

LIFE AERFIT

D1 Monitoring end report Apeldoorn – Henk van Tongeren

Bernie ter Steege

14 November 2024

2-12-2024

Inhoud

1. Preface	3
1.1 Introduction.....	3
1.2 Overview of installed FHVI's.....	3
1.3 Overview of objectives of the project AERFIT and the monitoring data.....	3
2. Monitoring set-up and installation protocol.....	5
2.1 Introduction.....	5
2.2 Monitoring infiltration rates at FHVI-sites	5
2.3 Water quality in the FHVI well and gutters	6
2.3 Protocol / Set-up of design, installation, maintenance and monitoring a FHVI-site	8
3. Results.....	9
3.1. Water quantity - analysis of heavy rainfall.....	9
3.2. Water quality – results	17
3.3. Description of the design of a FHVI-site.....	17
4. Conclusions	21
4.1. In what way and to what extent do the dimensioning of the FHVI wells and the maintenance, under various circumstances, influence the multi-year infiltration capacity?	21
4.2. To what extent has the number, duration and level of flooding/water nuisance decreased?	21
4.3. Is there an improvement in the effluent of the WWTP?	22
Annexes.....	23
1. Annex - Map of all FHVI-sites installed in LIFE-AERFIT	24
2. Annex - Soil logs of FHVI-wells	40
3. Annex - FHVI table	41
4. Annex - Blue-print FHVI-site Apeldoorn	44
5. Annex - Graps of waterquality analysis in gutter before pre-filter and in the FHVI-well.....	46
6. Annex – data of all automated water level measurements with FHVI systems	53
7. Annex Datasets water quality analyses.....	79
8. Annex - Fieldtest results	80
9. Annex - Reports on monitoring and results street and fieldtests.....	82

1. Preface

1.1 Introduction

For the sake of cost eligibility and suitability as a reference basis, this report is made stand-alone readable, outlining purpose, outcomes, results, and conclusions of the project within the municipality Apeldoorn. Thus results of site locations in Germany and Lithuania are not in this report.

Included are all tests drilling logs of all wells plus alternatively a table with key data - depth, date of installation. Also is included a map indicating the locations of the numbered wells.

So in short, now is also added to deliverable D1:

- introduction, explaining what has been done, who, when, how and why;
- where/how can the monitoring data be viewed or retrieved;
- conclusion on the effect of FHVI on pluvial flooding, on the robustness of FHVI and on groundwater levels, water quality and soil quality;
- explain how the monitoring results lead to the reduced flood risk;
- drilling logs of 8 monitoring wells that are currently missing;
- start date of measurement for each of the wells.

1.2 Overview of installed FHVI's

In **Annex 1** several maps provide detailed overview of the sites. **Annex 2** provides a table with nr., date of installation, street name/nr of the location, X/Y, and depth of the drilling. In **annex 3** all soil-drill logs are available.

1.3 Overview of objectives of the project AERFIT and the monitoring data

Fast High-Volume Infiltration (FHVI) is an innovative adaptation technology that drains and infiltrates rainwater very fast into a permeable layer or aquifer. It is especially of interest for urban areas as it requires little space.

The objective of AERFIT was:

- To demonstrate that Fast High-Volume Infiltration (FHVI) is an effective adaptation strategy against pluvial flooding caused by extreme rainfall.

The outcome is that the infiltration of rainwater stands with a reliable and low-maintenance pre-filter. In the report are all design-criteria described in **paragraph 3.3**

The desired outcome of the project is:

- A blueprint for a durable functioning FHVI-system and its design criteria.

In this report several lessons learned are describes, which eventually lead to a blueprint of a FHVI-site. This blueprint is provided in **Annex 3**.

Key targets of AERFIT were the demonstration of FHVI as:

- An effective option to handle T=10¹ events without any flooding in surrounding urban areas.
- A technology with implementation and maintenance costs lower than alternative infiltration methods.

¹ 1 time in 10-year event

The central research question is:

- In what way and to what extent do the dimensioning of the FHVI wells and maintenance, under various circumstances, influence the multi-year infiltration capacity?

In chapter two and three is described how functioning of the FHVI's is monitored and the results of this research are described. Leading to conclusion in **chapter four**.

Two other effects of the decoupling of rainwater from the sewer system are in the Grant Agreement mentioned to be answered:

- To what extent does the number, duration and level of flooding/water nuisance decreased.
- Has the effluent from the WWTP improved.

See also **chapter four** where conclusions of these effects are described.

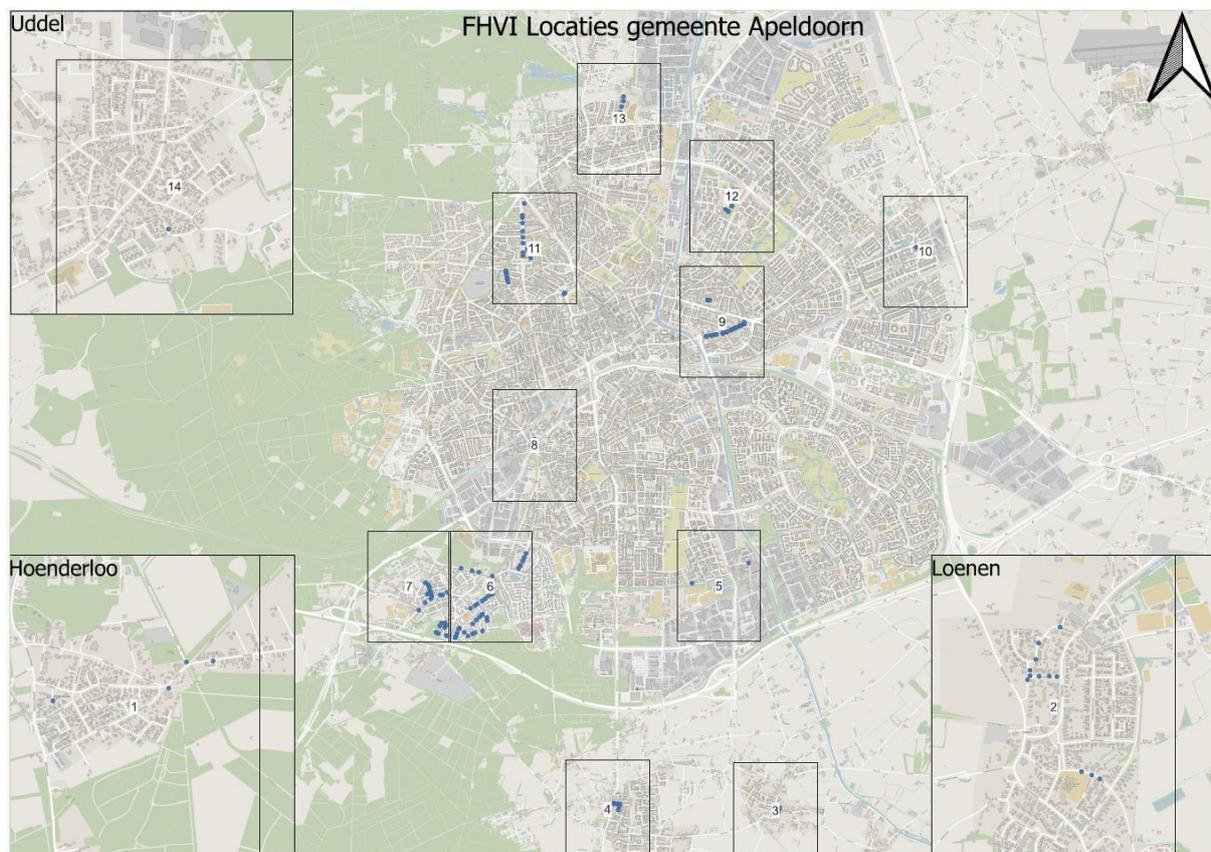


Figure 1. Map with all clusters of installed FHVI-systems in the Municipality of Apeldoorn. See Annex @ for a detailed overview of site locations.

2. Monitoring set-up and installation protocol

2.1 Introduction

This document combines information of two earlier provided documents: “Knowledge document” which was submitted as deliverable D2 plus the original monitoring plan submitted in Q1 of 2022:. This monitoring plan was updated several times from 26th November 2019 until 29th of June 2021. Chapter two and three describes what has been done, who, when, how and why monitoring was executed. It also summarizes how analysis and feedback of the data takes place with the lessons learned and conclusions. This can be read in chapter four. In this chapter:

- monitoring of infiltration rates at FHVI- sites;
- water quality measurements of FHVI-sites;
- protocol / set-up of design, installation, maintenance and monitoring a FHVI-site.

2.2 Monitoring infiltration rates at FHVI-sites

Infiltration rates are measured:

1. by measuring water tables during rainfall events with automated sensors, or
2. measuring the infiltration time from a known volume of water.

Measuring water levels with automated sensors

The aim was to equip 15 to 20 FHVI-sites with water level sensors. Per site we measure water level in the FHVI well plus the water level in the pre-filter.

Eventually in total 19 locations are equipped with automatic pressure transducers.

This data is sent over-the-air to an online portal (Telecontrolnet, Interact), in which all data are made visible in tables and graphs (X-axis concerns the factor "time"). All the data is stored. The duration of the operation of the FHVI during a rainfall event can be measured with the pressure transducers. The height of the water level has not (always) been reliably determined until now due to the influence of air inclusion in the air pressure compensation of the sensor.

See paragraph 3.1 for the results.

Measuring infiltration time of a known volume of water

In order to test whether the FHVI wells comply with the requirements of the Technical Application Form Part A – Administrative Information, the capacity is tested at various times with practical tests.

- The ‘field test’: a bin system where manually the water is at a rate of 10 m³/h.
- Street test: When testing the system, 6 m³ of clean water (volume of tanker), spread over 19 minutes, is drained via the street work towards the system, whereby the flow must be limited to a maximum of 0.3 m³/min. This corresponds to the 14.3 m³ in 45 minutes, as described in the Technical Application Form Part A – Administrative Information.

The final quantities are linked to the functioning of the FHVI wells. Using the same method as the delivery test, approximately 20 FHVI wells were tested again at the end of the project, so that a comparison can be made with the delivery test and the associated conclusions can be drawn.

See Annex 8 for a quick overview of field tests and in Annex 9 reporting on street- and field tests are added. These monitoring test reports are an important basis for the insights in the further design of a simple, robust and durable FHVI-site design. Recommendation and conclusion drawn from the monitoring with field- and street tests can be read in **paragraphs 3.1. and 3.3.**



Figure 2. Field tests with on the left the 'street test' for testing the entire system and on the right the 'field test' setup for testing the FHVI.

2.3 Water quality in the FHVI well and gutters

For the water quality, the parameters regarding the functioning of the FHVI wells are examined – in the current situation, there is no infiltration with an FHVI in drinking water extraction areas.

In practice, rainwater is drained from:

- roofs and facades - drains indirectly via;
- squares and parking facilities (to be seen as slightly polluted surfaces);
- residential areas, district access roads, main roads (to be seen as moderately polluted surfaces).

From GA – Part A – administrative information:

Other environmental benefits

Implementation of the FHVI technology will prevent damage from pluvial flooding. Other benefits of uncoupling rain water from the sewer system and fast infiltration of the rain water:

- *Improved surface water quality:*
 - Prevention of discharge of excessive, untreated sewage water to surface water.
 - Improved effluent quality from WWTPs: Uncoupling rain water drainage from the sewer systems results in a more stable and efficient purifying process in the WWTP. Stability is obtained by the more stable composition of the influent, causing a good biological environment and cleaner effluent.
 - *Reduced risk of soil pollution by spills:* If a spill occurs (e.g. chemicals due to a fire or road accident), conventional infiltration facilities like crates create an easy pathway for penetration of the spill into the soil. The facilities cannot be closed and removing the polluted soil means is a massive operation involving removing the facilities and the affected soil. A particular advantage of FHVI is that the infiltration wells can be easily closed and pollution that has already entered the soil can be removed by pumping up ground water.
 - *Improved underground water levels:* Infiltration in general elevates groundwater levels. This means that water is stored that can be used in dry periods for drinking water production or other urban uses or to prevent desiccation of valuable nature and biodiversity.

It is a fact that in the debris from the streets various substances will be presents which are preferably not infiltrated to the groundwater. Due to soil passage along roadsides or in wadi's, most substances will be filtered or fixated and stored in top-soils. Some dissolved substances could potentially and up in the groundwater. As a matter of fact almost every infiltration method has currently the potential to pollute the groundwater.

In the project the main "To demonstrate that Fast High-Volume Infiltration (FHVI) is an effective adaptation strategy against pluvial flooding caused by extreme rainfall."

Besides the aim is to measure that groundwater is not polluted by means of the infiltration method. As a side effect it is possible to measure the potential of filtering undissolved and dissolved particles.

The combination of gutters with debris collection and the pre-filtersystem filters particals bigger than >5 µm. Within this – also dissolved particals could potentially be removed: as these are captured by chemical process with e.g. oxygen or subtraction with organic particles such as humus.

A total of 24 different FHVI-sites were sampled:

05 Koning Iodewijklaan	142 De Hegge 2	2A Hoogbuurloseweg
06 Koning Iodewijklaan	19 Koning Lodewijklaan 27	31 Kostverloren 26
07 Koning Iodewijklaan	24 Veenweg	36 Gentiaanstraat 146
08 Koning Iodewijklaan	25 Zwaansprengweg	54 leeuwenbergweg 17b
09 Koning Iodewijklaan	26 Kostverloren 33	90 hagenweg
100 Doornenburg	27 Kostverloren 9D	91 Hagenweg 17b
137 Molenstraat 168	28 Kostverloren 13	92 Hagenweg
140 Molenstraat 168	29 Kostverloren 20B	94 Waterjufferstraat 40

The water in the FHVI wells is sampled and analyzed. At some locations extra samples of the water in the gutter is sampled and analyzed. In total 37 water samples of FHVI-wells and 5 water samples of gutters. The following parameters are were analyzed:

PH, Temperature, Chloride, Oxygen, undissolved particles, metals, Aromatics, Xylenen, Styreen, Chlorinated hydrocarbons, Som cis/trans- 1,2- Dichlooretheen, Brominated hydrocarbons, Mineral oils. All sample data can be found in **Annex 7**.

sample nr.	FHVI nr, adress	FHVI well or gutter	date of sample	
550867	05 Koning Iodewijklaan	well	20.12.2019	Labresults in ZIP-file
550868	06 Koning Iodewijklaan	Well	20.12.2019	,,
550869	07 Koning Iodewijklaan	Well	20.12.2019	,,
550870	08 Koning Iodewijklaan	well	20.12.2019	,,
550871	09 Koning Iodewijklaan	well	20.12.2019	,,
444109	29 Kostverloren 20B	well	22.07.2022	,,
444110	26 Kostverloren 33	well	22.07.2022	,,
444111	140 Molenstraat 168	well	22.07.2022	,,
444112	28 Kostverloren 13	well	22.07.2022	,,
444113	31 Kostverloren 26	well	22.07.2022	,,
447329	36 Gentiaan	well	25.07.2022	,,
447330	54 leeuwenbergweg 17b	well	25.07.2022	,,
447331	19 koningIodewyklaan 27	well	25.07.2022	,,
447332	90 hagenweg	well	25.07.2022	,,
447333	94 waterjufferstraat 40	well	25.07.2022	,,
443123	91 Hagenweg 17b	well	10.10.2023	,,
443124	94 Waterjufferstraat 40	well	10.10.2023	,,
443125	54 Leeuwenbergweg	well	10.10.2023	,,
708475	92 Hagenweg	well	19.12.2022	Graph annex 4
708476	92 Hagenweg	gutter	19.12.2022	Graph annex 4
708511	25 Zwaansprengweg	well	19.12.2022	Graph annex 4
708512	25 Zwaansprengweg	gutter	19.12.2022	Graph annex 4
708528	100 Doornenburg	well	19.12.2022	Graph annex 4
708529	100 Doornenburg	gutter	19.12.2022	Graph annex 4
452546	2A Hoogbuurloseweg	well	28.07.2022	Graph annex 4
753501	100 Doornenburg	well	23.01.2023	Graph annex 4
753502	100 Doornenburg	gutter	23.01.2023	Graph annex 4
753503	92 Hagenweg	well	23.01.2023	Graph annex 4
753504	92 Hagenweg	gutter	23.01.2023	Graph annex 4
309911	94 Waterjufferstraat 40	Well	25.07.2023	Labresults in ZIP-file
309912	54 Leeuwenbergweg 17	well	25.07.2023	,,

309913	36 Gentiaanstraat 146	well	25.07.2023	„
309915	25 Zwaansprengweg 9	well	25.07.2023	„
309914	31 Kostverloren 26	well	25.07.2023	„
334561	29 Kostverloren 20B	well	09.08.2023	„
334562	28 Kostverloren 13	well	09.08.2023	„
334563	27 Kostverloren 9D	well	09.08.2023	„
334564	26 Kostverloren thv anklaarseweg 33	well	09.08.2023	„
339069	137 Molenstraat 168	well	11.08.2023	„
339070	19 Koning Lodewijklaan 27	well	11.08.2023	„
339071	24 Veenweg	well	11.08.2023	„
339072	142 De Hegge 2	well	11.08.2023	„
339073	119 Ugchelseweg 70A	well	11.08.2023	„

Figure 3. Overview of all water quality sample locations and dates.

2.3 Protocol / Set-up of design, installation, maintenance and monitoring a FHVI-site

Below are the steps from realization to monitoring and management and maintenance:

1. LamersWater and Municipality of Apeldoorn has determined on the basis of available data (groundwater levels and soil conditions) that the location is suitable for disconnecting rainwater by means of FHVI.
2. Determine in the field during the first drilling whether the infiltration point has sufficient capacity. It is possible that one point cannot absorb enough. In that case, it is considered whether an additional point connected in series provides sufficient capacity.
3. If there is insufficient capacity, the work will be stopped. Then, in consultation, consider whether decoupling of the rainwater can be achieved in another way.
4. If there is sufficient capacity, deliver FHVIs, including in accordance with BRL2100, protocol. 2101.
5. The municipal civil contractor will then install the rainwater drainage system in the street.
6. Continuous monitoring of pressure sensors: The Monitoring working group has determined which locations will/will not be equipped with a pressure sensor. This is used to measure the water level in the relevant FHVI and pre-filter. The intention is to provide 15 to 20 locations with a set of pressure sensors out of a total of 150 points.
7. Practical test (called “street test”) of the entire system: After completion.
8. Several set-ups of FHVI’s were tested under controlled conditions (a controlled amount of water is discharged within a certain time via a set-up / tank).
 - different locations with and without pressure sensors;
 - different types of pre-filters;
 - after cleaning the pre-filter and /or FHVI system and/or pre-filter.
9. Practical test FHVI only: In addition to the “street test” of the entire system, clean water will be discharged directly into the FHVI-well (called “field test”). The aim is to determine the infiltration capacity. In the design, this is derived from the BRL2100 extraction tests (so-called capacity tests).
10. Monitoring maintenance of pre-filters: All locations will be monitored. At the start, an estimate was made for each location based on environmental characteristics as to whether there could be less or more detritus (pollen, blossom, leaves).

3. Results

3.1. Water quantity - analysis of heavy rainfall

Monitoring if infiltration rates change during the lifetime of a FHVI: Monitoring infiltration rates at FHVI-sites. by measuring water tables during rainfall events with automated sensors: E.g. less or more rapid infiltration due to changing groundwater levels? Is there degeneration time after installation? What is the infiltration capacity (m³/h) immediately after delivery? What is the infiltration capacity (m³/h) before and after cleaning the FHVI well?

In this paragraph:

- Status and usability of data at sites with automated water level sensors.
- Analysis of two rainfall events (2022 and 2023) and the lessons learned from these site-specific situations.
- Overall reflection on measuring the water tables with automated water level sensors compared with data retrieved from the street- and field test with controlled experimental conditions.

Status and usability of data at sites with automated water level sensors.

A number of FHVIs have been monitored for two to three years. In Annex 6 All data of all monitored sites are pictured in graphs. For each monitored FHVI, it has been checked whether it is still operational, whether it has been corrected to NAP, and whether the measurements are logical. The results of this analysis are shown in the table below.

Green = usable data for present day

Yellow = usable data but not measuring anymore

Orange = processing needed, but usable

Red = not usable for new analysis

	Location	Note	Data quality	Pre-filter type
1	FHVI 002A - Hoogbuurloseweg 38	Stopped measuring since June 5, 2023	Yellow	Wavin-Apeldoorn
2	FHVI 007 - Hoenderloseweg 89	New FHVI drilled but no new measurements since August	Yellow	Wavin-Apeldoorn
3	FHVI 014 - Hoenderloseweg 12		Yellow	Wavin-Apeldoorn
4	FHVI 015 - Koning Lodewijklaan 59	Measuring well	Green	Wavin-Apeldoorn
5	FHVI 019 - Koning Lodewijklaan 27	Measuring well	Green	Wavin-Apeldoorn
6	FHVI 023 - Koning Lodewijklaan 1	Measuring well	Green	Wavin-Apeldoorn
7	FHVI 025 - Zwaansprengweg 9	Measuring well	Green	HWZI
8	FHVI 026 - Kostverloren at Anklaarseweg 33 (side)	FHVI not measuring since September 2022	Yellow	Wavin-Apeldoorn
9	FHVI 028 - Kostverloren 13	Stopped measuring since January 2023	Yellow	Wavin-Apeldoorn
10	FHVI 032 - Gentiaanstraat 508	Measuring well	Green	Wavin-Apeldoorn
11	FHVI 036 - Gentiaanstraat 146	Measuring well	Green	Wavin-Apeldoorn
12	FHVI 040 - FHVI_040 modem not yet installed	Not installed – no data	Red	Wavin-Apeldoorn
13	FHVI 046 - Voshuizen 15 (Lieren)	Not NAP compensated	Orange	Wavin-Apeldoorn
14	FHVI 050 - Koudhoornlaan 11	Measurements reversed	Orange	Wavin-Apeldoorn

15	FHVI 054 - Leeuwenbergweg 17B	Measuring (with strange jumps) not NAP compensated		Wavin-Apeldoorn
16	FHVI 090 - Hagenweg 1 Beekbergen	Measuring well since June 8, 2023. Not NAP compensated		HWZI
17	FHVI 094 - Waterjufferstraat 40	Not measuring and when measurements were taken time's where inconsistent		HWZI
18	FHVI 119 - Ugchelsegrensweg / corner Charley900661	Measuring incorrectly		HWZI
19	FHVI 123 - Klein Hattem 61 Ugchelen	Strange measurements, possibly usable with other settings in TCN.		HWZI
20	FHVI 128b - Molenstraat 128b	Not measuring since September 8, 2023		HWZI
21	FHVI 136a - Molenstraat 168	Measuring since February 2024		HWZI

Figure 4. Overview of Status and usability of data at sites with automated water level sensors.

Rainfall event 2022

Important insights were gained during the Dudley and Eunice storms in February 2022 (below T=5 events), accompanied by very heavy rainfall with reported floods all over the country. AERFIT monitoring data suggested that FHVI infiltrates rainwater rapidly, and water on the flooding street was drained effectively. Figure 6 reflects the monitoring results at the Zwaansprengweg during this time, with reported rainfall of 150mm at some locations, compared to average rainfall of 60mm in February. The figure shows the level of water in the pre-filter with a dark blue line, providing an indication for water on street level. The peaks reflect rainfall, cross referenced by the yellow line representing rainfall in MM/hour from a precipitation meter. The water level in the FHVI is demonstrated by the red line in meters. The peaks with steep vertical blue and red lines, show that the FHVI infiltrates the rainwater rapidly and water on the street is drained.



Figure 5. rainfall data of the Dudley and Eunice storms of Februari 2022

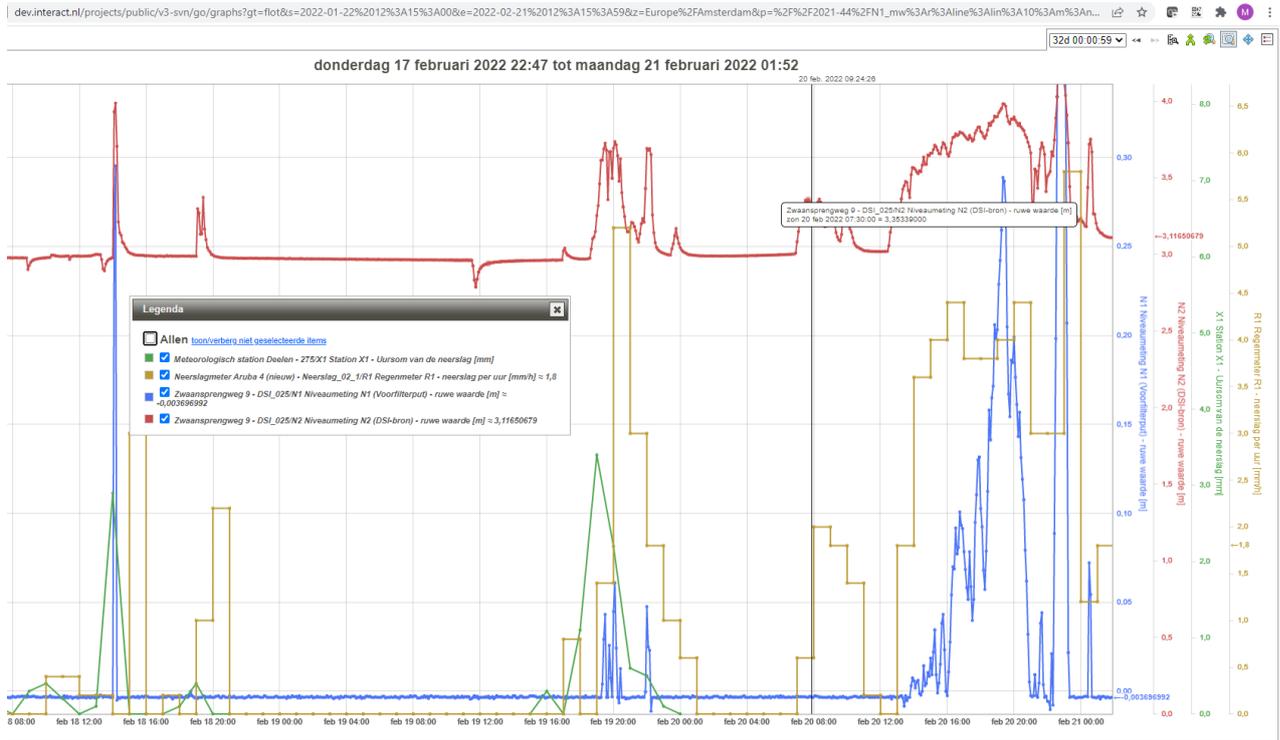


Figure 6 Measurements of the water level at the Zwaansprengweg, 9 during the storms and heavy rainfalls of the 18th until 21th of February. The yellow line represents the rainfall in mm/hour

This specific data from a single event with heavy rain interval is confirmed with long term monitoring insights throughout the monitoring period see figure 7. In this figure the water level of two FHVI wells at Kostverloren is reflected from Mid-2021 until Mid-2023. Also, here the infiltration rates are reflected by a step rise and decline in the line, indicating that water is infiltrated rapidly and most importantly consistently for a long duration.

The number of not-dissolved particles and their relation to the infiltration capacity over time (hydraulic head measurements and field tests) were measured. FHVI with prefiltration maintains its infiltration capacity. The prefiltration protects the FHVI and moves the risks of blockage to a location which is easier to access for regular maintenance.

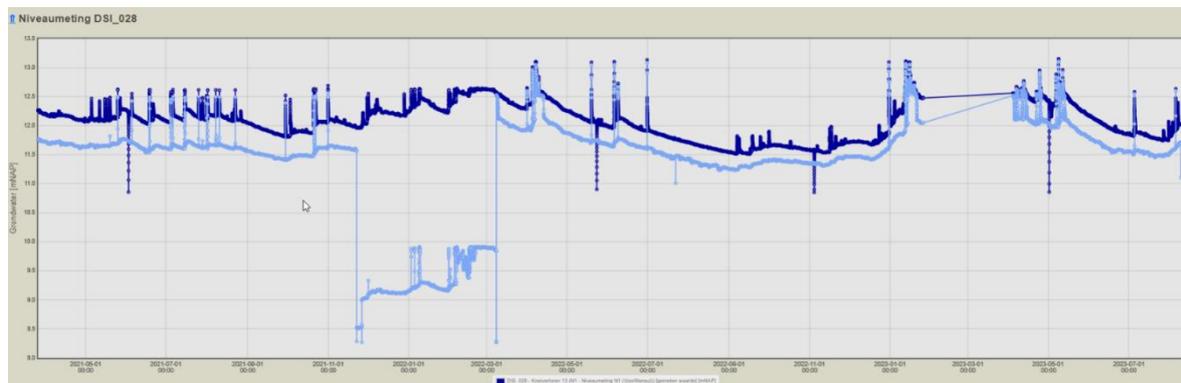


Figure 7 Infiltration capacity at two FHVI wells at Kostverloren from 01-05-2021 to 01-07-2023

Rainfall event 2023

In 2023, there were regular instances of heavy rainfall. Therefore, this paragraph examines two situations. The first of these occurred on March 10, 2023, where 34.3 mm of rainfall was recorded in 24 hours. This corresponds to a rainfall event of $T = 2$ with a maximum intensity of 6.1 mm/hour. The most intense rainfall event in these months occurred on May 8, 2023. On this date, there was a rainfall event of 18.2 mm in 30 minutes, equating to a $T = 5$. This rainfall event was very localized, so not all FHVI's would have experienced significant rainfall. Two locations did measure this rainfall. These were Zwaansprengweg 9 and Voshuizen 15. Therefore, these locations have been selected for further analysis.



Figure 8. Goto of rainwater runoff in Apeldoorn 10th of march 2023

Location Zwaansprengweg 9 focused on infiltration rate

The location of Zwaansprengweg 9 has a pre-filter type HWZI. About 90 percent of volume in the system can discharge in to the FHVI. The rest can exit the bottom of the pre-filter via two holes in the concrete.

The rainfall on May 8, 2023, was measured at Zwaansprengweg as 15 mm in 15 minutes, which is a $T=5$ rainfall event. Because of extensive experiment at this site with different types of pre-filtration methods this location has a known decreased infiltration rate. This is shown in graph 1 where the water level in the FHVI does not decrease for a long period of time. The water level doesn't decrease because of the slow infiltration rate and because buffered water in the pre-filter and pipes are still flowing into the FHVI. At a water level of 13,80 m+NAP the level drops almost 80 centimeter in fifteen minutes. This steep drop is also approximately the height (precise height is unknown) where water stops flowing into the FHVI. Because of the small diameter of the FHVI the 80 cm drop only equates to about 10 liters of water. The calculation and visualization for this is provided in the visualization below.

