Underground regional planning for the sustainable greenhouse heating – a study for the municipality of Westland, the Netherlands.

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Resumen: La energía geotérmica se ha convertido en una opción interesante en los Países Bajos especialmente para usuarios con una demanda de calor alta como es el caso de horticultores. Para obtener un permiso de exploración del calor geotérmico es necesario hacer una solicitud al Ministerio de Recursos Económicos. Sin embargo, dividir el subsuelo en base a solicitudes individuales no garantiza el aprovechamiento optimo del calor geotérmico e incluso puede limitar a futuros usuarios interesados. Este ha sido el caso en el municipio de Westland, localizado en el oeste de los Países Bajos. El municipio, con la intención de ofrecer iguales oportunidades a todos los interesados, solicitó la realización de un estudio de plantación del subsuelo a escala regional. Los resultados de dicho estudio muestran que es posible extraer una cantidad calor geotérmico mucho mayor si se considera el subsuelo a escala regional y no a escala de las solicitudes individuales. Sin embargo, y a pesar de que desde el punto de vista legislativo es posible este tipo de plantación regional, al momento de la implementación otras dificultades pueden aparecer. Para resolver estos contratiempos es necesaria la cooperación conjunta de todas las partes interesadas.

Key words: Underground regional planning, geothermal energy

1. INTRODUCTION

Geothermal energy has become an interesting option in the Netherlands especially for high heat demand users such as greenhouses. In the municipality of Westland, several greenhouse owners applied for an exploration permit for geothermal heat. However, the pattern of these individual applications soon showed a non-optimal distribution of the space given the high concentration of greenhouses in the region. In particular, since the surface area of the requested area greatly exceeded the extent of the greenhouse itself. Confronted with this situation, the City Council wanted to offer equal opportunities to all greenhouse owners in the region. This means ensuring a more optimal and sustainable distribution of the subsurface. A way forward is by managing the underground at a regional level and the geothermal heat contained within. The following sections outline the methodology followed in this study for the regional planning. Three main aspects are considered: 1) Geothermal setting. The geology, geothermal characteristics and physical properties of the underground are investigated. On the basis of this geological inventory, suitable reservoirs are selected. 2) Well-field design. For each selected reservoir a well-field configuration is designed and numerical modelling is carried out. 3) Legal framework. The legislation in the Netherlands on exploration permits is reviewed as well as the opportunities for Westland to implement the underground regional planning within the legal framework. The transferability of such methodology to other locations and countries is also briefly discussed.

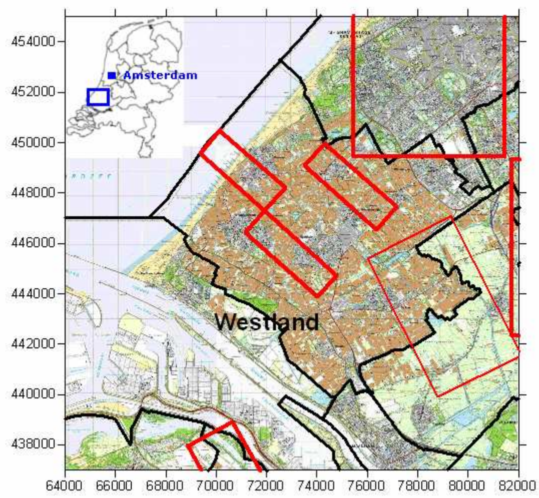

Figure 1. *Location of Westland within the Netherlands (blue block). Granted and requested exploration permits (red areas). The boundaries of the Westland are delineated in black.*

2. GEOTHERMAL SETTING

2.1 GEOLOGY

Westland is located within the West Netherlands Basin (WNB). Table 1 outlines the regional geological sequence and lithology. Subsidence and erosion of the hinterland filled the basin with thick packages of sediments (mainly sands and clays). During the Late Cretaceous the basin was inverted and older normal faults, partly Jurassic, were reactivated as reversed faults. Several of these faults cross Westland. Although only briefly summarised, these geological processes are responsible for the structural and depositional setting found at Westland.

