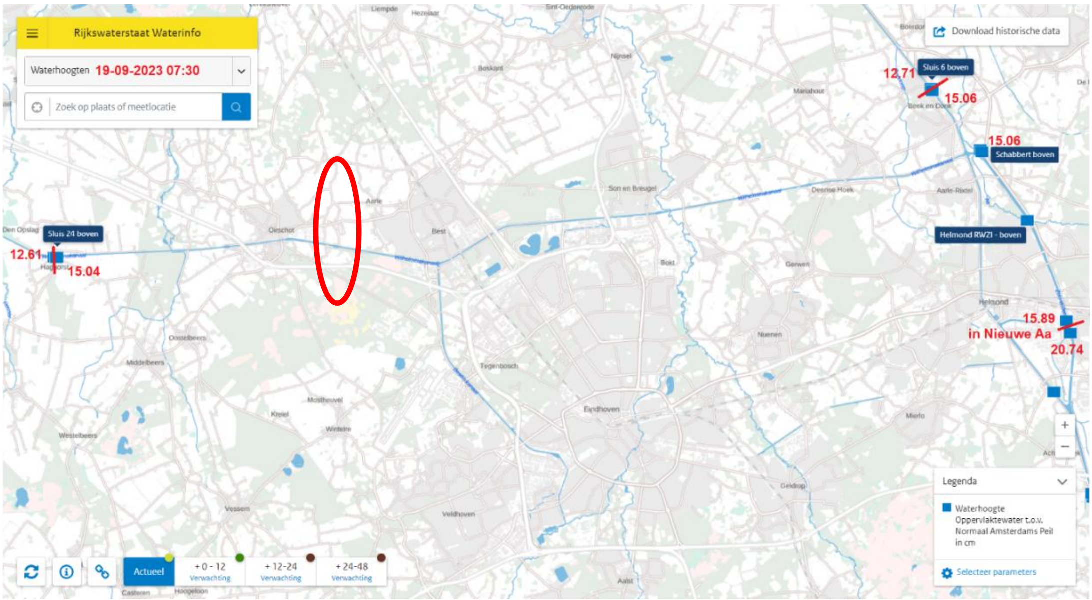


Figure 5 Observed canal water levels at 19-09-2023 at 07:30 hrs (Source: RWS Waterinfo). The value 15.89 (m+NAP) is the water level of the Nieuwe Aa that discharges over a weir just north of Sluice Helmond into the Zuid-Willemsvaart (Figure 3). The red circle is the Low-Tech Campus.

Het Grote Pand also receives water from the local streams:

- River Aa
- River Bakelse Aa
- River Dommel

The main water discharges from the Het Grote Pand are at sluice IV at Haghorst (Wilhelminakanaal) and at sluice 6 at Beek en Donk (Zuid-Willemsvaart).

Figure 6 provides an overview of the main discharges to and from Het Grote Pand. The figure shows the WATAK (WATerAKkoord) values (1993) in m^3/s for the major regional discharges. These WATAK values are not actual discharges but can be seen as maximum allowed discharges during wet periods.

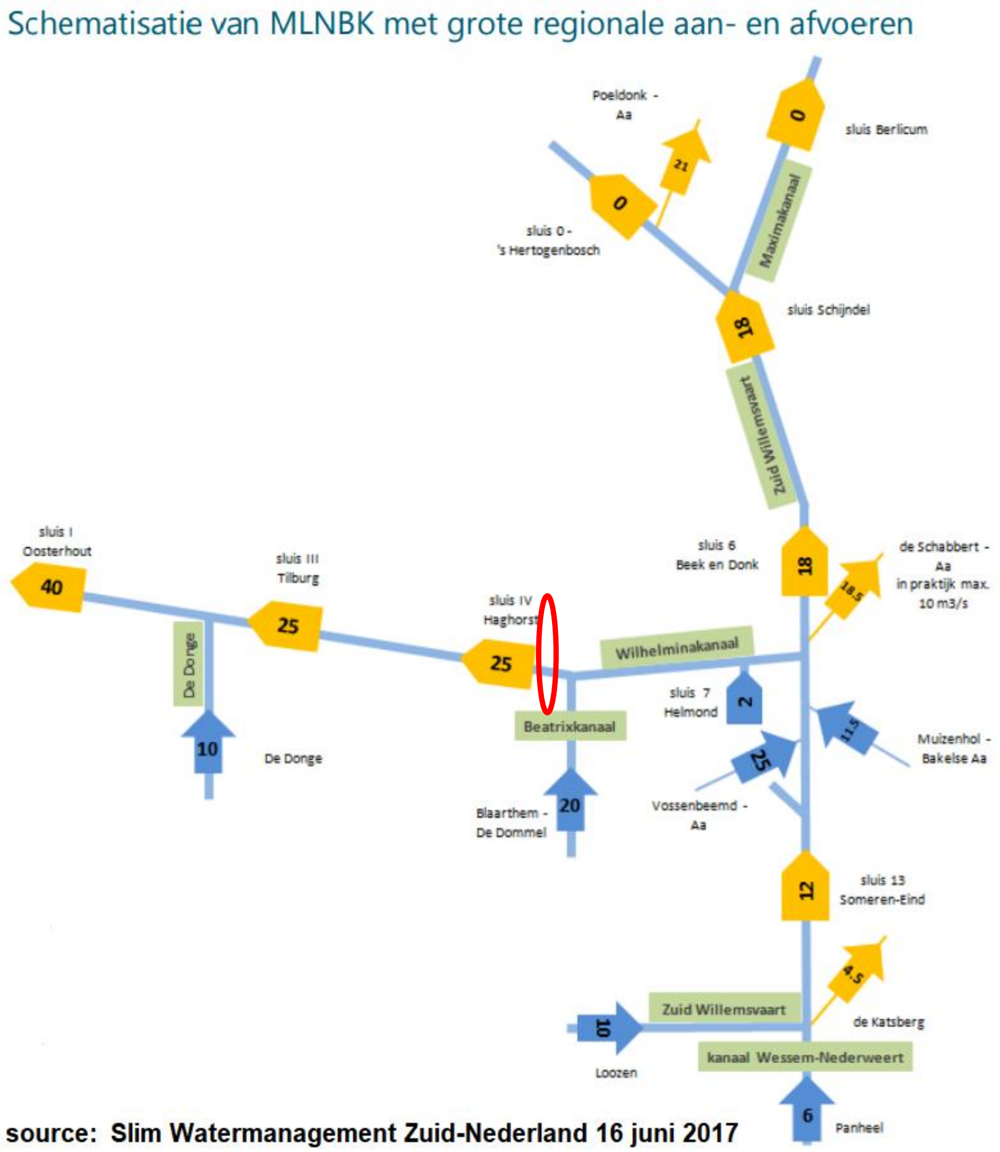


Figure 6 Overview of larger discharges to and from Het Grote Pand.

Under normal conditions water that is let in from Water board Aa en Maas is discharged again to the river Aa at structure de Schnabbert. Water from Water board De Dommel is discharged through the Wilhelminakanaal in western direction.

Peak discharges from the waterboards can somewhat be controlled by using the different water storage areas that have been constructed. These water storage areas are not located within the Low-Tech Campus area.

Table 1 show its dimensions and basic characteristics are given in the factsheet presented in Figure 7.

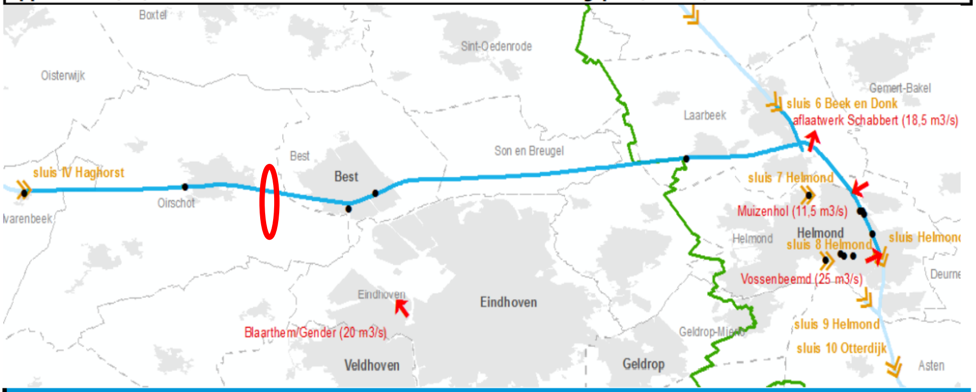
Table 1 Dimensions of Het Grote Pand

Section	**Length**	**Surface area (estimated)**
Wilhelminakanaal Sluis IV - Zuid Willemsvaart	31.091 km	74 ha
Zuid Willemsvaart between Sluis 6 and Sluis Helmond	9.094 km	42 ha
Former Zuid Willemsvaart between sluice 7 and Wilhelminakanaal	2.690 km	6 ha
Beatrixkanaal / Afwateringskanaal between Dommel and Wilhelminakanaal	10.756 km	18 ha

Factsheet: kanaalpand 'het Grote Pand'

1. Basisgegevens

naam:	kanaalpand 'het Grote Pand'	**streefpeil (m NAP):**	15
waterbeheerder:	Rijkswaterstaat Zuid-Nederland	**MAP1 (m NAP):**	15.08
gemeenten:	Hilvarenbeek, Oirschot, Best, Eindhoven, Son en Breugel, Gerwen en Nederwetten, Laarbeek en Helmond	**MIP1 (m NAP):**	14.85
waterschappen:	De Dommel en Aa en Maas	**MAP2 (m NAP):**	15.15
bedrijven:		**MIP2 (m NAP):**	14.8
oppervlakte (m^2):	1415819	**toetsingspeil (m NAP):**	15.3



2. Water aan- en afvoer in huidige situatie

in	WATAK (m3/s)	uit	WATAK (m3/s)
doorlaatwerk Helmond	9	sluis IV Slaghorst	25
sluis 7 Helmond	2.1	sluis 6 Beek en Donk	18
aflaat Vossenbeemd	25	uitlaatpunt Schabbert (praktijk max. 10 m3/s)	18.5
stuw Muizenhol	11.5	RWZI Helmond	4
aflaatwerk RWZI	4	Gem. Laarbeek Lieshout (40 m3/h)	
gemaal Mierloo	1.8	Donkervoortste loop	0,2
gemaal Wilhelminakanaal	1.8	inlaat visvijver	0,1
aflaatwerk Blaarthem (incl. Gender)	25	inlaat Gulden Aa	0,2
Wetering	0.2	inlaat de Vries	0,01
Weyer	0.5	inlaat Eijkenlust	0,05
Deense hoek	0,1	inlaat Schootense loop	0,05
gemaal Goorloop	2	jachthaven Dieskant	
stedelijke overstorten Best, Oirschot, Son en Eindhoven			