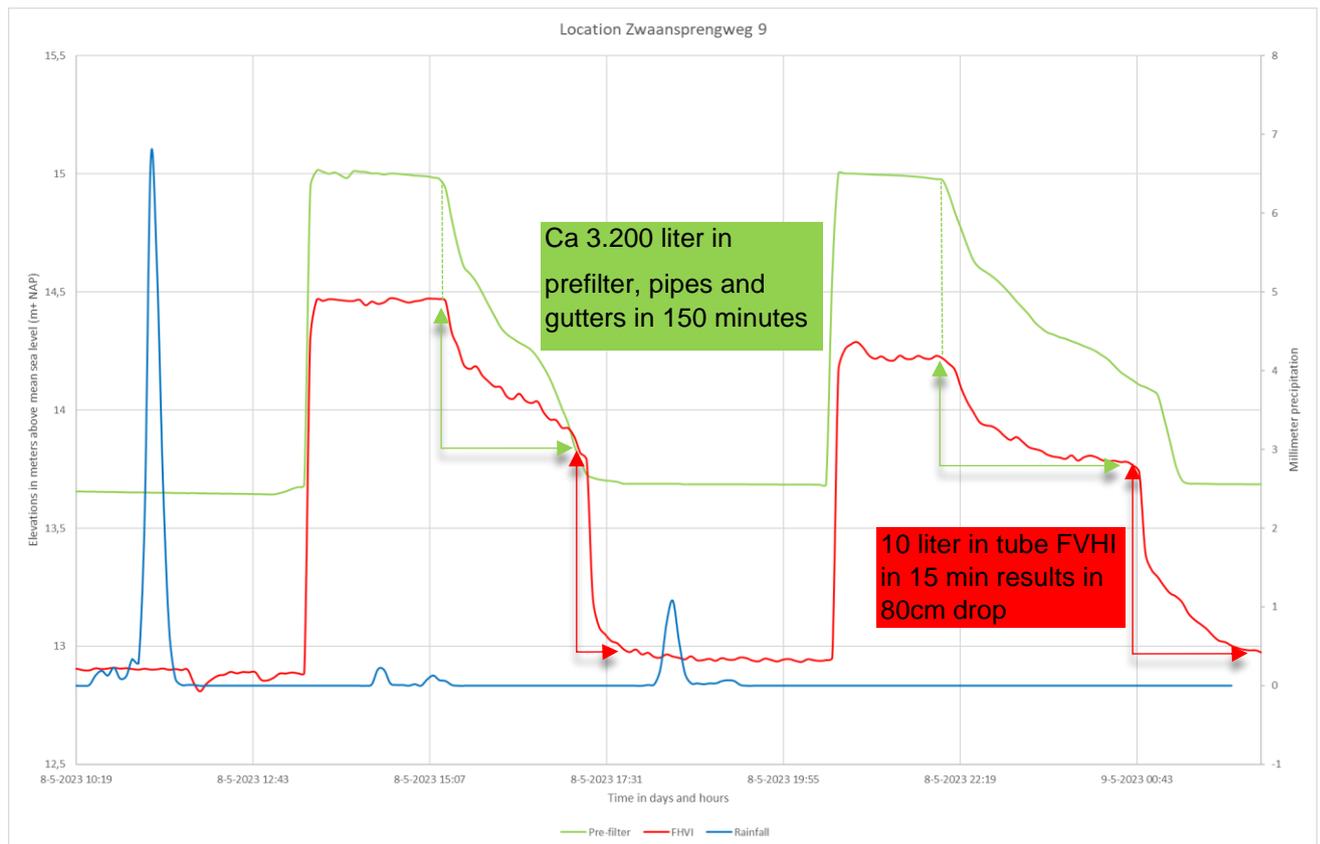


Figure 9. Graph of measured waterlevels 8th may 2023 at Zwaansprengweg 29.

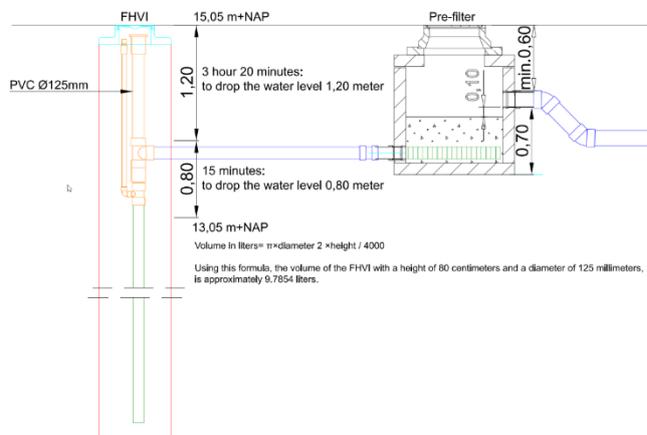


Figure 10. Pre-filter HWZI

What can we learn from the data on this location?

1. The pre-filter was filled to its maximum level of about 15,05 m+NAP.
2. The static storage volume in the system is approximately 3,2 m³ (pre-filter, connected pipes and street gutters).
3. The last data point is the time it takes to empty from filled to the ground water level. This takes 2 hours and 30 minutes.

With these data we can divide the static storage with time which gives us an infiltration rate in m³/h. With these measurements this is: $\text{Infiltration rate} = 3,26 \text{ m}^3 : 2 \text{ hours and } 30 \text{ minutes} = 1,3 \text{ m}^3/\text{h}$. This is in line with the amount of infiltration measured in field test in 2023. In this field test performed in August 2023 (3 months after this rainfall) gave an infiltration rate of 0,9 m³/h. After this test the FHVI

and pre-filter were cleaned and the field-test was done again. The infiltration rate for this test was 2,2 m³/h.

This is less than the preferred 10m³/h and even lower than our minimal preferred discharge of 5m³/h. Still the intake is enough to avoid flooding of the site: the amount and time of water on the street is acceptable and did not lead to discomfort to users of this part of the street.

Location Voshuizen 15 focused on infiltration time

At Voshuizen 15, the pre-filter is the type Wavin-Apeldoorn. The pre-filter can not fully empty in to the FHVI. The housing of the pre-filter is a vertical placed infiltration pipe: water can infiltrate thus the surrounding soil.

The rainfall on May 8, 2023, was measured at Voshuizen 15 as 12 mm in 15 minutes, which is a T=3 rainfall event. This event is only slightly visible in the FHVI. However, they are clearly visible in the pre-filter. It is also noticeable that the water level seems to drop in the FHVI initially. The cause is unknown at this moment. We now think this is likely an error in the measurements due to te set-up of the water level meter and how air pressure compensation sensor is placed in this measuring devise. A similar problem occurred on the location Zwaansprengweg. Here a second water level set-up was installed with has the air-pressure sensor placed outside of the FHVI-well.

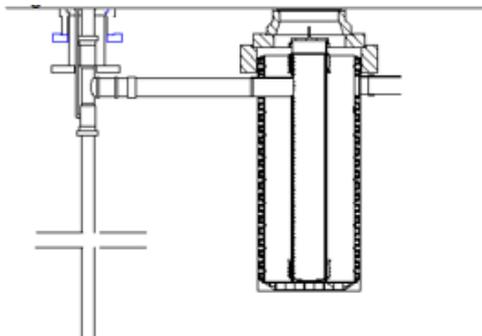


Figure 11. Pre-filter Wavin-Apeldoorn

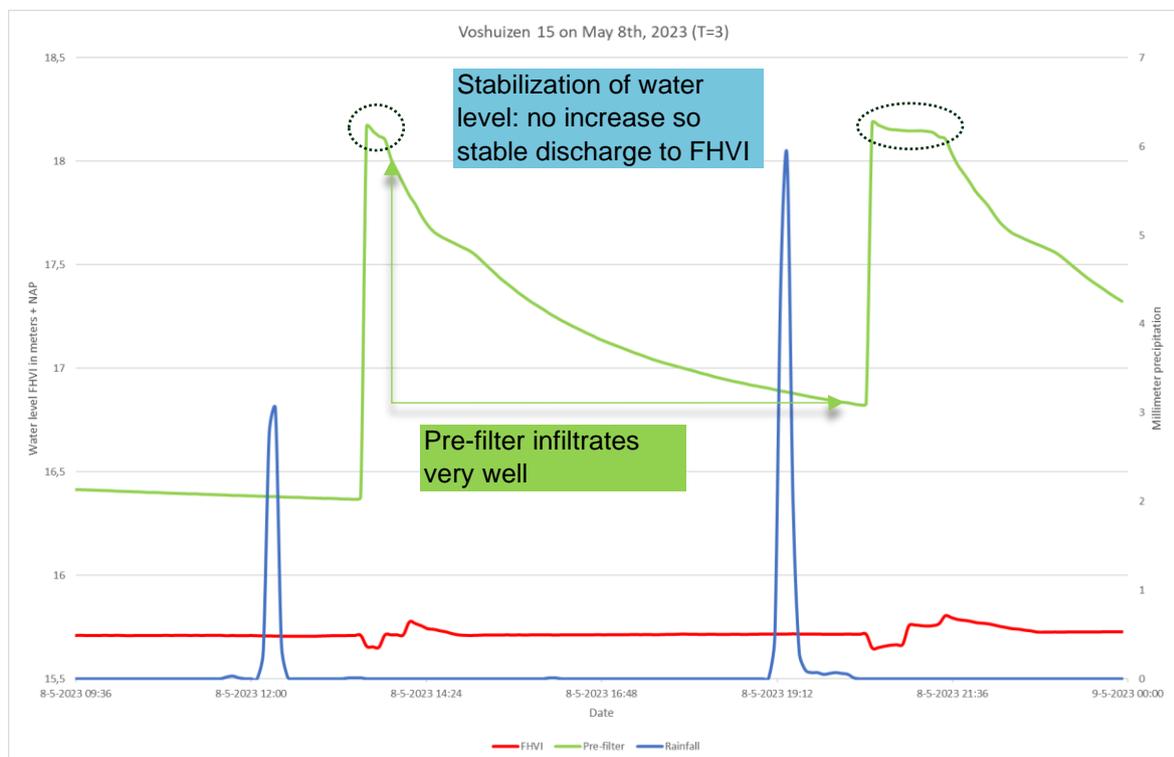


Figure 12. Graph of measured water levels 8th may 2023 at Zwaansprengweg 29.

The heaviest recorded downpour in the FHVI occurred on April 10, 2023. This increase of the water table in the FHVI was relatively small, with only 20 cm. The downpour on April 12, 2023, had a similar intensity and measurement in the FHVI. Therefore, these two downpours are easily compared with each other. This shows that a certain downpour event is preferred for the analysis of the effectiveness of a specific FHVI-system.

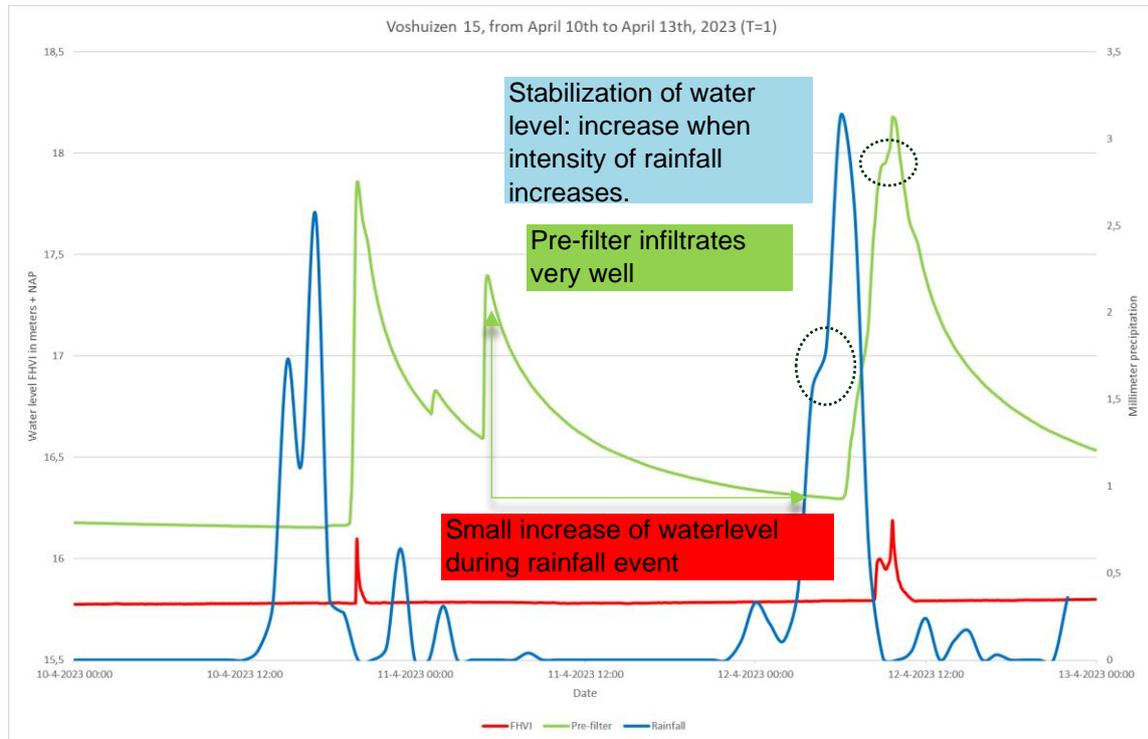


Figure 13. Graph of measured water levels 10 and 11th April 2023 Voshuizen.

If we then zoom in on the downpours, it is visible that the downpour on April 10, 2023 (yellow line), infiltrates in 40 minutes. The downpour on April 12, 2023, infiltrates in approximately 45 minutes, but then keeps slowly decreasing until about 1 hour and 30 minutes (green line). When we compare the precipitation data with these figures, it becomes clear why. The downpour on April 10, 2023, has a sharp peak but then almost immediately stops (yellow bar). The downpour on April 12, 2023, lasts longer and has a fairly stable intensity (green bar). As a result, rainwater enters the FHVI for a longer period, which muddles the measurement.

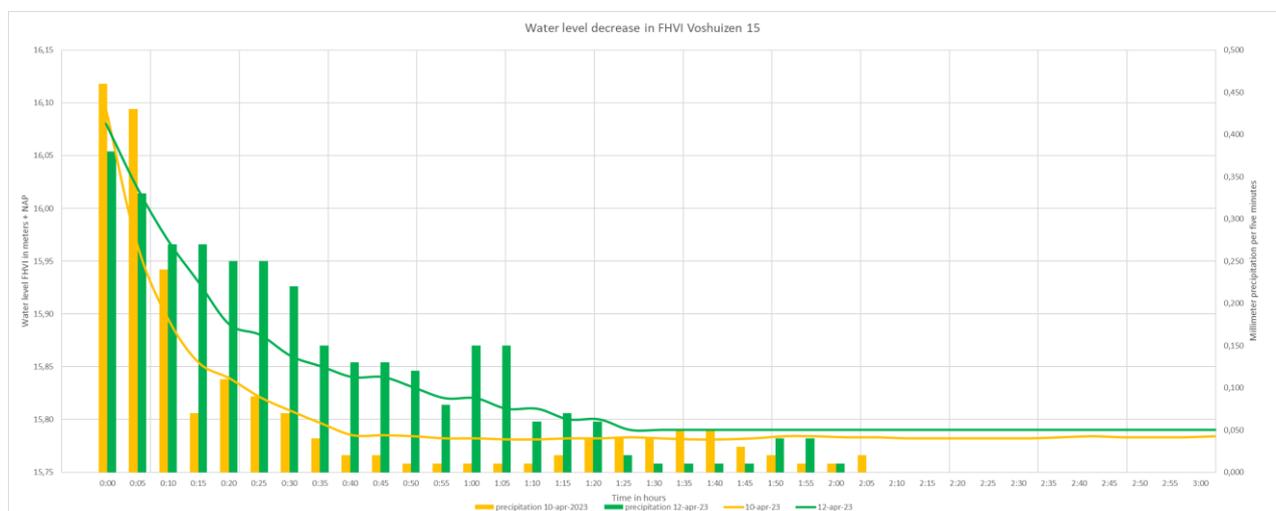


Figure 14. Graph of measured waterlevels 10th April 2023 Voshuizen.

Overall reflection on measuring the water tables and infiltration rates

- Available data for analyses is only a fraction of the total data-set.

Although a lot of effort was taken in measuring at many locations, technical details and hick-ups result in loss of data or not usable data.

The data which is then considered of good quality require a lot of manual labor to standardize the data to focus on single downpour event. Even if selection of rainfall events could be automated (which is not the case now), it will still require manual effort to filter for downpours and account for location-specific variations.

- No standardized analysis per location possible.

The composition of layout of the system and infiltration rates of FHVI and pre-filter influence the information that can be received.

When looking at the data of Voshuizen 15: If the rain does not completely stop or restart during the time it takes to empty the system, the results become muddled and are not directly comparable to other events. Events where the downpour completely stops and does not restart are relatively rare and require extensive searching.

At Zwaansprengweg 9 the system has currently a low infiltration rate as a result of severe testing and altering pre-filter component. Thus after a little downpour FHVI and pre-filter are saturated (full). Downside is that while the system is full, the infiltration rate or time is unmeasurable. Upside is that once the system empties, we can precisely determine how much water has infiltrated over a certain period.

Recommendations

- Measuring water levels as early warning tool for maintenance

Given the variations in location and downpour events, it is a good tool to use the measurement system primarily as an early warning tool. When a location remains full for a certain period, it indicates that maintenance is required.

- Field testing is so far the only reliable method for measuring the infiltration rate of an FHVI:

The better option for measuring the infiltration rate over a long period is to perform field tests at regular intervals. When comparing field tests, it is also crucial to know if and what kind of maintenance was performed.

3.2. Water quality – results

Two types of water quality can give output for the final design criteria.

- Particles which block the possibility of infiltration.
- Substances which can pollute the groundwater.

Location factors which add up to the load of dirt are the amount of paved surface and the amount of run-off from unpaved roadside's and trees in the area.

Preventing blockage. Prevent particles in the FHVI with a fraction larger then 2-5 µm.

Lessons learned are that a filter cloth alone is not enough to filter this fraction. When installing a pre filter, the FHVI will keep its infiltration capacity. It was noted that the type of pre-filter named 'HWZI' it will protect the infiltration-system and moves the risks of blockage to a location which is easier to access. The HWZI itself seems (relatively) not vulnerable for blockage. If we use a other type of pre-filter: the Apeldoorn – Wavin prefilter, this filter can cause clogging of the filtermedium. A continuous maintenance protocol is required and 2 to 4 times per year the filtercloth has to be renewed. Which results as a safe-guard of the FHVI but relative intense maintenance workload.

Thus far only one location was reported with a blockage of the HWZI due to extreme run-off in a slope area put here the desired maximum area with intense rainfall: well over 400 m² of run-off due to the sloping street (location intersection Libellelaan/Hagenweg in Beekbergen).

Preventing pollution. Substances which can pollute the groundwater.

The quality of the water after the pre-filter never exceeds the intervention values, which are used for remediation of groundwater or to determine if remediation is necessary. More research is needed and maybe additional monitoring methods. The pre-filter with filtercloth can be clogged: resulting in zero pollution but also less or no infiltration – maintenance is required 2 to 4 times per year. It seems that HWZI acts as a soil passage. But easy to access and to clean. Without causing soil pollution.

Additional purification methods can easily be tested. Thus far only one location was reported with a blockage of the HWZI due to extreme run-off in a slope area; the desired maximum area was well over 400 m² due to the sloping street (location intersection Libellelaan/Hagenweg in Beekbergen). In **Annex 5**. An overview of graphs is of the analysis of water sample from gutters and FHVI wells.

3.3. Description of the design of a FHVI-site

Desk research

Prior to the installation/design of FHVI wells, it is determined from the literature (DINOLoket, REGIS, available local data) whether water-bearing layers are present with a minimum horizontal permeability of 20 m/d and whether the groundwater level is at more than 1 meter minus ground level.

Rainwater drainage design

Depending on the nature of the and the available space for rainwater, a choice can be made for the design of the rainwater drainage. Basically, there is:

1. FHVI is supplementary to underground and/or above-ground storage and infiltration facilities. The drainage function of the FHVI will only be used during peak showers.
2. A 'stand-alone' system with FHVI as primary drainage of rainwater.

In all cases, consideration must be given to where the water can flow if it cannot be drained in the FHVI during an extreme shower: is it acceptable for water to temporarily occur on the street (between thresholds and sills)? Or is additional discharge capacity necessary (an additional FHVI) or is water discharged to downstream public space.

Water quantity - Hydrological design-criteria

To design the required capacity of a FHVI-site a reference rainfall shower is used, as stated on page 29 of the Technical Application Form Part A – Administrative Information. This rainfall shower produces 357 m³ of precipitation per hectare. In the project design of municipality of Apeldoorn, 400 m² is connected to one infiltration/ FHVI -location. This amounts to a volume to be infiltrated of 14.3 m³, which falls during the relevant rain shower of T=10. During the duration of this T=10 event, the assumption is that the FHVI location infiltrates 10 m³ and 4.3 m³ is buffered on the street or in a buffer, until the FHVI location is available again or that the current system itself infiltrates 4.3 m³.

Following further experiences in the field during the operation, several new refinements were made in the design. A general conclusion of the project design is that customization is often needed, based on the different challenges in the field, related to the ground water table, soil composition and clogging. The partners are currently developing a 'menu' for municipalities that provides different designs for different circumstances and street levels in the field in order to facilitate the after-LIFE phase. Basic guidelines for use of FHVI at street level are (see also figure 6):

- 5-10 m³/u per FHVI-system is starting point. If this succeeds, it can be used as input for design.
- Area (for example 400m²) or rainfall events is not input for the capacity of one FHVI-system, but determines the amount needed.

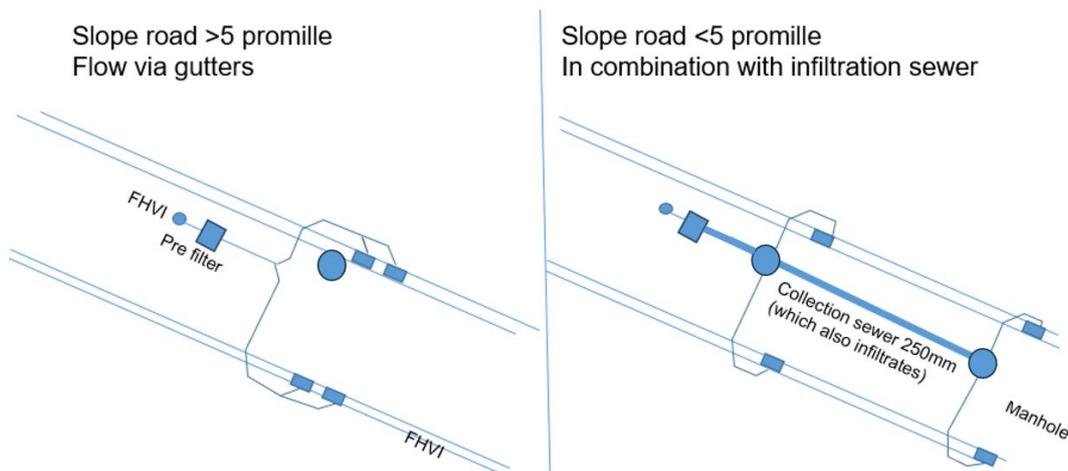


Figure 15. Schematic design of FHVI-water collection layout

After various stages of design, the preferred setup of FHVI-sites is drawn-up.

Water quality – pre-filtering Criteria

Two types of water quality can give output for the final design criteria.

- Particles which block the possibility of infiltration.
- Substances which can pollute the groundwater.

Location factors which add up to the load of dirt are the amount of paved surface and the amount of run-off from unpaved roadside's and trees in the area.

Preventing blockage

Design criteria: Prevent particles in the FHVI with a fraction larger than 2-5 μm .

Lessons learned are that a filter cloth alone is not enough to filter this fraction.

When installing the HWZI as a pre-filtration, the FHVI will keep its infiltration capacity. The HWZI protects the infiltration-system and moves the risks of blockage to a location which is easier to access.

Footnote: the HWZI itself seems (relatively) not vulnerable for blockage. See also **Annex 4** for the blue print of a FHVI-site with HWZI-prefilter.

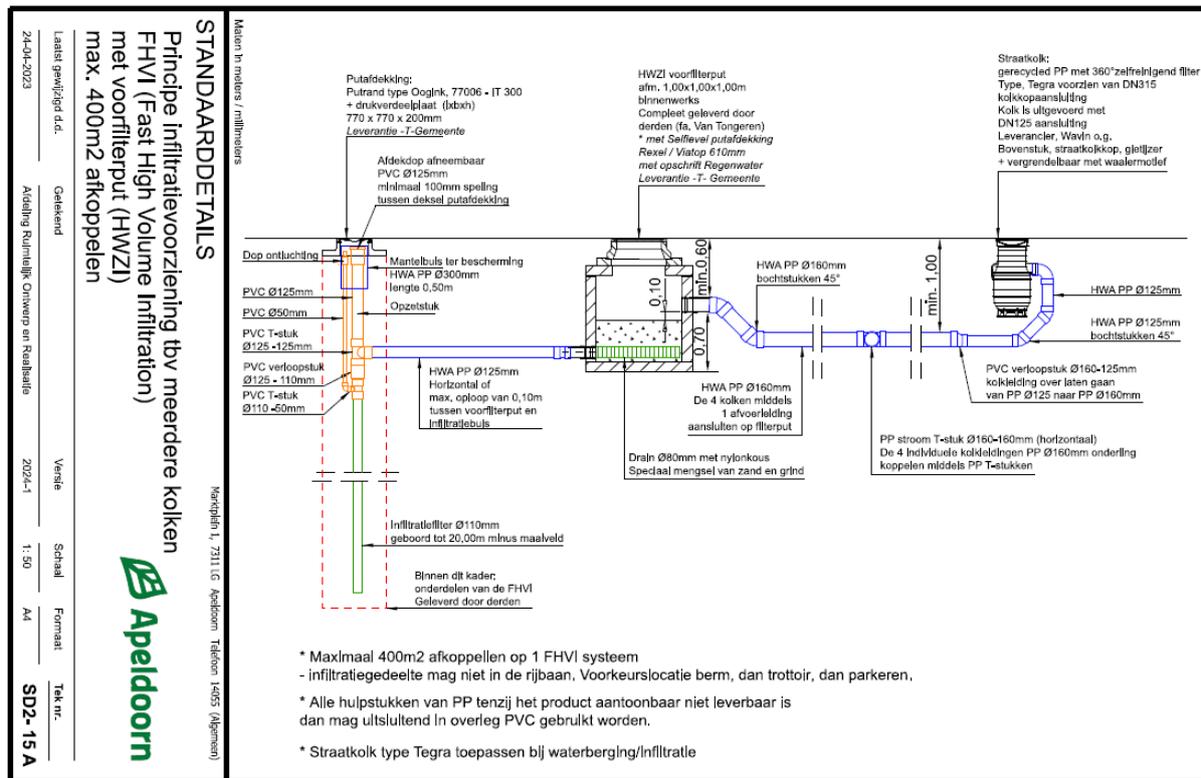


Figure 16.. Principle design of FHVI piping in combination with HWZI. Image x. Principle of elaboration of FHVI piping in combination with HWZI.

Installation process

During the placement process (vertical soil drilling), it is determined at what exact depth the FHVI well is placed. This is done by testing whether more than 5 m³/h of working water must be added to the drilling process. In other words; because the soil absorbs water during soil drilling, which is used during drilling, water must be added to the drilling process. If this is more than 5 m³/h, then it is called an infiltration point. This determines the depth at which the FHVI well is placed. All these data are recorded by the BRL2100, protocol 2101 Mechanical drilling recognized drilling master. NB. Each location is designed for an infiltration capacity of 10 m³/h. However, if literature research or fieldwork shows that one FHVI well is not sufficient, an additional FHVI well is placed in line, both of which are then also linked to one pre-filter (together still called an infiltration location). This guarantees that a location has the infiltration capacity of 10 m³/h.

The other data are also recorded; local groundwater level, use of ground level, rainwater drainage design, volume of static storage.

Maintenance protocol

On top of this a maintenance protocol was designed for the FHVI systems and a re-design of the pre-filter for the pre-treatment stage was carried out to tackle the problem of clogging of the pre-filter (see fig. 5).

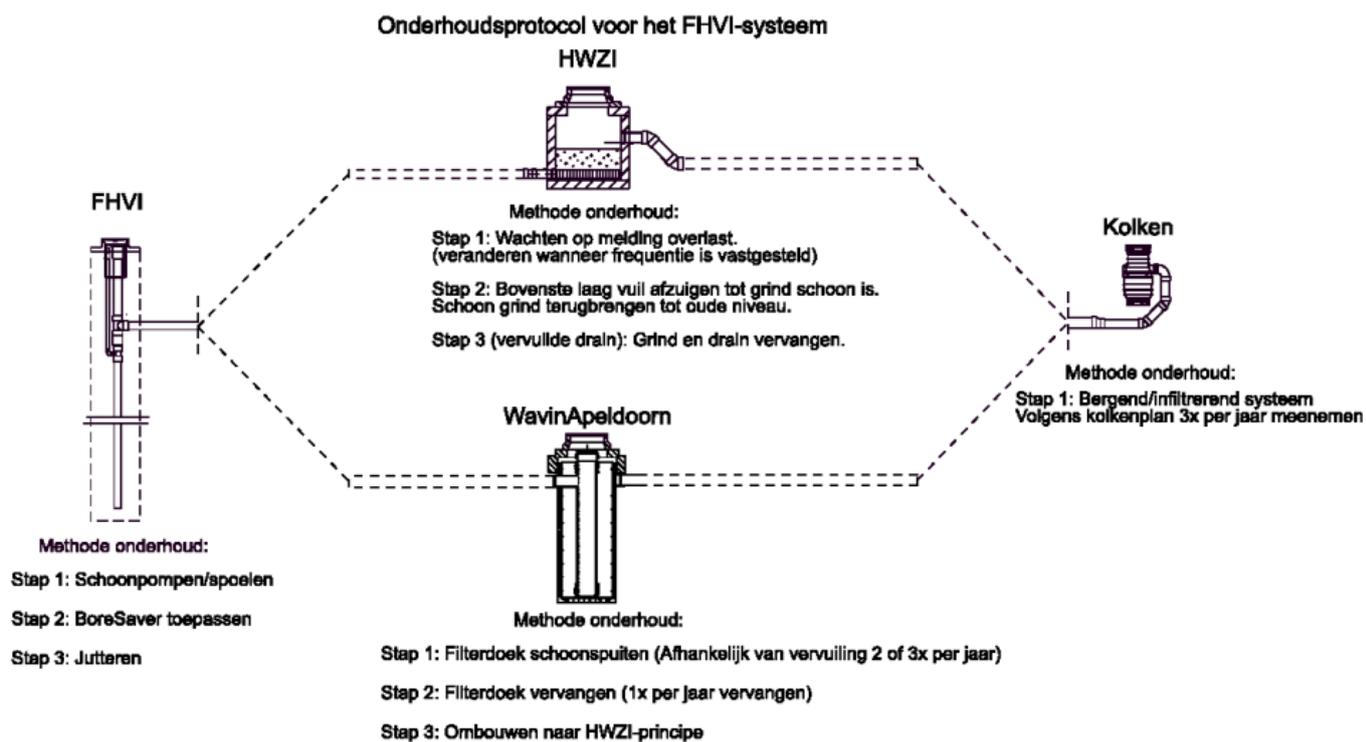


Figure 17. Schematic overview of the maintenance protocol with different protocols for the FHVI (left) and two prefilter options (middle).

