



Seismic Risk Management Plan

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

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SUMMARY

For the development of geothermal operations, IPS submitted a request for approval for the Bleiswijk extraction plan (*winningsplan*) to the Secretary of State for Economic Affairs and Climate Policy on 30 March, 2023 (IPS, 2022). The geothermal operation intends to extract heat from the subsurface at the current mining site located at Petuniaweg 28 in Bleiswijk (municipality of Lansingerland) in the province of Zuid Holland.

Part of the extraction plan is this *Seismic Risk Management Plan*, which is accompanied by a *Seismic Monitoring Plan* and *Seismicity Response Protocol*. This plan describes the integration of the KNMI data and analysis of seismic activity in the region of the geothermal operation. Its purpose is to limit the frequency and magnitude of any related induced events as much as possible (in the unlikely event such this occurs).

NEDERLANDSE SAMENVATTING

Op 30 maart 2023 heeft IPS een verzoek tot goedkeuring voor het Bleiswijk winningsplan voor de ontwikkeling van aardwarmte ingediend bij de staatssecretaris van Economische Zaken en Klimaat (IPS, 2022). Dit plan beoogd warmte te onttrekken aan de ondergrond op de de bestaande mijnbouwlocatie aan de Petuniaweg 28 in Bleiswijk (gemeente Lansingerland) in de provincie Zuid-Holland.

Dit *Seismisch Risico Beheersplan*, dat vergezeld gaat van een *Seismisch Monitoring Plan* en een *Seismiciteit Respons Protocol* vormt onderdeel van het Bleiswijk winningsplan. Dit plan beschrijft de integratie van de KNMI-gegevens en de verwerking en analyse van seismische activiteit in het gebied van de geothermische operatie. Het doel is om de frequentie en omvang van gerelateerde geïnduceerde gebeurtenissen zoveel mogelijk te beperken (in het onwaarschijnlijke geval dat een dergelijke gebeurtenis zich voordoet).

INTRODUCTION

IPS Geothermal Energy B.V., hereinafter referred to as IPS, operates as a license operator, on behalf of licensor 85 Degrees Renewable 1&2 B.V., hereinafter referred to as 85, a geothermal installation for geothermal heat extraction. IPS & 85 intend to realize a geothermal operation at the mining site located at Petuniaweg 28 within a greenhouse horticulture area in Bleiswijk (municipality of Lansingerland) in the province of Zuid Holland and within the Bleiswijk exploration area (*Opsporingsvergunning aardwarmte Bleiswijk*). The geothermal installation to be realized for the Bleiswijk project concerns a doublet formed by a new production well (VDB-GT-101) and an existing injection well (VDB-GT-02-S1), which will extract geothermal heat from the Berkel/Rijswijk Sandstone package at 1500 m depth.

Mining activities, including geothermal energy extraction, are associated with risks. Control and mitigation of these risks, such as the possible cause of seismicity, is of great importance in Dutch geothermal projects. Although the consensus is that the risk associated with the type of geothermal energy projects such as in Bleiswijk (i.e., low-enthalpy geothermal energy in matrix-dominated sandstone reservoirs) is low (e.g., TNO., 2019; Professors Panel, 2020; TNO-AGE, 2020), the guidelines on how to properly assess this risk have been in flux and a topic of debate in recent years. In the absence of clear guidelines, it is therefore advisable to at least monitor for seismicity in the area where the geothermal operation takes place, and to adhere to a so-called Seismic Risk Management Plan. That plan includes a Seismicity Response Protocol that states how and by whom action is taken in all situations, and with whom communication should take place. This protocol, in turn, depends on the Seismic Monitoring Plan.

The Seismic Monitoring Plan (SMP) and a Seismicity Response Protocol are part of the Tullip Energy Health and Safety (“V&G”) system, and describe the monitoring with the KNMI network and response and communication procedures in line with the existing emergency response and crisis plans.

