



Seismic Monitoring Plan

IPS Geothermal Doublet VDB-GT-101 / VDB-GT-02S1

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SEISMIC MONITORING PLAN

Various parameters are monitored for the *Seismic Risk Management Plan* (Tullip, 2023a) of geothermal operations at mining site AWI01-Petuniaweg-Bleiswijk. This *Seismic Monitoring Plan* describes the processing and analysis of the various parameters in the region and *immediate vicinity* of the mining site (see Appendix for the determination of *region* and *environment*). Depending on the evaluation of these parameters, there are four scenarios where the Seismicity Response Protocol (Tullip, 2023b) comes into effect. During the *normal working scenario*, seismic activity is monitored, analyzed, and documented as described below.

The *Seismic Monitoring Plan* can be updated when required. Reasons for updating include recent new technical and scientific insights, results of the analysis of the previous monitoring period, additional station in the network or improved procedure or workflow. The integration of the KNMI data, and the parameters to be monitored and their processing and analysis are explained in more detail below.

Seismic events from KNMI

Parameters: the *location, magnitude, type, and frequency* of the events registered by KNMI.

The KNMI provides continuous monitoring of seismic activity in and near the Netherlands through the national seismic measurement network. As soon as the KNMI detects a seismic event (natural or induced), it is registered (automatically at higher magnitudes) and published on the KNMI (KNMI 2023a) web page. These events are usually verified manually within 24 hours. SRCT reviews the events published by the KNMI. The minimum magnitude of a seismic event that can be localized, the *magnitude of completeness* (KNMI, 2023b), is M1.0-1.5 in the region of the mining site (Figure 1).

By means of an *Automatic Seismicity Alert*, a notification is immediately made by SMS to the subsurface specialist of the SRCT (see Seismicity Response Protocol) if a new event has been registered in the region of the mining site (see appendix 2.1 for determination of region). This is based on the FDSNWS client server (KNMI 2023c) to which the KNMI seismic measurement network is connected.

Baseline/background seismic activity near the mining site

Parameters: the *median, P90, standard deviation, maximum amplitude, and data availability* of dense seismic monitoring stations (Table 2).

During the exploitation phase, seismic data from the KNMI measurement network (KNMI, 1993), is reviewed quarterly (Figure 1 and Table 1). Trend analysis of this data through time is compared and contrasted with well activity data at mining site AWI01-Petuniaweg-Bleiswijk to establish potential correlations. The findings are summarized and documented quarterly.