4. Conclusions

4.1. In what way and to what extent do the dimensioning of the FHVI wells and the maintenance, under various circumstances, influence the multi-year infiltration capacity?

Conclusion: Pre-filtering or filtration before infiltration is the key to be able to have a positive impact on a long lasting infiltration capacity. In the situation where the deep infiltration is a supplement to a buffering facility (wadi or storage sewer), the FHVI works incidentally and the chance of physical blockage is (much) lower. A simple dirt trap at gullies and in the storage facility itself often seems sufficient and blockage of the FHVI wells occurs less. In the case where the FHVI wells are the primary facility for draining rainwater, it appears that flushing of particles occurs more often. This leads to blockage at the infiltration point. In this situation, pre-filtering is crucial: particles may not pass through to the FHVI wells. This requires an additional investment, which will pay for itself. By preventing the infiltrating effect from having to be restored, the occurrence of water nuisance and additional operational costs are also prevented.

The physical parameters of the target locations are clear and this results in a blueprint for discharge to the pre-filter and FHVI, FHVI can be effectively protected against pollution, maintenance of the pre-filter has been 'tackled'.

4.2. To what extent has the number, duration and level of flooding/water nuisance decreased?

Decoupling rainwater from the old mixed sewerage system to reduce the impact of climate change on water nuisance.

Since around 2011, the paved surface on the combined sewer has decreased from approximately 1,000 ha to approximately 900 ha in 2023 due to decoupling of rainwater from the old sewer system. The amount of paved area that has been disconnected via the FHVI systems installed during the AERFIT project is approximately 6 hectares. With a total 6 ha of decoupled rainwater is due to this project not entering the sewer system and reduces overflow of the sewer system in Apeldoorn.

In general due to the annual changing weather conditions and intensities of rain showers, it is not easy to objectively indicate the influence of decoupling rainwater.

Citizen notifications on water flooding

Apeldoorn has a monitoring system in which citizens can report notifications on e.g. pluvial flooding. All notifications are stored in a database. Apeldoorn can relate the notifications to time and locations and extract all notifications matching with the new FHVI sites. Apeldoorn analyses notifications directly in order to relate them to cause and effect, rainfall event, or maintenance or technical failure of a specific asset (see figure 15 and 16). Trends in water/sewerage notifications are evaluated every 4 years: the aim is to stay under 1.000 notifications per year. So far not one FHVI-system failure was related to failures of the FHVI itself. There were notifications which correlated with clogging of a pre-filter. Other overlap with a location of a FHVI with notifications had to do with coincide overlap, due to clogging of gutters and high groundwater tables, which has no relation with the function of the FHVI. Since the beginning of 2022, there were no citizen notifications on flooding events at FHVI locations.

What is known about flooding on locations before FHVI was installed

At multiple locations (Koning Lodewijklaan, Hagenweg, Leeuwenbergweg) we reduced existing water nuisance which was at hand when rainwater of the street was connected to the old combined sewer

system. On all the other locations there were no nuisances of rainwater – but the decoupling reduced the inflow in the old combined sewer system. This water does not add up during peak-rainfall showers and less clean rainwater is transported to the waste water treatment plant (WWTP).

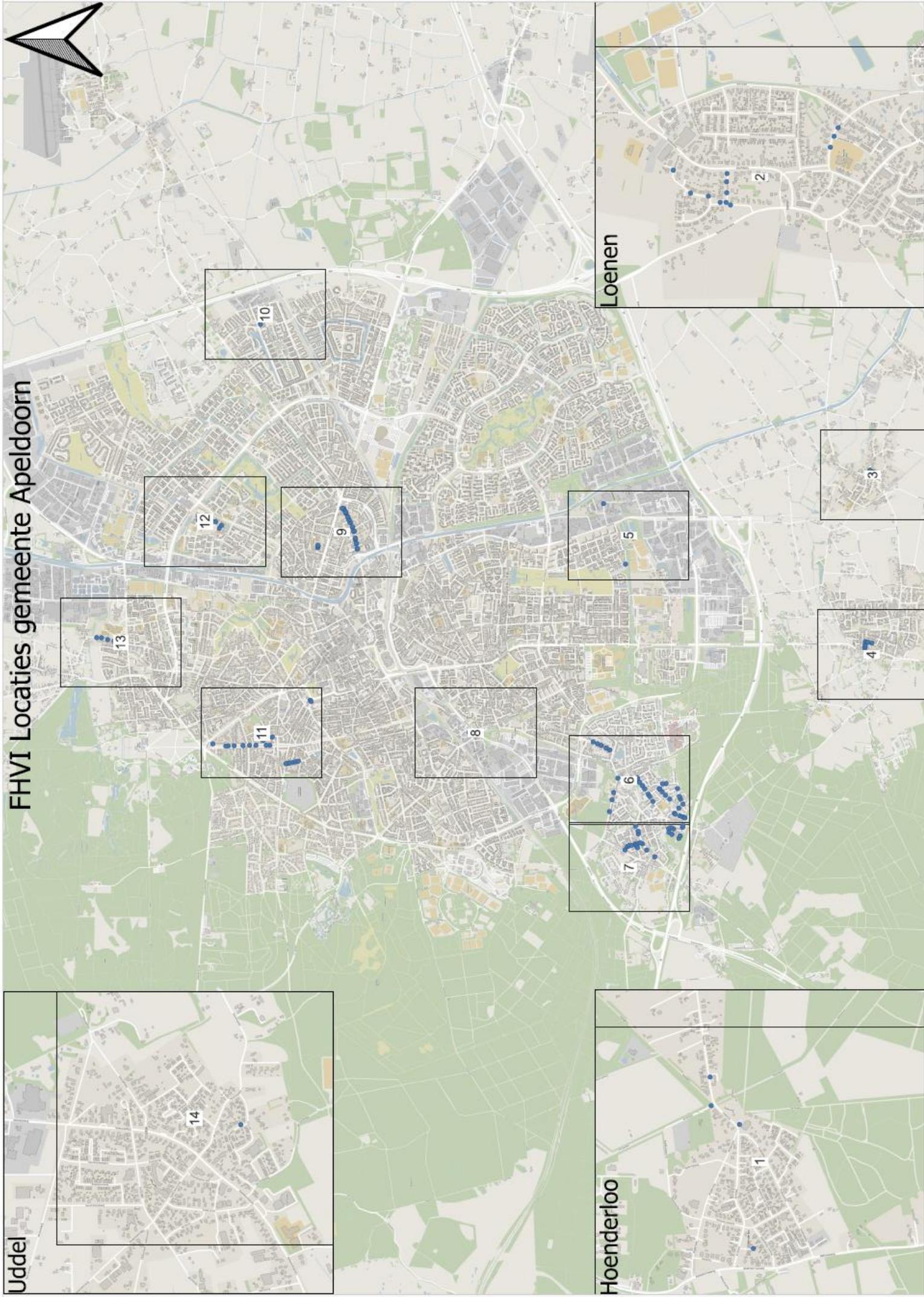
4.3. Is there an improvement in the effluent of the WWTP?

The Grant Agreement states that an assessment of the effluent of the WWTP must take place, in relation to the FHVI wells. However, a correct analysis, in which a connection can be made with the effluent of the WWTP, is not possible in practice. Nevertheless, decoupling rainwater from the old mixed sewer system results in a decrease in the volume of rainwater that would end up at the WWTP.