LEGAL FRAMEWORK

On 30 March, 2023, IPS submitted a request for approval for the Bleiswijk extraction plan (*winningsplan*) to the Secretary of State for Economic Affairs and Climate Policy (IPS, 2022). In the pre-drill extraction plan, IPS describes the mining site and extraction plant, the production forecast and strategy, and the likelihood of soil movement and possible underground effects on the environment (as well as the measures to be taken).

This *Seismic Risk Management Plan* is a supporting document of the aforementioned extraction plan *Bleiswijk*, as submitted on 30 march 2023.

The Seismic Risk Management Plan comprises a Seismic Monitoring Plan and Seismicity Response Protocol. The Seismic Monitoring Plan following the temporary guidelines 1.2 issued by *Staatstoezicht op de Mijnen* (SodM, 2023).

The Seismicity Response Protocol is a document that is often required as a condition for approval of an extraction plan (e.g., EZK, 2021). This condition requires the operator to draw up a document which clearly describes how and when the environment is informed if ground vibration is measured. Further agreements with the KNMI on the registration of soil vibration must be integrated into that protocol. The operator must submit a Seismicity Response Protocol to the State Secretary for Economic Affairs and Climate Policy at least 2 months before the start of the extraction.

STAKEHOLDERS

The purpose of the *Seismic Risk Management Plan* of geothermal operation Bleiswijk is to mitigate soil vibrations if possible and to limit the frequency and magnitude of any related induced events as much as possible (see the background appendix in this document). The *Seismic Monitoring Plan* (Tullip, 2023b) describes the integration of the KNMI data, and the processing and analysis of seismic activity in the region of the geothermal operation. Depending on the results of the monitoring, the *Seismicity Response Protocol* (Tullip, 2023c) in turn describes which actions are taken, and how and when the environment is informed in the event that the KNMI measurement network registers seismic activity in the vicinity of the mining site.

For the Seismic Risk Management Plan, the following organizations are important:

- **IPS Geothermal Energy B.V.:** as *license operator* responsible for the implementation of the *Seismic Risk Management Plan*, compliance with the *Seismicity Response Protocol*, and, if necessary, taking measures. The operator is also responsible for sharing relevant observations with the State Supervision of Mines (SodM). IPS Geothermal Energy B.V. is also the operator of the nearby (future) geothermal mining activities Bleiswijk 1B and Zoetermeer.
- **85 Degrees Renewable 1&2 B.V.:** as *co-license holder* jointly with IPS responsible for the implementation of the *Seismic Risk Management Plan*, compliance with the *Seismicity Response Protocol*, and, if necessary, taking measures.
- **Tullip Energy Exploration and Development B.V.:** as *service provider* to the license operator responsible for the implementation of the Seismic Monitoring Plan towards the operator, and has a supporting role in the implementation of Seismic Risk Management Plan including the Seismicity Response Protocol.
- **KNMI:** as manager of the national seismic measurement network: maintenance and possibly installation of new measuring stations, and manager and distributor of the raw seismic measurement data. In addition, the KNMI is responsible for the detection, analysis and publication of seismic events measured by this network.
- **State Supervision of Mines** (*Staatstoezicht op de Mijnen*, SodM): supervisor of mining activity.
- **Rotterdam-Rijnmond Safety Region** (VRR): primarily ensures the safety of everyone within the Rotterdam-Rijnmond region lives, works and/or visits. With regard to a seismic event related to geothermal heat production, possible organizations involved are: fire brigade care, medical assistance, and the 112 control room of the fire brigade and ambulance.
- **Ministry of Economic Affairs and Climate:** permit provider for geothermal operations, and responsible for granting approval of the *Seismic Risk Management Plan* and resumption of geothermal heat production after possible shutdown of extraction.
- **NAM:** operator of the nearby mining activities related to oil and gas extraction.
- **Geothermie Nederland:** trade association for companies and institutions working in geothermal energy.
- **Municipality of Lansingerland:** municipality in which the mining site is located.