3. Kenmerken stedelijke afvoeren

naam	stelsel	m^2	overstort hoogte	naam	stelsel	m^2	overstort hoogte
meerdere overstorten op het Beatrixkanaal vanuit				G010 Rijpelbaan	GM	30000	16.8
gemeente Eindhoven				BBB 045 Rijpelberg	GM	620,000	17.4
Best		170000		BBB 0458 Gulden Aa	GM	1,000,000	
Rendac (max. 120 m3/uur)				BBL 063 Braak	GM	1,000,000	
Ekkersrijt (2900 m3/h bij BUI08)				BBB 080 De Weijer	GM	300,000	
Gebr. Swinkels Lieshout	GS	20000		Hortensiapark	GM		
Bavaria (5000 m3/dag)				Smyrnoffstraat	GM	30,000	
Koppelstraat 37	GS	6,750	13.5	Breinterlaan	GM		

4. Toekomstig (gewenste) aan- en afvoeren

in	uit
mogelijk vergroten industrieterrein BZOB (ongeveer 50 ha komt op Aa die wordt afgelaten)	
luchtmachtterrein afkoppelen met overstort op Beatrixkanaal	

5. Opmerkingen:

Figure 7 Overview of dimensions of Het Grote Pand (Source: Stedelijk waterbeheer kanalen 2017). The red circle is the Low-Tech Campus.

2.2.1 Water levels

Het Grote Pand has a fairly constant water level, which is just above NAP +15 m (Figure 8). The average water level from 30 March 2014 to 18 September 2023 is NAP +15.01 m. The water level variation is limited to a few centimetres, except for a few outliers. The standard deviation of the 10-minute values is 3.5 cm and that of the daily average values is 2.8 cm. De lowest water levels predominantly occur in winter, indicating that these are likely not related to droughts.

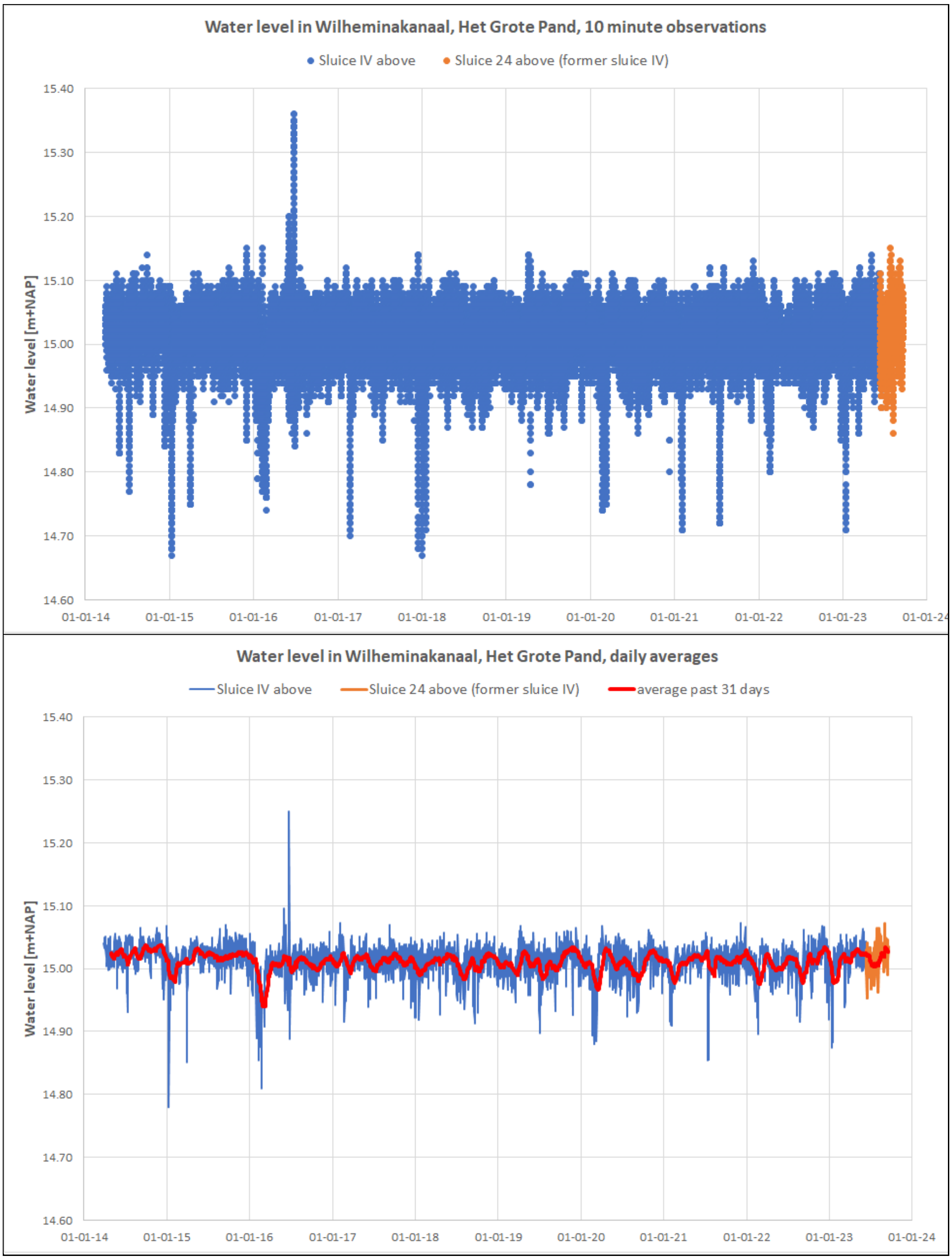


Figure 8 Observed water levels in Wilhelminakanaal, Het Grote Pand (source: RWS Waterinfo)

2.2.2 Urban areas

The Wilhelminakanaal receives and supplies water from and to various urban areas. Urban areas that discharge water into the Wilhelminakanaal are Oosterhout, Tilburg, Haghorst, Best, Laarbeek, Eindhoven, Helmond, Weert, Nederweert, Veghel, Schijndel and 's-Hertogenbosch. Part of these areas discharge into Het Grote Pand.

Most discharge from urban water are from Eindhoven (airport) into the Beatrix Canal and from Best directly into the Wilhelminakanaal. Figure 9 provides an overview of the urban areas that drain into Het Grote Pand.

Water from Het Grote Pand is supplied to various municipalities (for example Oosterhout and Lieshout). It is used to supply parks and ponds with water and to flush the urban water infrastructure.

Stedelijke afvoeren

locatie	vergunninghouder	adres	omschrijving lozing	ø mm	type GM/GS/VGS	opp. verhard (ha)	berging (mm)	poc (mm/h)	overstorthoogte (m NAP)	opmerkingen	X	Y	km
WHK													
SLUIS IV													**36,900**
Oirschot				700 mm		4				Verder geen gegevens: schatting 3 ha	151006	390130	45,435
Best	Philips P.M.S.	Veenpluis 4 - 6 Best	hemelwater		GS	13.5				afkomstig van 13,5 ha bedrijfsterrein (info oude Wvo-verg '85)	154657	389377	49,100
Best				1000 mm		0.5				Verder geen gegevens schatting 0,5 ha	154927	389322	49,400
Best	Gem. Best			1000 mm		0.5				Nooduitlaat gem. Best, schatting 0,5ha	155329	389285	49,800
Best	Gem. Best			1000 mm		0.5				Nooduitlaat gem. Best, schatting 0,5ha	155702	389403	50,140
Best	NS Raillinfrabeheer BV			0,950x0,250						max.20.000 m3/jaar Gem.Best	156044	389598	50,530
Best	Gem. Best			1000 mm		0.5				Nooduitlaat gem. Best schatting 0,5 ha	156333	389792	50,900
Best	Gem. Best			1000 mm		0.5				Nooduitlaat gem. Best schatting 0,5 ha	156475	389871	51,050
Best	Gem. Best			800 mm		0.5				Nooduitlaat gem. Best schatting 0,5 ha	156806	390027	51,416
Best	Gem. Best					0.5				Nooduitlaat gem. Best schatting 0,5 ha	156853	390084	51,470
Best	Rendac Son	Kanaaldijk Noord 20								1000000 m3/jaar incidenteel een max. van 120 m3/uur	158856	390535	53,681
Son	gem Son en Breugel	Ekkersrijt/Oirschotsedijk	hemelwater	1000mm	GS					nieuwe overstort hemelwater Ekkersrijt gem Son 2900 m3/h (bij T=2)	161885	390670	56,700
Laarbeek (Lieshout)	Swinkels bouwmaterialen	Gebr. Swinkels		200 / 2x125 m	GS	2				regenwater ongeveer afkomstig van 2ha	168592	391594	63,500
Beatrixkanaal													
Eindhoven	Gemeente Eindhoven	Looierstraat	lozing verhard opp.			408							

Figure 9 Overview of urban discharges to Het Grote Pand (Source: Stedelijk waterbeheer kanalen 2017).

2.2.3 Companies

Several large companies at and along the canal system depend on water from the canal system for production processes or cooling or discharge water into the canal system. These are often constant discharges or withdrawals. According to the report Stedelijk waterbeheer kanalen (2017) discharge and withdrawals into and from Het Grote Pand are limited to the water discharge of 57000 m^3/year by Brabant Water (Waterleidingmaatschapij Oost-Brabant).

2.2.4 Water discharge and water supply

It is important to discharge water quickly in situations when a surplus of water is supplied to the canal system (Stedelijk waterbeheer kanalen, 2017) and is shown in Figure 10. At a discharge of more than 8 m^3/s at structure De Schabbert, the excess water in Het Grote Pand is discharged by the spout divers under Sluice 6, up to a maximum of 18 m^3/s. When this is not sufficient, the discharge through De Schabbert can be increased again. Theoretically, the water discharge via De Schabbert and WWTP Helmond can be increased up to 22.5 m^3/s, but in practice this is not feasible, because this causes flooding in the downstream part of the Aa. The maximum discharge of De Schabbert and WWTP Helmond on the Aa is approximately 12 m^3/s (8 m^3/s via De Schabbert and 4 m^3/s by WWTP Helmond with discharge via the Hermeanderende Aa). Therefore, 8 m^3/s of this discharge is drainage of canal water. Additional water discharge can still occur by opening the rinkets (spuideuren) of sluices 4, 5 and 6 (10 m^3/s). However, as soon as the rinkets are opened, it is no longer possible to lock ships, so ship locking must then be stopped on the Zuid-Willemsvaart.