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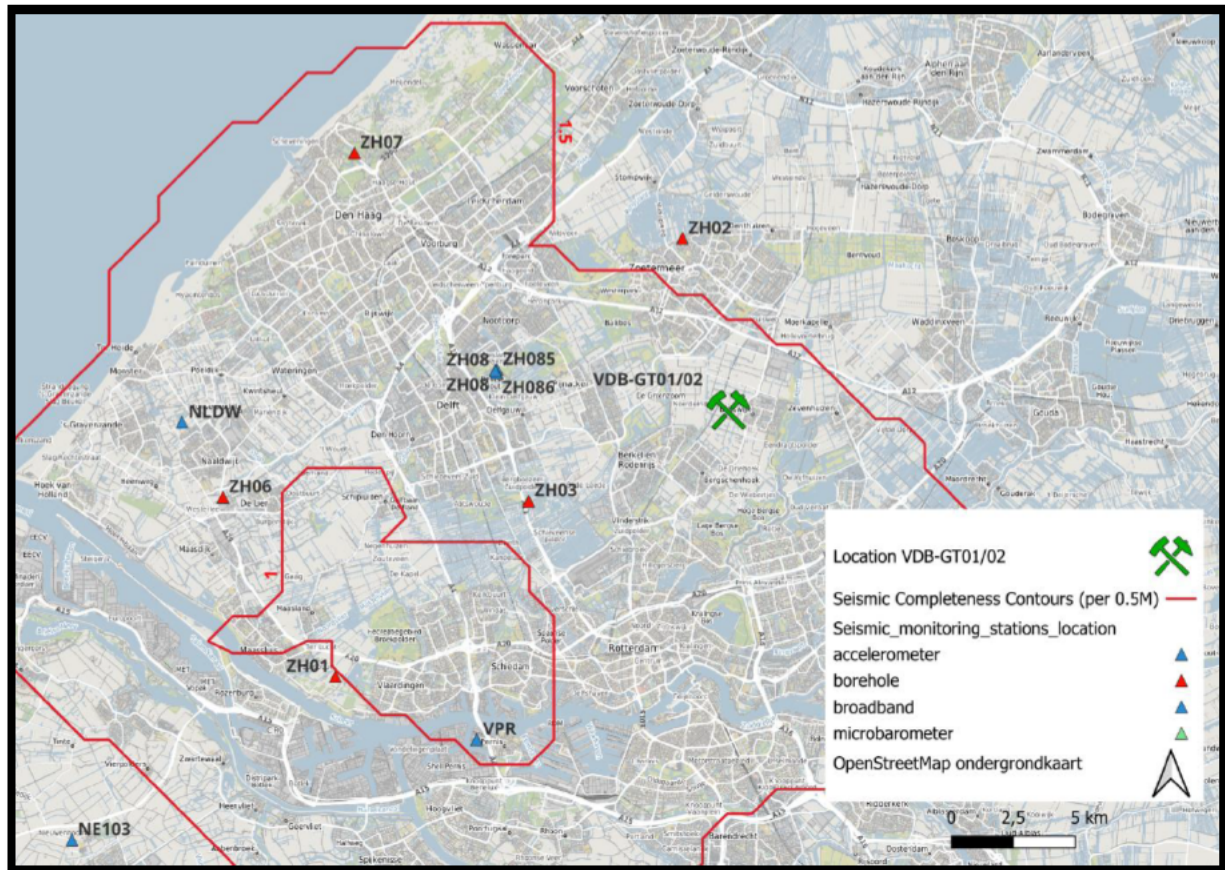


Figure 1 Overview of KNMI seismic monitoring stations and magnitude of completeness based on station list of September 2022, oil and gas fields, and other geothermal operations near the mining site AWI01-Petuniaweg-Bleiswijk.

Table 1 Measuring stations of the KNMI seismic measurement network in the vicinity (less than 25 km) of the mining site of Bleiswijk. Data from taken from KNMI (<https://www.knmi.nl/nederland-nu/seismologie/stations>) on 17-08-2023.

Measuring station	Site name	Type of measuring station	Online since	Distance to mining site
ZH02	Zoetermeer	Borehole	28-05-2020	7.63 km
ZH03	Delfgauw	Borehole	06-04-2020	8.89 km
ZH085	Delftse Hout	Broadband	15-05-2023	9.44 km
ZH086	Delftse Hout	Broadband	15-05-2023	9.44 km
ZH08	Delftse Hout	Broadband	15-05-2023	9.50 km
ZH08	Delftse Hout	Broadband	15-05-2023	9.50 km
VPR	Rotterdam	Accelerometer	15-10-2020	16.81 km
ZH07	Den Haag - Westbroekpark	Borehole	22-04-2022	18.21 km
NE104	Wassenaar	Broadband	01-01-1980	18.57 km
ZH05	Barendrecht	Broadband	03-02-2023	19.10 km
ZH01	Vlaardingen	Borehole	14-12-2018	19.19 km
ZH06	Naaldwijk	Borehole	06-04-2020	20.66 km
ZH04	Spijkensisse	Borehole	05-01-2021	21.82 km
NLDW	Naaldwijk	Accelerometer	2021-04-06	21.99 km

Well Activity Data

Parameters: *flow rate, injection temperature and -pressure*

During the exploitation phase, all well activity data are available to SRCT. These data include flow rate, injectivity, and injection temperature and pressure. This data regularly analyzed to establish a potential correlation or lack thereof with baseline/background seismic activity data (see section *Baseline/background seismic activity near the mining site*) for potential correlation.

TECHNICAL APPENDIX

Determination of the region of the mining site

The *Seismicity Response Protocol* (Tullip, 2023b) depends on the evaluation of seismic activity in the *region* of the geothermal operation. The *region* is defined as the area between the monitoring stations used for the *Seismic Monitoring Plan* (Figure 1).