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- **Province of South Holland:** province in which the geothermal operation is located.
- **Schieland and Krimpenerwaard Water Board:** water board in which the geothermal operation is located.
- **A+G Van den Bosch B.V.:** site owner of the petuniaweg 28 mining location and main customer with offtake agreement for all heat from doublet GT-101 / GT-02S1.
- **Wayland Energy B.V.:** operator of the adjacent geothermal operation in the Lansingerland III permit, east of the mining site, and the Nootdorp-oost I permit, southwest of the mining site.
- **Wayland Energy Bergschenhoek B.V.:** operator of a geothermal operation in the Lansingerland permit, south of the mining site.
- **Duijvesteijn Energie B.V.:** operator of a geothermal operation in the Pijnacker-nootdorp 5 permit, west of the mining site.
- **Ammerlaan Geothermie B.V.:** operator of a geothermal operation in the Pijnacker-nootdorp 4 permit, west of the mining site.
- External stakeholders: future heat consumers of Bleiswijk.

BACKGROUND

Seismic activity occurs naturally with an abrupt release of accumulated elastic stress along a fault in the subsurface. Some faults cause seismicity during such stress release, whereas other faults release stress a-seismically. A seismic event can lead to measurable ground vibrations at the surface. In the vast majority of cases, seismic activity is related to release of tectonic stress. This occurs in naturally tectonically active areas such as the Ruhr Valley Graben or *Roerdalslenk* in the southeast of the Netherlands. In some cases, a seismic event can be induced by anthropogenic activity such as gas extraction. Monitoring is central to seismic risk management.

Seismicity Monitoring

The KNMI records seismic activity in and near the Netherlands on the basis of an extensive network of different types of seismic measuring stations (KNMI, 1993; Figure 1). The distribution of the measuring stations is mainly focused near the gas fields (with most measuring stations around the Groningen gas field) and the southeast of the Netherlands (since seismicity occurs naturally here). This distribution makes it possible to locate seismic events with magnitude ≥ 2.0 on the Richter scale anywhere in the Netherlands, while locally magnitudes as low as 0.5 are detectable (KNMI, 2023) (Figure 1). This limit value of the minimum magnitude to be located is called the *magnitude of completeness*.

Since 2018, the first seismic measuring station (ZH01) near the mining activities in South Holland has been active (Figure 2). From the spring of 2020, the KNMI seismic measurement network in this region has been expanded with twelve measuring stations (five borehole and seven surface meters) (Figure 2 and Table 1). The current *magnitude of completeness* near the mining site AWI01-Petuniaweg-Bleiswijk is established to be between $ML=1.0-1.5$ (Figure 1).