Normally, the discharge of excess water from the river Dommel flows entirely via the Wilhelminakanaal through sluice Haghorst (lock IV). This sluice can discharge 25 m^3/s without causing problems. In case of a larger water supply, bypass sewers can be used. This only occurs in extreme situations. In practice, only one bypass sewer can be used (capacity 5 m^3/s) and when the bypass sewer is used, shipping must be stopped.

The maximum discharge capacity is then 36 m^3/s (including 10 m^3/s rinkets) via the Zuid-Willemsvaart and 30 m^3/s (including 5 m^3/s circulation sewer) via the Wilhelminakanaal (and 40 m^3/s at Oosterhout), but then no shipping can occur. In case that shipping cannot be stopped, the maximum discharge capacities are 26 m^3/s (18 + 8 m^3/s) for the Zuid-Willemsvaart and 25 m^3/s for the Wilhelminakanaal. During a 10-year event (T10) water discharge to the canal is approximately 47.3 m^3/s from Waterboard Aa en Maas and 23.5 m^3/s from Waterboard De Dommel. This implies a discharge shortage of approximately 5.8 m^3/s for a period up to 20 hours when shipping is stopped. The discharge shortage for periods that shipping is continued is 20.8 m^3/s for a period of 10 to 50 hours. For this analysis a uniform T10 situation is assumed to occur simultaneous at all waterboards that discharge via streams into the Midden-Limburg and Noord-Brabant Canals (MLNBK).

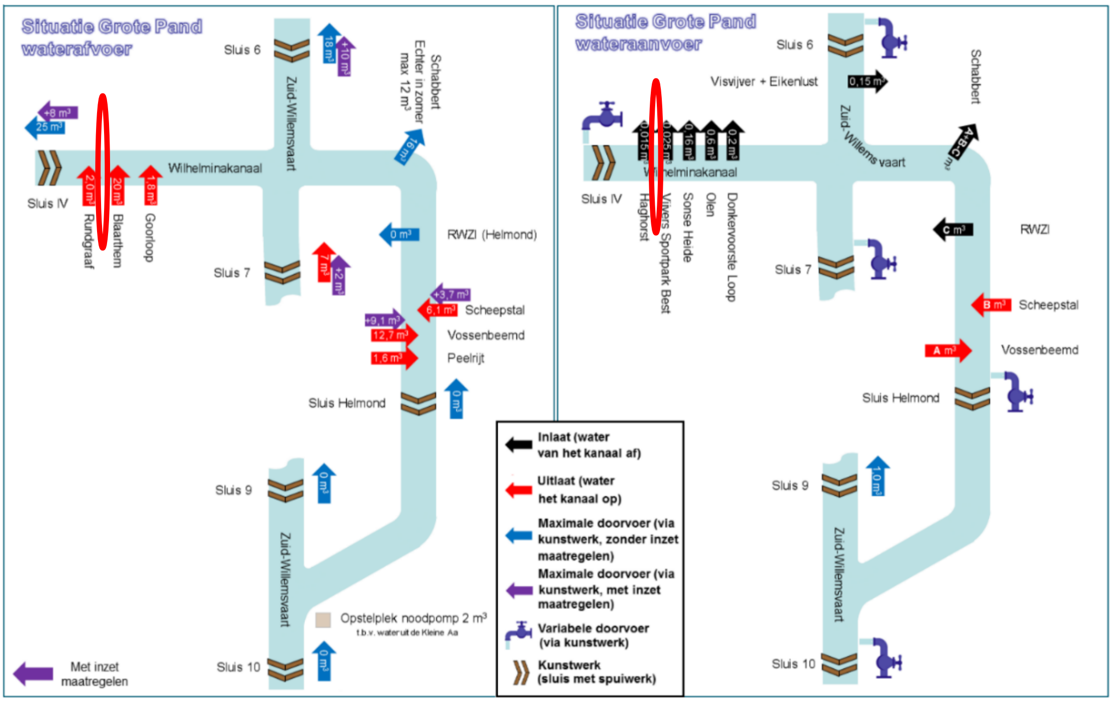


Figure 10 Overview of water agreement for discharge (left) and for water supply (right) for Het Grote Pand (Source: Waterakkoord Midden-Limburgse en Noord-Brabantse Kanalen 2021, Definitieve versie 1.2). The Low-Tech Campus (red circle) is situated between 'Vijvers Sportpark Best and Haghorst.

The black arrows in Figure 10 indicate the supply of water from Het Grote Pand. The main inlets from the Wilhelminakanaal are shown in Table 2. These inlets are the permitted volumes. The actual inlet volumes have not been requested from the local water authority. These are expected to be much smaller on an annual basis.

Table 2 Inlet from Het Grote Pand according to Waterakkoord Midden-Limburgse en NoordBrabantse Kanalen 2021. The Low-Tech Campus is situated between 'Vijvers Sportpark Best and Haghorst.

Water inlets from Wilhelminakanaal	**Inlet volume in m3/s (permit)**
Visvijver + Eikenlust	0.15
Donkervoortse Loop	0.2
Olen	0.6
Sonse Heide	0.16
Vijvers Sportpark Best	0.025
Haghorst	0.015

3 Groundwater system

The land surface of the Low-Tech slopes inclines downward from the higher situated south to the lower situated north. The groundwater levels in the Low-Tech Campus follows the same gradient as the land surface. This results in groundwater flow from south to north.
The Low-Tech Campus area is dominated by infiltration and groundwater recharge as can be seen in Figure 11.

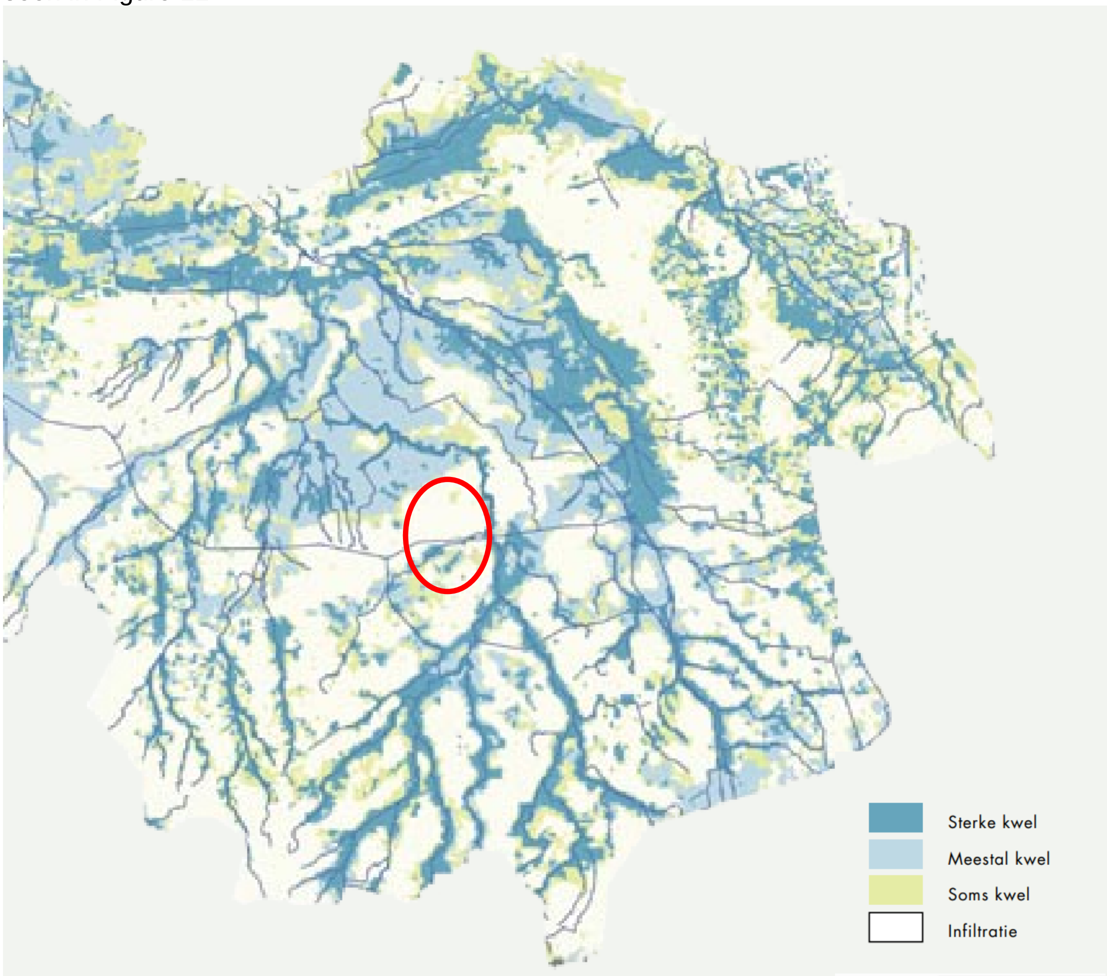


Figure 11 Simulated infiltration (infiltratie) and exfiltration (kwel) of groundwater. Low-Tech Campus indicated by red circle (Brabant Waterland, Watersystemen in beeld).

3.1 Groundwater exchange Wilhelminakanaal

An earlier study of Deltares (2022) provides a brief description of the groundwater system in the central area of Low-Tech Campus. It states that the Wilhelminakanaal has a draining effect on the groundwater resulting in a lower groundwater level. The groundwater flow from south to north is cut off by the Wilhelminakanaal. The shallow layers of loam in the subsurface are expected to limit this effect to the shallow groundwater. The canal might also affect the area north of the Wilhelminakanaal by intercepting or redirecting the groundwater flow.

Only a limited number of groundwater observation wells with recent observations is available. None of these wells are situated closely to the highway A58 or the Wilhelminakanaal (Figure 12). Therefore, no direct information can be derived about the effect of the Wilhelminakanaal or A58 on groundwater levels or flow.

Due the lack of observations, the results from the Landelijk Hydrologisch Model (LHM) are used to explore the effect of the Wilheminakanaal. Dynamic groundwater simulations were carried for a period of 10 years (2009 to 2018) resulting in maps of the average high and low groundwater levels (Figure 13) Based on the results of these simulations, some tentative conclusions can be drawn about the hydrology around Wilhelminakanaal and A58.