Determination of the immediate vicinity of the mining site

The *immediate vicinity* of the mining site is defined as the *Geothermal Area of Influence* (GT-Aol) in the Seismic Hazard and Risk Assessment for geothermal projects in The Netherlands report of June 2023 (Mijnlieff et al, 2023). This GT-Aol is defined by the zone within the buffers around the well top reservoir penetration points and TD of the production and injection well (Mijnlieff et al, 2023). The buffer around the production well is 300 m. The buffer around the injection well is $0.7 \times \text{horizontal distance between producer and injector at mid-Berkel/Rijswijk reservoir level}$: $0.7 \times 1790 = 1253 \text{ m}$ (IPS, 2022). The *Geothermal Area of Influence* is the area that envelops these two buffers (Figure 2).

The *immediate vicinity* of the mining site within which the *seismicity response protocol* applies depends on the *uncertainty* of the location determination of a seismic event by the *KNMI measurement network*. At the mining site AWI01-Petuniaweg-Bleiswijk this location uncertainty is 1.2 km for a magnitude 1.5 event (Figure 2; Ruigrok et al., 2023). For the seismic events recorded by the KNMI network, the *immediate vicinity* near the mining site is therefore defined as the zone within the new *Geothermal Area of Influence* plus an additional buffer of 1.2 km to account for location uncertainty effects (Figure 3).

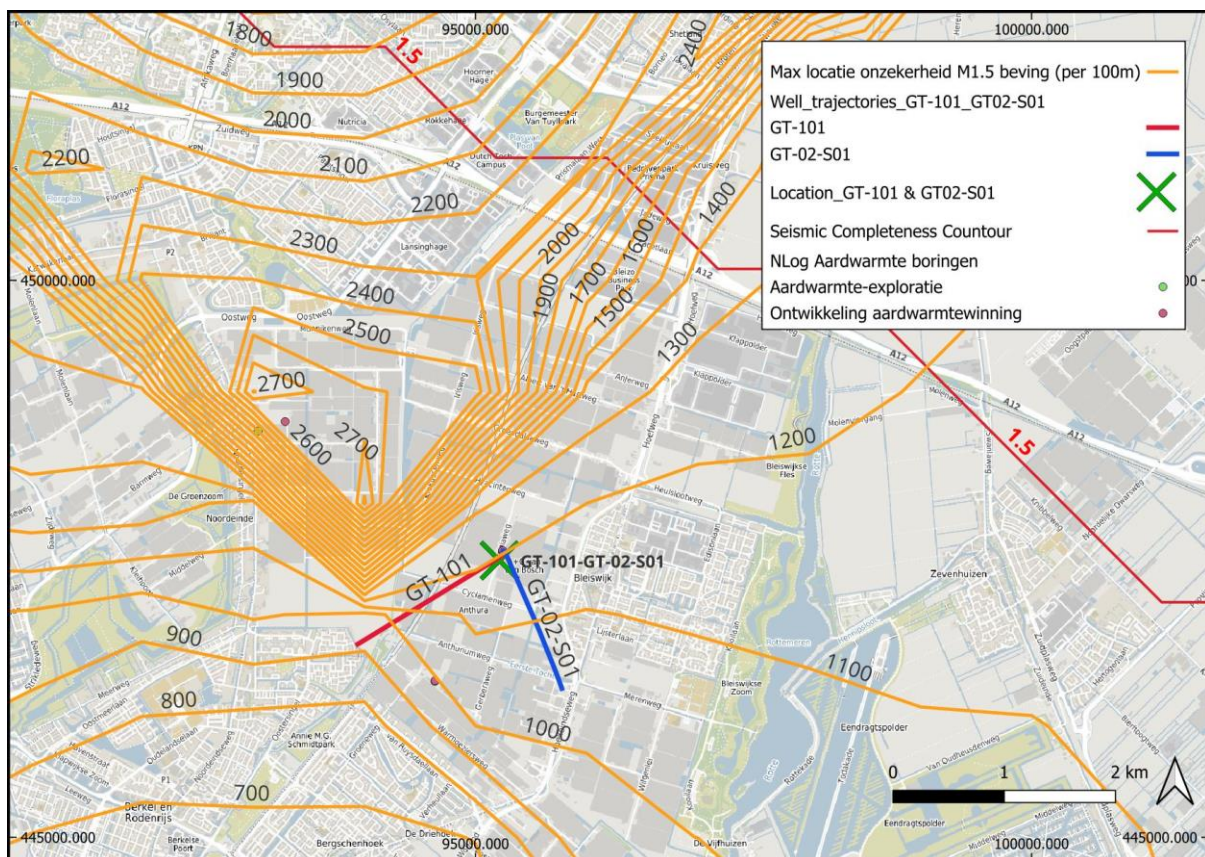


Figure 2 Maximum location uncertainty for a $M=1.5$ seismic event (Ruigrok et al., 2023) with respect to the mining site where doublet GT-101 / GT-02S1 is located.