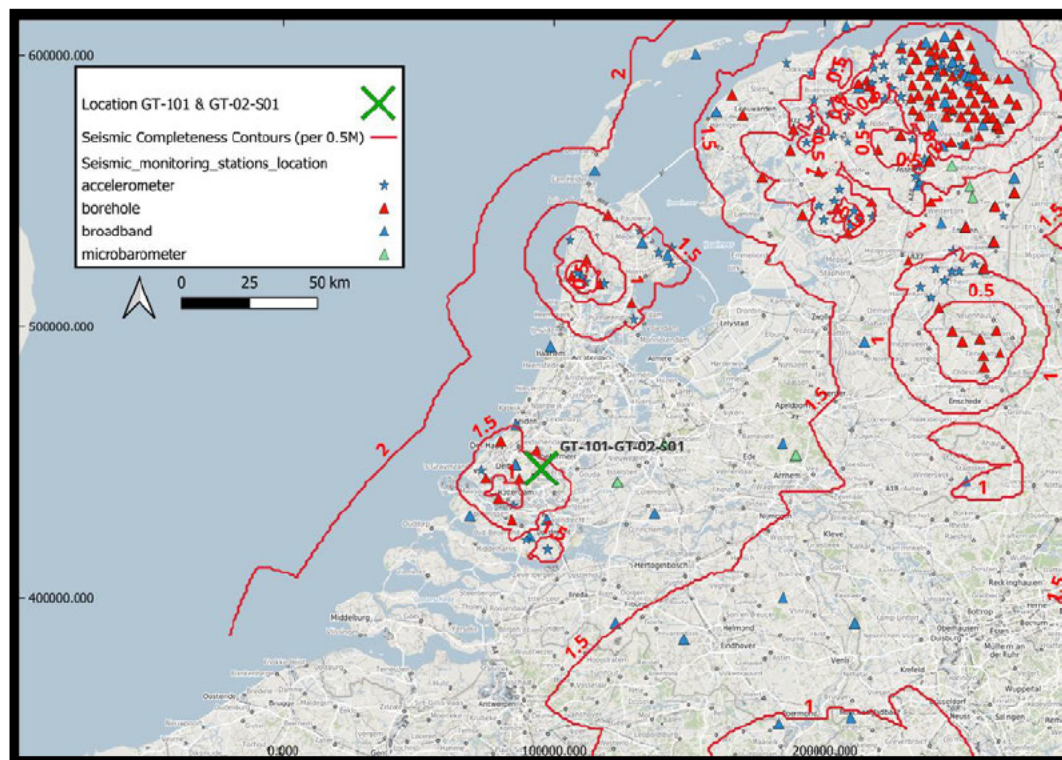


Figure 1 Overview of the seismic stations of the KNMI seismic measurement network (as of 4 August 2023), the magnitude of completeness (KNMI, 2023a) and the location of the AWI01-Petuniaweg-Bleiswijk mining site.

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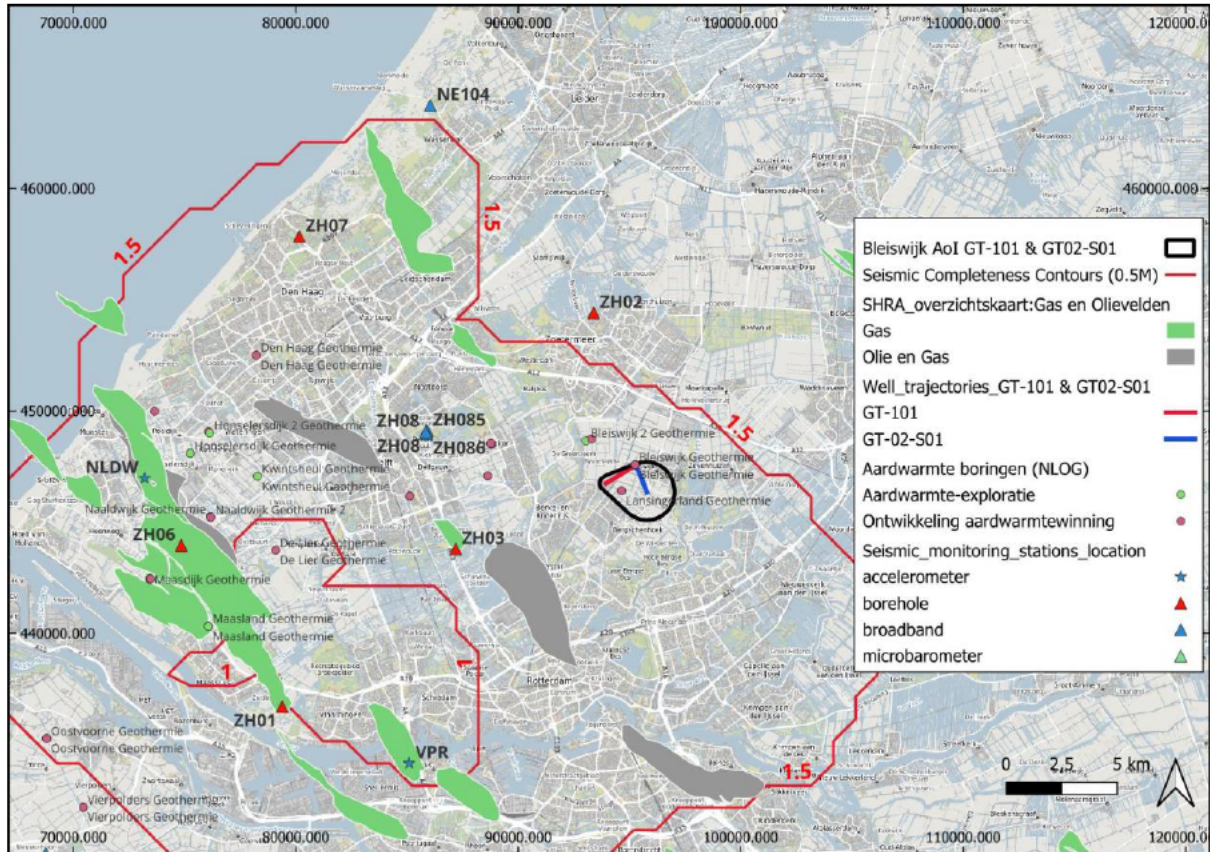