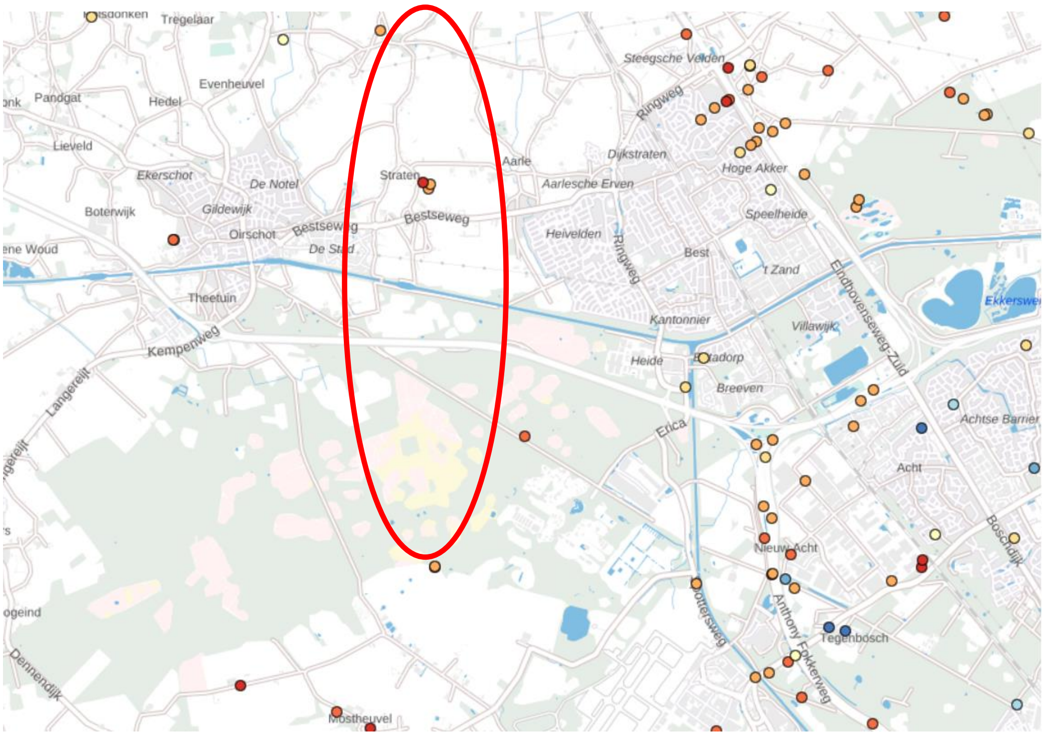
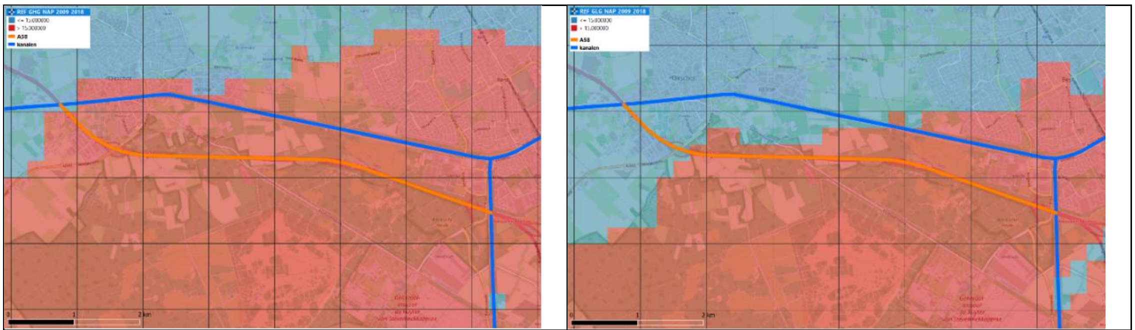


Figure 12 Groundwater observation wells in the vicinity of the project area (source: https://www.grondwatertools.nl/gwsinbeeld/). The red circle indicates the position of the Low-Tech Campus.



GHG higher (red) or lower (blue) then water level of Wilhelminakanaal (NAP +15 m)	GLG higher (red) or lower (blue) then water level of Wilhelminakanaal (NAP +15 m)

Figure 13 Average high groundwater levels (GHG) and average low groundwater levels (GLG) (source: Deltares, based on LHM version 4.3).

For the Wilhelminakanaal the following can be concluded in relation to the interaction with groundwater (see also Figure 14):

- West of Oirschot (about 250 m east of the junction with the A58) the Wilhelminakanaal is infiltrating almost continuously. The calculated average low and average high groundwater levels (GLG and GHG) are both lower than the canal water level (approx. NAP +15 m).
- From the west of Oirschot to approximately the border between the municipalities Oirschot and Best the Wilhelminakanaal is alternately infiltrating (summer) and draining (winter). The calculated average low groundwater level (GLG) is lower than the canal water level and the calculated average high groundwater level (GHG) is higher.
- East of the border between the municipalities Oirschot and Best, the Wilhelminakanaal is draining almost all year. The calculated GLG and GHG are both higher than the water level of the canal.

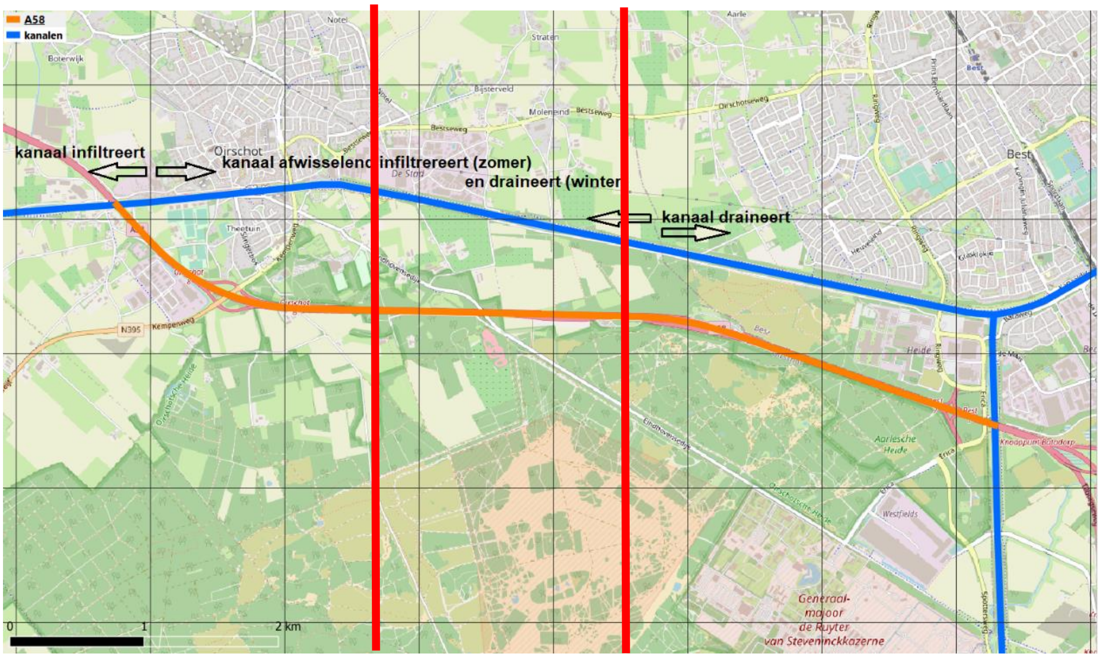


Figure 14 Estimated interaction of Wilhelminakanaal with groundwater: in western section infiltration ("kanaal infiltreert"), in eastern section drainage ("kanaal draineert") and in middle section alternately infiltrating (summer) and draining (winter). The Low-Tech Campus is situated between the red lines.

Based on the calculated high and low groundwater levels for the entire area of Het Grote Pand (including the Beatrixkanaal), draining and infiltrating sections have be distinguished in more detail (Table *3*).

Table 3 Overview of sections of the Wilhelminakanaal that are draining (indicated in pink) or infiltrating (indicated in blue) during high average groundwater levels (GHG) and low average groundwater levels (GLG).

WHK from sluice IV8 (24) to ZWV								
Distance			**GHG [m+NAP]**		**GLG [m+NAP]**		**location**	
from [m]	**to [m]**	**Length [m]**	**from**	**to**	**from**	**to**		
0	6466	6466	13.35	14.94	12.47	13.75	Sluis IV (24)	
6466	10280	3814	15.37	15.87	14.07	14.87		
10280	12860	2580	16.32	16.98	15.36	16.32	Beatrixkanaal	
12860	16375	3515	16.98	16.10	16.32	15.21	Beatrixkanaal	
16375	16865	490	15.83	16.06	14.73	14.96		
16865	17373	508	16.04	15.77	15.35	15.06		
17373	17875	502	15.43	15.18	14.55	14.29		
17875	18375	500	14.93	14.91	14.00	14.06		
18375	18628	253	15.05	15.05	14.11	14.11		
18628	19873	1245	14.98	15.00	14.15	14.32		
19873	20124	251	15.11	15.11	14.27	14.27		
20124	29084	8960	14.73	14.50	13.89	13.83		
29084	29468	384	15.40	15.40	14.41	14.41		
29468	31090	1622	14.25	14.00	13.66	13.66	ZWV	
minimum and maximum			10.81	17.99	10.34	16.85		
estimated average		31090	15.09		14.22			
Beatrixkanaal from Dommel to WHK								
Distance			**GHG [m+NAP]**		**GLG [m+NAP]**		**location**	
from [m]	**to [m]**	**Length [m]**	**from**	**to**	**from**	**to**		
0	1076	1076	16.15	17.19	15.55	16.43	Dommel	
1076	1346	270	15.20	15.20	14.70	14.70		
1346	1615	269	16.37	16.34	15.47	15.89		
1615	1885	270	14.60	14.60	14.29	14.29		
1885	8467	6582	16.28	15.93	15.75	15.24		
8467	8714	247	14.63	14.63	14.22	14.12		
8714	8967	253	15.84	15.84	14.82	14.82		
8967	10756	1789	18.14	16.98	15.98	16.98	WHK	
minimum and maximum			14.63	19.28	14.22	17.63		
estimated average		10756	17.50		16.50			
ZWV from sluice Helmond to sluice 6								
Distance			**GHG [m+NAP]**		**GLG [m+NAP]**		**location**	
from [m]	**to [m]**	**Length [m]**	**from**	**to**	**from**	**to**		
0	533	533	16.15	16.22	15.55	15.31	Sluis Helmond	
533	790	257	15.14	15.14	14.81	14.81		
790	2110	1320	15.60	16.10	15.16	15.47		
2110	2562	452	15.30	15.15	14.87	14.74		
2562	2909	347	16.18	15.91	15.46	15.24		
2909	6982	4073	14.87	14.00	14.43	13.66	WHK	
6982	9094	2112	14.00	13.86	13.66	12.91	WHK - sluis 6	
minimum and maximum			12.62	18.88	12.24	17.47		
estimated average		9094	14.75		14.24			

ZWV-old from sluice 7 to WHK							
Distance			GHG [m+NAP]		GLG [m+NAP]		location
from [m]	to [m]	Length [m]	from	to	from	to	
0	1004	1004	14.75	13.73	14.18	13.62	sluis 7
1004	1510	506	15.29	15.25	14.88	14.89	
1510	2690	1180	13.83	14.00	13.68	13.66	WHK
minimum and maximum			13.57	15.29	13.16	14.89	
estimated average		2690	14.29		13.98		

For the entire length of Het Grote Pand the average high groundwater level is NAP +15.48 m and the low groundwater is NAP +14.67 m. This implies a net canal inflow in wet periods and a net canal outflow in dry periods. In this approach the differences in canal width between the four sections are neglected. The canal width is of less importance than the canal length, because for relatively wide canals most of the exchange between canal water and groundwater takes place along the sides of the canal bottom, as is schematized in Figure 15.