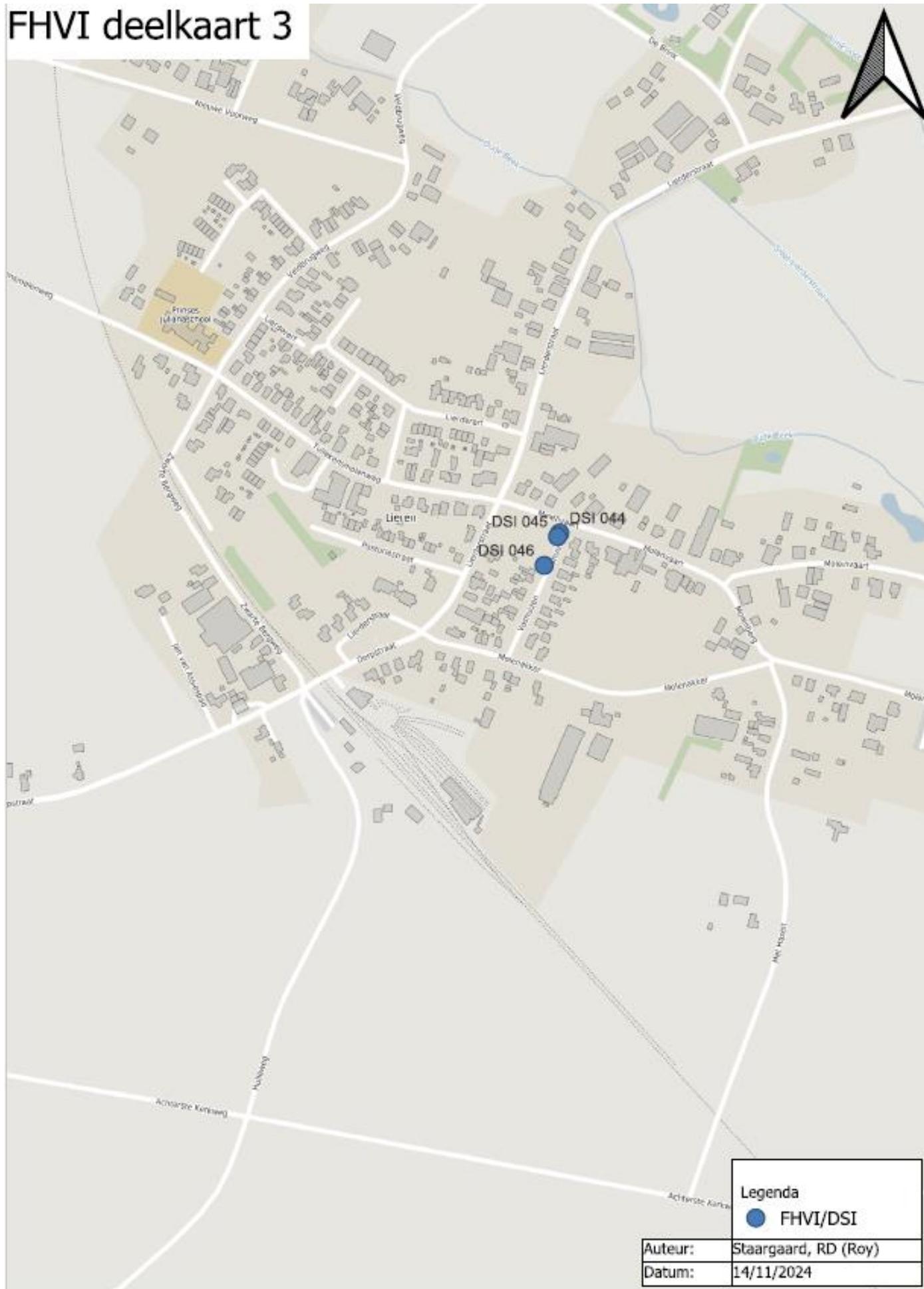
Annexes

1. Annex - Map of all FHVI-sites installed in LIFE-AERFIT

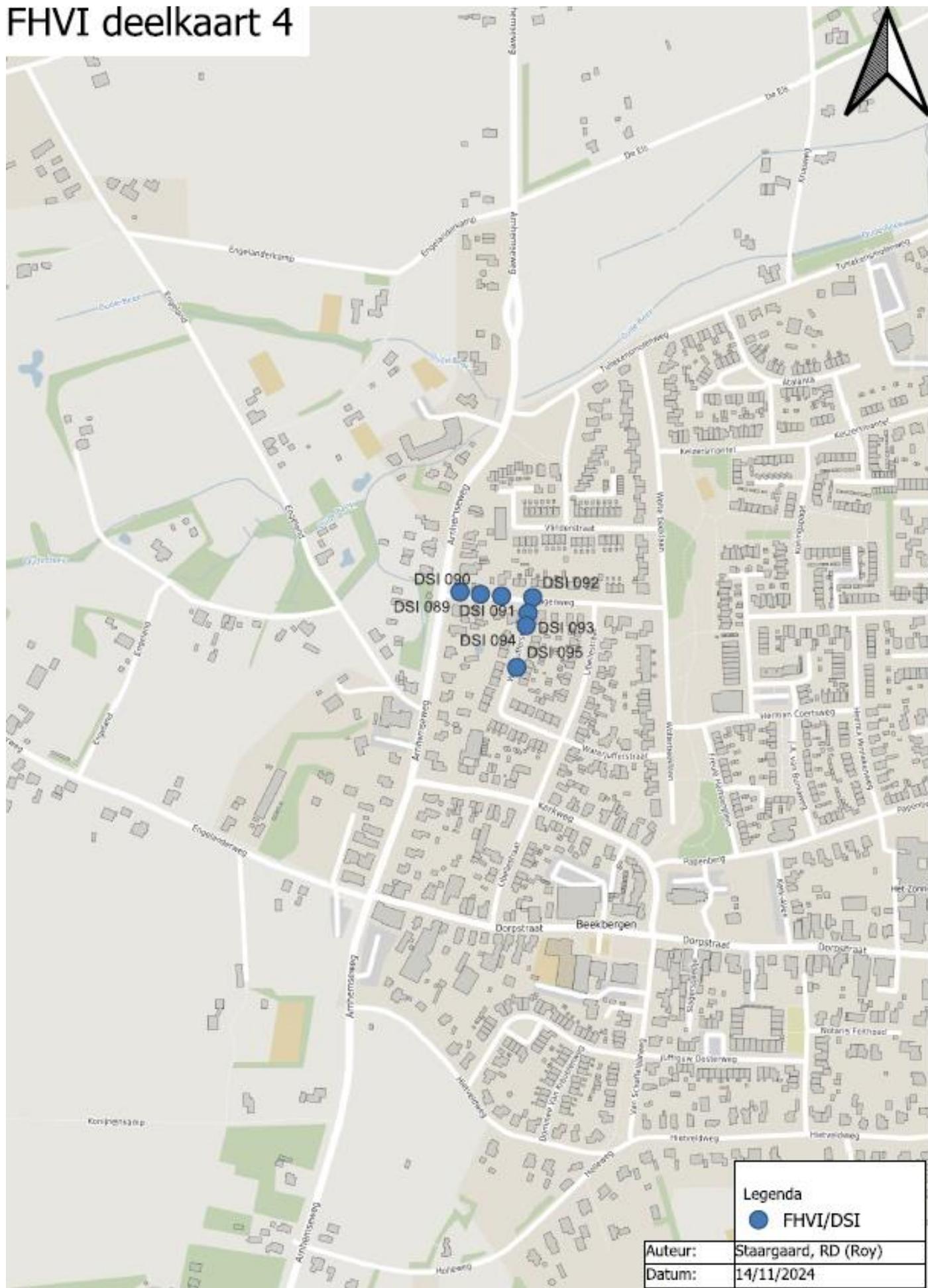
FHVI Locaties gemeente Apeldoorn



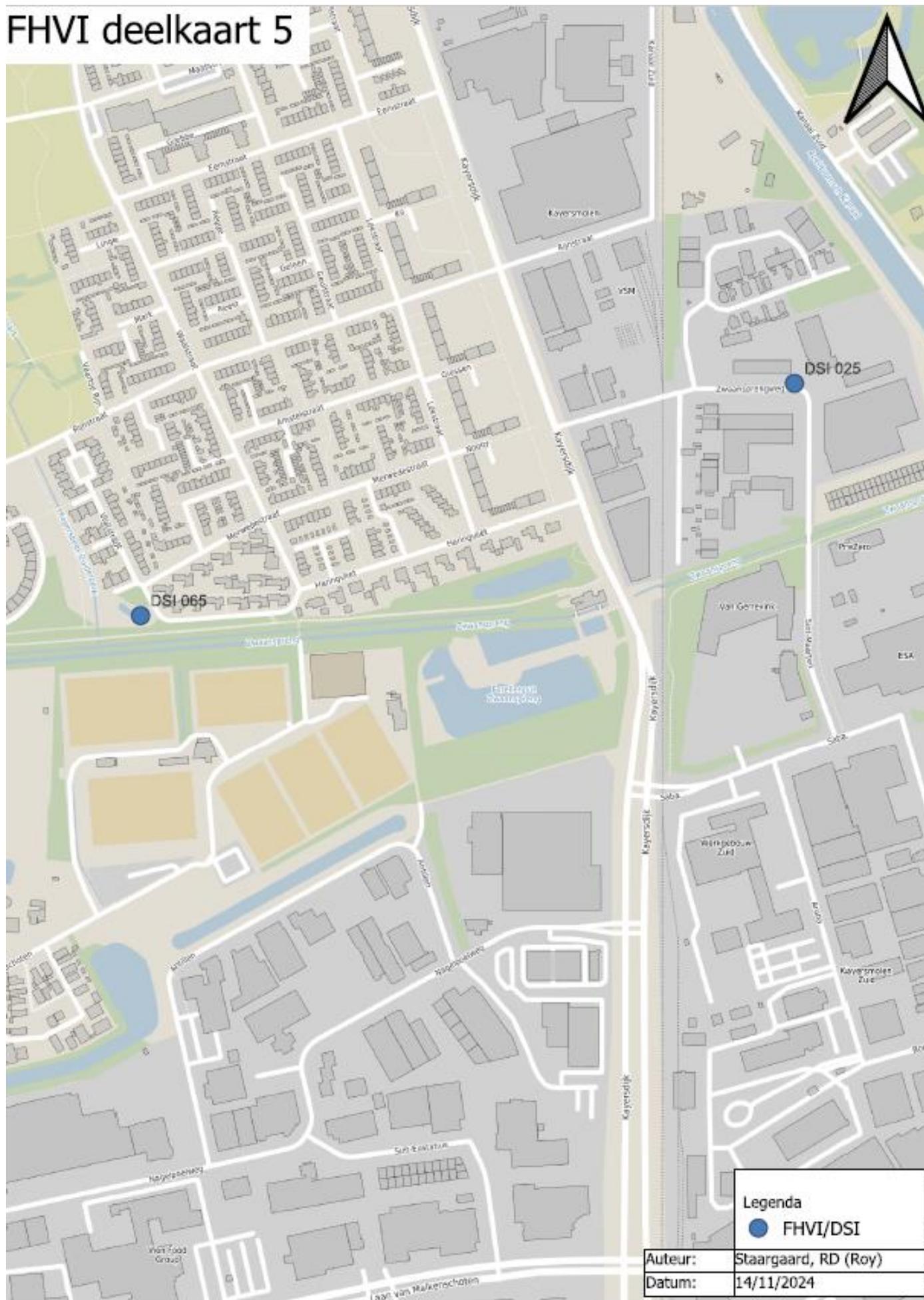
FHVI deelkaart 3



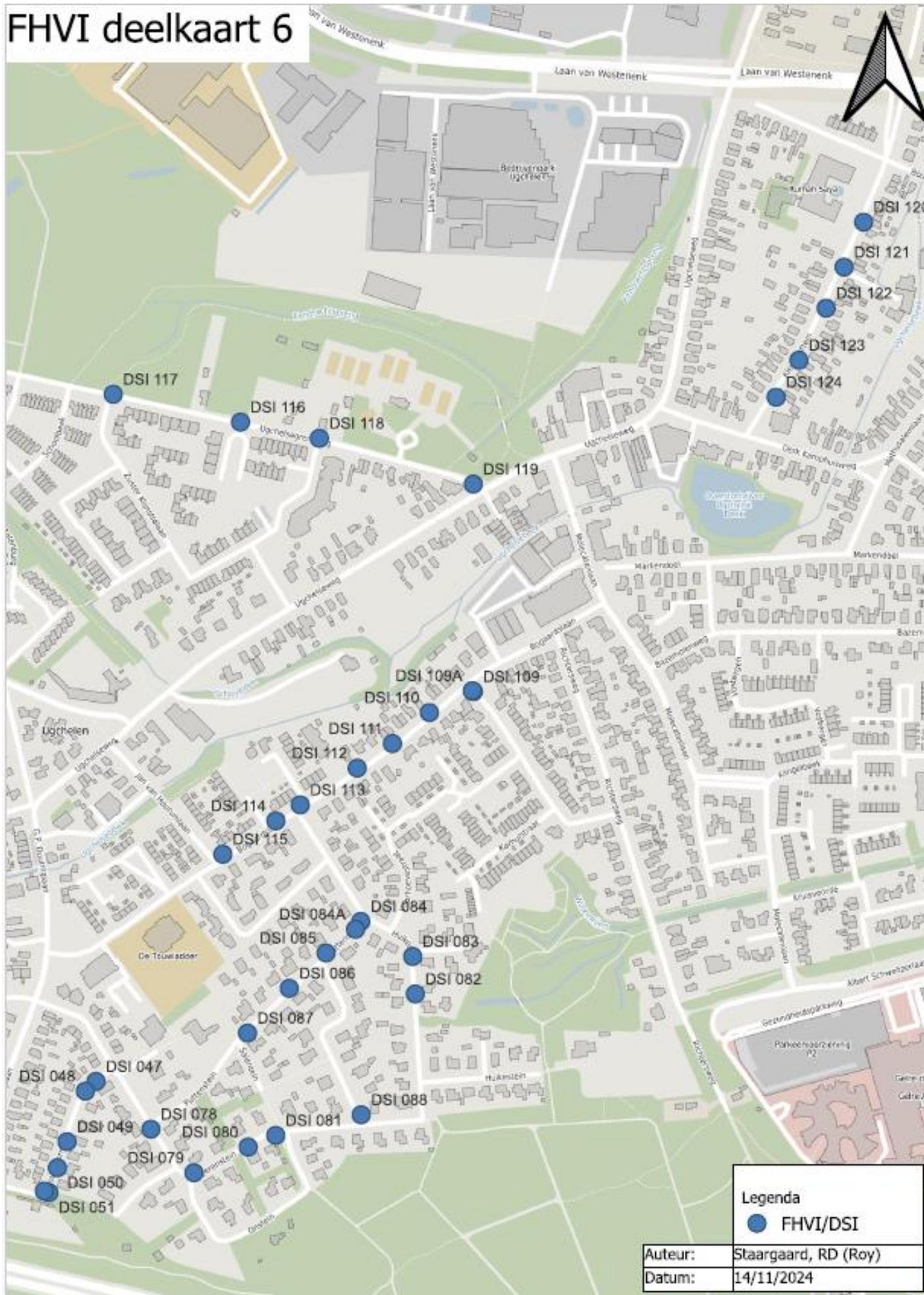
FHVI deelkaart 4



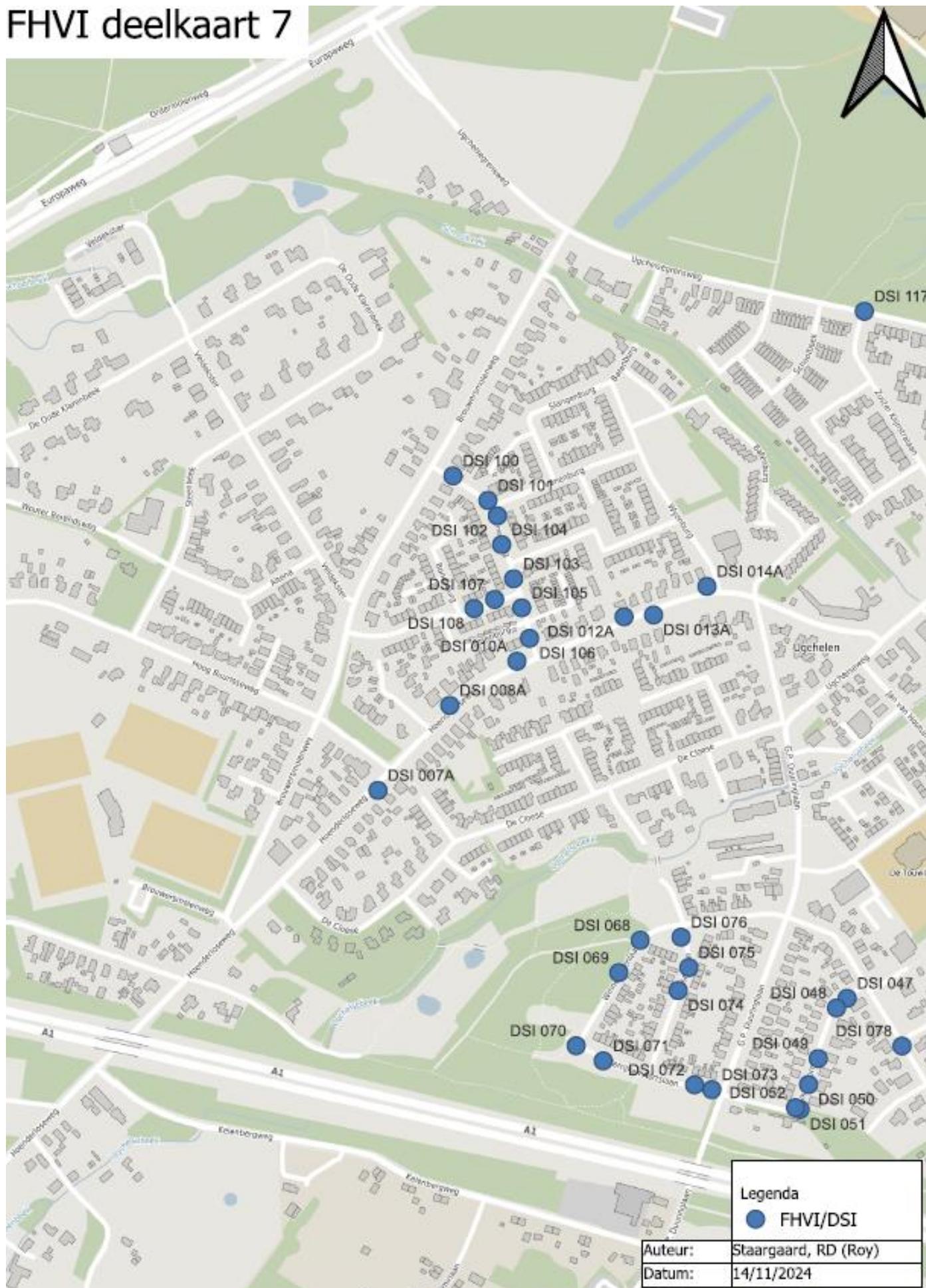
FHVI deelkaart 5



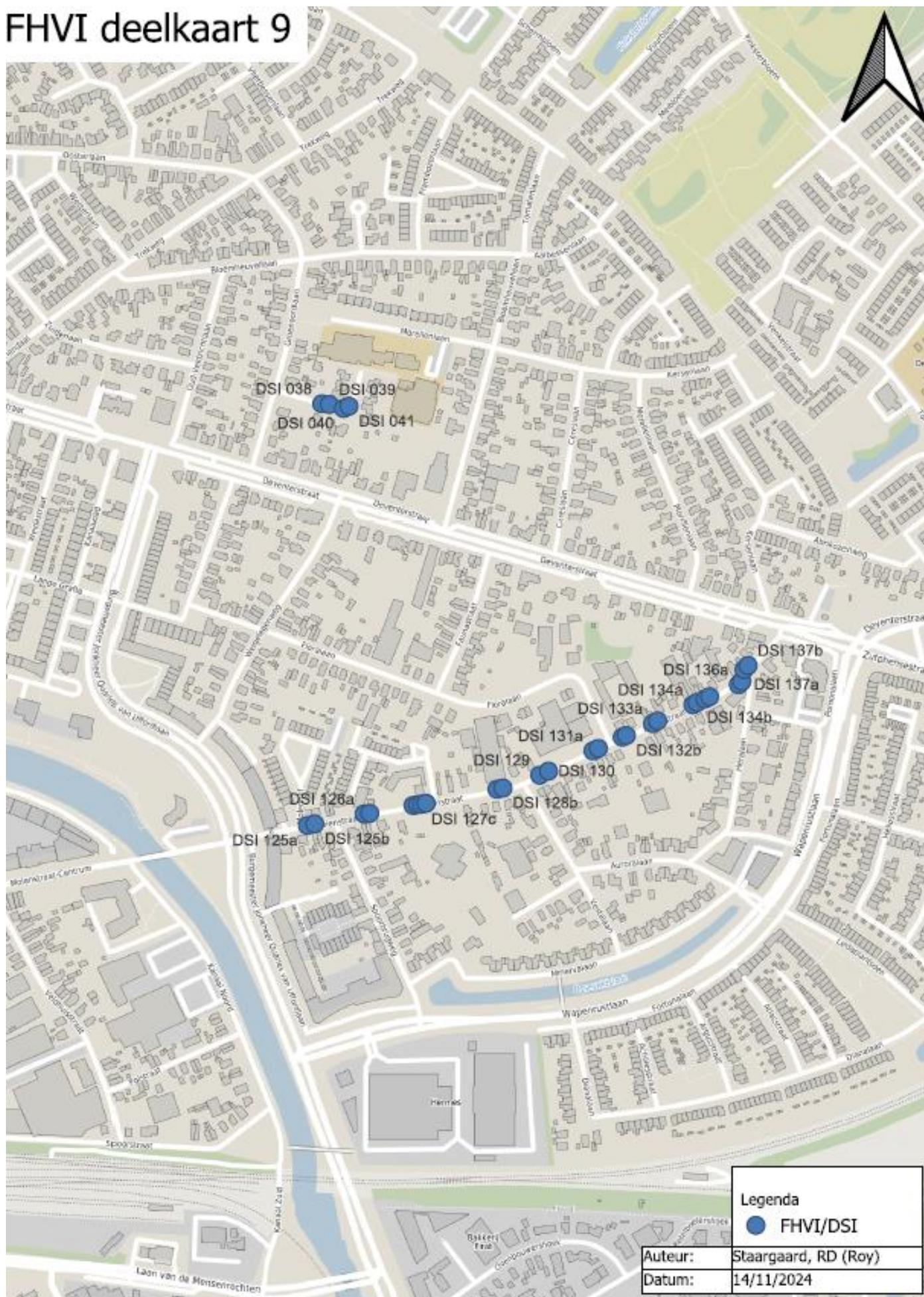
FHVI deelkaart 6



FHVI deelkaart 7



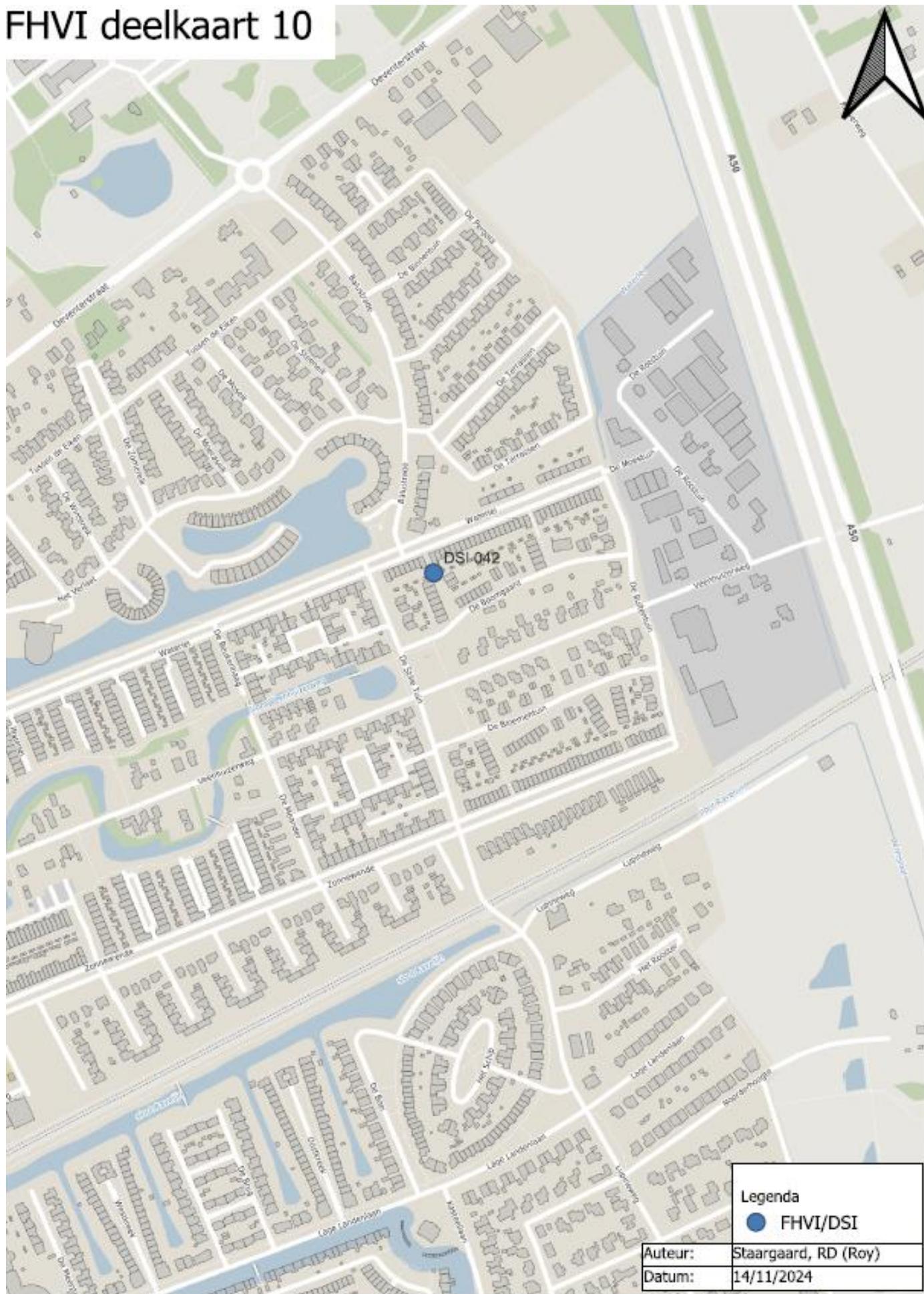
FHVI deelkaart 9



Legenda
● FHVI/DSI

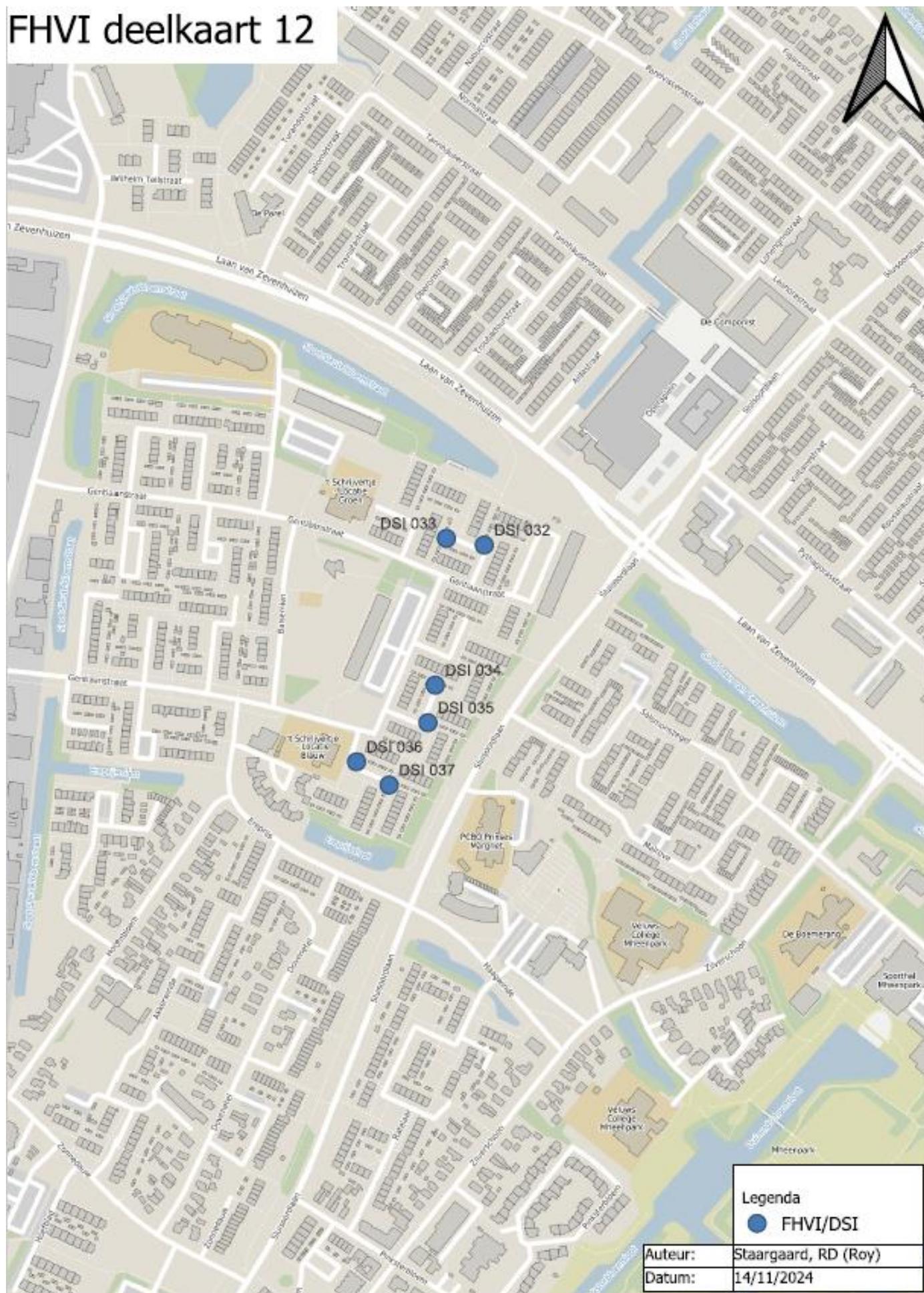
Auteur:	Staargaard, RD (Roy)
Datum:	14/11/2024

FHVI deelkaart 10



Legenda	
	FHVI/DSI
Auteur:	Staargaard, RD (Roy)
Datum:	14/11/2024

FHVI deelkaart 12



2. Annex - Soil logs of FHVI-wells

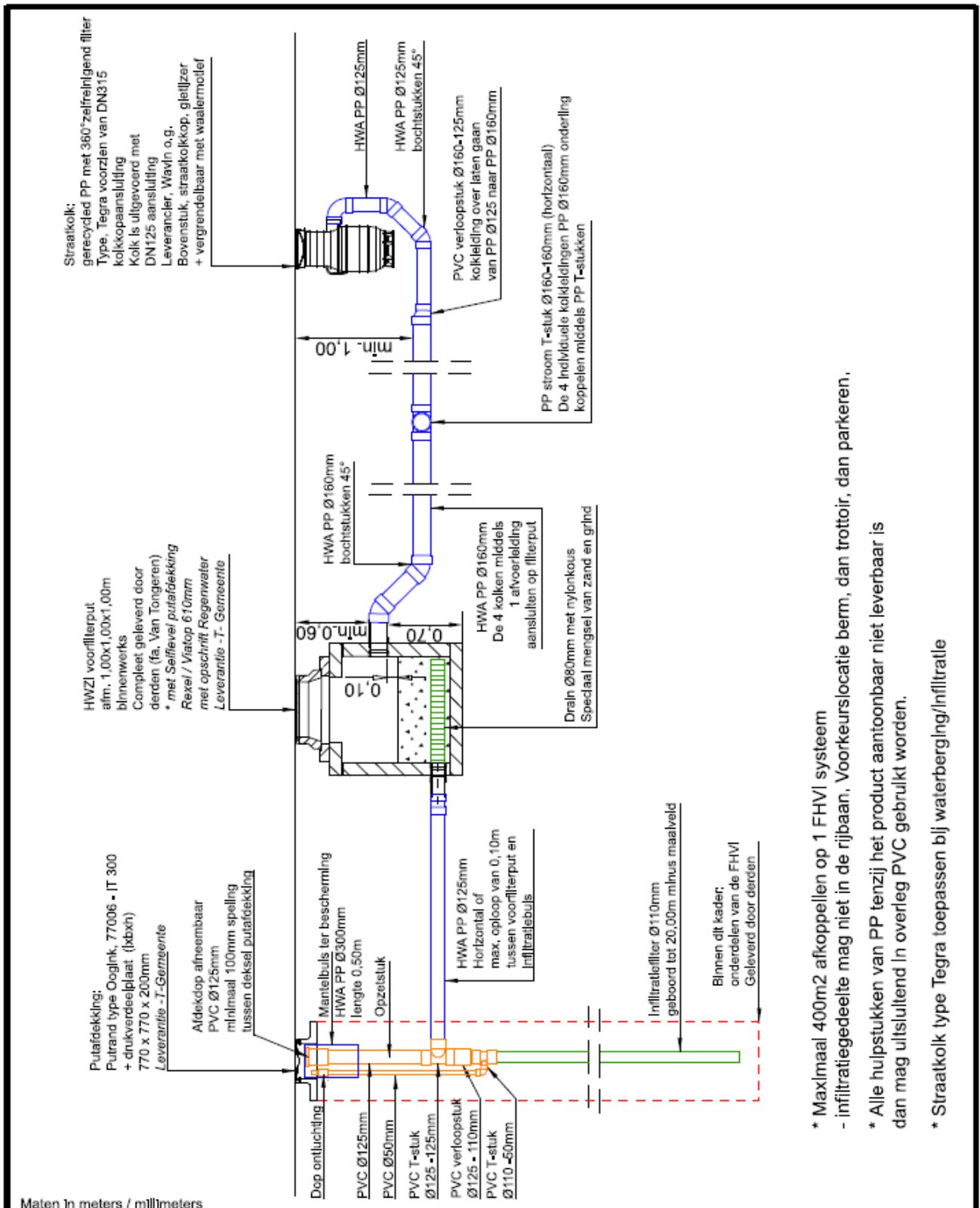
3. Annex - FHVI table

Overview of

	DSI / FHVI nummer	Adres GIS	Datum aanleg	Diepte (m)	X-coor	Y-coor	Type voorfilter	X-filter	Y-filter	Fase
1	FHVI 007A	Hoenderloseweg 89	8-12-2022	26,0	191970.85	466261.39	WavinApeldoorn	191972.46	466263.7	LIFE
2	FHVI 008A	Hoenderloseweg 44B	8-12-2022	26,0	192044.57	466349.25	WavinApeldoorn	192043.57	466348.19	LIFE
3	FHVI 010A	Hoenderloseweg 32	8-12-2022	25,0	192113.48	466394.89	WavinApeldoorn	192116.03	466396.06	LIFE
4	FHVI 012A	Hoenderloseweg 27	8-12-2022	25,0	192223.32	466440.84	WavinApeldoorn	192221.16	466440.18	LIFE
5	FHVI 013A	Hoenderloseweg 36	8-12-2022	22,0	192253.61	466442.69	WavinApeldoorn	192255.82	466444.59	LIFE
6	FHVI 014A	Hoenderloseweg 13	8-12-2022	23,0	192308.42	466472.24	WavinApeldoorn	192310.41	466472.3	LIFE
7	FHVI 015	Koning Lodewijklaan 59	16-12-2019	17,5	193201.43	470474.7	WavinApeldoorn	193279.34	470498	LIFE
8	FHVI 016	Koning Lodewijklaan 51B	16-12-2019	17,5	193201.71	470515.4	WavinApeldoorn	193256.37	470547.18	LIFE
9	FHVI 017	Koning Lodewijklaan 37	16-12-2019	16,0	193201.15	470628	WavinApeldoorn	193256.37	470547.18	LIFE
10	FHVI 018	Bosweg 27	16-12-2019	16,0	193200.59	470698.51	WavinApeldoorn	193256.37	470547.18	LIFE
11	FHVI 019	Koning Lodewijklaan 27	26-12-2019	16,0	193198.09	470769.03	WavinApeldoorn	193256.37	470547.18	LIFE
12	FHVI 020	Koningin Hortensenlaan 24	16-12-2019	18,0	193196.97	470866.58	WavinApeldoorn	193256.37	470547.18	LIFE
13	FHVI 021	Koning Lodewijklaan 15	16-12-2019	18,0	193195.86	470930.4	WavinApeldoorn	193256.37	470547.18	LIFE
14	FHVI 022	Koning Lodewijklaan 13B	16-12-2019	17,0	193193.35	470958	WavinApeldoorn	193256.37	470547.18	LIFE
15	FHVI 023	Koning Lodewijklaan 1	16-12-2019	18,0	193217.45	471099.92	WavinApeldoorn	193256.37	470547.18	LIFE
16	FHVI 024	Veenweg 24	13-5-2020	26,0	193343.95	468296.16	WavinApeldoorn	193346.67	468301.01	LIFE
17	FHVI 025	Zwaansprengweg 9	14-5-2020	32,0	195869.96	466820.63	HWZI	195872.84	466819.86	LIFE
18	FHVI 026	Anklaarseweg 33	22-6-2020	25,0	194322.79	472055.85	WavinApeldoorn	194335.32	472125.8	LIFE
19	FHVI 027	Kostverloren 9D	26-6-2020	25,0	194336.67	472126.21	WavinApeldoorn	194335.32	472125.8	LIFE
20	FHVI 028	Kostverloren 13	25-6-2020	25,0	194351.53	472180.71	WavinApeldoorn	194350.78	472182.42	LIFE
21	FHVI 029	Kostverloren 20B	25-6-2020	25,0	194368.38	472252.06	WavinApeldoorn	194350.78	472182.42	LIFE
22	FHVI 030	Kostverloren 24	24-6-2020	25,0	194388.2	472318.46	WavinApeldoorn	194350.78	472182.42	LIFE
23	FHVI 031	Kostverloren 26	23-6-2020	20,0	194390.18	472370.98	WavinApeldoorn	194350.78	472182.42	LIFE
24	FHVI 032	Gentiaanstraat 508	6-10-2020	36,0	195727.46	471253.39	WavinApeldoorn	195728.48	471255.53	LIFE
25	FHVI 033	Gentiaanstraat 558	7-10-2020	20,0	195688.63	471260.27	WavinApeldoorn	195688.66	471259.91	LIFE
26	FHVI 034	Gentiaanstraat 200	19-5-2021	16,0	195677.29	471108.46	WavinApeldoorn	195677.08	471106.08	LIFE
27	FHVI 035	Gentiaanstraat 172	8-10-2020	17,0	195669.68	471069.62	WavinApeldoorn	195668.39	471070.91	LIFE
28	FHVI 036	Gentiaanstraat 146	18-5-2021	17,0	195596.47	471029.12	WavinApeldoorn	195597.98	471028.26	LIFE
29	FHVI 037	Gentiaanstraat 122	17-5-2021	19,0	195629.91	471005.15	WavinApeldoorn	195627.38	471004.14	LIFE
30	FHVI 038	Bongerdpad 4	21-10-2021	32,0	195382.46	469952.11	WavinApeldoorn	195476.84	469536.64	LIFE
31	FHVI 039	Bongerdpad 6	25-10-2021	15,0	195390.05	469951.34	WavinApeldoorn	195476.84	469536.64	LIFE
32	FHVI 040	Bongerdpad 14	27-10-2021	24,0	195404.76	469947.23	WavinApeldoorn	195486.85	469538.67	LIFE
33	FHVI 041	Bongerdpad 11	26-10-2021	20,0	195410.12	469949.6	WavinApeldoorn	195486.85	469538.67	LIFE
34	FHVI 042	De Boomgaard 310	21-5-2021	12,0	197849.05	470578.52	WavinApeldoorn	197854.27	470574.14	LIFE
35	FHVI 043	Meester Boelenweg 12	11-10-2022	14,0	182105.16	474325.55	WavinApeldoorn	193000.32	470297.14	LIFE
36	FHVI 044	Voshuizen 16	24-5-2021	19,0	196236.47	463905.07	WavinApeldoorn	196236.07	463902.63	LIFE
37	FHVI 045	Voshuizen 16	24-5-2021	19,0	196234.24	463901.45	WavinApeldoorn	196236.07	463902.63	LIFE
38	FHVI 046	Voshuizen 15	24-5-2021	19,0	196220.49	463871.53	WavinApeldoorn	196220.7	463870.03	LIFE
39	FHVI 047	Koudhoornlaan 1	5-10-2021	22,0	192452.19	466046.5	WavinApeldoorn	192453.14	466047.25	LIFE
40	FHVI 048	Koudhoornlaan 4	5-10-2021	18,0	192441.32	466036.46	WavinApeldoorn	192442.78	466037.9	LIFE
41	FHVI 049	Koudhoornlaan 7	6-10-2021	18,0	192422.51	465984.21	WavinApeldoorn	192422.77	465985.47	LIFE
42	FHVI 050	Koudhoornlaan 11	6-10-2021	22,0	192412.62	465957.31	WavinApeldoorn	192413.15	465958.79	LIFE
43	FHVI 051	Koudhoornlaan 13	7-10-2021	23,0	192403.98	465931.67	WavinApeldoorn	192402.55	465929.69	LIFE
44	FHVI 052	Koudhoornlaan 20	7-10-2021	27,0	192399.24	465933.34	WavinApeldoorn	192398.76	465931.51	LIFE
45	FHVI 053	Leeuwenbergweg 4	21-10-2021	15,0	198348.58	459417.18	WavinApeldoorn	198353.01	459415.29	LIFE
46	FHVI 054	Leeuwenbergweg 17B	21-10-2021	20,0	198264.23	459353.81	WavinApeldoorn	198264.58	459354.78	LIFE
47	FHVI 055	Leeuwenbergweg 21B	13-9-2021	20,0	198252.89	459288.78	WavinApeldoorn	198253.29	459290.66	LIFE
48	FHVI 056	Leeuwenbergweg 52	14-9-2021	24,0	198229.85	459245.67	WavinApeldoorn	198228.23	459248.33	LIFE
49	FHVI 057	Engelenweg 7	12-11-2021	21,0	198220.56	459208.14	WavinApeldoorn	198220.17	459209.8	LIFE
50	FHVI 058	Engelenweg 7	12-11-2021	27,0	198230.04	459224.12	WavinApeldoorn	198231.69	459222.56	LIFE
51	FHVI 059	Engelenweg 5	15-9-2021	21,0	198265.34	459222.07	WavinApeldoorn	198269.08	459221.93	LIFE
52	FHVI 060	Engelenweg 10	15-9-2021	14,0	198305.66	459222.63	WavinApeldoorn	198305.43	459225.33	LIFE
53	FHVI 061	Engelenweg 2	12-11-2021	12,0	198336.13	459220.77	WavinApeldoorn	198338.29	459220.89	LIFE
54	FHVI 062	Reuweg 21	12-11-2021	30,0	198432.94	458843.39	HWZI	198506.29	458812.91	LIFE
55	FHVI 063	Reuweg 26	12-11-2021	30,0	198504.67	458814.78	HWZI	198506.29	458812.91	LIFE
56	FHVI 064	Reuweg 29	12-11-2021	30,0	198473.08	458830.01	HWZI	198506.29	458812.91	LIFE
57	FHVI 065	Haringvliet 3	12-11-2021	25,0	195201.59	466581.22	HWZI	195872.84	466819.86	LIFE
58	FHVI 066	Badhuisweg 45	24-11-2021	19,0	193699.22	470033.49	HWZI	193697.48	470033.52	LIFE
59	FHVI 067	Handelstraat 2	23-11-2021	18,0	193685.28	470023.18	HWZI	193687.54	470022.47	LIFE
60	FHVI 068	Winnemolenlaan 13	12-10-2021	17,0	192239.95	466106.42	WavinApeldoorn	192240.93	466107.55	LIFE
61	FHVI 069	Winnemolenlaan 19	16-11-2021	23,0	192217.93	466072.98	WavinApeldoorn	192220.37	466076.44	LIFE
62	FHVI 070	Merrijken Aertslaan 32	13-10-2021	19,0	192174.17	465997.44	WavinApeldoorn	192171.49	465998.81	LIFE
63	FHVI 071	Merrijken Aertslaan 28	13-10-2021	18,0	192201.91	465981.84	WavinApeldoorn	192203.34	465981.13	LIFE
64	FHVI 072	Merrijken Aertslaan 8	14-10-2021	17,5	192295.69	465957.03	WavinApeldoorn	192293.41	465956.91	LIFE
65	FHVI 073	Merrijken Aertslaan 2	14-10-2021	19,0	192313.39	465952.01	WavinApeldoorn	192314.9	465951.83	LIFE
66	FHVI 074	Tonissenlaan 13	15-11-2021	18,0	192278.83	466054.58	WavinApeldoorn	192278.07	466052.16	LIFE
67	FHVI 075	Tonissenlaan 22	15-11-2021	23,0	192289.84	466078.27	WavinApeldoorn	192289.8	466077.24	LIFE
68	FHVI 076	Tonissenlaan 30	8-10-2021	20,0	192281.9	466109.63	WavinApeldoorn	192281.82	466111.1	LIFE
69	FHVI 077	Javalaan 16	11-10-2022	20,0	193293.13	470448.5	HWZI	193279.34	470498	LIFE
70	FHVI 078	Angerenstein 18	8-12-2021	15,0	192508.49	465997.17	WavinApeldoorn	192509.15	465995.2	LIFE
71	FHVI 079	Angerenstein 29	8-12-2021	12,0	192552.53	465952.15	WavinApeldoorn	192554.47	465951.55	LIFE
72	FHVI 080	Angerenstein 44	7-12-2021	18,0	192608.14	465978.77	WavinApeldoorn	192606.19	465977.97	LIFE
73	FHVI 081	Angerenstein 46	7-12-2021	18,0	192636.43	465990.76	WavinApeldoorn	192637.49	465991.53	LIFE
74	FHVI 082	Hulkestein 25	18-11-2021	18,5	192779.41	466136.94	WavinApeldoorn	192778.59	466137.89	LIFE
75	FHVI 083	Hulkestein 13	18-11-2021	18,0	192776.76	466175.68	WavinApeldoorn	192776.59	466178.86	LIFE
76	FHVI 084	Hulkestein 6	22-11-2021	18,5	192723.52	466211.92	WavinApeldoorn	192724.23	466212.89	LIFE

77	FHVI 084A	Hulkestein 8	17-11-2021	18,5	192718.23	466203.83	WavinApeldoorn	192720.24	466205.67	LIFE
78	FHVI 085	Puttenstein 6	17-11-2021	19,0	192687.99	466179.31	HWZI	192688.38	466177.87	LIFE
79	FHVI 086	Puttenstein 12	16-11-2021	18,0	192650.22	466142.8	HWZI	192650.9	466142.12	LIFE
80	FHVI 087	Puttenstein 13	15-11-2021	17,5	192607.44	466096.53	HWZI	192605.67	466095.38	LIFE
81	FHVI 088	Rhienderstein 17	6-12-2021	18,5	192723.94	466012.08	HWZI	192722.47	466014.73	LIFE
82	FHVI 089	Arnhemseweg 503	2-3-2022	30,0	194271.7	463959.7	HWZI	194273.21	463958.41	LIFE
83	FHVI 090	Hagenweg 1	2-3-2022	30,0	194292.51	463957.47	HWZI	194293.79	463957.37	LIFE
84	FHVI 091	Hagenweg 3	1-3-2022	28,0	194314.07	463955.61	HWZI	194315.43	463955.95	LIFE
85	FHVI 092	Hagenweg 7	2-3-2022	28,0	194346.03	463954.13	HWZI	194347.78	463953.88	LIFE
86	FHVI 093	Hagenweg 4	2-3-2022	30,0	194341.2	463938.15	HWZI	194340.9	463939.95	LIFE
87	FHVI 094	Waterjufferstraat 40	3-3-2022	28,0	194339.34	463925.14	HWZI	194337.69	463923.44	LIFE
88	FHVI 095	Waterjufferstraat 32	3-3-2022	27,0	194329.68	463882.03	HWZI	194327.76	463879.68	LIFE
89	FHVI 096	Krimweg 33	7-3-2022	22,0	189057.1	459085.6	HWZI	188424.65	458926.56	LIFE
90	FHVI 097	Krimweg 2B	7-3-2022	20,0	188425.9	458927.66	HWZI	188424.65	458926.56	LIFE
91	FHVI 098	Krimweg 25	25-11-2021	25,0	188882.44	458978.38	HWZI	188424.65	458926.56	LIFE
92	FHVI 099	Krimweg 33	24-11-2021	24,0	188951.28	459081.88	HWZI	188424.65	458926.56	LIFE
93	FHVI 100	Doornenburg 35	4-11-2021	15,0	192047.85	466586.51	HWZI	192046.36	466586.89	LIFE
94	FHVI 101	Doornenburg 33	4-11-2021	15,0	192083.66	466561.15	HWZI	192081.54	466561.9	LIFE
95	FHVI 102	Doornenburg 20	3-11-2021	15,0	192093.42	466545.26	HWZI	192091.97	466545.95	LIFE
96	FHVI 103	Doornenburg 7	3-11-2021	15,0	192110	466480.04	HWZI	192109.74	466481.48	LIFE
97	FHVI 104	Doornenburg 19	2-11-2021	15,0	192097.74	466515.44	HWZI	192097.89	466517.14	LIFE
98	FHVI 105	Doornenburg 4	18-10-2022	14,5	192118.36	466450.08	WavinApeldoorn	192117.84	466452.34	LIFE
99	FHVI 106	Doornenburg 1	17-11-2022	15,0	192126.44	466418.59	WavinApeldoorn	192127.01	466416.22	LIFE
100	FHVI 107	Essenburg 1	1-11-2021	15,0	192090.63	466458.72	HWZI	192092.32	466458.7	LIFE
101	FHVI 108	Essenburg 11	27-12-2021	15,0	192069.45	466449.38	HWZI	192067.4	466448.09	LIFE
102	FHVI 109	Boogaardslaan 26	13-12-2021	19,5	192838.91	466449.38	HWZI	192836.8	466451.69	LIFE
103	FHVI 109A	Boogaardslaan 26	10-12-2021	19,0	192837.85	466450.42	HWZI	192836.8	466451.69	LIFE
104	FHVI 110	Boogaardslaan 32	14-12-2021	18,5	192793.9	466427.78	HWZI	192792.63	466427	LIFE
105	FHVI 111	Boogaardslaan 42	15-12-2021	19,0	192755.99	466395.73	HWZI	192754.89	466395.08	LIFE
106	FHVI 112	Boogaardslaan 50	16-12-2021	23,0	192719.9	466370.37	HWZI	192718.32	466369.2	LIFE
107	FHVI 113	Boogaardslaan 100	17-12-2021	23,0	192661.51	466332.32	HWZI	192663.45	466333.77	LIFE
108	FHVI 114	Boogaardslaan 106	17-12-2021	20,0	192636.56	466315.88	HWZI	192634.92	466314.99	LIFE
109	FHVI 115	Boogaardslaan 158	20-12-2021	18,5	192582.21	466281.32	HWZI	192584.13	466282.27	LIFE
110	FHVI 116	Ugchelsegrensweg 103	1-12-2021	24,0	192600.26	466727.96	WavinApeldoorn	192598.67	466728	LIFE
111	FHVI 117	Ugchelsegrensweg 141	30-11-2021	16,5	192469.82	466756.67	WavinApeldoorn	192470.93	466757.45	LIFE
112	FHVI 118	Ugchelsegrensweg 20	1-12-2021	22,0	192681.09	466711.24	WavinApeldoorn	192678.96	466712.06	LIFE
113	FHVI 119	Ugchelseweg 70a	2-12-2021	23,0	192838.84	466663.86	WavinApeldoorn	192836.68	466665.32	LIFE
114	FHVI 120	Klein Hattem 23	21-7-2022	24,0	193238.87	466934.63	HWZI	192836.68	466665.32	LIFE
115	FHVI 121	Klein Hattem 33	21-7-2022	29,5	193218.8	466888.08	HWZI	192836.68	466665.32	LIFE
116	FHVI 122	Klein Hattem 51	21-7-2022	30,0	193200.41	466845.72	HWZI	192836.68	466665.32	LIFE
117	FHVI 123	Klein Hattem 61	21-7-2022	22,5	193172.54	466791.93	HWZI	192836.68	466665.32	LIFE
118	FHVI 124	Klein Hattem 69	21-7-2022	17,0	193149.12	466753.74	HWZI	192836.68	466665.32	LIFE
119	FHVI 125a	Molenstraat 106	21-7-2022	27,5	195367.76	469517.1	HWZI	195369.09	469516.29	LIFE
120	FHVI 125b	Molenstraat 106	21-7-2022	27,5	195375.14	469518.77	HWZI	195369.09	469516.29	LIFE
121	FHVI 126a	Molenstraat 127	21-7-2022	32,0	195425.73	469528.95	HWZI	195426.79	469527.1	LIFE
122	FHVI 126b	Molenstraat 127	21-7-2022	32,0	195431.44	469529.64	HWZI	195426.79	469527.1	LIFE
123	FHVI 127a	Molenstraat 131	21-7-2022	31,5	195475.9	469537.73	HWZI	195476.84	469536.64	LIFE
124	FHVI 127b	Molenstraat 131	21-7-2022	31,5	195480.5	469538.56	HWZI	195476.84	469536.64	LIFE
125	FHVI 127c	Molenstraat 131	21-7-2022	33,0	195484.68	469538.98	HWZI	195486.85	469538.67	LIFE
126	FHVI 127d	Molenstraat 131	21-7-2022	33,0	195489.14	469539.96	HWZI	195486.85	469538.67	LIFE
127	FHVI 128a	Molenstraat 145	20-7-2022	30,5	195561.74	469554.45	HWZI	195563.16	469553.89	LIFE
128	FHVI 128b	Molenstraat 145	20-7-2022	30,5	195567.73	469555.7	HWZI	195565.27	469554.34	LIFE
129	FHVI 129	Molenstraat 149	21-7-2022	32,0	195605.5	469568.94	HWZI	195606.38	469568.31	LIFE
130	FHVI 130	Molenstraat 136	24-5-2022	32,0	195614.42	469573.12	HWZI	195614.24	469571.96	LIFE
131	FHVI 131a	Molenstraat 155	20-7-2022	33,0	195659.99	469594.03	HWZI	195663.12	469594.61	LIFE
132	FHVI 131b	Molenstraat 155	20-7-2022	33,0	195665.43	469596.54	HWZI	195663.12	469594.61	LIFE
133	FHVI 132a	Molenstraat 165	20-7-2022	31,5	195689.99	469608.16	HWZI	195692.8	469608.27	LIFE
134	FHVI 132b	Molenstraat 165	20-7-2022	31,5	195694.08	469609.95	HWZI	195692.8	469608.27	LIFE
135	FHVI 133a	Molenstraat 171	20-7-2022	36,0	195721.03	469622.18	HWZI	195723.58	469622.36	LIFE
136	FHVI 133b	Molenstraat 171	20-7-2022	36,0	195726.05	469624.97	HWZI	195723.58	469622.36	LIFE
137	FHVI 134a	Molenstraat 179	20-7-2022	32,0	195762.28	469641.55	HWZI	195765.57	469642.15	LIFE
138	FHVI 134b	Molenstraat 179	20-7-2022	32,0	195766.46	469643.92	HWZI	195765.57	469642.15	LIFE
139	FHVI 135a	Molenstraat 183	20-7-2022	32,5	195774.54	469647.54	HWZI	195776.91	469647.81	LIFE
140	FHVI 135b	Molenstraat 183	20-7-2022	32,5	195779.28	469649.91	HWZI	195776.91	469647.81	LIFE
141	FHVI 136a	Molenstraat 168	20-7-2022	32,0	195808.82	469662.31	HWZI	195808.01	469664	LIFE
142	FHVI 136b	Molenstraat 168	20-7-2022	32,0	195812.17	469665.52	HWZI	195808.01	469664	LIFE
143	FHVI 137a	Molenstraat 193	20-7-2022	29,5	195814.68	469677.92	HWZI	195817.18	469678.64	LIFE
144	FHVI 137b	Molenstraat 193	20-7-2022	29,5	195818.58	469682.1	HWZI	195817.18	469678.64	LIFE
145	FHVI 142	De Hegge 2	21-7-2022	18,5	193000.48	470282.11	HWZI	193000.38	470284.66	LIFE
146	FHVI 143	De Hegge 2	21-7-2022	18,5	192999.92	470299.11	HWZI	193000.32	470297.14	LIFE
147	FHVI 144	De Hegge 4B	21-7-2022	18,0	193007.72	470258.14	HWZI	193006.33	470258.95	LIFE
148	FHVI 145	De Hegge 10	21-7-2022	16,5	193014.97	470219.12	HWZI	193013.71	470221.92	LIFE
149	FHVI 146	De Hegge 14	21-7-2022	18,0	193020.54	470194.04	HWZI	193017.44	470193.05	LIFE
150	FHVI 147	De Hegge 18	21-7-2022	17,5	193027.23	470163.93	HWZI	193025.56	470165.24	LIFE
151	FHVI 148	Timorlaan 5	11-10-2022	16,0	193276.68	470499.51	HWZI	193279.34	470498	LIFE
152	FHVI 149	Timorlaan 11	11-10-2022	22,0	193254.67	470548.84	HWZI	193256.37	470547.18	LIFE