Figure 2 Overview of KNMI seismic monitoring stations and magnitude of completeness (KNMI, 2023a), oil and gas fields and other geothermal operations near the mining site AWI01-Petuniaweg-Bleiswijk.

Table 1 Measuring stations of the KNMI seismic measurement network in the vicinity (within 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	06-04-2021	21.99 km

Historic seismic events

Figure 3 shows all seismic events published so far (June 2022) by the KNMI. To date, the KNMI has not published any natural or induced seismic events in the vicinity of the mining site. However, because until 2020 the magnitude of completeness in Zuid-Holland was $M_L=2.0$, it cannot not be excluded that weak seismic events (e.g., related to local oil and gas extraction) have taken place in this region.

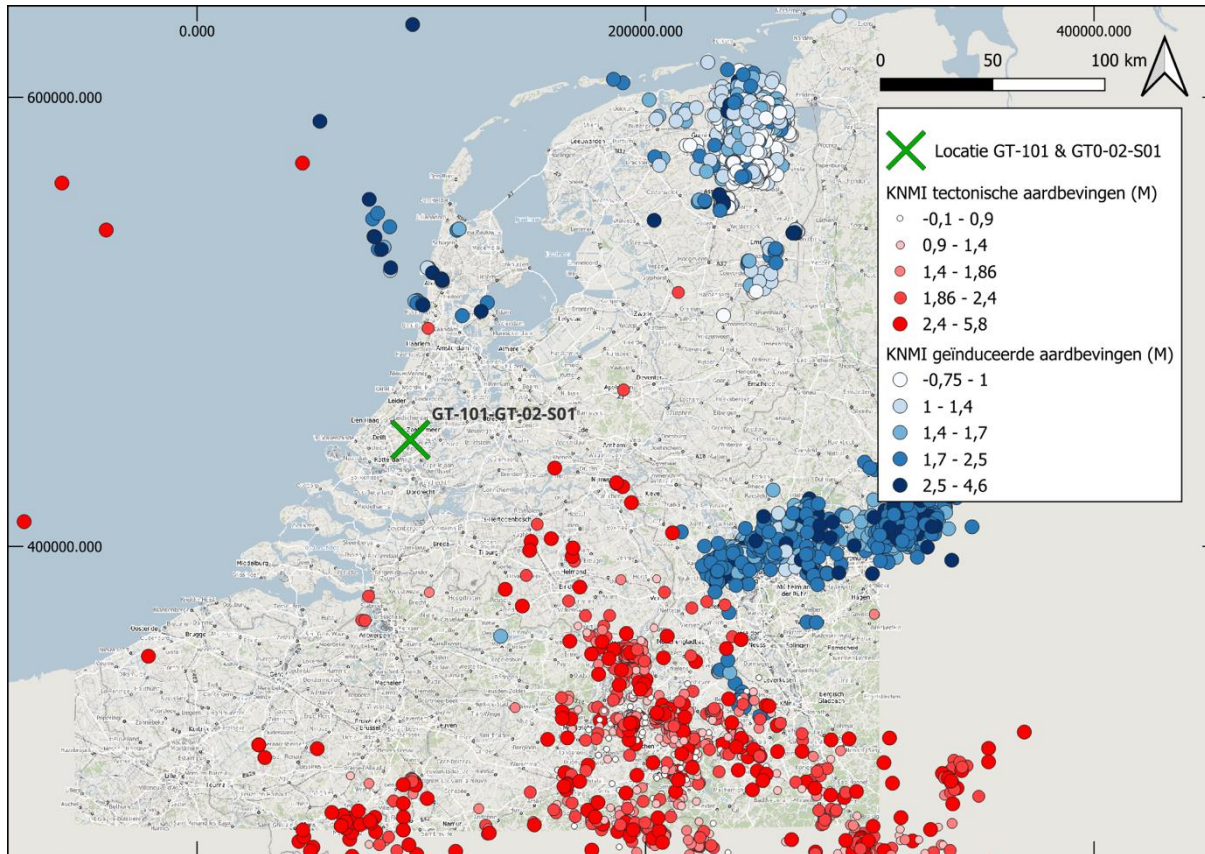


Figure 3(KNMI, 2023b).

The State Supervision of Mines (*Staatstoezicht op de Mijnen* or *SodM*) confirms in the “*Staat van de Sector Geothermie*” that the risk of earthquakes in geothermal projects in Zuid-Holland is very low (SodM, 2017). TNO-AGE also assesses that the chance that fractures in the type of geothermal reservoirs such as in Zuid-Holland are critically prestressed as very low, so that the chance that substantial seismicity will occur under these types of geothermal conditions (plays) is very limited (TNO-AGE, 2020).

Monitoring in geothermal operations

With regard to the risks of possible seismicity in geothermal energy, TNO-AGE emphasizes the importance of monitoring in geothermal operations: this can lead to a better understanding of possible seismicity (TNO, 2020). Seismic monitoring of the subsurface focuses on mitigating the risk of especially high magnitude events that can be felt and lead to material damage. For geothermal operations on a local scale, it is important that weaker events can also be detected: these can be an indicator of an occurrence of a heavier event in future.

