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Subsurface Spatial Planning for Geothermal Heat Production in Greenport Westland-Oostland, the Netherlands

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ABSTRACT

In 2007 a geothermal project was realized for a tomato grower in Bleiswijk, The Netherlands. This project was realized in a cretaceous sandstone reservoir at a depth of approximately 1,700 m. Since then, numerous other greenhouse owners became interested in this energy source. However, the subsurface area required for the heating of a greenhouse is much larger than the areal extent of the greenhouse itself. Also, in 2008, oil and gas prices reached extremely high levels. This combination of circumstances initiated a ‘gold rush’ for the subsurface in order to claim the rights for the exploration of the geothermal heat contained within.

In the greenport Westland-Oostland several requests to claim for these rights were made by individual applicants. The pattern of individual claims suggested a future suboptimal use of the subsurface. Confronted with this, the Greenport Westland-Oostland asked for the development of a masterplan according to which the subsurface could be divided in a more optimal way. First, a geological model of the region’s subsurface was created. Two sandstone layers occurring at depths of 1,500 and 2,500 m, respectively were identified as potential heat reservoir layers. Based on the geological findings, a geothermal modeling study was carried out to determine a more optimal well configuration. Results from these calculations show that the amount of heat extracted according to the masterplan (the optimal well configuration) doubles compared to the extraction of geothermal heat by individual projects. The masterplan comprises a total of 153 geothermal doublets spread over an area of roughly 170 km², realized in the two sandstone layers. Assuming an injection temperature of 40°C, at least 49% of the estimated 707,750 TJ of heat in place can be produced during the lifetime of a geothermal doublet. This corresponds to an average capacity of around 4.2 MW thermal per geothermal doublet. Moreover, with the masterplan approximately 25% of the greenhouses in the greenport Westland Oostland can be heated with geothermal energy for thirty years

1. INTRODUCTION

When in 2007 the geothermal project for a tomato grower in Bleiswijk was realized, only few would have anticipated the impact of this project in the growing interest for geothermal heat in the Netherlands. The project was realized in the Berkel Sandstone Member, a shallow marine sandstone, located at a depth of approximately 1,700 m. At this depth water is extracted with a temperature of 60°C. The warm water is led through a heat exchanger and injected back into the sandstone with a temperature of 25°C. The thermal capacity delivered to the greenhouse amounts to 6 MW_{th}.

Geothermal energy is a relatively unknown type of energy source in the Netherlands. The rising of oil and gas prices combined with the success of the Bleiswijk project made geothermal energy an interesting option for the traditionally innovative greenhouse sector in the Netherlands. Greenhouses have typically a high heat demand. However, the current high gas prices make possible a payback time of 10 to 15 years for a geothermal project. Such encouraging prospects prompted several other greenhouse owners to apply for an exploration permit for geothermal heat. The majority of the applications came from an area where the concentration of greenhouses is the most dense, initiating a ‘gold rush’ for these exploration rights for geothermal heat. This area is situated in the west of the Netherlands (see Figure 1) and is known as the Greenport Westland-Oostland.

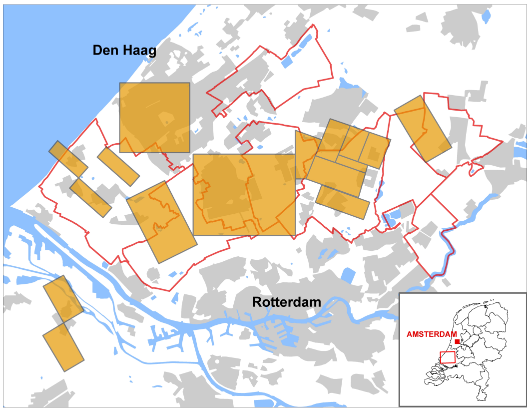

Figure 1: Location of the Greenport Westland-Oostland in the Netherlands (red boundaries) showing the requested and granted exploration permits (orange areas).