Table 1. *Geological sequence and lithology at Westland*

Era	Group	Main lithology
Quaternary	North Sea Supergroup	Sand and clay
Tertiary	North Sea Supergroup	Sand and clay
Cretaceous	Chalk Group	Limestone
	Rijnland Group	Sand and claystone
Jurassic	Schieland Group	Sand and claystone
	Altena Group	Claystone
Triassic	Upper Germanic Trias Group	Sand, clay, and limestone and evaporites
	Lower Germanic Trias Group	Sand, clay, and siltstones
Permian	Zechstein Group	Carbonates, evaporites and limestone
	Upper Rotliegend Grouop	Sandstones
Carboniferous	Limburg Group	Clay, silt, and sandstones with coal layers

2.2 GEOTHERMAL PROPERTIES

The geothermal gradient is determined by evaluating the uncorrected borehole temperatures (BHT) of seventeen wells. Figure 2 is a plot of the BHT measurements per borehole. The corresponding borehole names from which BHT measurements were taken are also given.

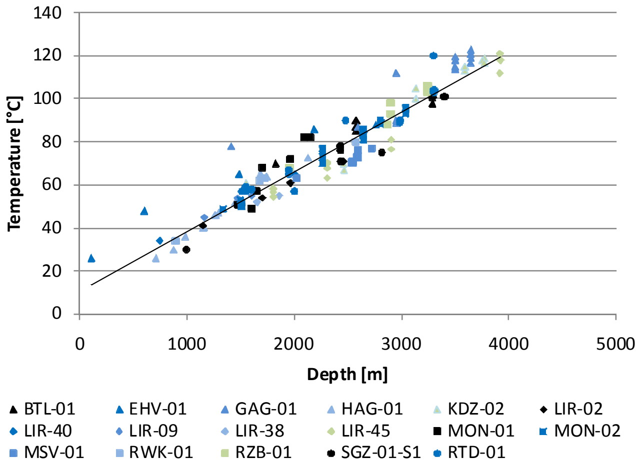

Figure 2. *Measured BHT in seventeen wells. The solid line is the linear regression curve.*

In Figure 2, the linear regression curve between temperature and depth is plotted. Based on this curve, the temperature at depth (T) can be calculated following:

$$T = 0.028 \cdot d + 11 \quad (1)$$

where d denotes the depth below ground level (m).

2.3 POTENTIAL RESERVOIRS

According to Simmelink (2008), the sandstone layers from the Upper Jurassic and Lower Cretaceous Groups have the highest potential as suitable geothermal reservoirs. Therefore, this study focuses only on those formations. Table 2 outlines the physical properties of the most potential reservoirs. The properties are determined from well logs, core measurements form oil and gas wells, and geological maps published by the Netherlands Institute of Applied Geosciences, TNO (NITG/TNO, 2002; Rondeel et al. 1996). It is noted that the thicknesses listed are gross values and the porosities values are averaged. The range of reported permeability is also given as well as the obtained geometric mean.

Table 2. *Physical properties of the potential reservoirs.*

Member	Thickness	Porosity	Permeability [mD]	
	[m]	[%]	Range	Geometric mean
Holland Greensand	20-110	21	1 - 185	12
De Lier	10-190	14	0 - 67	<1
Berkel Sandstone	10-60	25	0 - 9,200	700
Rijswijk	10-80	19	1 - 1,980	83
Delft Sandstone	10-100	22	2 - 4,690	798

Based on these properties two formations are selected as most potential reservoirs: the Berkel Sandstone Member and the Delft Sandstone Member. Figure 3 shows the maps of the thickness distribution of both reservoirs within Westland.

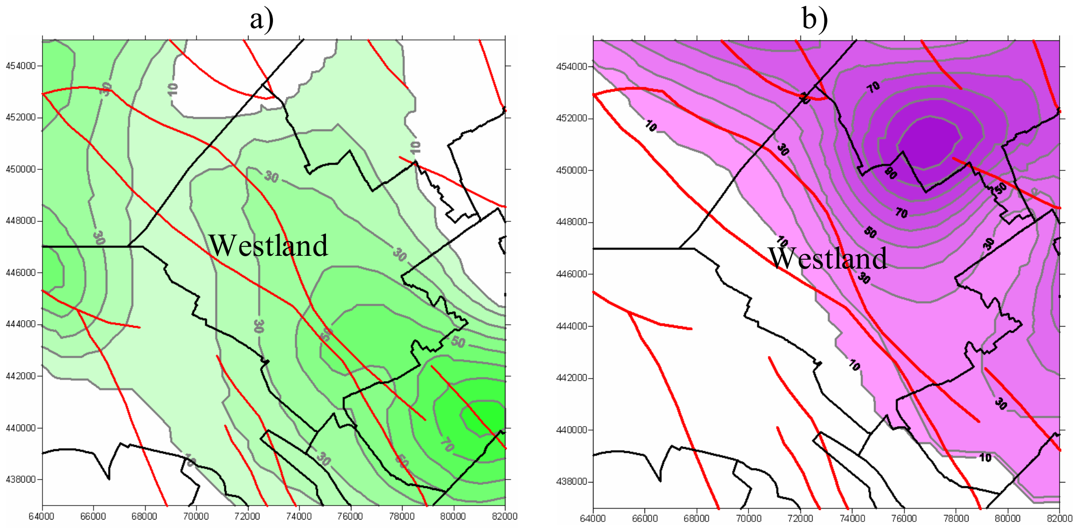

Figure 3. *Reservoir thickness distribution at Westland. a) Berkel Sandstone Member, b) Delft Sandstone Member. Red lines denote the faults. Boundaries of Westland are delineated in black.*