4. Annex - Blue-print FHVI-site Apeldoorn



- * Maximaal 400m² afkoppelen op 1 FHVI systeem
- infiltratiegedeelte mag niet in de rijbaan, Voorkeurslocatie berm, dan trottoir, dan parkeren.
- * Alle hulpstukken van PP tenzij het product aantoonbaar niet leverbaar is dan mag uitsluitend in overleg PVC gebruikt worden.
- * Straatkolk type Tegra toepassen bij waterberging/infiltratie

STANDAARDEDETAILS

Marktplein 1, 7311 LG Apeldoorn Telefoon 14055 (Algemeen)

Principe infiltratievoorziening tbv meerdere kolken
FHVI (Fast High Volume Infiltration)
met voorfilterput (HWZI)
max. 400m² afkoppelen

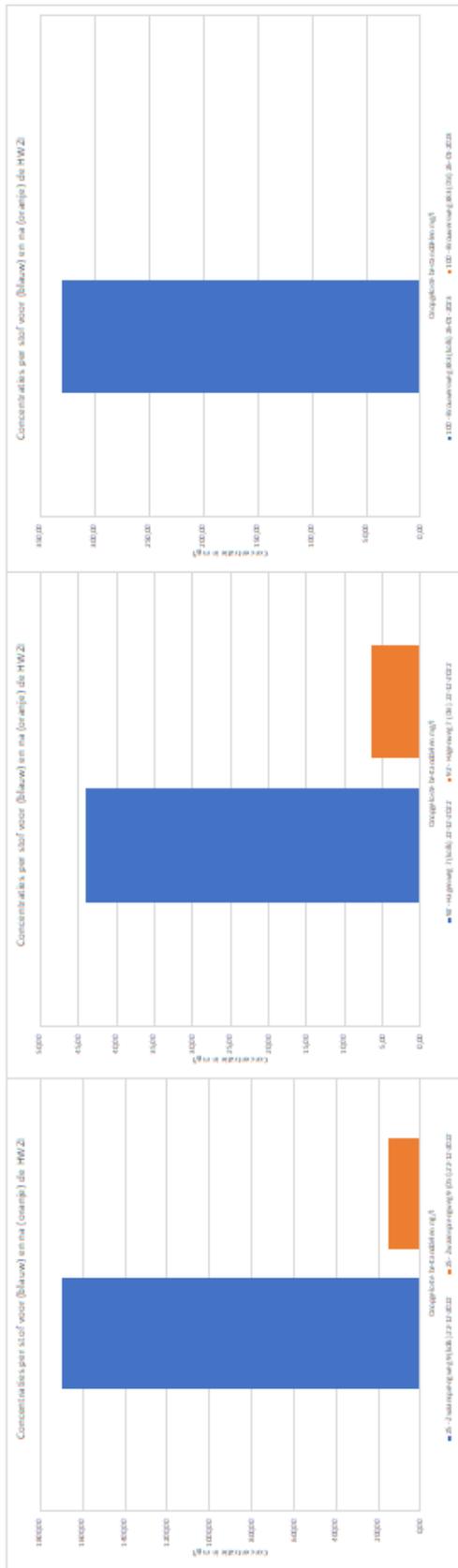
 **Apeldoorn**

Laatst gewijzigd d.d.	Getekend	Versie	Schaal	Formaat	Tek nr.
24-04-2023	Afdeling Ruimtelijk Ontwerp en Realisatie	2024-1	1: 50	A4	SD2- 15 A

5. Annex - Graps of waterqualiy analysis in gutter before pre-filter and in the FHVI-well.

Figure @. In blue the amount of undissolved component in the gutter. In orange in the FHVI-well.

Undissolved components

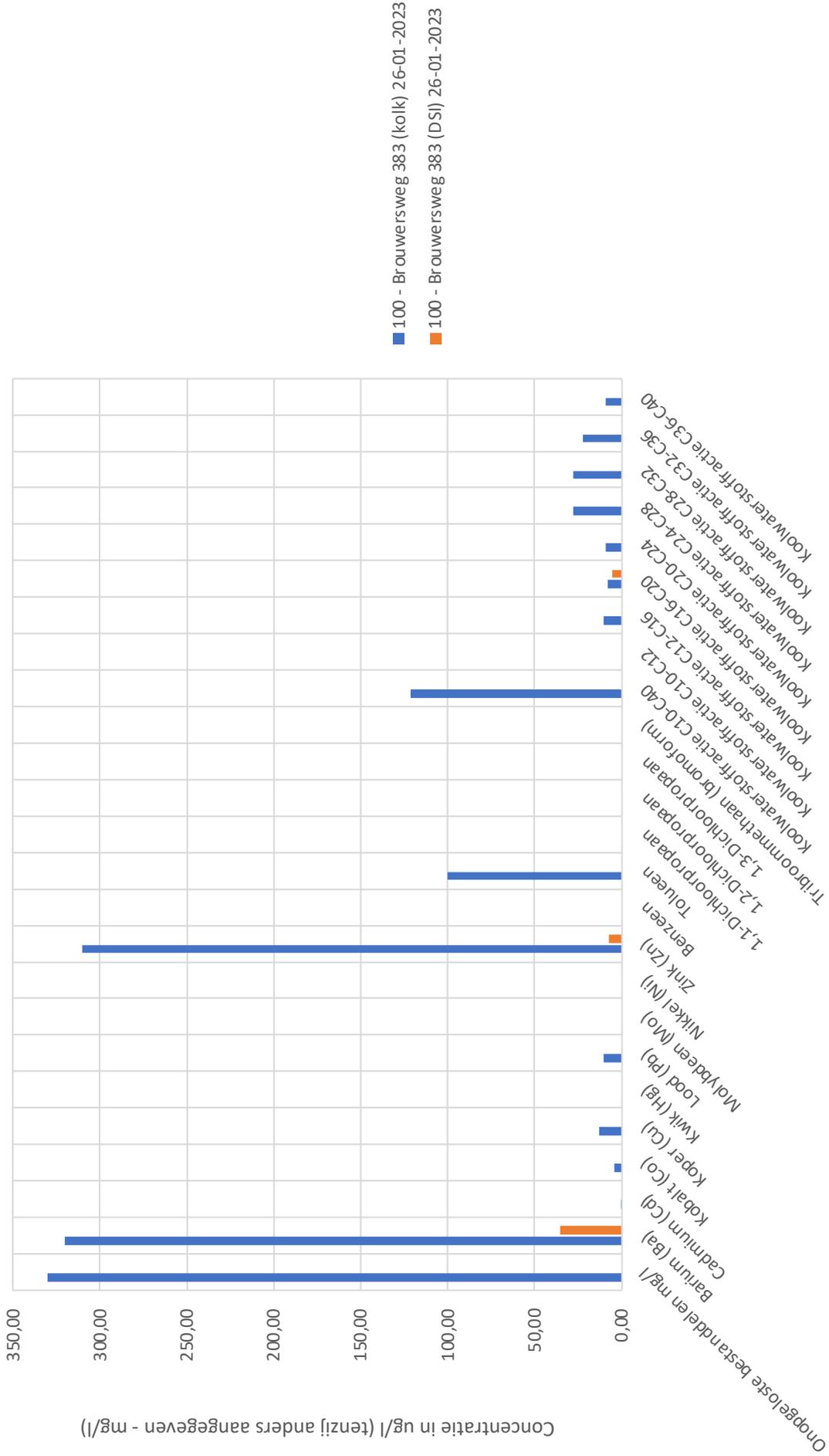


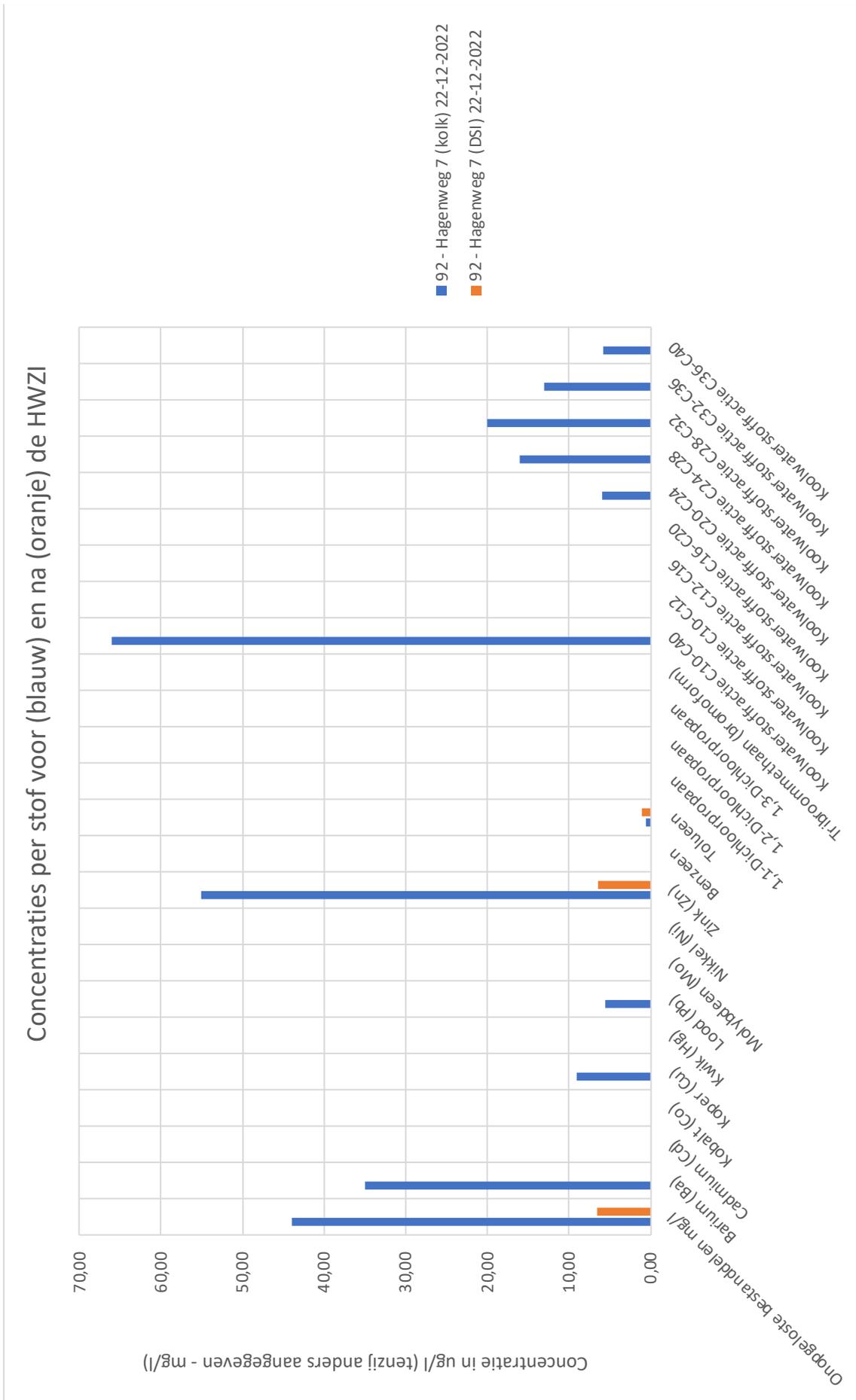
Zwaansprengweg

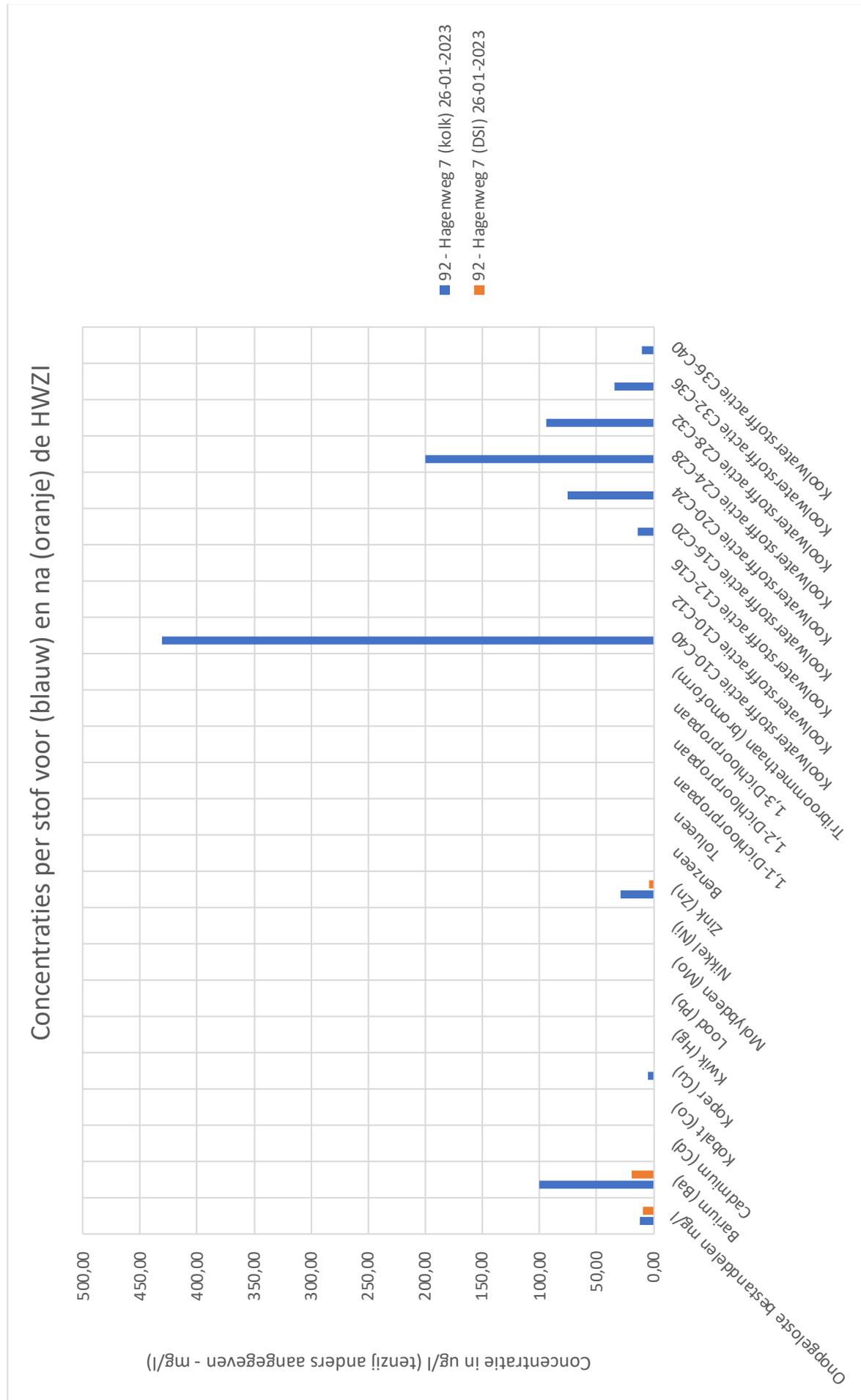
Hagenweg

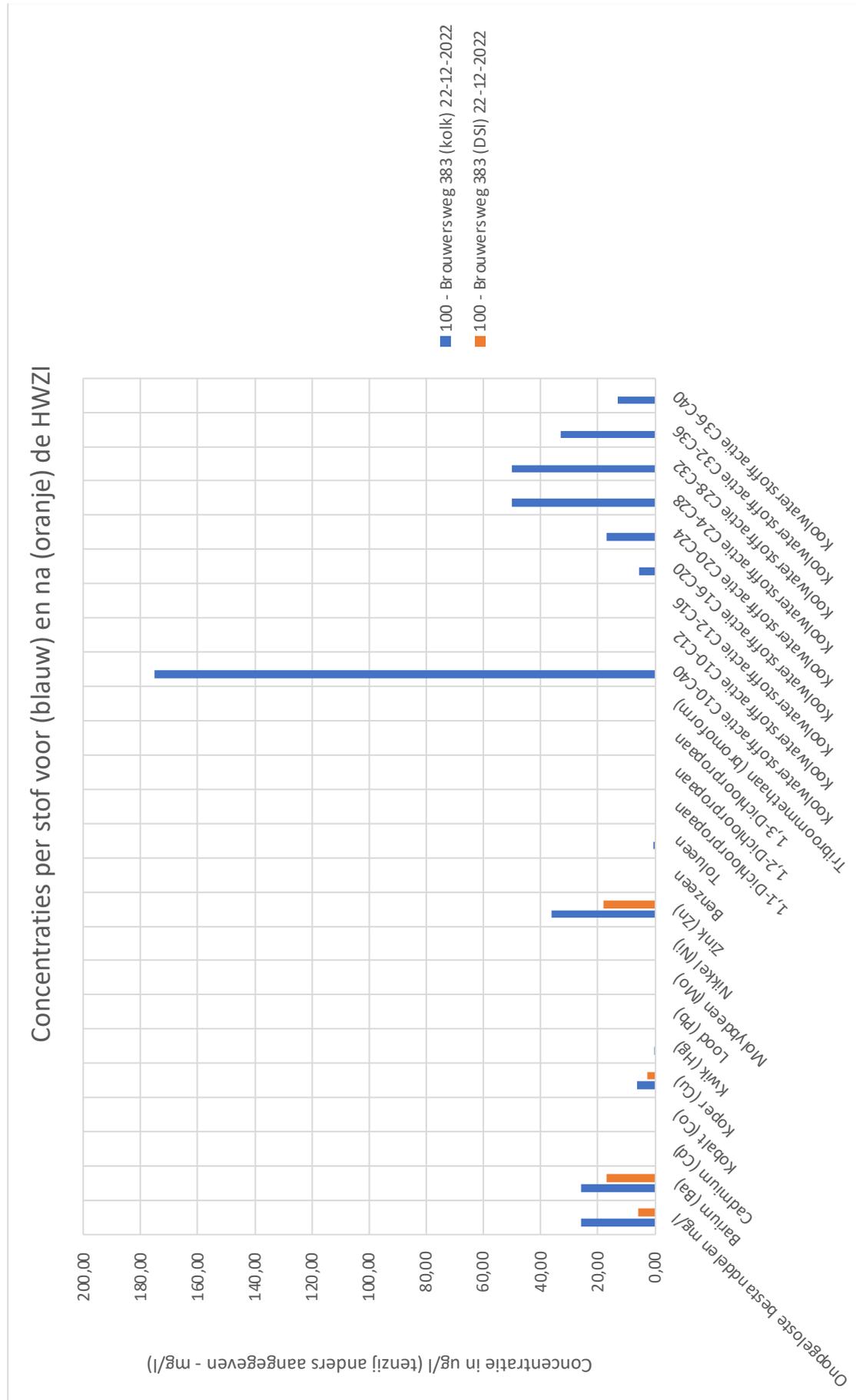
Brouwersweg

Concentraties per stof voor (blauw) en na (oranje) de HWZI

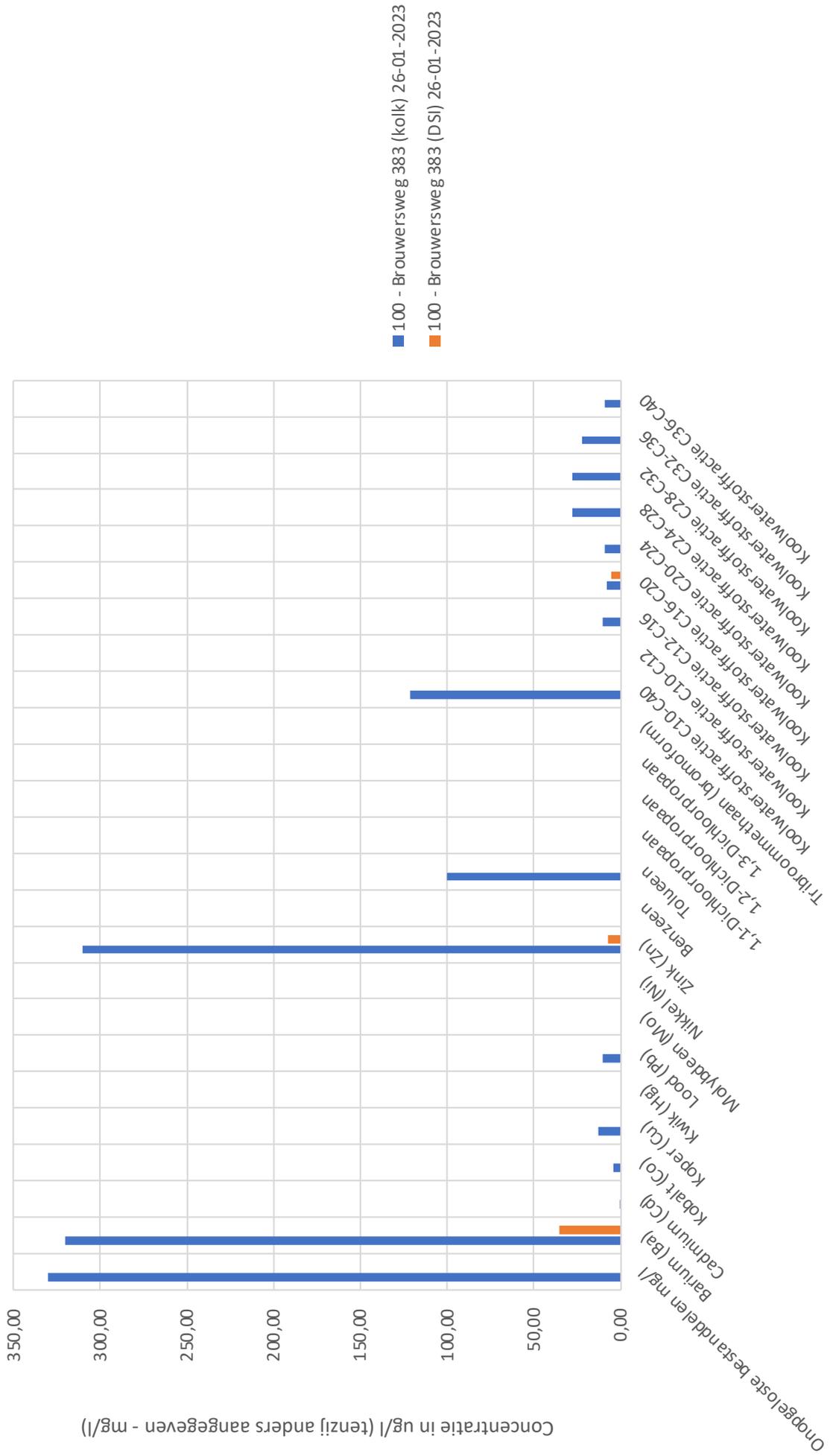








Concentraties per stof voor (blauw) en na (oranje) de HWZI



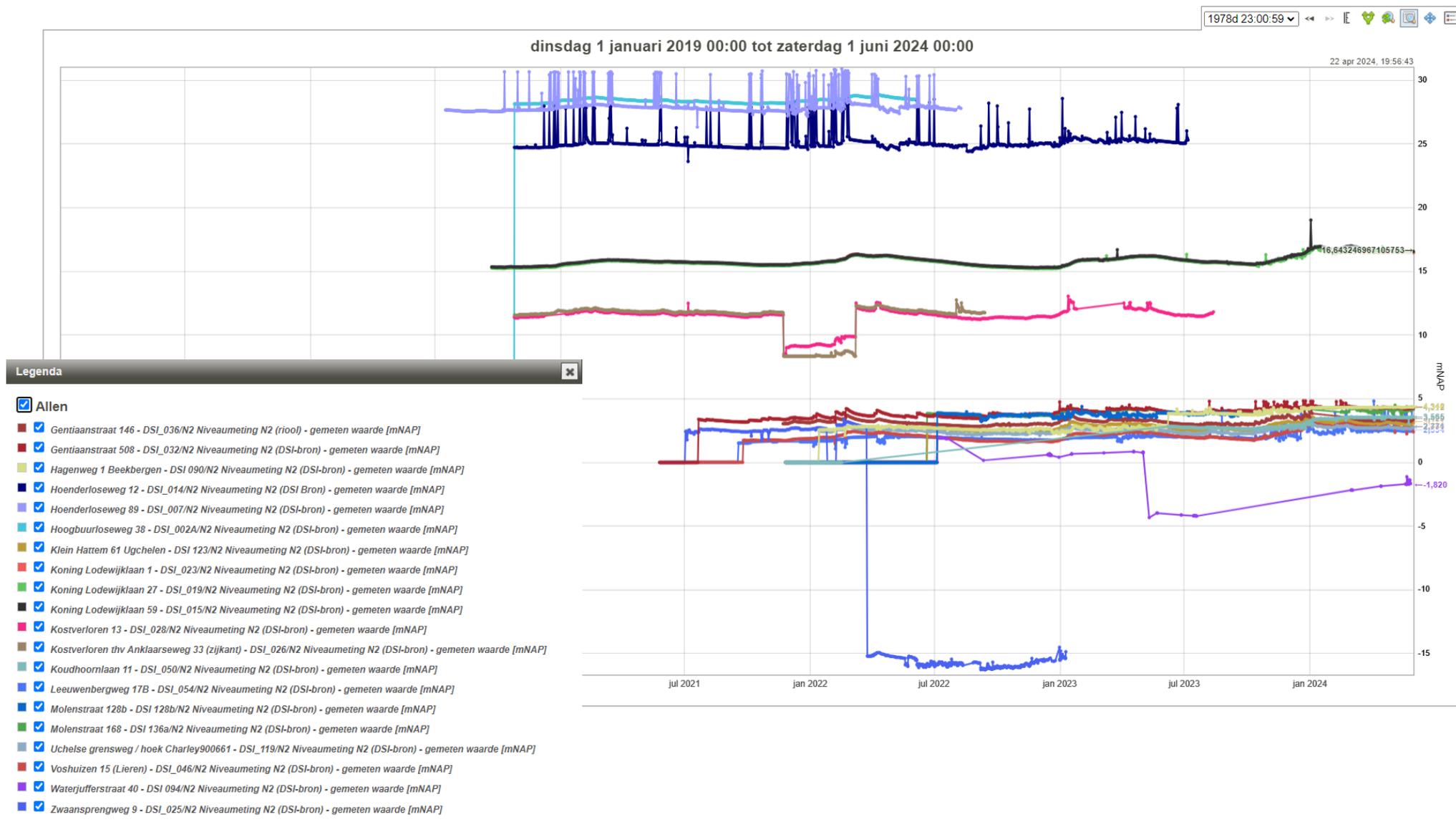
6. Annex – data of all automated water level measurements with FHVI systems