Two factors contributed to the so-called gold rush for geothermal heat: (1) the subsurface area required for the heating of a greenhouse is much larger than the areal extent of the greenhouse itself, and (2) the density of greenhouses in the Greenport Westland-Oostland is very high. In addition to the already granted exploration and exploitation permits for the Bleiswijk project, this gold rush resulted in 15 individual applications for exploration permits for geothermal heat by the end of 2008 (see Figure 1). By the 1st of January 2009 only one of the requested permits has been granted.

However, the pattern of these individual requests for an exploration permit (as shown in Figure 1) suggested a future suboptimal use of the subsurface. Confronted with this, the Greenport Westland-Oostland wanted within the framework of their environmental goals and their political responsibility, equal opportunities for all greenhouse owners in the region. As a consequence, an optimal use of the subsurface should be developed. A way to do this is to design a 'masterplan' according to which the subsurface could be exploited in a more optimal way. This masterplan for subsurface spatial planning was developed for the Greenport Westland-Oostland.

The masterplan according to which the subsurface spatial planning should be realized, was developed in three steps.

1) The geology of the region was outlined based on well logs and core information from oil and gas wells found in the public domain (see Annex), as well as a number of publications such as Rondeel (1996), DeVault and Jeremiah (2002), NITG/TNO (2002), and Wong et al. (2007). On the basis of this geological inventory, the suitable geothermal reservoirs were indentified and their properties as well as the heat in place (HIP) were determined.

2) Based on the reservoir properties an optimal well configuration was designed and subsequent geothermal modeling was carried out. The well configuration is based on a well spacing between production and reinjection wells to ensure thermal breakthrough occurs only after certain years. In order to extract maximum heat, this spacing takes into account variations in reservoir thickness and temperature.

In addition to the geological, hydrological and physical aspects of a geothermal system, the (legal) implementation of the masterplan in the region was also an important issue. On one hand, the Greenport Westland-Oostland has the intention to create equal opportunities with respect to the realization of geothermal projects to all involved parties and wants to fit this within a legal framework. On the other hand, is it of extreme importance not to frustrate the current running projects. Ultimately, the Greenport Westland-Oostland has to create a social understanding by all concerned parties. The third step in realizing subsurface spatial planning is a result of the points mentioned above.

3) The legislation in the Netherlands about exploration permits is briefly sketched as well as the opportunities for the Greenport Westland-Oostland to implement the masterplan within a legal framework.

2. GEOLOGY

2.1 Geothermal Gradient

The geothermal gradient is determined by evaluating the uncorrected bore hole temperatures (BHT) of seventeen wells. The measured BHT are plotted in Figure 2. The referenced wells are listed in the table 1. During the drilling of a borehole temperature measurements are commonly made. However, shortcomings can occur during the measurements. For instance, a cold drilling fluid effects the temperatures in the borehole. This effect decreases the BHT and results in an underestimation of 2 to 5°C of the measured BHT. On the other hand, the water temperature between the subsurface production point, up to depths of approximately 3,500 m, and the surface decrease with a maximum of 5°C. It is assumed that these two factors offset each other and can thus be left out of consideration.

The measured BHT of the 17 wells are shown in Figure 2. The linear regression curve between the temperature and the depth is also plotted. Considering the above, the following geothermal gradient can be calculated using the formula:

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

where T is the temperature at depth in degrees Celsius and d is the depth in meters.

Table 1: List of the wells and the information used form these wells. KNNSB denotes Berkel Sandstone Member, SLDA denote Alblasserdam Member, KNNR denotes Rijswijk Member, KNGLG denote Holland Greensand Member and KNNSL denotes De Lier Member.