For this situation of negligible seismicity risk (situation 1 of the SodM guideline (SodM, 2023)) the purpose of seismicity management is to identify and manage deviations from the risk assessment in a timely manner. Since the Magnitude of Completeness for this project has been established to be between 1 to 1,5, the KNMI network will suffice as the monitoring network. The tables below outline the monitoring and Traffic Lights System guidelines applicable to the situation of this project (SodM, 2023).

Table 2 Traffic Light System of SodM Guideline version 1.2 for low probability of seismicity or damage (SodM, 2023).

The following only applies to projects that fall into the lowest risk category for seismic risk or where it has been demonstrated that the risk of damage is negligible.			
Monitoring	Monitoring can take place using the KNMI network provided the Magnitude of Completeness ≤ 1.5		
Magnitudes	No measured seismicity	$M < 1,5$	$M \geq 1,5$ or > 1 event per year
Traffic Lights System			

Table 3 Actions for Traffic Light System of SodM Guideline version 1.2 for low probability of seismicity or damage (SodM, 2023).

Actions
Green → No Action
Orange → Analysis of seismic activity in space, time and magnitude. → Re-evaluation of risk assessment, update system. → Only return to old situation with agreement of SodM. → All measured seismicity is reported to SodM.
Red → Shut down; not without adjustment and agreement of SodM. → Analysis of seismic activity in space, time and magnitude. → Re-evaluation of risk assessment. → All measured seismicity shall be reported to SodM without delay.