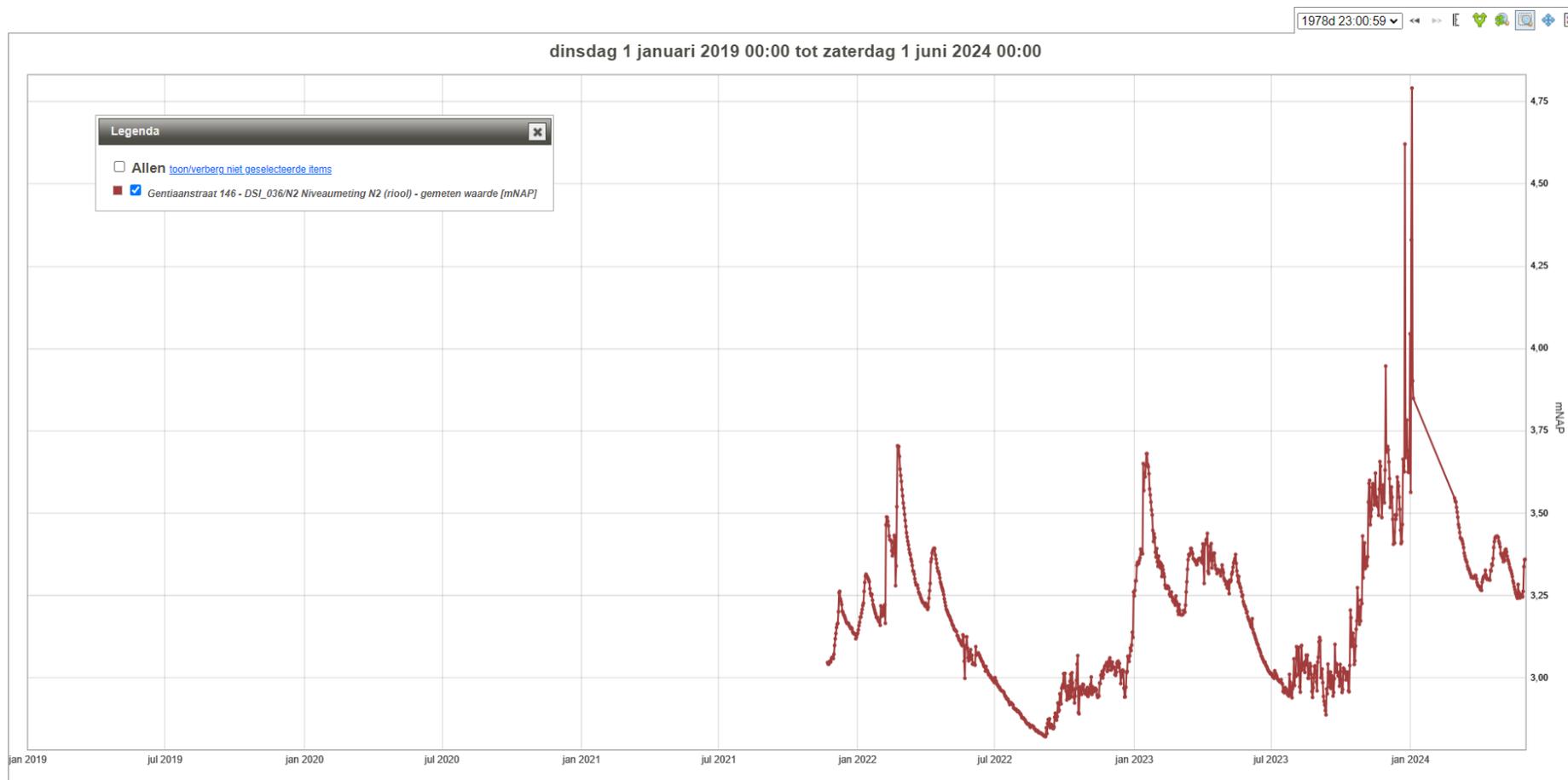
Bemeten FHVI/ DSI locaties

DSI_036 - Gentiaanstraat 146
DSI_032 - Gentiaanstraat 508
DSI_090 - Hagenweg 1 Beekbergen
DSI_014 - Hoenderloseweg 12
DSI_007 - Hoenderloseweg 89
DSI_002A - Hoogbuurloseweg 38
DSI_123 - Klein Hattem 61 Ugchelen
DSI_023 - Koning Lodewijklaan 1
DSI_019 - Koning Lodewijklaan 27
DSI_015 - Koning Lodewijklaan 59
DSI_028 - Kostverloren 13
DSI_026 - Kostverloren thv Anklaarseweg 33 (zijkant)
DSI_050 - Koudhoornlaan 11
DSI_054 - Leeuwenbergweg 17B
DSI_128b - Molenstraat 128b
DSI_136a - Molenstraat 168
DSI_119 - Uchelse grensweg / hoek Charley900661
DSI_046 - Voshuizen 15 (Lieren)
DSI_094 - Waterjufferstraat 40
DSI_025 - Zwaansprengweg 9

Meteorological stations

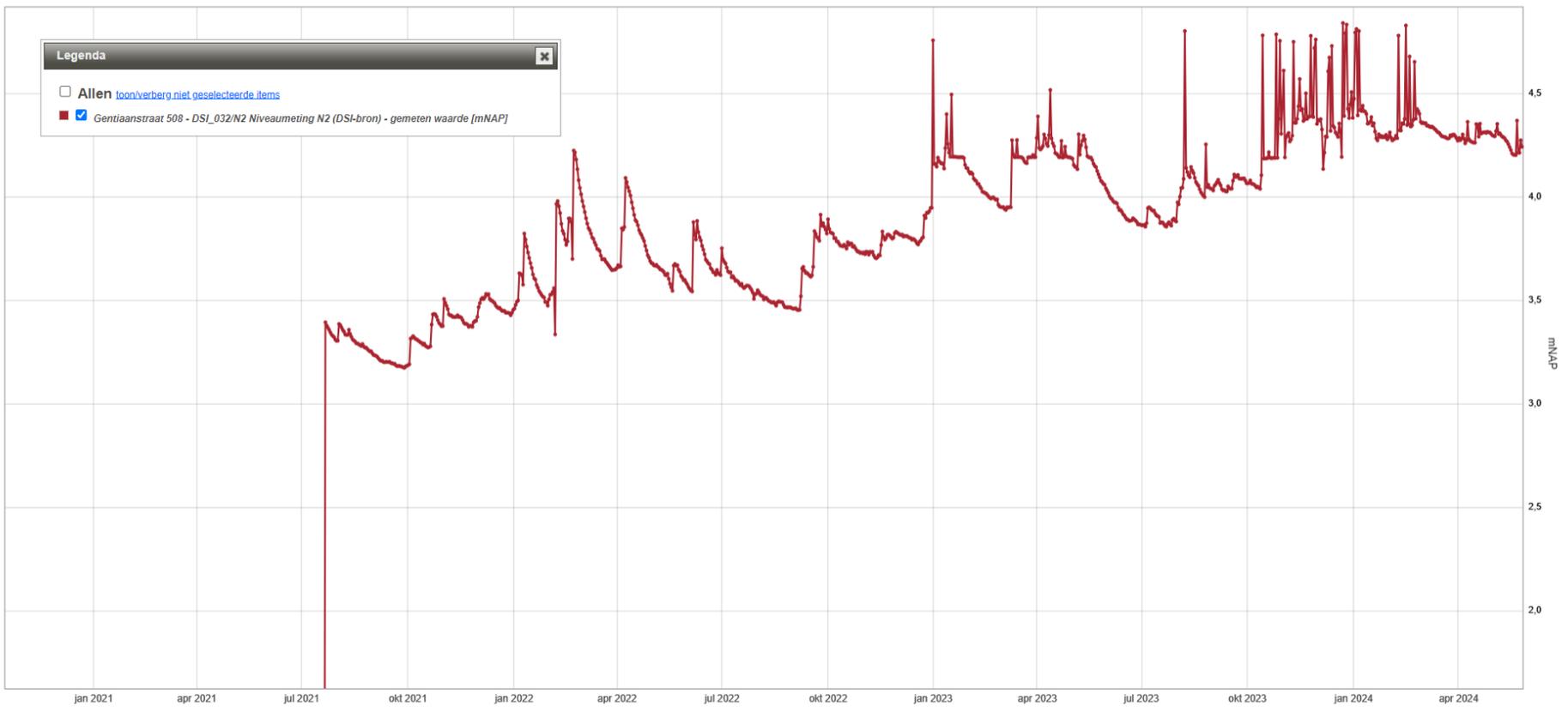
275 - Meteorologisch station Deelen
567 - Neerslag station Kootwijk Radio

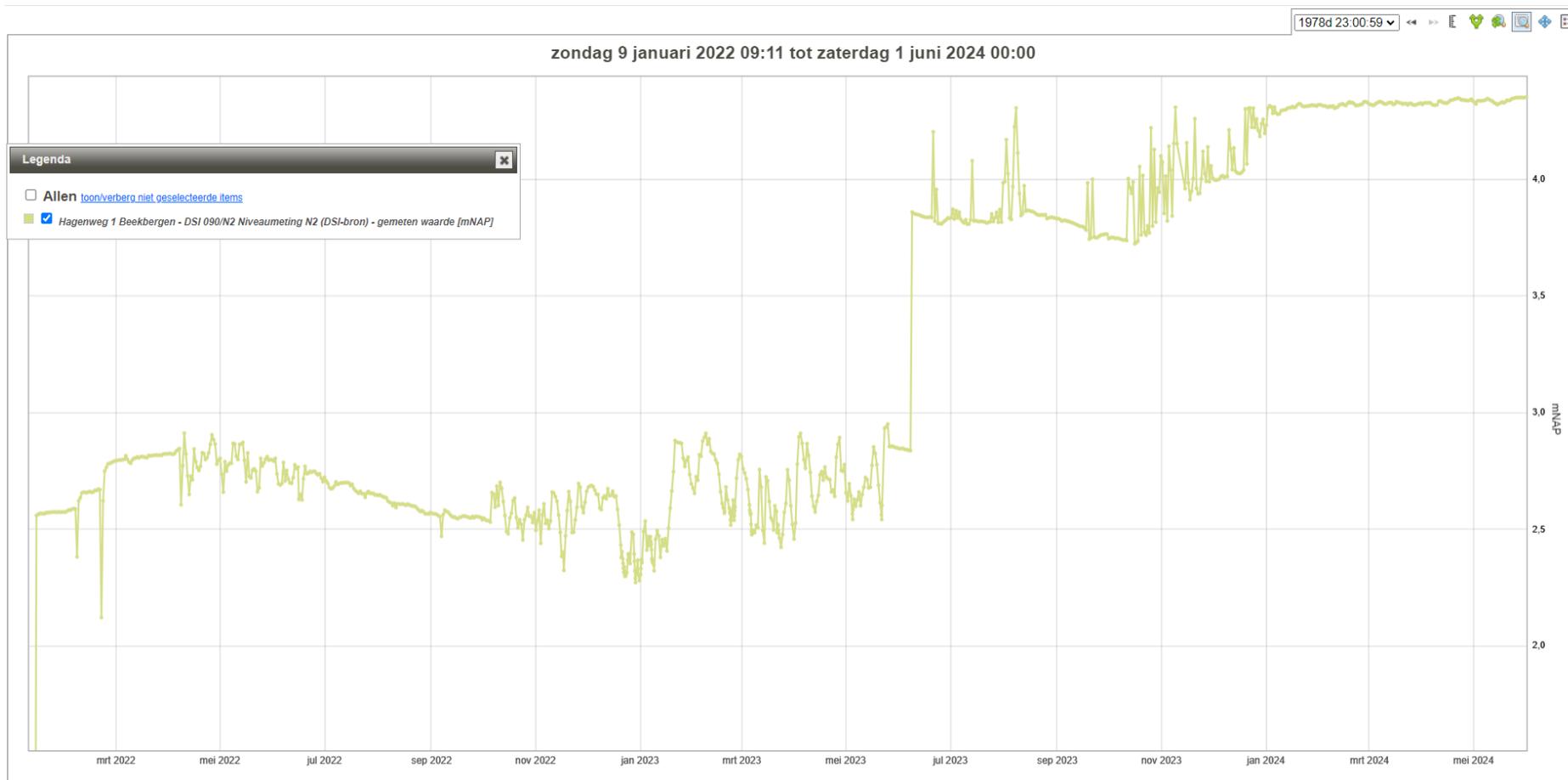


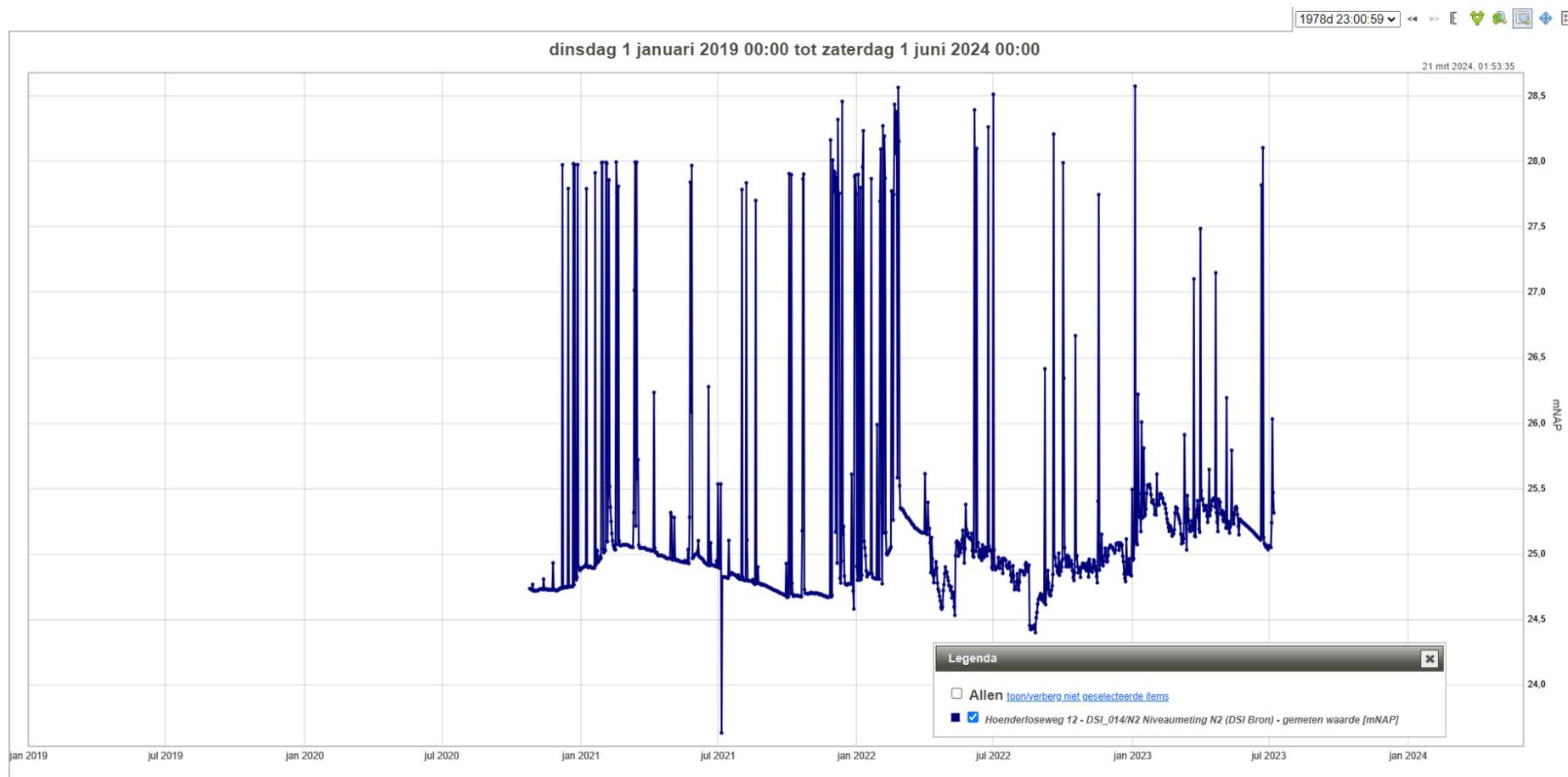


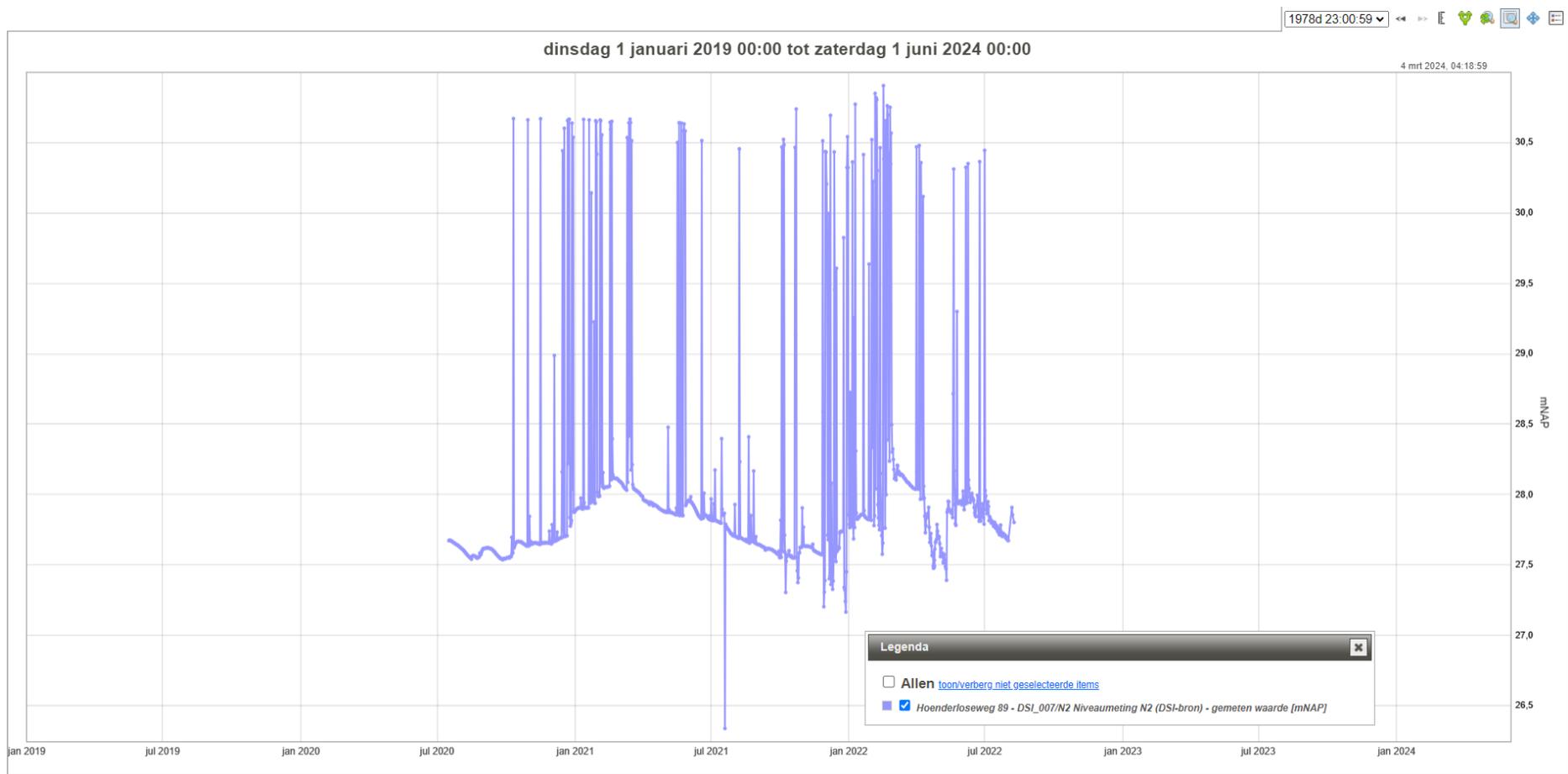
1978d 23:00:59 << >> [E] [G] [H] [I] [J] [K]

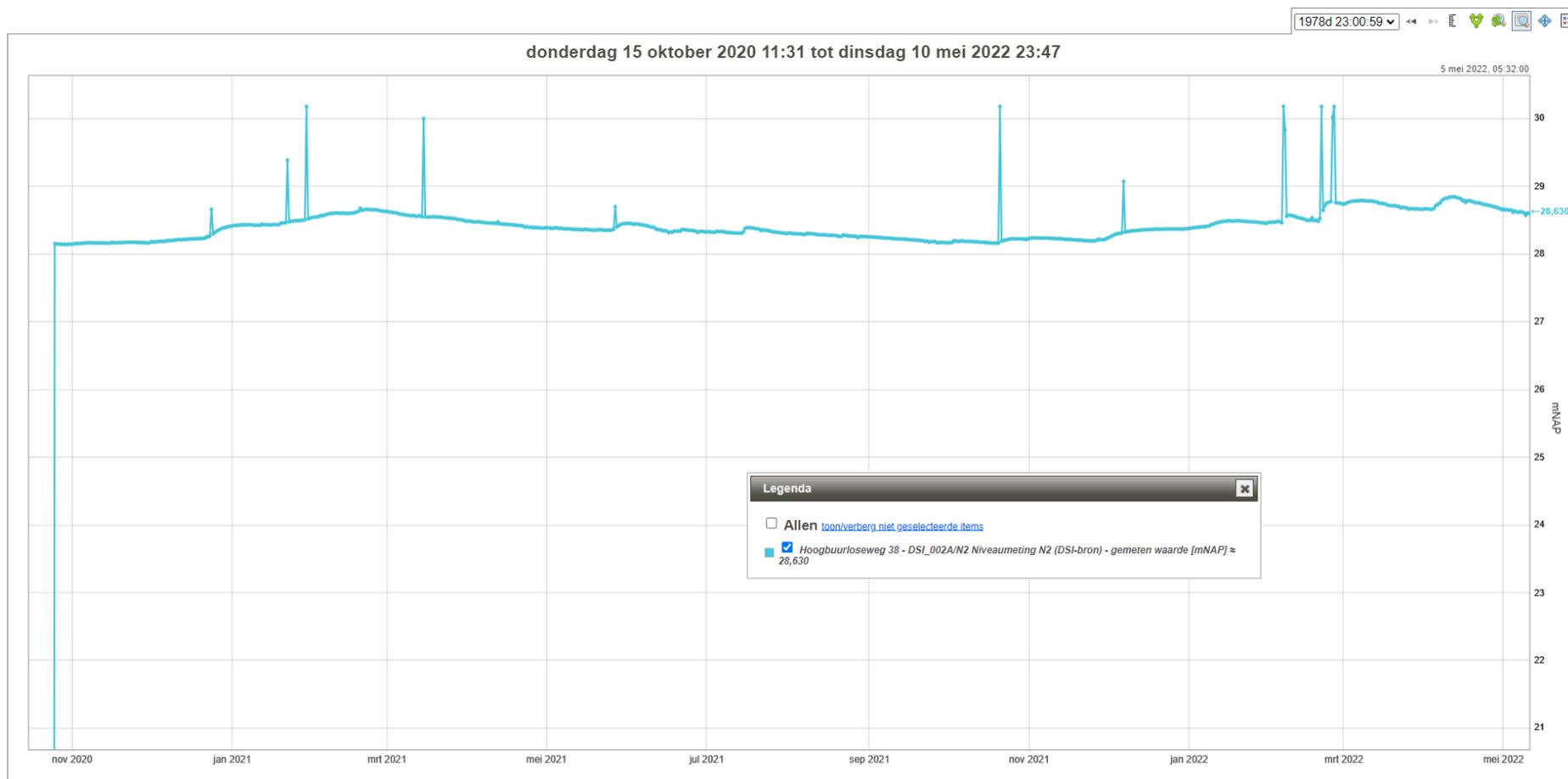
vrijdag 16 oktober 2020 07:42 tot zondag 26 mei 2024 23:03