3. WELL-FIELD DESIGN

To ensure a sustainable extraction of geothermal heat, the design of an optimal well-field is of paramount importance. A well-field configuration determines the number of geothermal doublets (a production well and an injection well) and their location within a specific area. However, a number of factors have to be considered, these include desired lifetime of the geothermal system, minimum reservoir thickness, temperature at depth, hydraulic and thermal impact, and other practical aspects such as the boundaries of the municipality. In this study, the starting point for the well-field design calculations is that the lifetime of the geothermal doublet should be at least 30 years. That is, each geothermal doublet should deliver the same capacity during the course of time. Table 3 lists the starting points for the well-field configuration.

Table 3. *Starting points for the well field design calculations*

Starting points	Berkel Sandstone	Delft Sandstone
Flow rate [m³/h]	150	150
Equivalent running hours [h]	5,000	5,000
Initial reservoir temperature [°C]	45-70	70-75
Injection temperature [°C]	40	40
Porosity [-]	0.19	0.23
Thickness range [m]	25-90	25-90
Volumetric heat capacity [MJ/(m³·°K)]	2.5	2.6
Desired lifetime of doublet [years]	30	30
Thermal retardation factor[-]	3.3	2.8

Other aspects considered for the well-field design are:
- A minimum reservoir thickness of 25 m
- Production wells are placed as much as possible in areas of higher temperature
- Thermal effects should not exceed beyond the boundaries of the municipality
- Faults are considered as no-flow boundaries

A number of computational trials with various numbers of wells and well spacing were required. The final well-field design was decided for the configuration which could host the largest number of doublets whilst still ensuring the above-mentioned restrictions. Figure 4 shows the well-field configuration proposed for both reservoirs.

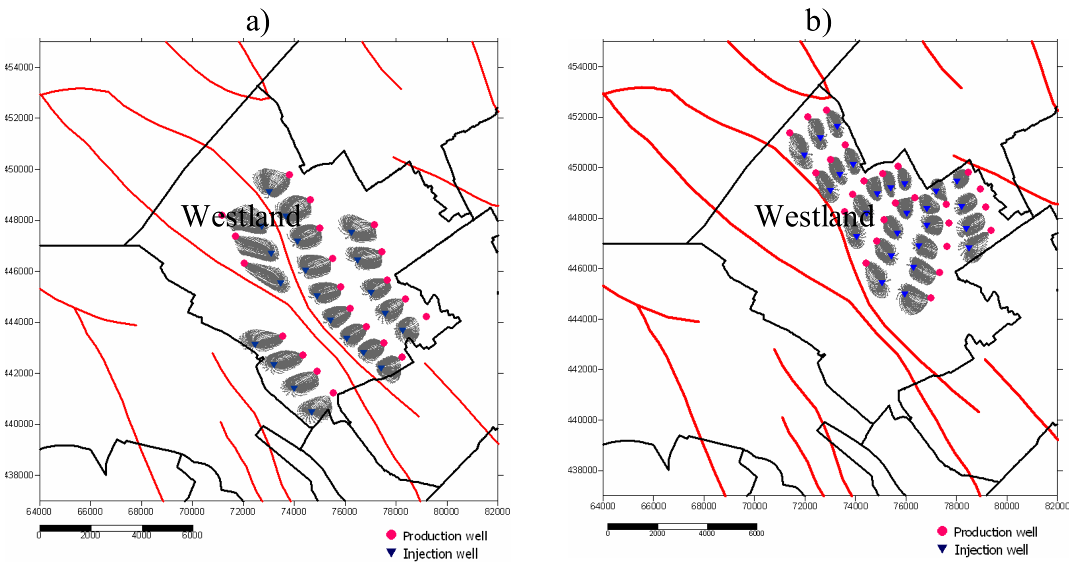

Figure 4. *Well field design. a) Berkel Sandstone Member, b) Delft Sandstone Member. Red lines denote the faults. Boundaries of Westland are delineated in black.*

The results from this regional planning reveals that geothermal systems cannot be implemented equally all across Westland. An advantage of the regional planning is that those areas with favourable conditions are more easily identified. It is estimated that the total number of geothermal doublets for the Berkel and Delft reservoirs are 21, and 25 respectively.