Well	Measurements
BRK-09	core KNNSB
BRK-13	core KNNSB
BRK-23	core KNNSB
BTL-01	BHT
EHV-01	BHT, core SLDA
GAG-01	BHT, core KNNSB
HAG-01	BHT, core KNNSR
HAG-02	core KNNSR
KDZ-02	BHT
LED-01	core KNNSR
LIR-02	BHT
LIR-09	BHT, core KNGLG
LIR-14	core KNNSL
LIR-38	BHT
LIR-40	BHT, cores KNGLG and KNNSL
LIR-45	BHT, core KNNSR
MED-01	core KNNSR
MON-01	BHT, cores KNGLG and KNNSL
MON-02	BHT, core KNNSR
MSV-01	BHT
RTD-01	BHT
RTD-01	core SLDA
RWK-01	BHT
RZB-01	BHT
SGZ-01-S1	BHT
BRK-09	core KNNSB

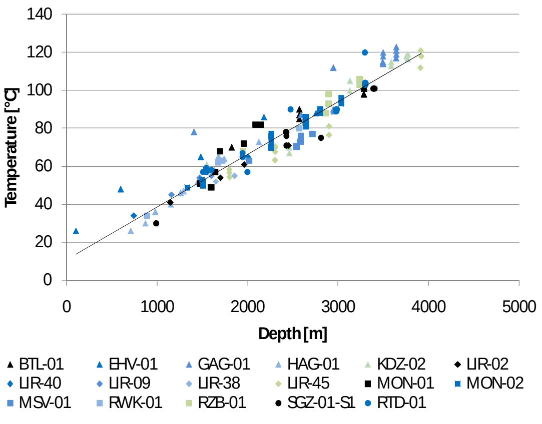

Figure 2: Measured BHT of 17 wells. The solid line is the linear regression curve.

2.2 Structural and Depositional Setting

The Greenport Westland-Oostland is located in a paleobasin, the West Netherlands Basin. Subsidence and erosion of the hinterland filled the basin with thick packages of sediments (sands and clays). In Figure 3 the main structural elements in the Netherlands from Late Jurassic to Early Cretaceous are outlined. During the Late Cretaceous the basin was inverted which caused erosion of the basin fill. Older normal faults, partly Jurassic, were reactivated as reversed faults.

Although only briefly summarized, these geological processes are responsible for the geological setting in the subsurface beneath the Greenport Westland-Oostland. The estimated most suitable reservoirs for geothermal energy were deposited during the periods of subsidence of the West Netherlands Basin. The Greenport is crossed by several northwest-southeast oriented reversed normal faults.

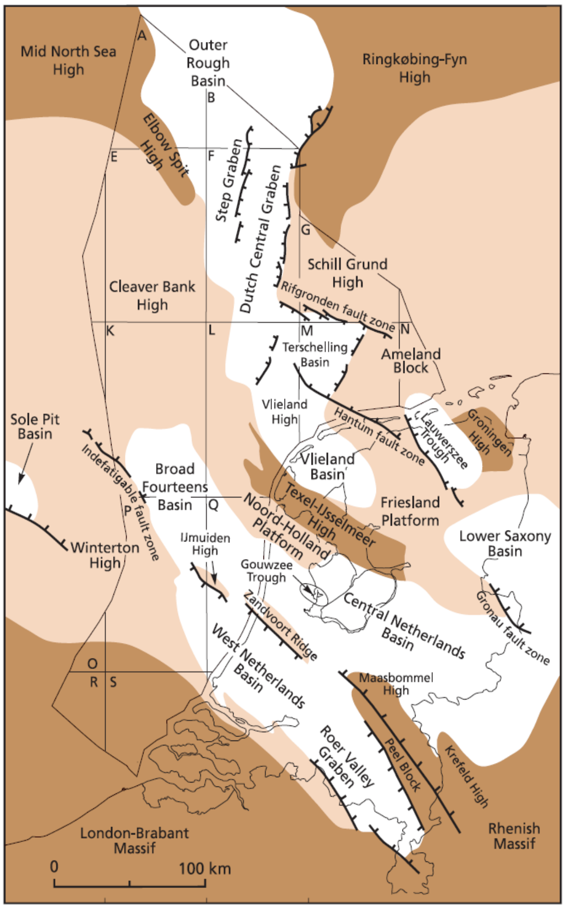

Figure 3: Map of Late Jurassic to Early Cretaceous structural elements in the Netherlands. Dark brown: structural high, partly subaerial landmass; light brown: platform, intermittently flooded; white: basin. (Wong et al., 2007).