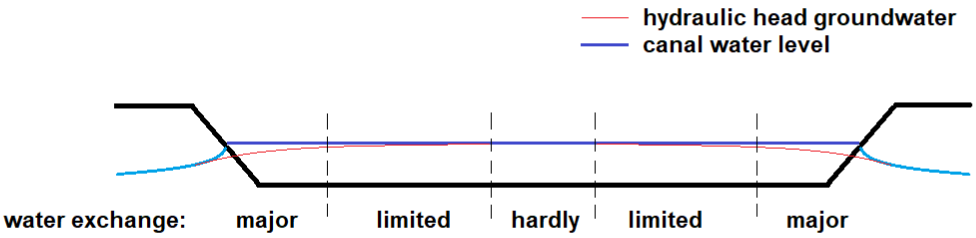


Figure 15 Schematic overview of water exchange between canal and groundwater. In the middle of the canal the difference between canal water level (dark blue line) and hydraulic head (red line) of the underlying groundwater is much smaller than at the side parts of the canal.

3.2 Groundwater situation at deepened section A2

The deepened section of highway A2 near Best has a length of approximately 2 km and a surface area of approximately 9.3 ha. The deepened section is sealed by bentonite walls to prevent groundwater drainage. However, earlier studies indicate that between 580,000 m^3 and 800,000 m^3 of groundwater is drained annually from the surrounding area (Rijkswaterstaat, 2004 and Oscar Smaal, 2023). This groundwater drainage is expected to have a significant effect on the groundwater system.

Figure 16 provides an overview of the surface elevation around the deepened section of highway A2 at Best. The surface of the highway is 5 to 10 meter lower than the surrounding area. It is also significantly lower than the groundwater level in this area (Figure 17). This results in groundwater drainage as the deepened section is not fully sealed off.

The drainage infrastructure in the deepened sections ensures sufficient drainage of the deepened highway to prevent groundwater flooding. Although the volume of drainage water is significant, the transects of groundwater observation wells show no clear drawdown of groundwater.

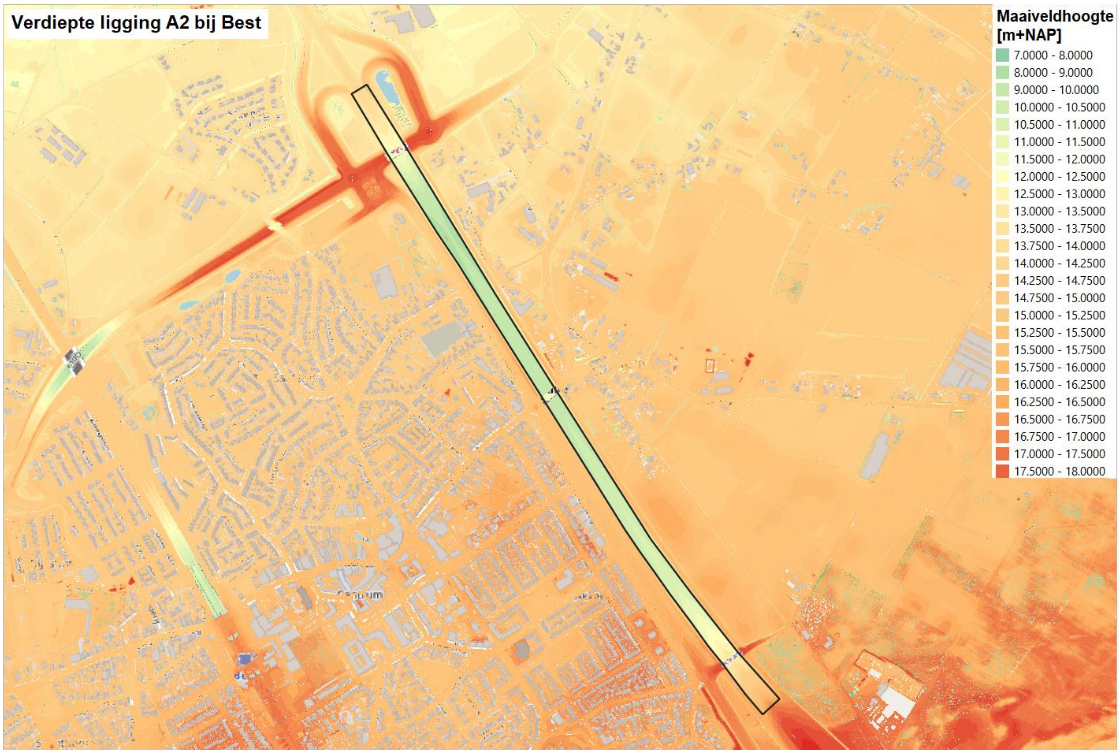


Figure 16 Surface elevation level around the deepened section of highway A2 at Best (source: AHN4)

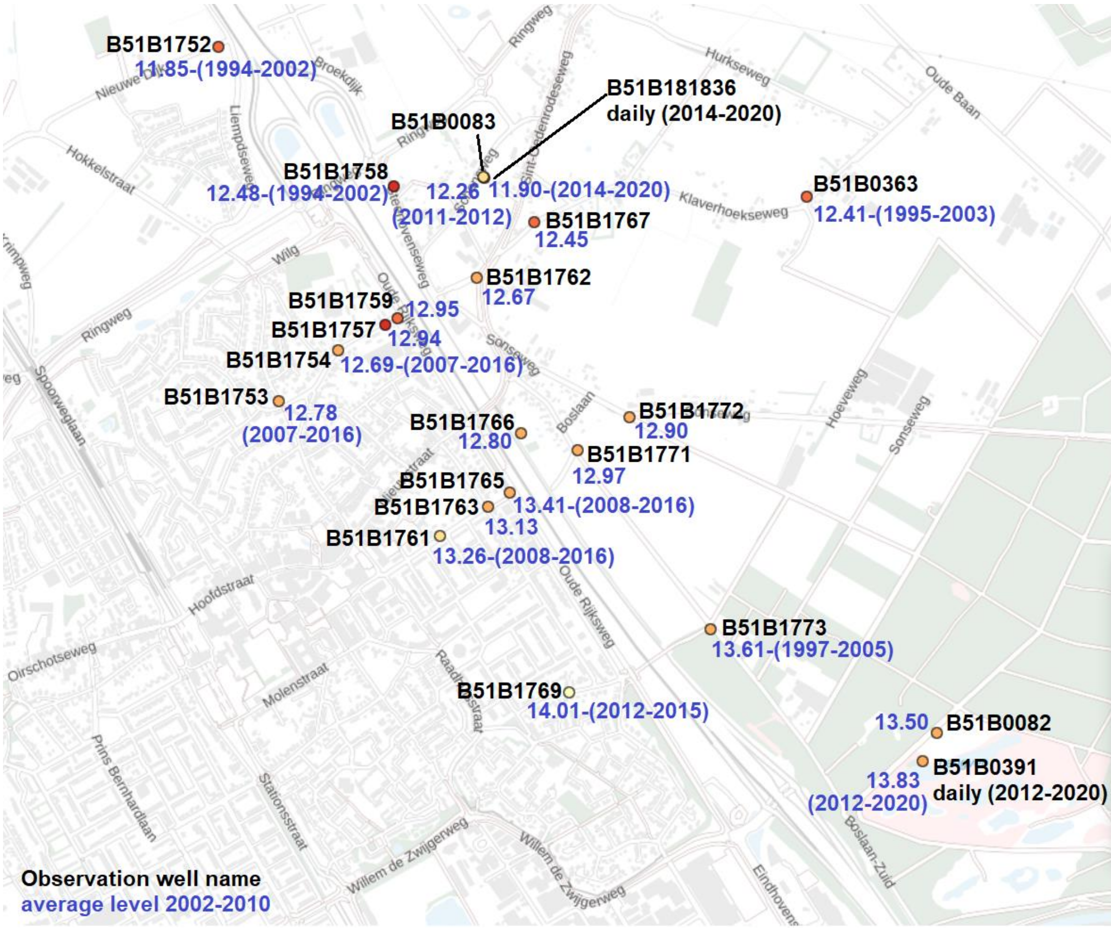


Figure 17 Observed average groundwater levels around the deepened section of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

Figure 17 shows 2 locations where observation wells are in a (more or less) straight line perpendicular to the direction of the A2. For these locations cross-sections are provided that are shown in Figure 18

- Cross-section 1 containing 6 observation wells from B51B1753 to B51B1767.
- Cross-section 2 containing 6 observation wells from B51B1761 to B51B1772, in which B51B1766 deviates 125 m from this line but is close to the A2.

The filters of the groundwater wells (the pervious part of the well that determines the depth at which the groundwater pressure is measured) are situated approximately between 7-8m+NAP. This means that they are situated in the first aquifer, i.e. below a less permeable loamy layer and slightly deeper than the land surface of the deepened section as can also be seen in Figure 22 and Figure 23.

Figure 18 shows the median values of the observed groundwater levels for the observation wells in cross-section 1 and Figure 19 shows the timeseries of these observation wells. Figure 20 and Figure 21 show the same for cross-section 2.