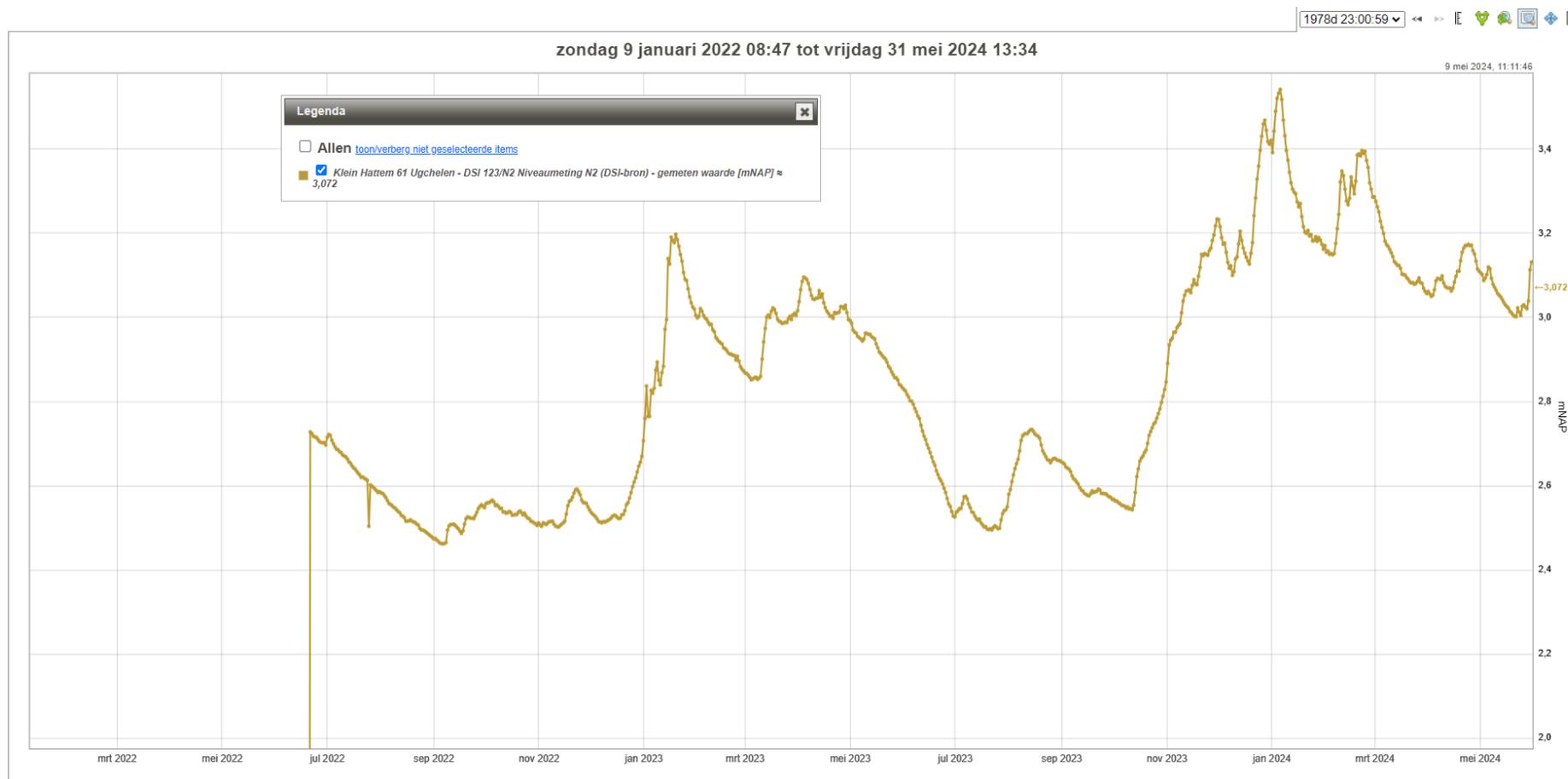


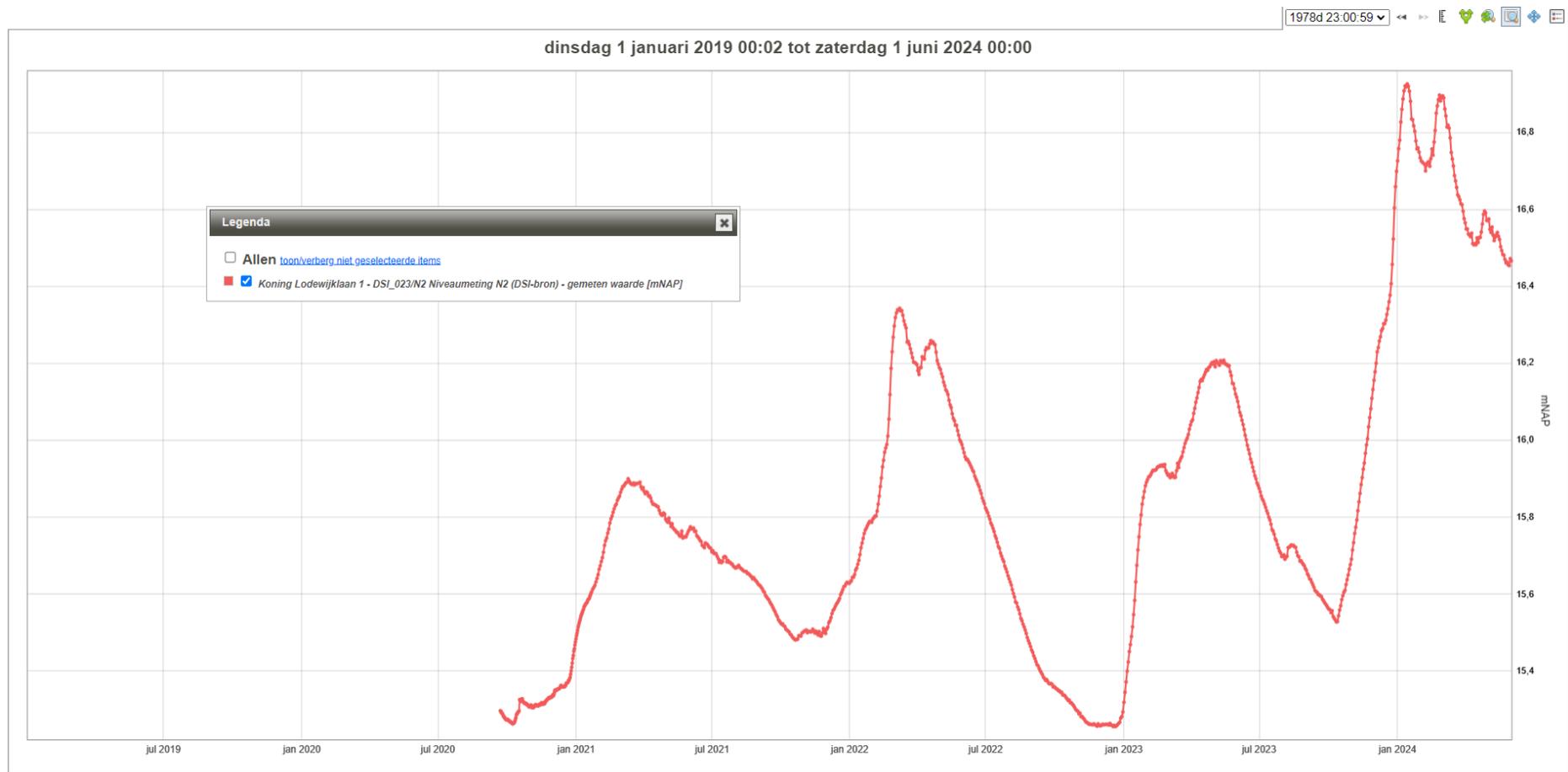






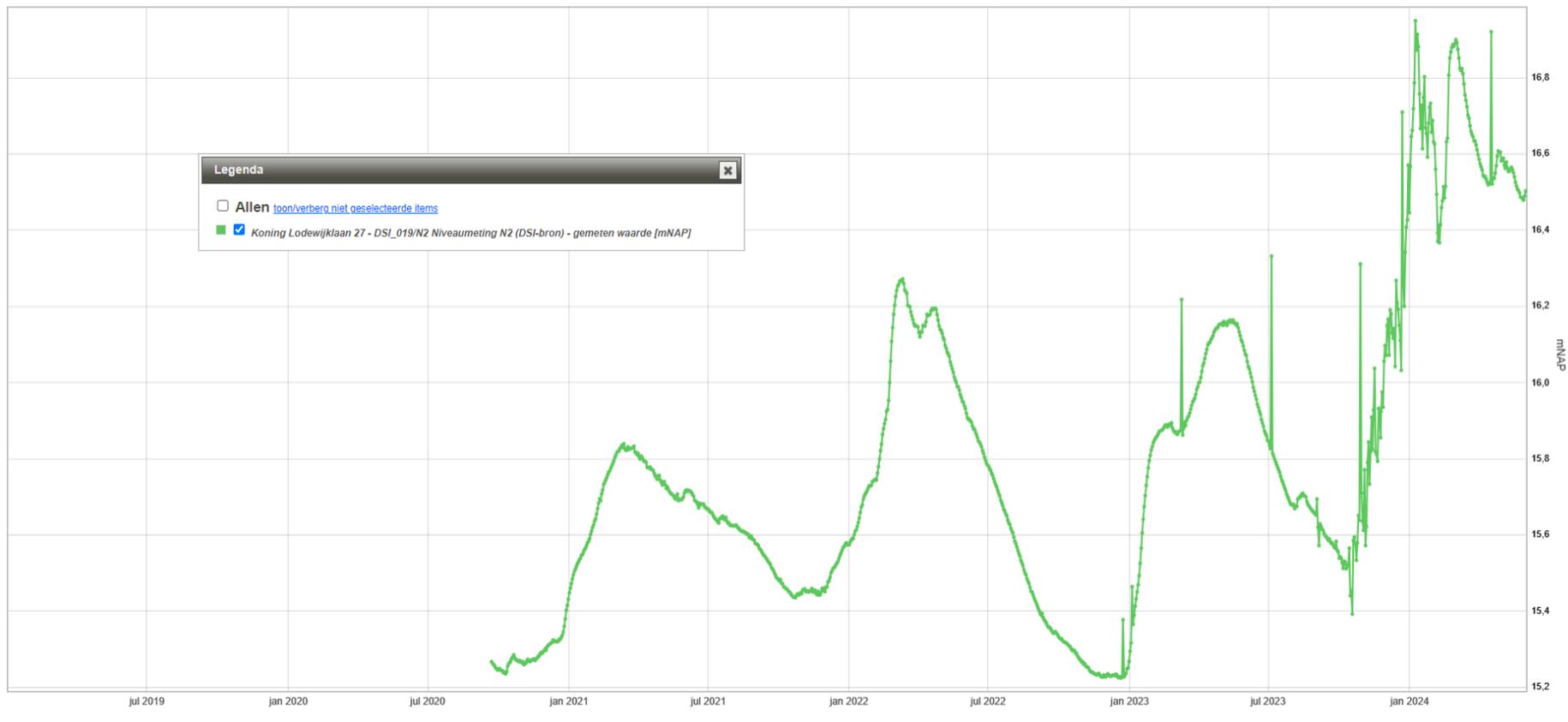


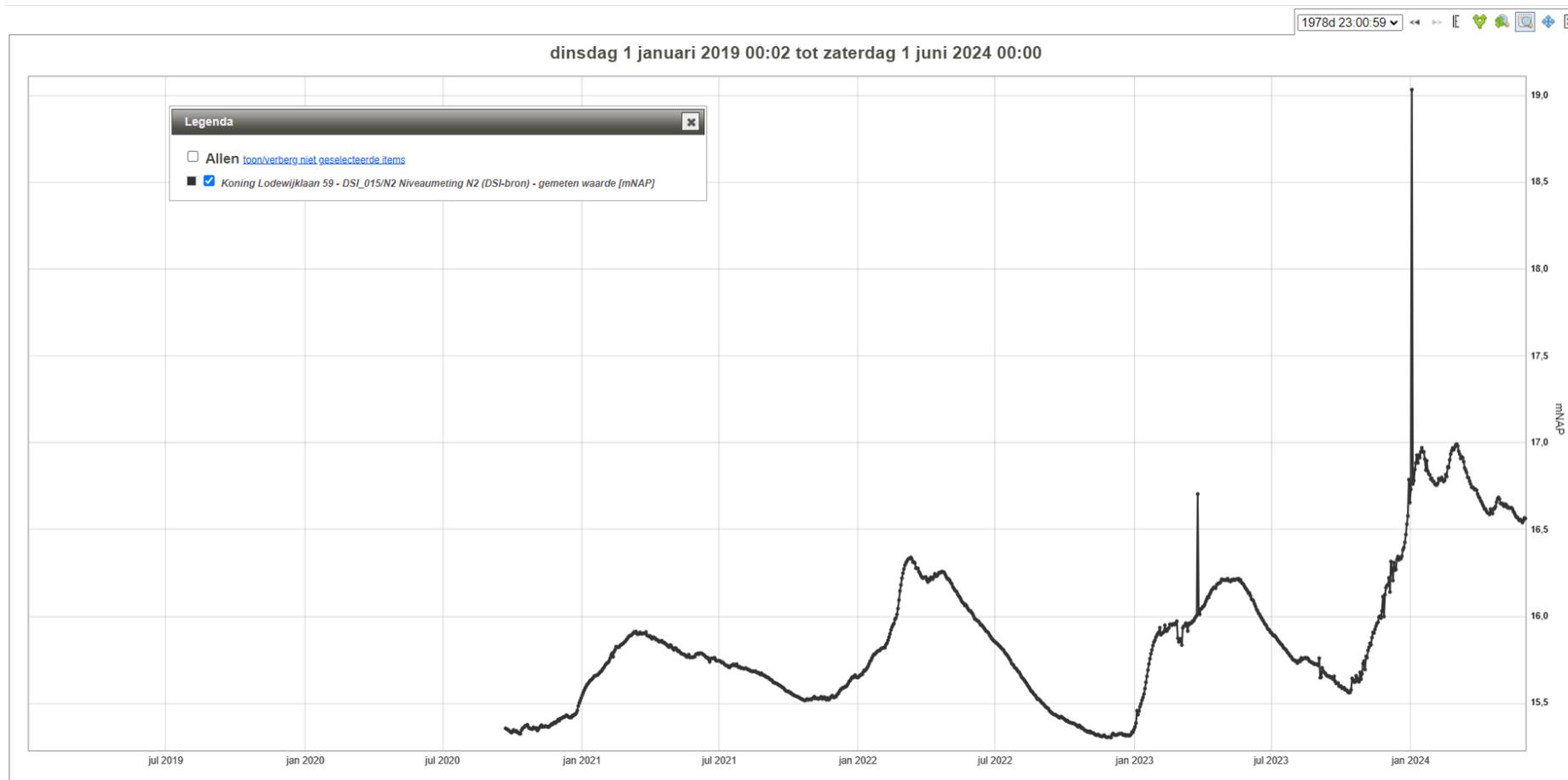




1978d 23:00:59

dinsdag 1 januari 1919 00:02 tot zaterdag 1 juni 2024 00:00





1978d 23:00:59 << >> [E] [V] [G] [A] [Z]

dinsdag 1 januari 1919 00:02 tot zaterdag 1 juni 2024 00:00

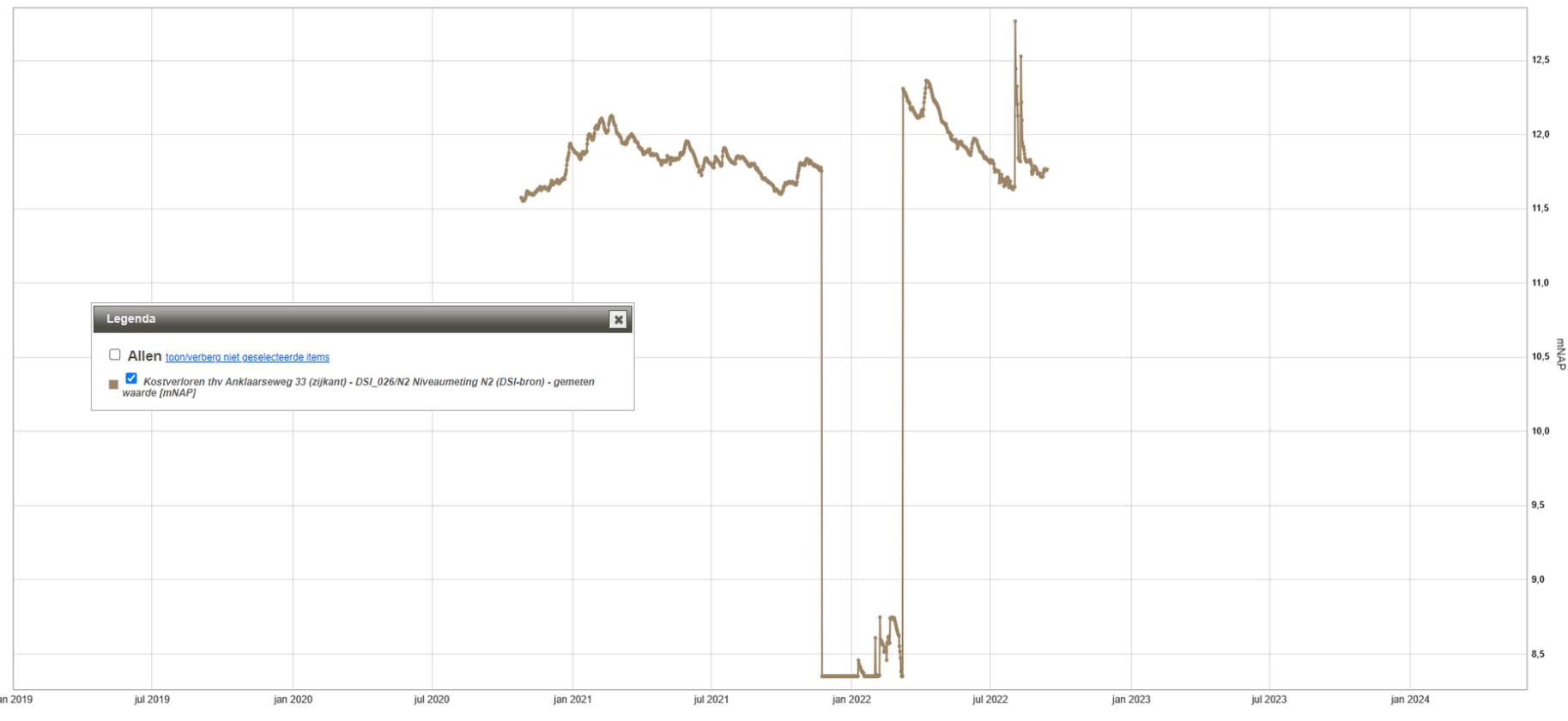
Legenda [X]

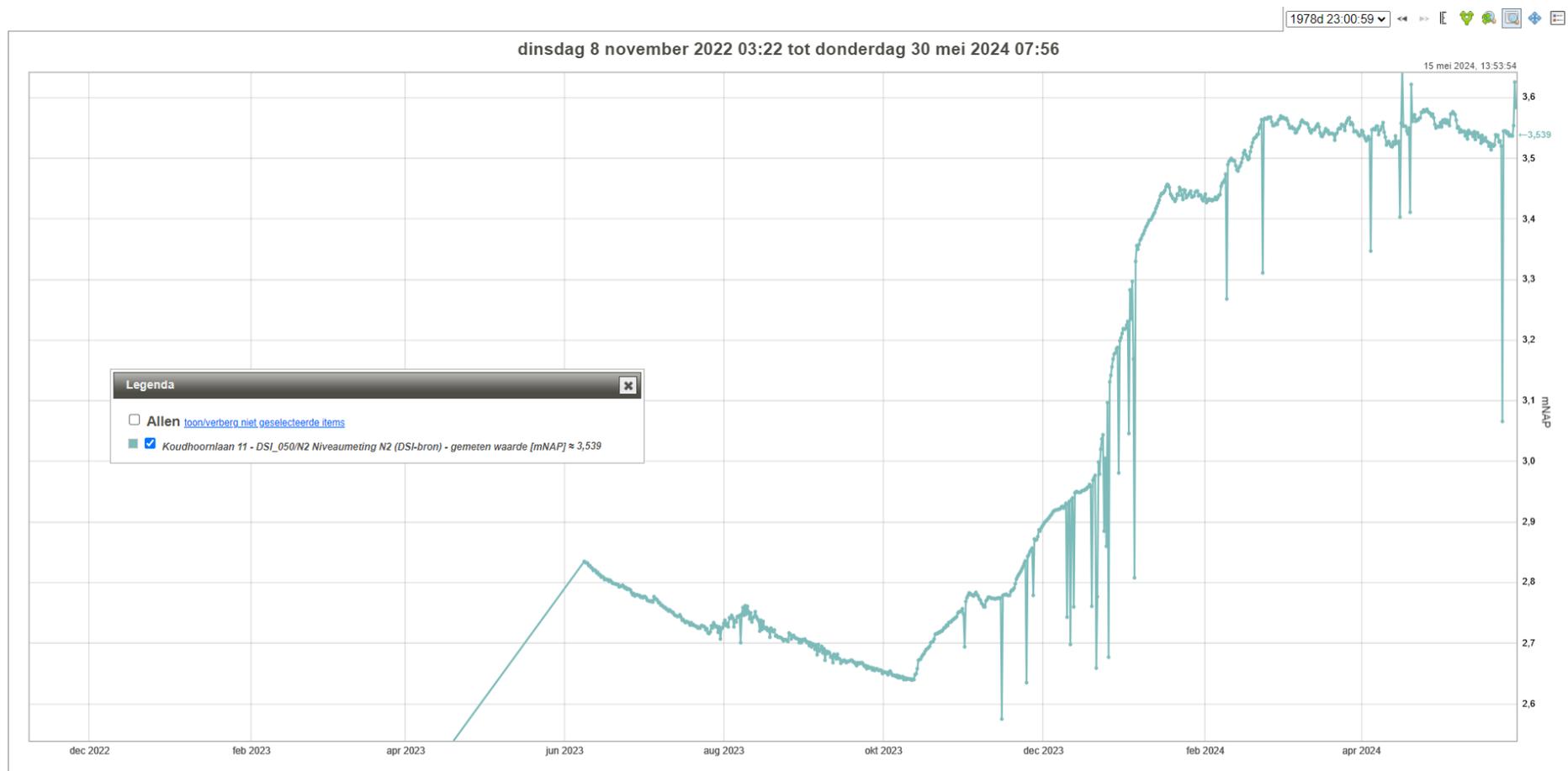
- Allen** [toon/verberg niet geselecteerde items](#)
- Kostverloren 13 - DSL_028/N2 Niveaumeting N2 (DSL-bron) - gemeten waarde [mNAP]**

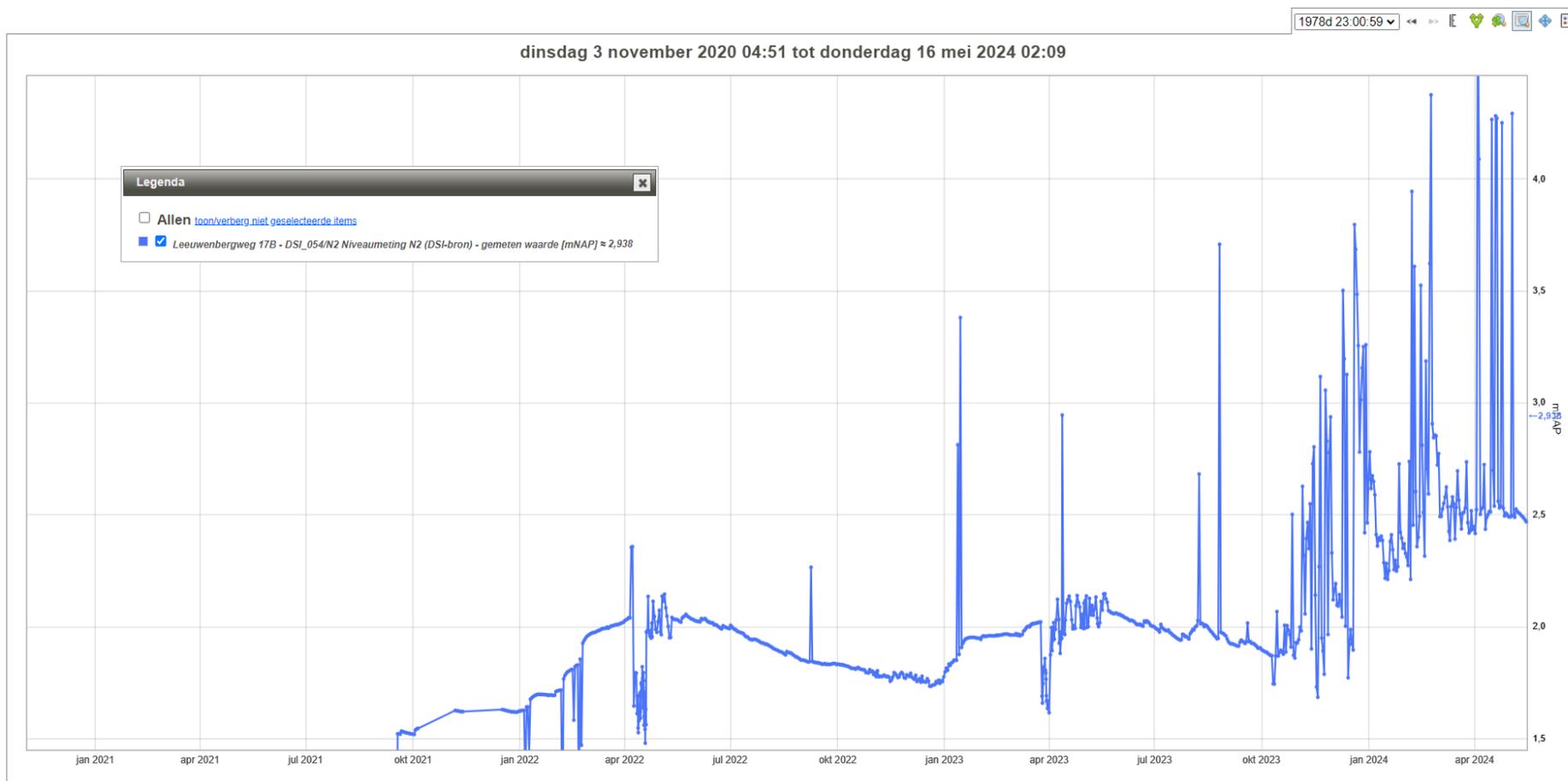


1978d 23:00:59 << >> [E] [G] [A] [B] [C]

dinsdag 1 januari 1919 00:00 tot zaterdag 1 juni 2024 00:00





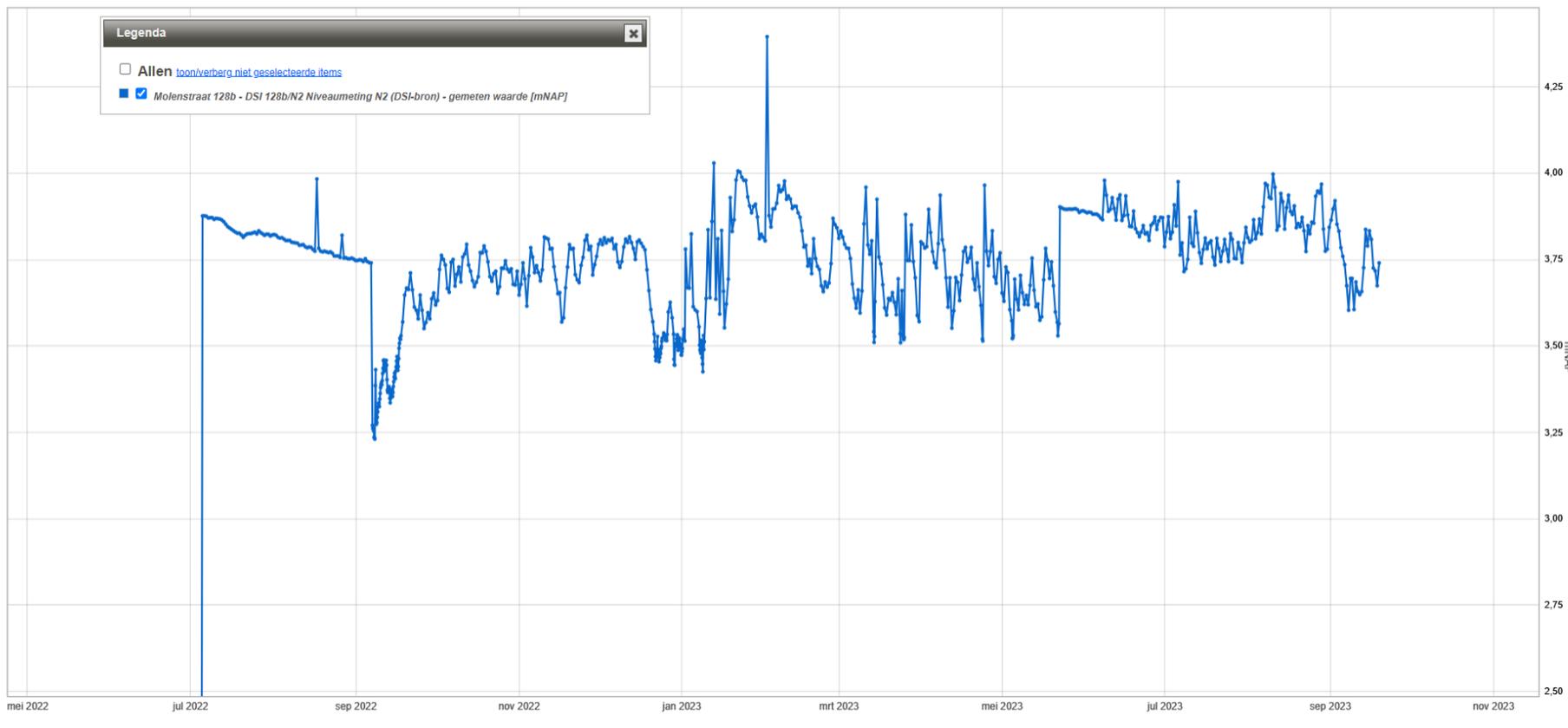


1978d 23:00:59

zaterdag 23 april 2022 16:07 tot vrijdag 17 november 2023 21:29

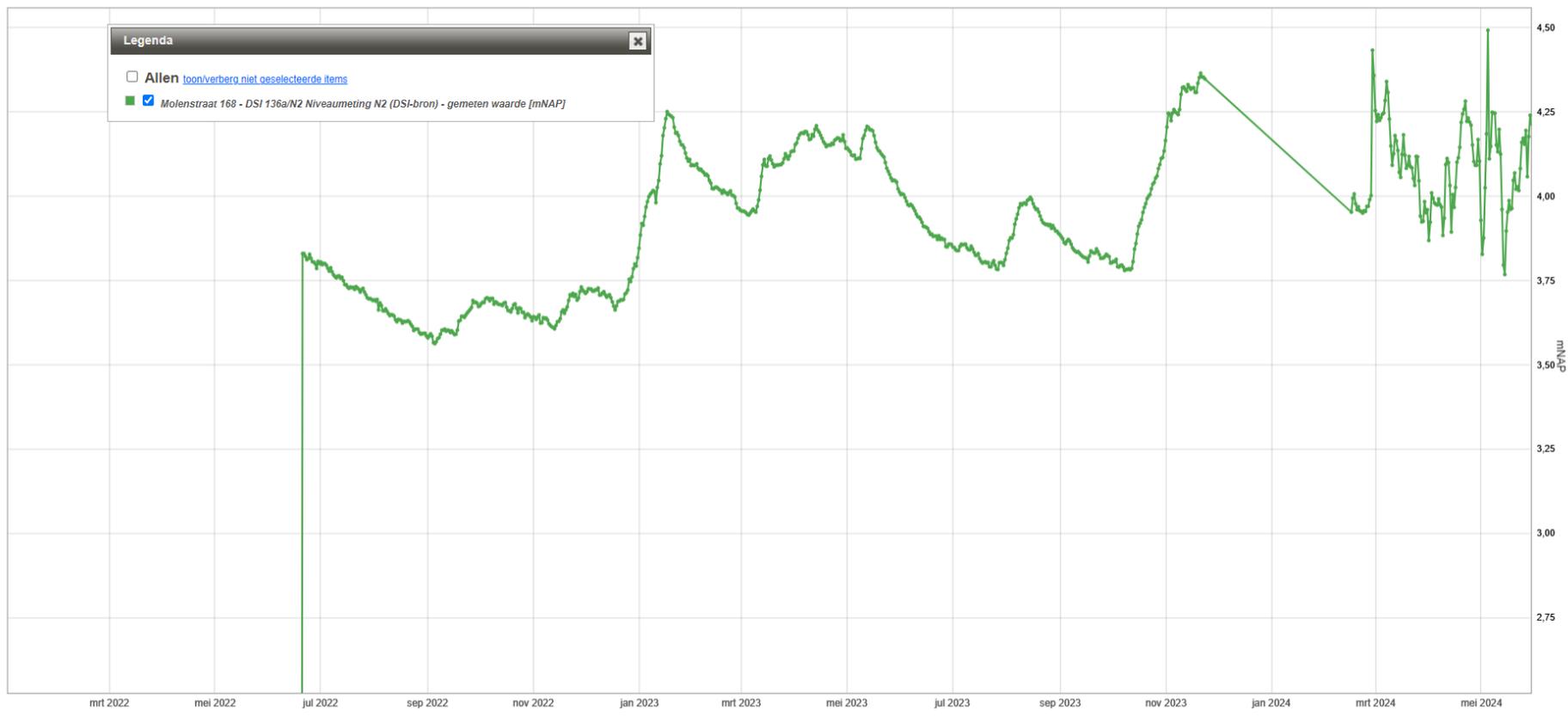
Legenda

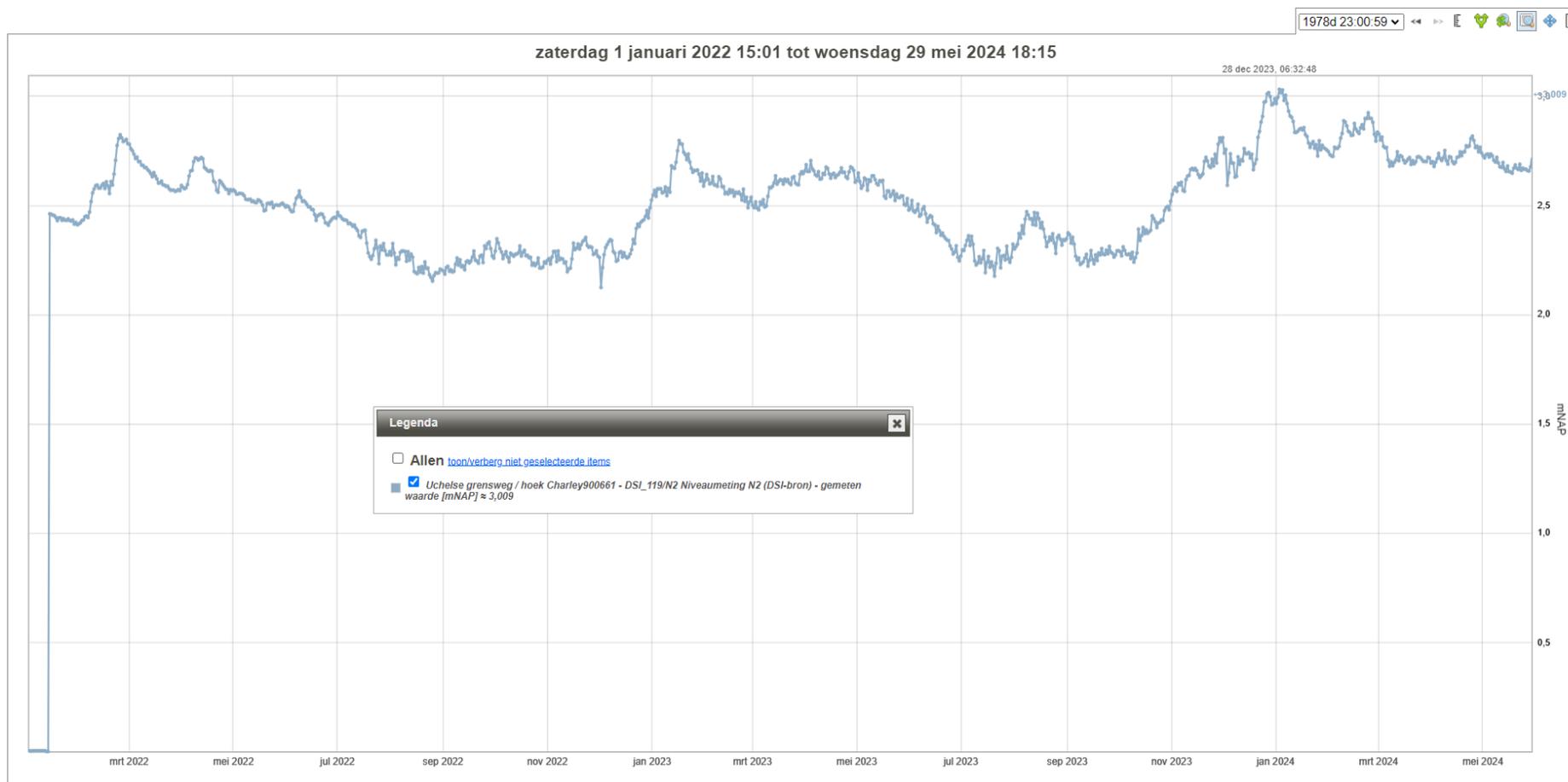
- Allen [toon/verberg niet geselecteerde items](#)
- Molenstraat 128b - DSI 128b/Nz Niveaumeting Nz (DSI-bron) - gemeten waarde [mNAP]