2.3 Geological Sequence and Potential Reservoirs

The geological sequence below the Greenport Westland-Oostland is given in Table 2. In this table also the dominant lithologies in the different groups are given. Simmelink (2008) showed that in this region the sandstone layers from the Upper Jurassic and Lower Cretaceous Groups have the highest potential regarding suitability as geothermal reservoir. Therefore, this study focuses only on the above-mentioned groups and the Triassic sandstones were not further examined.

The sandstone layers in the Rijnland Group are sediments deposited in a prograding coastal barrier system and consist of coarse to very fine-grained sand- and siltstones which are partly reworked by bioturbation, waves and storms (van Adrichem Boogaert and Kouwe, 1993). Therefore, the sandstones vary laterally and vertically in thickness and grain size. This thickness variations are illustrated in the isopach map of the Berkel Sandstone Member shown in Figure 4.

Table 2: Geological sequence in the Greenport Westland-Oostland

Era	Group	Dominant lithology
Quaternary	North Sea Supergroup	Sands and clays
Tertiary	North Sea Supergroup	Sands and clays
Cretaceous	Chalk Group	Limestones
	Rijnland Group	Sand- and claystones
Jurassic	Schieland Group	Sand- and claystones
	Altena Group	Claystones
Triassic	Upper Germanic Trias Group	Sand-, clay-, and limestones and evaporites
	Lower Germanic Trias Group	Sand-, clay -, and siltstones
Permian	Zechstein Group	Carbonates, evaporites and limestones
	Upper Rotliegend Grouop	Sandstones
Carboniferous	Limburg Group	Clay-, silt-, and sandstones with coallayers

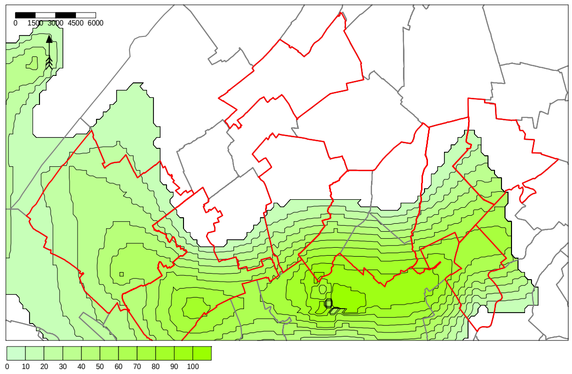

Figure 4: Isopach map of the Berkel Sandstone Member in the Greenport Westland-Oostland, showing the lateral variations in thickness.

Within the Greenport Westland-Oostland the Schieland group consists of the Nieuwerkerk Formation. Two different perspectives about the genesis of this formation exist. DeVault and Jeremiah (2002) divide the formation into the Rodenrijs Claystone Member and the Alblasserdam Member. Whilst Rondeel et al. (1996) and van Adrichem Boogaert and Kouwe (1993) divide the Nieuwerkerk Formation into the Rodenrijs Claystone Member, the Delft Sandstone Member and the Alblasserdam Member. Based on the available information in the form of well logs and literature the first description accords better with the data.

However, the Delft Sandstone Member is compared to the other fluvial sandstone layers in the Alblasserdam Member more continuous and laterally easier recognizable. This makes it more practical to apply in the western part of the Greenport Westland-Oostland the second view which divides the Nieuwerkerk Formation into three members. In the eastern part, where the Delft Sandstone Member is not recognized, the first view is applied. In Figure 5 the area where the Delft Sandstone Member occurs is shown.

2.4 Reservoir Properties

In Table 3 an overview of the reservoir properties of the potential reservoirs in the study area is given. The reservoir properties are determined on the basis of well logs and core measurements from oil and gas wells.