The green lines in Figure 18 and Figure 20 show the surface elevation level at the wells and the deepened part of highway A2.
These four figures indicate no local drawdown of the groundwater level at the A2 in the first aquifer. This could mean that due to the relatively hight porosity of the aquifer drawdown occurs over an area that is much larger than the length of the transects or that groundwater is supplied through another layer. The slightly deeper median value east of the A2 in cross-section 2 is caused by the fact that observation well B51B1766 is situated 125 m north-northwest of the cross-section and regional groundwater level inclines in the same direction, as can be observed by comparing the groundwater levels in cross-sections of Figure 18 and Figure 20.

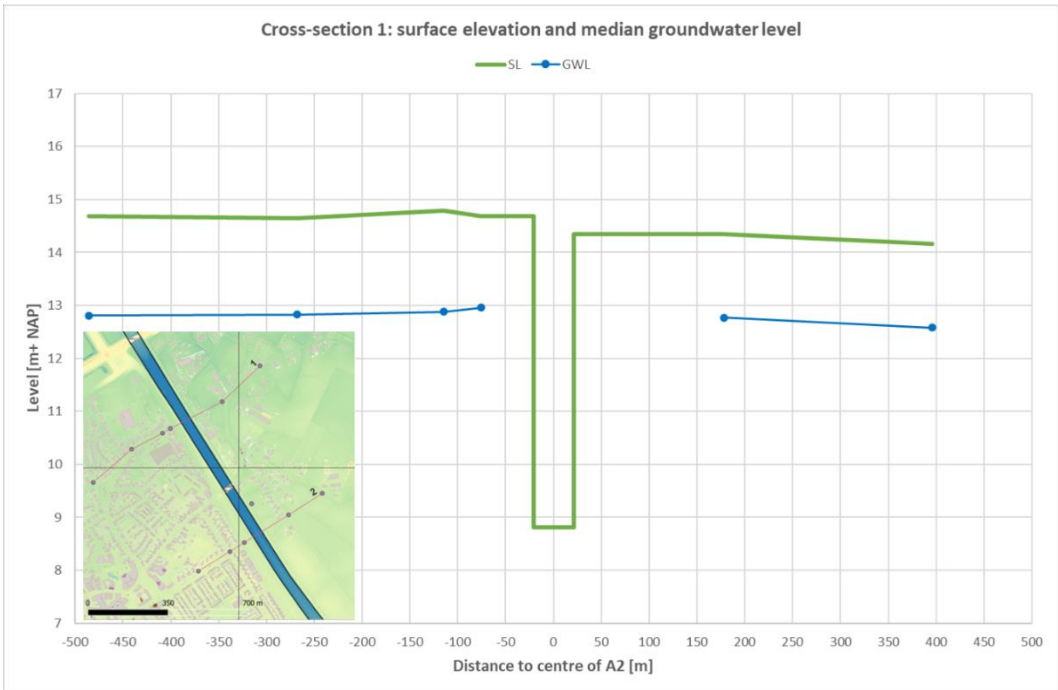


Figure 18 Median values of observed groundwater levels at cross-section 1 over the deepened part of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

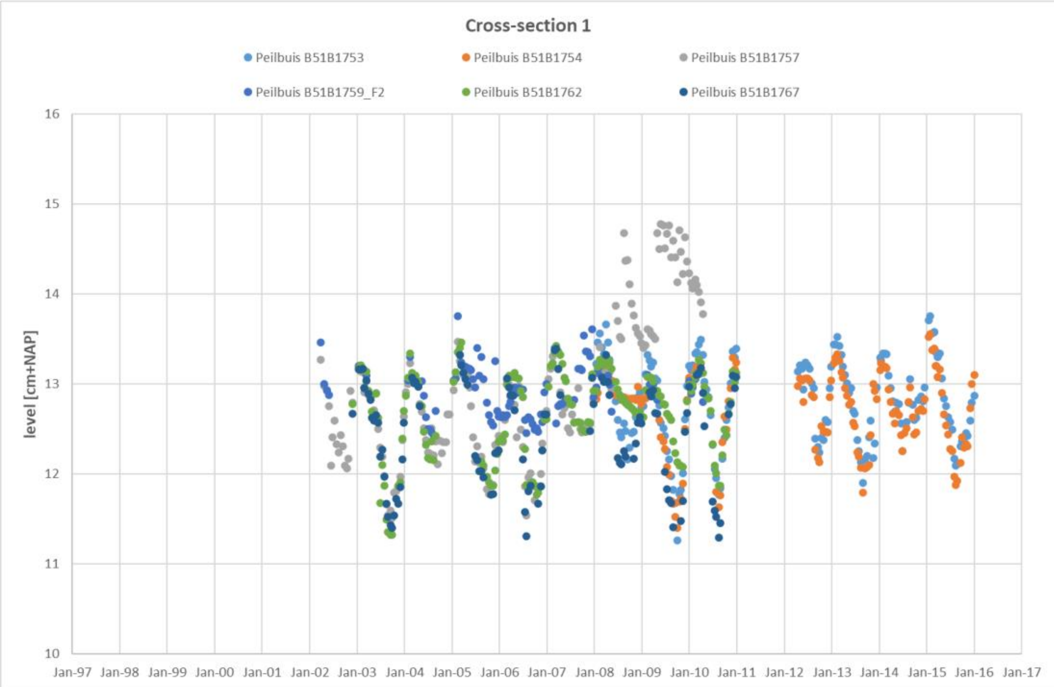


Figure 19 Timeseries of observed groundwater levels at cross-section 1 over the deepened part of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

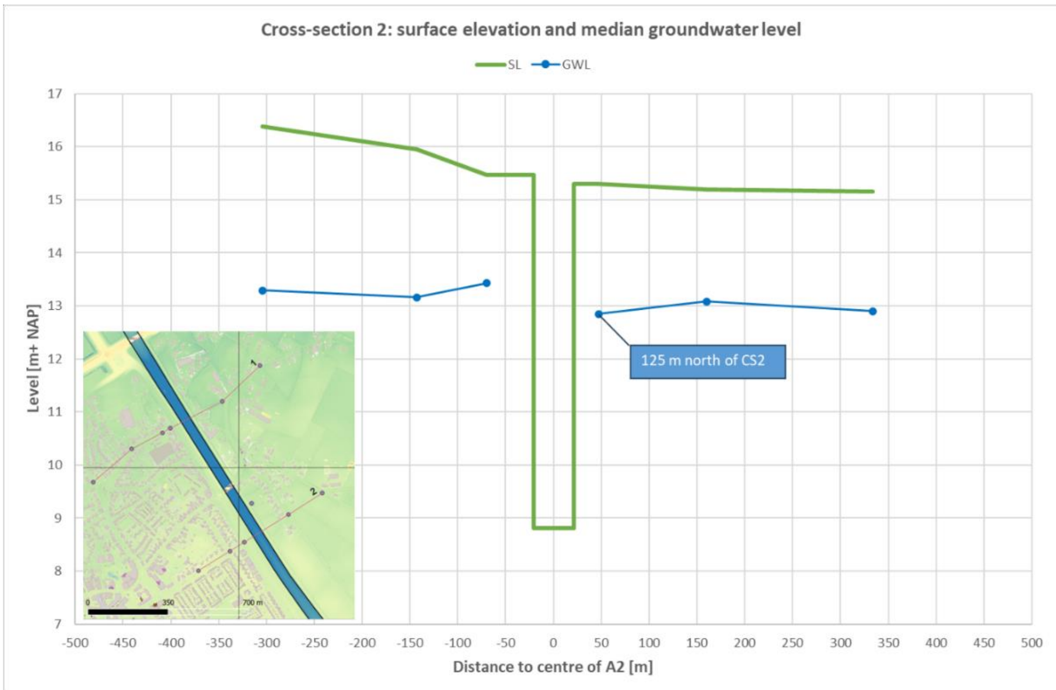


Figure 20 Median values of observed groundwater levels at cross-section 2 over the deepened part of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

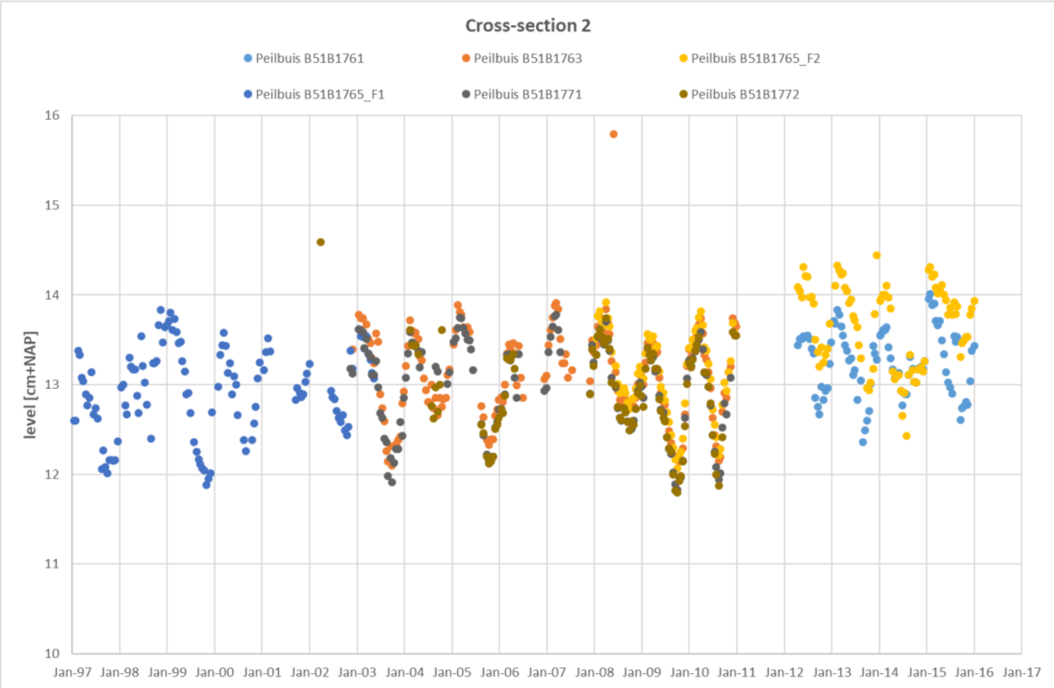


Figure 21 Timeseries of observed groundwater levels at cross-section 2 over the deepened part of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

At a regional level it is expected that groundwater flow is not significantly influenced by the Wilhelminakanaal and highway A2 due to the large thickness and high hydraulic conductivity of the aquifer. Figure 22 and Figure 23 show the top part of the geological profile at cross-sections 1 and 2 of the deepened part of highway A2. All profiles indicate fine sand, through which groundwater can flow relatively undisturbed below the two highway sections as well as the Wilhelminakanaal.