1978d 23:00:59

zaterdag 1 januari 2022 15:01 tot woensdag 29 mei 2024 18:15



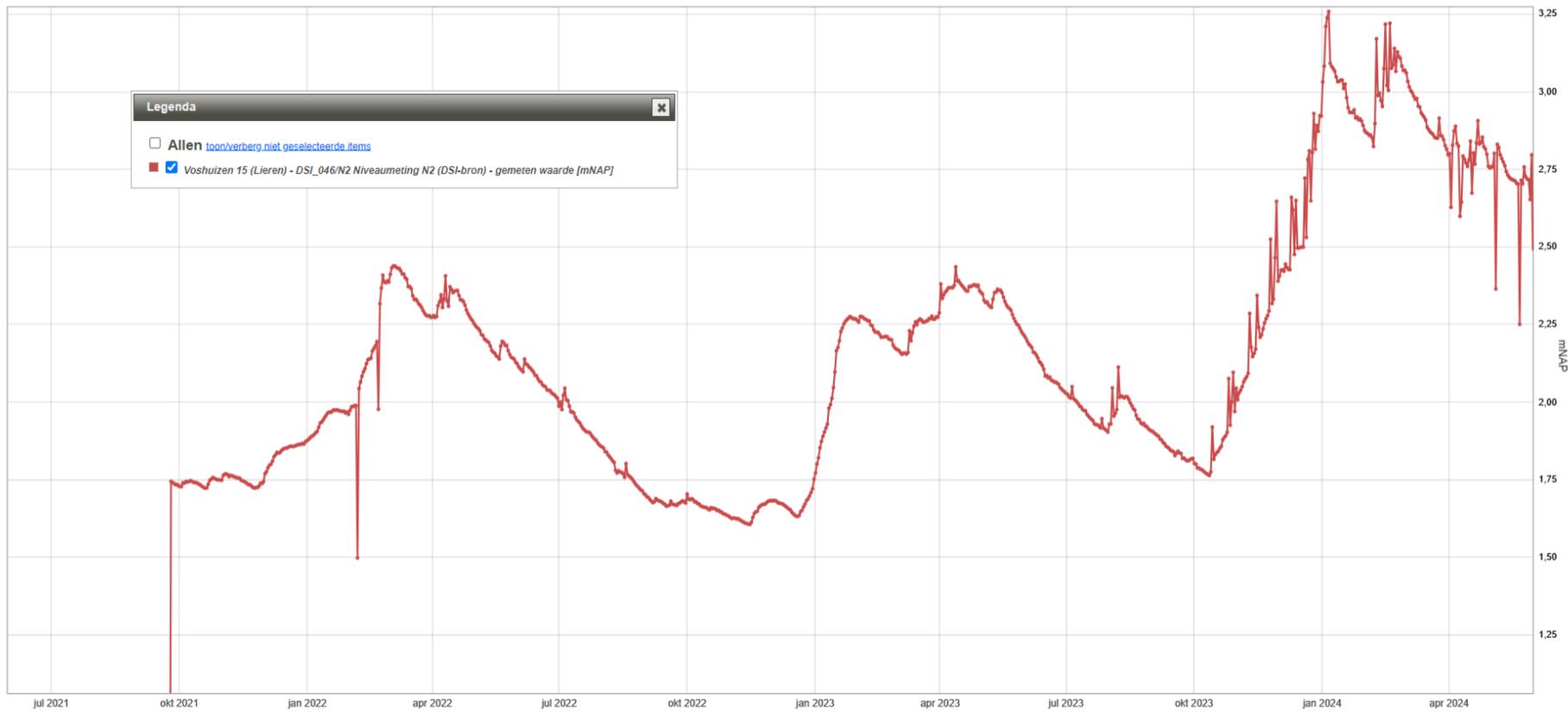


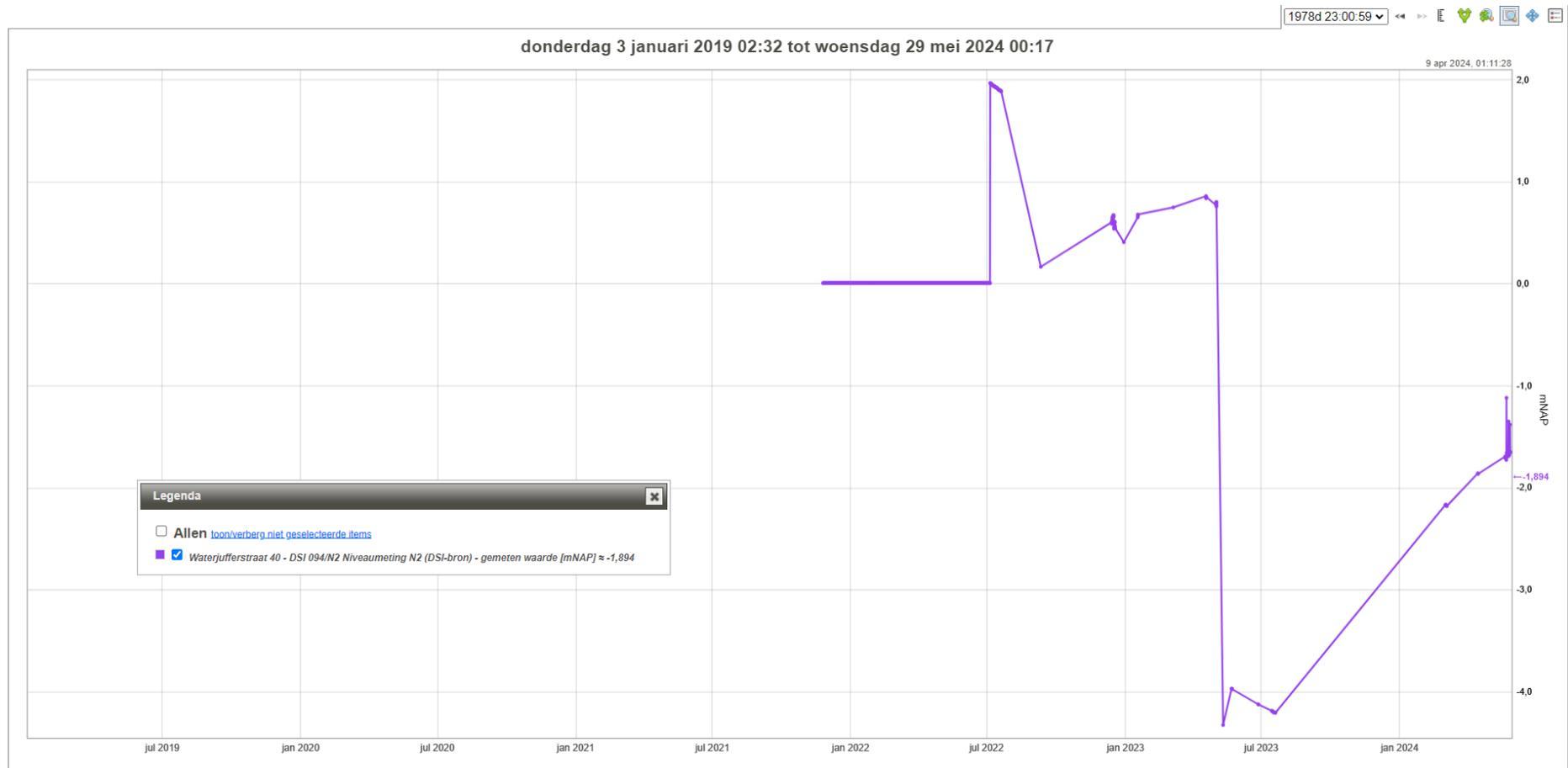
1978d 23:00:59 << >> [Icons]

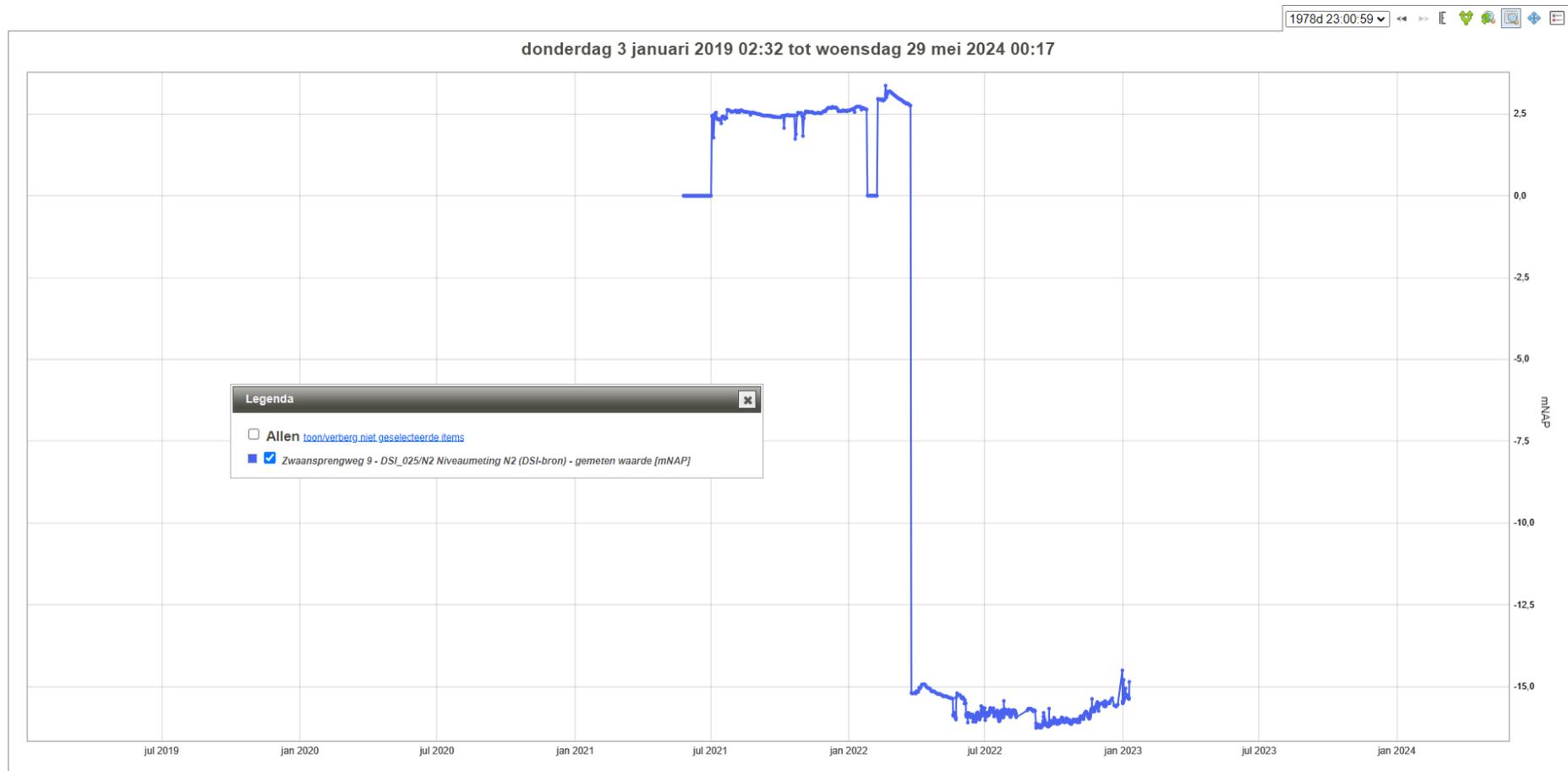
zondag 30 mei 2021 15:15 tot vrijdag 31 mei 2024 11:36

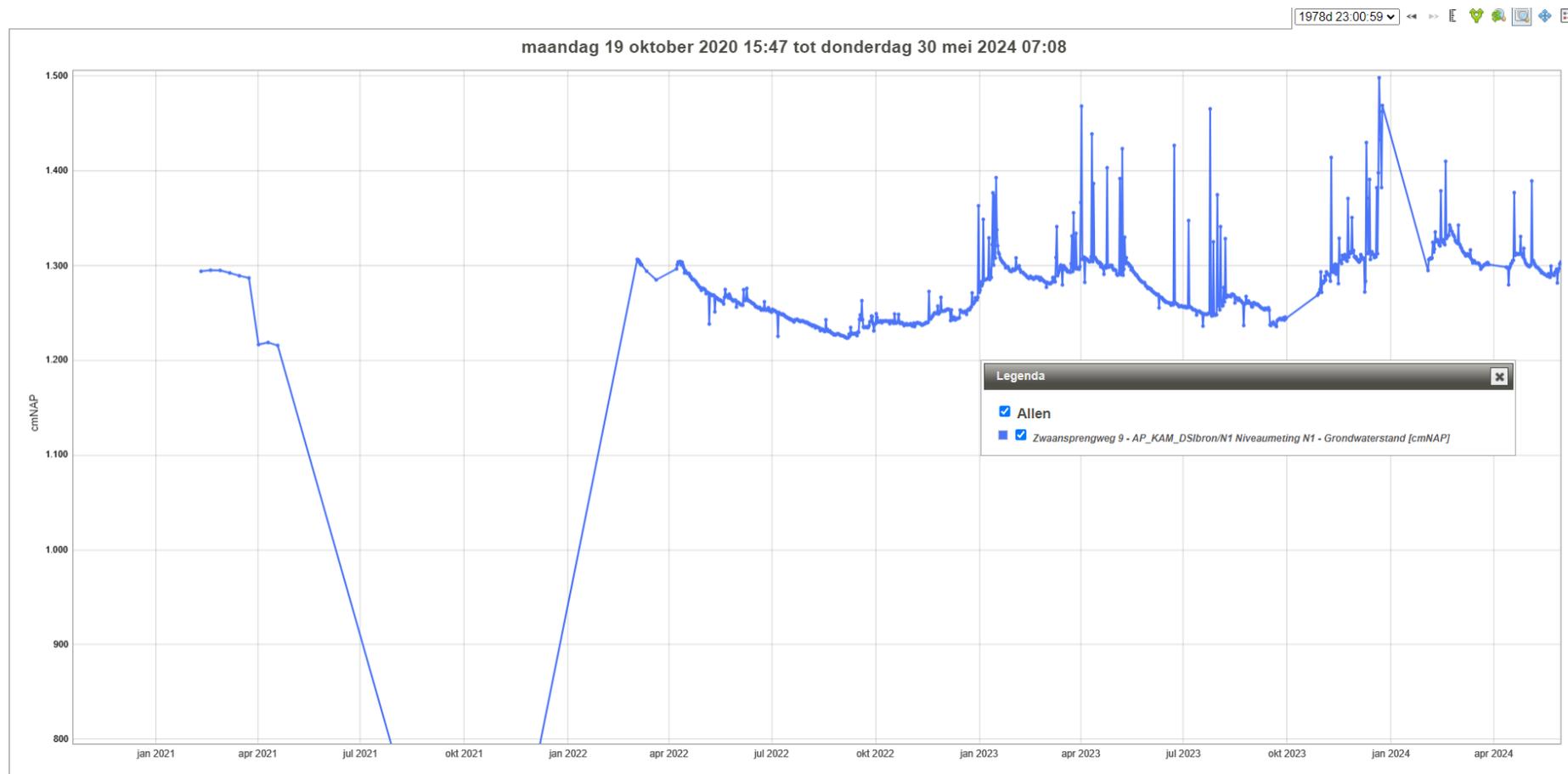
Legenda [X]

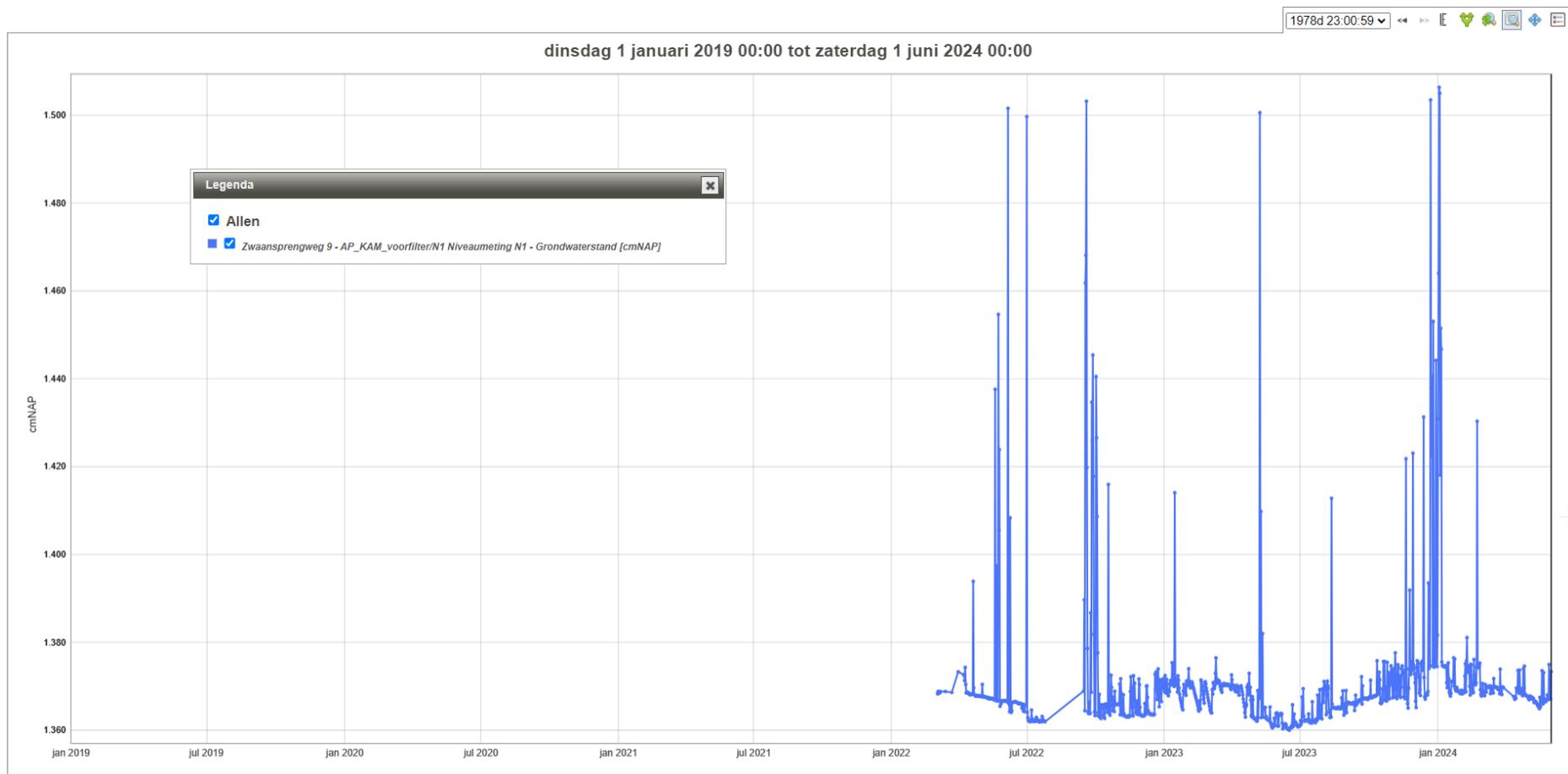
- Allen [toon/verberg niet geselecteerde items](#)
- Voshuizen 15 (Lieren) - DSI_046/N2 Niveaumeting N2 (DSI-bron) - gemeten waarde [mNAP]

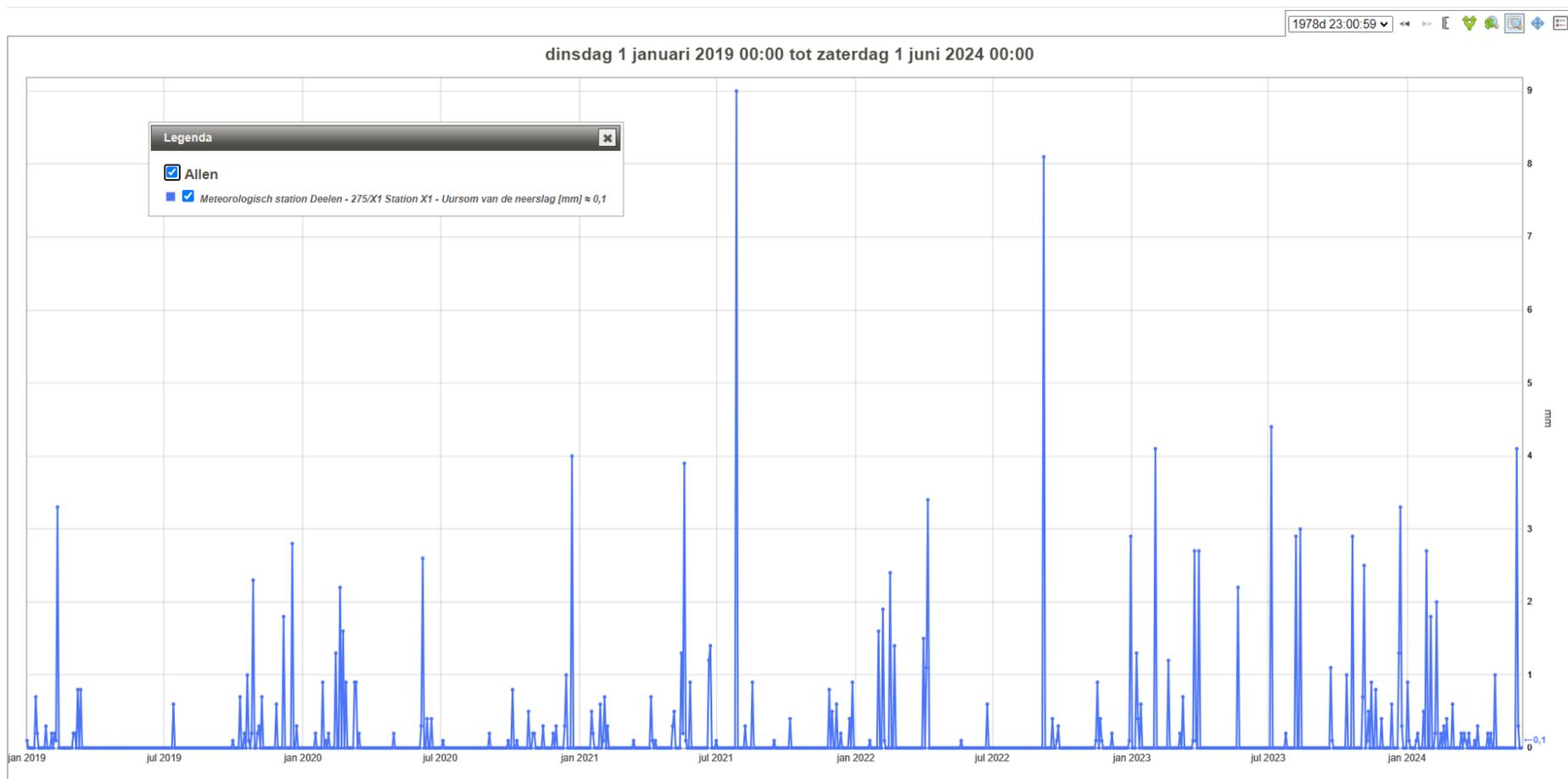






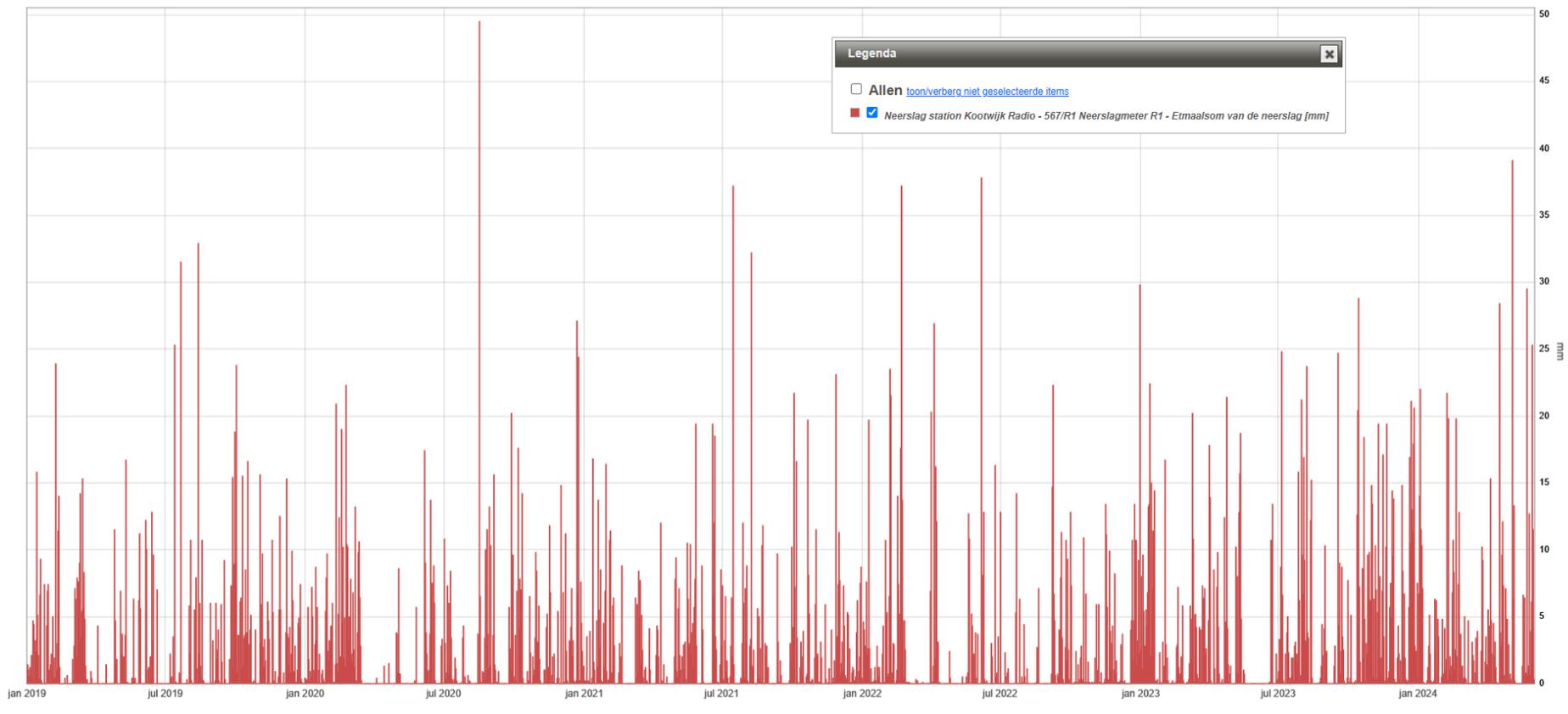






1978d 23:00:59

dinsdag 1 januari 1919 00:00 tot zaterdag 1 juni 2024 00:00



7. Annex Datasets water quality analyses

8. Annex - Fieldtest results

DSI-nummer (ook op boorstaat)	Locatie	Uitvoering veldtest [datum]	Grondwaterstand voor test [m -mv]	Gemeten opnamecapaciteit - Tijdsduur leegloop meetstopstelling [X liter in X minuten]	Gemeten opnamecapaciteit - Tijdsduur leegloop meetstopstelling [m3/uur]	Uitvoering veldtest [datum]	Gemeten opnamecapaciteit - Tijdsduur leegloop meetstopstelling [m3/uur]
DSI 001	Hoog Buurloseweg 56	5-2-2021	geen meting	Na 1min10sec is de put vol en loopt de DSI. Na ca 12 minuten zijn de twee kuubs vaten leeggelopen. Na 14min loopt de put leeg tot onder rand en daarna trage leegloop. Na 16min tijd gestopt.	Het is de vraag wat we hebben gemeten. Of we hier nu de FHVI of de drainage infiltratie zien. Aannahme is dat de FHVI wel verstopt is geraakt door de jaren heen.		
DSI 002	Hoog Buurloseweg 37	12-4-2021	2,25	1000l in 5,10	11,6		
	Hoog Buurloseweg 38	12-4-2021	2,5	1000l in 15,20	4	30-8-2023	0,40
DSI 003	Hoog Buurloseweg thv Steenbeek			1m3 in 4,40	12,9		
DSI 004	Hoog Buurloseweg 16B	12-4-2021	2,65	1m3 in 4,24	13,6		
DSI 005	Hoog Buurloseweg 21	12-4-2021	2,5	1000l in 8,04	7,5		
DSI 006	Hoenderloseweg 50 pannekoekhuis	14-4-2021	3,03	1m3 in 5,15	11,4		
DSI 007	Hoenderloseweg 89	14-4-2021	3,4	1m3 in 180min	0,3	30-8-2023	1,7
DSI 008	Hoenderloseweg 44B	14-4-2021	3	1m2 in 5,15	11,5		
DSI 009	Hoenderloseweg 65	14-4-2021	2,9	1m3 in 22,25	2,4		
DSI 010	Hoenderloseweg 32	14-4-2021	2,25	1m3 in 18,30	2,9		
DSI 011	Hoenderloseweg 59	14-4-2021	3,85	1m3 in 6,15	9,6		
DSI 012	Hoenderloseweg 26	14-4-2021	3,2		4,1		
DSI 013	Hoenderloseweg 35	14-4-2021		1m3 in 24,4	2,2		
DSI 014	Hoenderloseweg 12	14-4-2021		1m3 in 22,30	2,8	30-8-2023	0,50
DSI 015	Koning Lodewijklaan 59	18-12-2020	4,3	2000liter in 14 min	8	30-8-2023	4,30
DSI 023	Koning Lodewijklaan 1	18-12-2020	4,4	1000liter in 16min30sec	4	30-8-2023	5,5
DSI 024	Veenweg 24	18-12-2020	1,94	2m3 in 6min34sec	10,8		
DSI 025	Zwaansprengweg 9					30-8-2023	0,9 na schoonmaak 2,2
DSI 026	Kostverloren thv Anklaarseweg 33	26-10-2021	1,68	2m3 in 35mion	4	30-8-2023	0,85
DSI 027	Kostverloren 9D	26-10-2020	1,6	2m3 in 18min 57	6		
DSI 028	Kostverloren 13	27-11-2020	1,71	1800liter in 12min06	9	30-8-2023	0,24
DSI 029	Kostverloren 20B						
DSI 030	Kostverloren 24	26-10-2020	1,51	2m3 in 38min28sec	3,7		
DSI 031	Kostverloren 26	26-10-2020	1,25	2m3 in 65 minuten	2		
DSI 032	Gentiaanstraat 508	13-10-2020	0,8	1.700liter in 32min	3,2		
DSI 033	Gentiaan 558	13-10-2020	1,76	300liter in 7min12sec.	2,5		
DSI 034	Gentiaanstraat 200	13-10-2020	2,2		8,4		

9. Annex - Reports on monitoring and results street and fieldtests

20200108_Besprekingsverslag_monitoring FHVI
20201023_Besprekingsverslag_monitoring FHVIv2
20201113_veldtest gentiaan_monitoring FHVI
20201127_Besprekingsverslag_monitoring FHVI
20201218_Besprekingsverslag_monitoring FHVI_vs2
20210205_veldonderzoekverslag_monitoring FHVI
20210210_Besprekingsverslag_monitoring FHVI
20210219_Besprekingsverslag_monitoring FHVI
20210311_Besprekingsverslag_monitoring FHVI - HWZI
20210319_Besprekingsverslag_monitoring FHVI
20210416_Besprekingsverslag_monitoring FHVI
20211001_test HWZI
20211210_Besprekingsverslag_monitoring FHVI
20220211_Besprekingsverslag_monitoring FHVI
20220420_HWZI test met zand van 20 april 2022