3.1 REGIONAL PLANNING VS INDIVIDUAL APPLICANTS

Table 4 shows the heat extracted if regional planning is applied and according to individual projects. It should be noted that for the latter calculations it was assumed that a pattern of individual permits as that shown in Figure 1. These values are compared to the estimated Heat in Place (HIP) within Westland. The HIP for each reservoir is calculated following:

$$HIP = V \cdot \Delta T \cdot C_a \qquad (2)$$

where V is the reservoir volume within Westland, ΔT is the temperature difference between the formation water temperature and the injection temperature (°C), C_a is the volumetric heat capacity of the reservoir (MJ/m^3°K).

Table 4. *Comparison between regional planning and individual projects.*

Reservoir	HIP [TJ]	Individual applicants [TJ]	Regional planning [TJ]
Berkel Sandstone	129,000	19,000 (15% of HIP)	48,500 (38% of HIP)
Delft Sandstone	175,000	32,000 (18% of HIP)	69,000 (39% of HIP)

Results outlines in Table 4 show that by introducing a regional planning the amount of heat extracted substantially increases (>200%) when compared to the heat extracted following individual applicants. The equivalent greenhouses area that could be heated can be calculated based on a annual consumption of natural gas of 40 m³/m². The results for the Berkel and Delft reservoirs are of 124 ha and 177 ha respectively.

4. LEGAL FRAMEWORK

Following the results of the regional planning study, the municipality of Westland made an application for an exploration permit in which the requested surface area follows the boundaries of the municipality. This application fits into the existing Mining Act, Mining Degree and Mining Regulation and has to be submitted to the Minister of Economical Affairs (EZ). The decision process can take between 6 months and up to 1 year. Once the permit is granted, the new permit holder (in this case the municipality of Westland) can decide to split the permit into parts and transfer to new permit holders (greenhouse owners). The EZ will carry out the latter procedure and will judge such transfer under the same merits as the original permit holder.

Despite the positive prospect shown by the regional planning compared to individual applicants, there have been a series of shortcomings in the actual implementation. For instance, the original individual applicants were initially concerned with the additional time delays it could bring the new application submitted by the municipality of Westland. However, the two parties seem to be cooperating together at present after a series of arrangements regarding financial and technical support.

5. TRANSFERABILITY

In regions where the concentration of users is high, introducing a regional planning offers the possibility of an increased exploitation of the geothermal energy. Nevertheless, a regional planning is highly dependent on the knowledge of the subsurface characteristics such as geological and geothermal properties. Provided this is the case, the methodology presented in this study can be readily adopted and applied at other locations and countries. However, the legal aspects for implementing such regional planning are not transferable as these can be location-dependent or country-dependent.

6. CONCLUSIONS

Geothermal energy has become an interesting option in the Netherlands for high heat demand users such as greenhouses. In order to obtain a permit for exploration of geothermal heat, an application has to be submitted to the Minister of Economical Affairs. However, in areas with high concentration of users, dividing the underground according to individual requested areas not always ensures an optimal distribution of the subsurface. In addition, this practice could restrict future new applicants. This phenomenon was observed at the municipality of Westland. In order to offer equal opportunities to all the interested parties, the City Council requested a study in which the underground is planned at a regional level. The methodology followed for the regional planning consisted in a geological inventory, selection of suitable reservoirs and a well-field design that could accommodate the largest possible number of geothermal doublets. It was shown that it is possible to extract a substantially higher amount of geothermal heat compared to individual extractions. However, and although feasible within the legislation point of view, the actual implementation of such planning option is not straightforward. All involved parties have to cooperate together to ensure limitations are overcome.

7. REFERENCES

NITG/TNO.: Geologische Atlas van de Diepe Ondergrond van Nederland, Toelichting bij Kaartbladen VII en VIII: Noordwijk-Rotterdam en Amsterdam-Gorinchem, Utrecht, (2002), 135.

RONDEEL, H.E., BATJES, D.A.J., and NIEUWENHUIJS, W.H.: Geology of Gas and Oil under the Netherlands, Kluwer Academic Publishers, (1996), 229-241.

SIMMELINK, H.J.: Geschikheid van de Diepe Ondergrond: Geothermisch Potentieel Zuid Holland, TNO, (2008), 13.