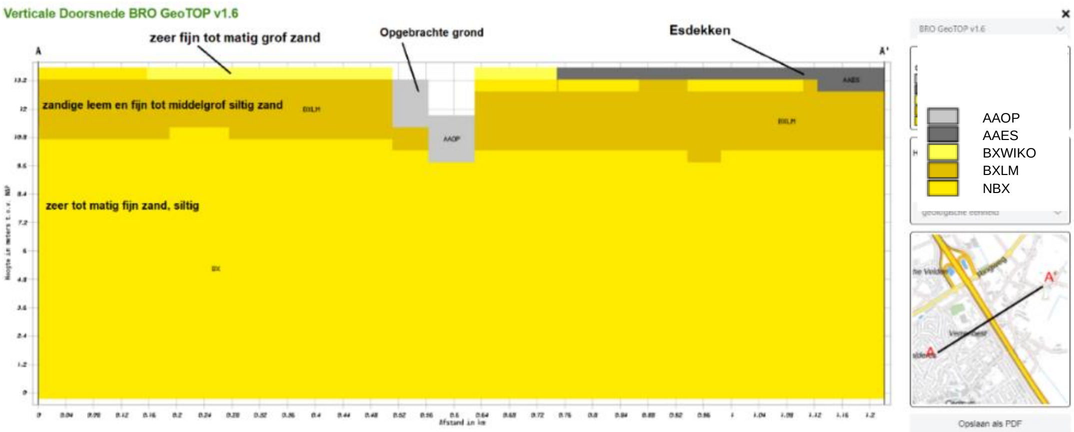


Figure 22 Geological profile at cross-section 1 over the deepened part of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

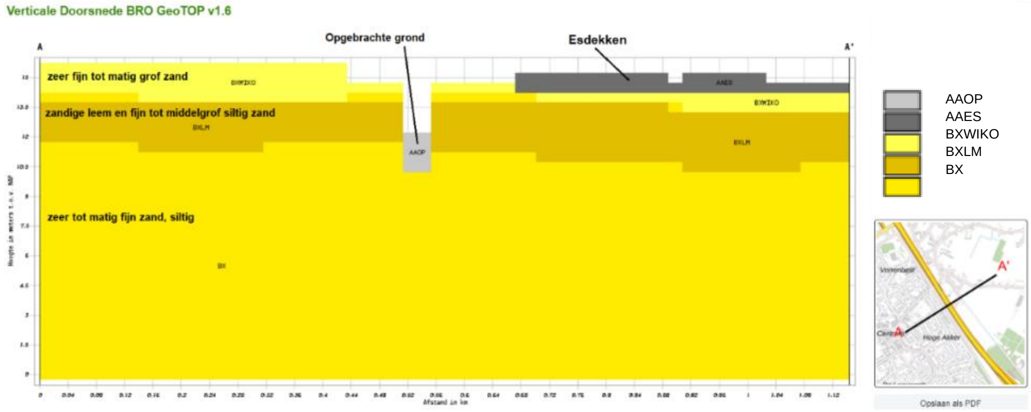


Figure 23 Geological profile at cross-section 2 over the deepened part of highway A2 at Best (source: https://www.grondwatertools.nl/gwsinbeeld/).

Figure 24 shows the simulated effect of the deepened sections of highway A2 near Best and A50 near Son en Breugel (Smaal, 2023). The groundwater levels have been simulated with the National Hydrological Model (LHM4.2) and the groundwater drainage has been simulated as filter wells. Layer 1 (Laag 1) is the phreatic groundwater and Layer 2 is the first aquifer (Laag 2) of the LHM. The effect on the phreatic groundwater level is relatively local. The transects of observation well cover the whole area of influence of the simulated groundwater levels.

Within this study we have not been able to substantiate the difference between the simulated effect and the observed effect. One option that explains the difference is that in reality the horizontal conductivity of the groundwater is larger than in the hydrological model.

In the simulation study of Smaal (2023) the following limitation of the study were listed: a) constructions are modelled in iMOD as perfect pit filters (over the entire base layer), b) exact location of leakage in construction is unknown and c) LHM has not been locally calibrated and validated.

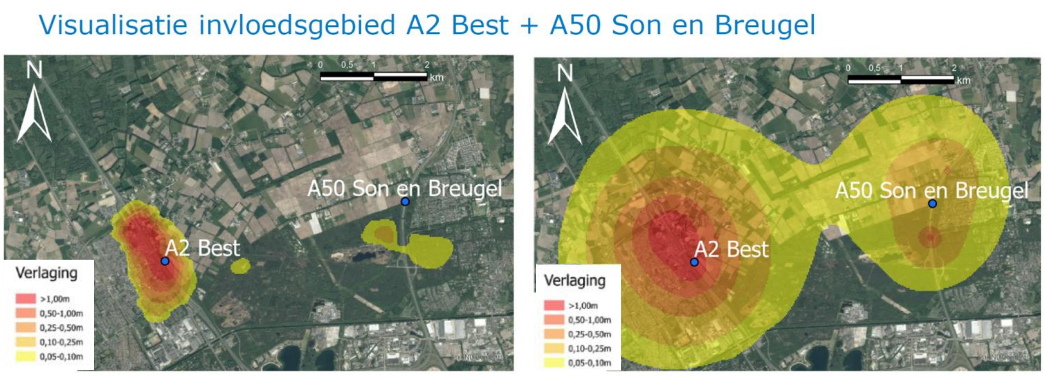


Figure 24 Simulated groundwater levels for left Layer 1 (phreatic groundwater) and right Layer 2 (first aquifer) source: Smaal 2023.

The study of Smaal (2023) reports that the ratio between winter and summer drainage volume is 1.3. From this study it is not clear which periods are exactly covered by winter and summer. From the observation wells it becomes clear that the highest groundwater levels are reached in the beginning of the year and lowest groundwater levels are reached late summer. This means that groundwater levels rise faster in autumn than they drop in spring and summer.

3.3 Groundwater interaction A58

The roadside ditches/canals along the A58, where present, are situated well above the Wilhelminakanaal water level and do, most likely, only drain shallow groundwater in winter and do not significantly influence groundwater flow from south to north.

Figure 25 and Figure 26 show this for two cross-sections at highway A58. All profiles indicate fine sand, through which groundwater can flow relatively undisturbed below the two highway sections as well as the Wilhelminakanaal.

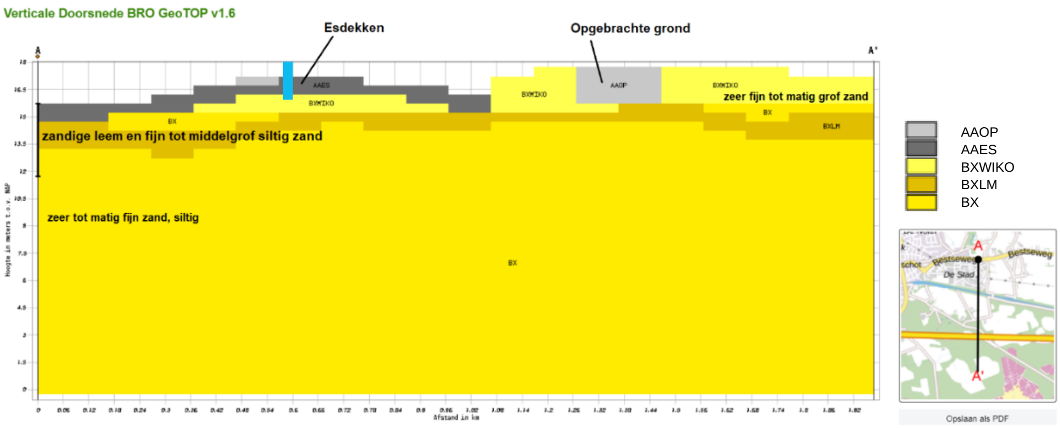


Figure 25 Geological profile at a cross-section over highway A58 at the west side of the research area (source: https://www.grondwatertools.nl/gwsinbeeld/).

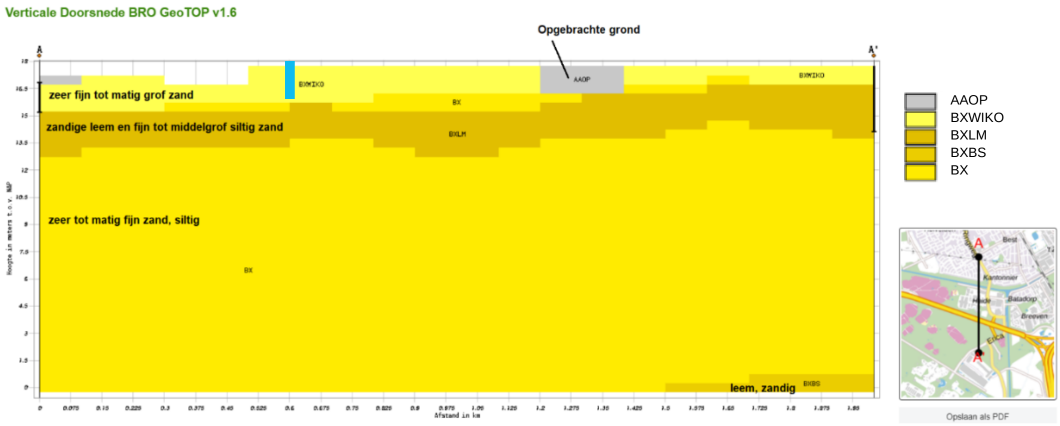


Figure 26 Geological profile at a cross-section over highway A58 at the east side of the research area (source: https://www.grondwatertools.nl/gwsinbeeld/).

4 Water system of highway sections

4.1 Highway section A58

At present roadwater runs off onto the shoulders of the highway and infiltrates into the soil. Along most of the A58 ditches (zaksloten) are present to collect overlandflow. A large part of the water that is collected in these ditches is expected to infiltrate. Water that infiltrates into the soil will either be taken up by vegetation or will percolate to the groundwater. The effect of the highway on the groundwater system is expected to be relatively small, because a large part of the stormwater runoff infiltrates into the shoulders of the highway.

Following an earlier study (Rijkswaterstaat, 2004) runoff from the highway can be expected to be about 320 mm per year. A recent literature review by Rijkswaterstaat indicates that 27-59%, median 35% of precipitation turns into runoff. This implies that the runoff varies between 210-450 mm/y with a median of 270 mm/y. There is a lot of uncertainty about runoff from highways with ZOAB. Both the interception storage capacity (water that is collected in the ZOAB and does not runoff) and the evaporation rates (the rate at which intercepted water is evaporated back into the atmosphere) are not well known for ZOAB. It is expected that the monitoring setup to measure runoff that is being constructed at the A58 will gain valuable insights (Figure 27).