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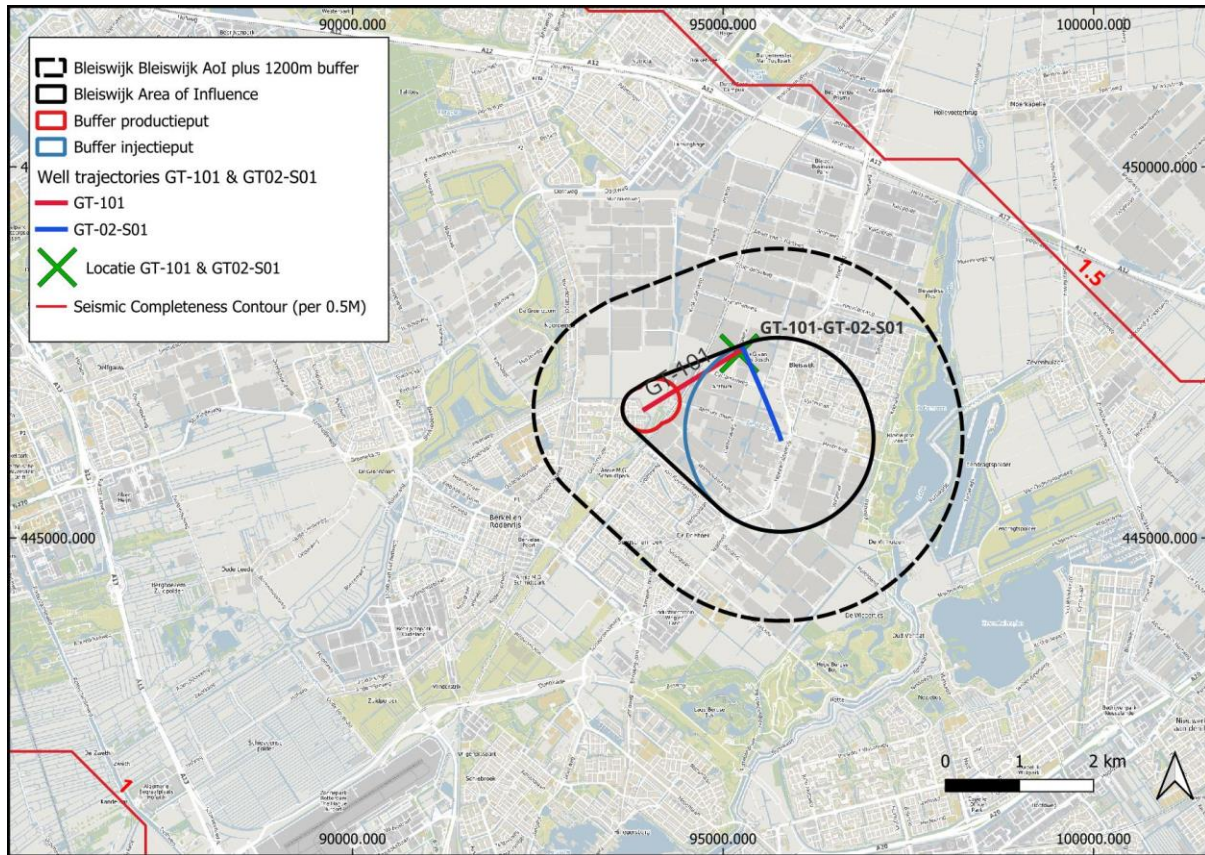


Figure 3 The immediate vicinity near the geothermal operation AWI01-Petuniaweg-Bleiswijk: the zone within which the Seismicity Response Protocol applies.

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