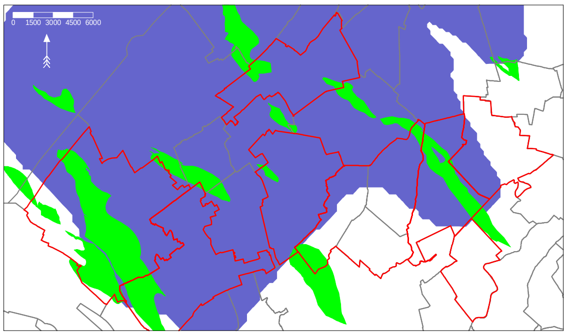

Figure 5: Presence of the Delft Sandstone Member (blue) in the Greenport Westland-Oostland. Also identified are the oil and gas occurrences in the area (green zones).

Table 3: Reservoir properties of the potential reservoirs. Porosities are presented as average porosities. The two permeability columns represent the geometric mean and the range respectively. * = no or insufficient data.

Member	Thickness [m]	Porosity [%]	Permeability [mD]	
Holland Greensand	20-110	21	12	1-185
De Lier	10-190	14	<1	0-67
Berkel Sandstone	10-60	25	700	0-9,174
Rijswijk	10-80	19	83	1-1,985
Delft Sandstone	10-100	*	*	*
Alblasserdam	30-300	22	798	2-4,687

The thicknesses listed are gross thicknesses and based on geological maps created by TNO (Netherlands Institute of Applied Geosciences) and the available well logs. The presented porosities are average values which are determined from well logs and were compared to the available core measurements. Two columns are presented for the permeability. The left column is the geometric mean of the permeabilities measured in the available cores. The right column is the range of the permeabilities measured in the cores.

The determined values of the reservoir properties are compared with a published project by TNO (Simmelink, 2007; Simmelink, 2008). The comparison for the Rijswijk Sandstone Member shows that the reservoir properties have slightly higher values. The reservoir properties of the Berkel Sandstone Member show substantially higher values. This increase can be attributed to a larger available dataset that could be analyzed.

At the time of this study no cores of the Delft Sandstone Member were available for the considered area. However, some core measurements of sandstone layers in the Alblasserdam Member were available for two nearby wells. Where TNO uses the complete dataset, comprising both impermeable clay layers and permeable sandstone layers, here only the measurements taken in the permeable sandstone layers are considered. This resulted in substantially higher values for the reservoir properties of the Delft Sandstone Member.

Based on the reservoir properties as presented in Table 3, the Berkel Sandstone Member and the sandstones in the Alblasserdam Member, of which the Delft Sandstone Member is a part, have the highest potential to act as geothermal reservoirs.

2.5 Oil and Gas

The Greenport Westland-Oostland is completely located within the concession Rijswijk of the NAM (Nederlandse Aardolie Maatschappij B.V.). Within this concession several oil and gas occurrences are present (see also Figure 5). Oil and gas reservoirs are located in the sandstone layers in the Rijnland Group and Schieland Group and gas reservoirs are located in Triassic sandstones.

Some of the gas and oil occurrences are located in the same reservoirs as the potential geothermal reservoirs. These occurences are the Berkel, the Moerkapelle, and the Pijnacker oil occurrences. The other oil and gas occurrences are present in sandstone layers in the Rijnland Group situated above the potential geothermal reservoirs. The reservoirs are separated by claystone layers and/or faults.

When designing a geothermal system it should be considered the possible presence of the oil and gas in the sandstone layers of the Rijnland Group that will be penetrated, as well as the location of the three mentioned oil occurrences situated in potential geothermal reservoirs.

The gas reservoirs in the Triassic sandstones are located below the potential reservoirs and are separated by thick layers of mainly claystones. Therefore, these gas occurrences can be neglected when designing a geothermal project in the Berkel Sandstone Member or the Delft Sandstone Member.

2.6 Probability Analysis

A probability analysis was carried out in order to quantify the uncertainty of the quality of the potential reservoir. The quality of a geothermal reservoir is determined by the transmissivity, the product of the thickness and the permeability, and the difference between the production and injection temperature. In Table 4 the 10th, 50th and 90th percent probabilities of the transmissivity of the Berkel Sandstone Member and the Delft Sandstone Member are given.