Figure 27 New monitoring station for road runoff along highway A58 near Kloosters.

The amount of stormwater runoff from the A58 can be estimated based on its dimension and runoff per m². The width of the A58 (excluding highway exits) is approximately 27 m (12 m northern lanes + 15 m southern lanes) and a has length of 5 km between highway Exit Best and Exit Oirschot resulting in a surface area of 13.5 ha. Based on these dimensions and a runoff amount that is equal to that of the A2, 0.0014 m³/s (43.000 m³/year) of runoff would be generated on average, which could be available for usage. The runoff rate and therefore the available water for usage is expected to be highest in winter as evaporation rates are then relatively low.

4.2 Deepened section of highway A2 near Best

The deepened section of highway A2 near Best has a length of 2000 m. The surface area of the deepened area is 9.3 ha (highway and grassed shoulders and slopes). The width of paved area of the highway itself is 32 m (2 lanes of 16 m) resulting in a paved area of 6.4 ha. Precipitation on that falls on the highway must be drained rapidly to prevent ponding and flooding.

An earlier study by Rijkswaterstaat (2004) reports that the deepened section is enclosed by bentonite walls and equipped with drains. The drainage infrastructure in the deepened sections ensures sufficient drainage of the deepened highway. Water in the drains flows into three subsurface reservoirs with pumps underneath the highwater. Runoff from the road surface is collected by a stormwater system that ends up in the same reservoir.

In the current situation, the water from the reservoirs is pumped and discharged into a canal (Grote Waterloop) on the east side of the A2 (Figure 28). The water is then led via the canal into a storage pond at the A2/Best-Noord junction. From the storage pond, the water flows through the system of main waterways of Waterboard de Dommel into the river Dommel. Currently, the water is drained from the area relatively quickly, which is not in accordance with the ambitions to use and store and water locally, i.e. to increase the sponge capacity.

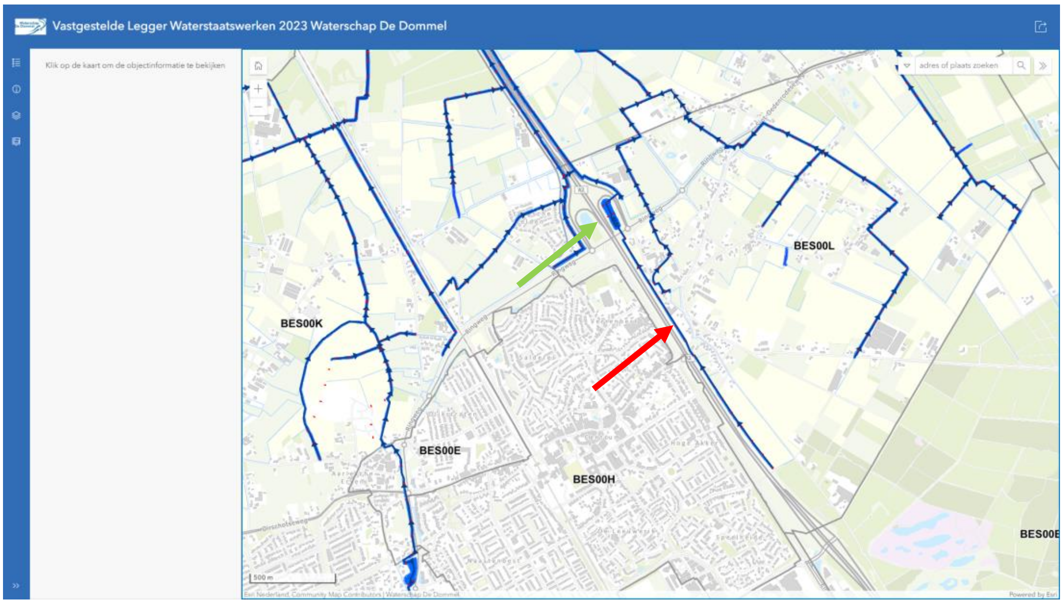


Figure 28 The Grote Waterloop that discharges the groundwater and stormwater of the A2 indicated with red arrow. The Grote Waterloop is connected to a pond that potentially serves as a treatment facility indicated by green arrow.

Research of Rijkswaterstaat (2004) has shown that, in addition to direct precipitation (57,200 m^3/year) and run-off rainwater (22,900 m^3/year), approximately 800,000 m^3 of groundwater is drained annually from the surrounding subsurface. This study refers to a paved area of 7.15 ha. This implies an average of almost 9.5 meters of water over the mentioned 9.3 ha of deepened section of the highway.

In this study we used the value of 800,000 m^3 of groundwater as previously reported.

5 Summary and potential next steps

Table 4 provides an overview of the water balance components related to the Wilhelminakanaal (68km section), the deepened section of the A2 (2km section) and the A58 in the Low-Tech Campus area (5km) from literature and general statistics. The following paragraphs elaborate on the components per section.

Table 4 Overview of water balance components for highway sections A2 and A58 and Wilhelminakanaal.

A2 Water discharge	m3/ year	m3/ day	m3/ second	mm/ year	*summer (m3)*	*winter (m3)*	Area (m2)	Length (m)
A2 Best groundwater (RWS)	800000	2192	0.0254	11200	*350000*	*450000*	71500	2 km
A2 Best runoff	22900	63	0.0007	320			71500	2 km
Domestic drinking water (persons)	*17000*							
Domestic grey water (persons)	*56600*							
A58 Water discharge								
A58 Runoff	43200	118	0.0014	320			135000	5 km
Domestic drinking water (persons)	*900*							
Domestic grey water (persons)	*3100*							
Water balance Wilhelminakanaal								
Inlet Visvijver + Eikenlust		*12960*	*0.15*					
Inlet Donkervoortse Loop		*17280*	*0.2*					
Inlet Olen		*51840*	*0.6*					
Inlet Sonse Heide		*13824*	*0.16*					
Inlet Vijvers Sportpark Best		*2160*	*0.025*					
Inlet Haghorst		*1296*	*0.015*					
Total inlet		99360	1.15					
Evaporation (year)	1076000	2948	0.034	759.78			1416000	68 km
Evaporation (summer)	*405000*	*4438*	*0.051*	*286*			1416000	68 km
Seepage/infiltration	unknown	unknown	unknown					

5.1 Wilhelminakanaal

For the Grote Pand no water balance has been created that describes the actual inflow and outflow of water. No data were found on actual discharge rates at the sluices at the upstream and downstream locations. The Waterakkoord describes that both inflow and outflow can reach up to approximately 60 m3/s without causing significant problems.

The water balance during dry periods is most relevant in relation to the potential use of water from highways. The water volumes that are supplied from the Wilhelminakanaal and particular Het Grote Pand can reach up to 1.15 m^3/s. This is the maximum water volume that can be let in from the canal that is permitted. During dry periods the Wilhelminakanaal will also lose water due to evaporation. For the Grote Pand this would account for 0.034 m^3/s.

The banks of the Wilhelminakanaal are constructed with sheet piles. The length of the sheet piles is expected to be limited to 6m. Because of the nature and depth of the sandy deposits no significant obstruction of groundwater flow from south to north is expected due to these sheet piles. Based on simulations with the National Hydrological Model it is expected that the Wilhelminakanaal drains the groundwater in the section east of Best and infiltrates west of Oirschot. The amount of groundwater drainage and infiltration has not yet been quantified.

Actions:

- Analysis of historic timeseries of discharges into and from the Wilhelminakanaal to determine the water balance especially during dry periods.
- Interviews with RWS water managers to determine the need and potential for using the canal as water storage and transport infrastructure for dry periods

5.2 A2 section

The deepened section of the highway A2 near Best drains a large amount of groundwater. Earlier studies report discharge volumes of 580,000 and 800,000 m^3/year for this two-kilometre highway section. Stormwater runoff for this section is estimated to be about 22,900 m^3/year. In winter about 1.3 times more water is discharged than in summer. The water demand of some of the potential water uses is strongly seasonal or related to meteorological drought. Therefore, a better understanding of the temporal variability of discharge would be beneficial.

Groundwater drainage and stormwater from the highway is currently discharged to the Grote Waterloop and the river Dommel. The discharge of this groundwater out of the area is perceived as unsustainable. Reducing groundwater drainage is the preferred option if this can be achieved at a reasonable cost. This would increase groundwater levels and water availability during dry periods. In case groundwater drainage cannot be reduced it is preferred to keep and use the water within the area. Different options are being investigated at the moment by a consortium led by de Waterbank.

Actions:

- A new and better documented analysis of the water discharge of the deepened section could reduce the uncertainty in discharge volume.
- Perform a time dependent analysis of water discharge (supply) to determine how much water is available when it is needed most. This analysis of discharge can be made at a monthly or seasonal basis.
- Monitoring and analysis of water quality of road runoff of highway A2 and A58 and groundwater drainage at deepened section of A2 near Best.

- Additionally, discharge can be estimated for dry periods when water demand is highest. This can be done for the relatively dry consecutive years 2018-2020 and for 2022.

5.3 A58 section

The annal runoff from the A58 for the section between Best and Oirschot is estimated to be about 0.0014 m3/s (43,200 m3/year or 320 l/m^2/year). There is a lot of uncertainty about runoff from highways with ZOAB. Both the interception storage capacity as well as the evaporation rates are not well known. It is expected that the monitoring facility that is being constructed at Kloosters will gain valuable insights into the actual water balance of ZOAB.

At present stormwater runs off onto the shoulders of the highway and infiltrates into the soil and partly recharges the groundwater. At some (maybe all) section ditches (zaksloten) are present. To what degree these are water baring has not been investigated. The effect of the highway on the groundwater system is expected to be relatively small at present, because the stormwater infiltrates into the shoulders of the highway and the ditches.

In case stormwater runoff would be used for purposes other than infiltration, it would affect the local groundwater levels, which needs to be considered.

Actions:
- Investigate water structures like ditches along A58 to determine their presence and estimate how much water these collect and then infiltrate or discharge. To promote infiltration and water storage the management of the infrastructures should be considered.
- Proceed with monitoring of stormwater runoff at Kloosters to gain a better understanding of the actual runoff of ZOAB highways.
- Additional monitoring of water quality would be beneficial to determine the need for better treatment of stormwater runoff for infiltration or potential other purposes.

6 Literature

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