Possible consequences of seismic events

TNO has carried out several studies into the possible damage caused by seismic events. These were summarised in a memorandum to the State Supervision of Mines in 2016 (TNO, 2016). The extent of the area where possible damage can occur is determined by the magnitude, depth, and duration of the quake in combination with the local soil composition and nature and condition of the buildings (TNO, 2009). In the case of a seismic event that is powerful enough to cause damage, the number of potential damage cases within this area strongly depends on the density of the buildings, while the degree of damage at a certain distance from the epicenter is largely determined by the type of buildings, the state of maintenance, and the local soil conditions (TNO, 2009).

In the case of an induced event with a substantial limit value of $M=3.5$ as a result of geothermal activity, TNO-AGE expects the damage to be limited to damage *state 2 (DS2)*: limited to repairable damage (TNO-AGE, 2020). However, according to the advice of the professors' panel on the seismicity risk policy of geothermal energy, an M_{max} of no more than 1.5 on the Richter scale is realistic (Hooglerarenpanel, 2020). Moreover, the professors' panel acknowledges that with such an $M_{max}=3.5$, the Local Personal Risk (LPR – i.e., the chance of victims on the surface) is less than 10^{-5} ;

this falls within the Dutch risk policy for seismic safety risk for all forms of geothermal energy (Hooglerarenpanel, 2020).

Moreover, the guidelines of the SDRA workflow (Mijnlieff et al., 2023) indicate that for cases such as Bleiswijk, where the Seismische Hazard Screening (*Seismische dreigingsscreening* or SDS) established negligible seismicity risks (Tullip, 2023), no further SDRA steps are required. Because the risk is negligible, no damage is expected and a calculation of potential damage is not possible (Mijnlieff et al., 2023).

Mining activity in the area

The mining site AWI01-Petuniaweg-Bleiswijk is located within the *Oostland* greenhouse horticulture area. In this, and the adjacent *Westland*, several geothermal operations are active (Figure 2). The Minister of Economic Affairs and Climate Policy at the time asked TNO to look at the possible cumulative effects of multiple geothermal heat extraction sites in the vicinity of the mining site. TNO indicates in their note that in this specific case the combined effect of the extraction of geothermal heat by the Lansingerland I and Bleiswijk systems, and the future temporary extraction by the Lansingerland II system, does not seem to indicate an increase in seismicity potential compared to the situation in which one of the doublets is in production. This conclusion is based on a qualitative analysis of the various systems (TNO, 2021).

In addition, in the vicinity of the mining site AWI01-Petuniaweg-Bleiswijk there are several oil and gas fields, both producing and shut in (Figure 2). Due to the distributing the measuring stations around these fields, it is possible to clearly differentiate between the different mining activities should an induced seismic event occur in the area.

Seismic Risk Analysis

For the Bleiswijk extraction plan (*winningsplan*) for doublet VDB-GT-101/VDB-GT-02S1, both a Seismic Hazard Risk Analysis Quickscan (Level 1) screening and subsequently a Location Specific Seismic Hazard Analysis (Level 2) were carried out (IPS Geothermal, 2022; Panterra 2022). The Seismic Hazard Risk Analysis Quickscan (Level 1), used a methodology established by Baisch et al. (2016). This analysis systematically evaluated nine possible situations that can increase the risk of seismicity, including the proximity of fractures in the formation and the distance to areas where tectonic and induced seismic events occur. The normalized score of the Quick Scan of the Bleiswijk geothermal operation was assessed to be 0.29 and is associated with a low risk (IPS Geothermal, 2022). The risk of soil vibration can therefore be considered as negligible.

Also, a location Specific Seismic Hazard Analysis (Level 2) was carried out for the Bleiswijk project (Panterra, 2022) and demonstrated that the likelihood of fault reactivation (and possible resulting seismicity) after 45 years of injection is close to that for zero injection.

As guidelines for seismic hazard analysis have been in development in recent time and out of abundance of caution, this project was also screened following the new Seismic Hazard Screening (SDS = seismische dreigings screening) method as described in Mijnlieff et al. (2023). This Seismic Hazard Screening (seismische dreigings screening or SDS) exercise confirmed negligible seismicity risk for this project (Tullip, 2023c).

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