Table 4: 10, 50 and 90 percent probabilities of the transmissivity in the potential geothermal reservoirs in the Greenport Westland-Oostland

Member	p10 [Dm]	p50 [Dm]	p90 [Dm]
Berkel Sandstone	709	22	1
Delft Sandstone	211	37	6

3. MASTERPLAN-SUBSURFACE SPATIAL PLANNING

The lifetime of a geothermal system ends when the water extracted from the production well reaches a certain minimum temperature as a result of the cold water injected through the infiltration well. This is referred to as thermal breakthrough. The thermal breakthrough time is particularly controlled by the thickness and the porosity of the reservoir as well as by the thermal properties of the fluids. The lifetime of a geothermal system can be controlled by the distance between the injection and the production wells. This well spacing also determines the amount of geothermal doublets that can be placed in one geothermal reservoir.

The well spacing needed is initially calculated using analytical formulas reported in Lippmann and Tsang Chin Fu (1981). With this spacing several possible well configurations can be designed in the different geothermal reservoirs. Finally, a choice is made on the most optimal well configuration for which numerical modeling is carried out. The focus of this modeling exercise is to verify the proposed well configuration (in terms of well spacing and thermal breakthrough behavior) and to determine the amount of heat extracted per configuration. The results from this modeling exercise are used to further optimize the masterplan. In addition, the results are compared to the estimated total heat in place and to the heat that would be extracted using the pattern of individual permit applications. The heat in place (HIP) is defined as the total amount of present heat.

3.1 Assumptions and Starting Points

The analytical formulas are based on the following assumptions: (1) The reservoir is horizontal with uniform reservoir properties. The layers above and below the reservoir are hydraulically impermeable and vertically infinite. (2) The recuperation time of the water in the reservoir is several orders of magnitude larger than the lifetime of the geothermal doublet. As a consequence the temperature of the injected water is assumed constant. The rate at which the water is injected equals the production rate. Groundwater flow within the reservoir is neglected. (3) The initial temperatures of the water, the reservoir and the cap and base rock are assumed similar and uniform. Thermal equilibrium occurs instantaneously between the water and the rock so everywhere in the reservoir the rock has the same temperature as the water. (4) The effects of thermal conduction in the horizontal direction are neglected in both the reservoir and the surrounding cap and base rock. In the cap and base rock the vertical thermal conductivity is finite. (5) Ultimately the water properties are assumed constant.

Lauwerier (1955) and Gringarten and Sauty (1975) showed that consideration of assumption (4) has a positive effect on the breakthrough time.

The spacing between the production and infiltration well is calculated as,

$$D = \sqrt{\frac{V \cdot 3}{\pi \cdot H \cdot R \cdot n}} \qquad (2)$$

where D is the required well spacing (m) V is the water volume (m³) H is the reservoir thickness (m), R is the thermal retardation factor and n is the porosity. The thermal retardation factor is calculated using the following equation (Doughty, Hellström et al., 1982):

$$R = 1 + \frac{(1-n) \cdot C_r}{n \cdot C_w} \qquad (3)$$

where C_r and Cw are the volumetric heat capacity MJ/(m³·K) of the rock and the water, respectively.

In Table 5 the starting points for the calculation of the required well spacing are listed. The thickness of the reservoir is a controlling factor in the required well spacing. A larger thickness means a smaller well spacing. In this study it is assumed that for these geothermal reservoirs a minimum thickness of 25 m is necessary to realize a geothermal doublet.

3.2 Results of Analytical Calculations

Figure 6 shows the well configuration for the Municipality of Westland for the Delft Sandstone Member. A starting location for the placing of the wells is where the reservoir has the greatest thickness. Production wells are preferably located where the temperature is the highest. The faults are considered as no-flow. It is noted that the well configuration also takes into account that the thermal effects are contained within the borders of the municipality.

Table 5: Starting points of the calculation for the required well spacing. SLDND denotes the Delft Sandstone Member.

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

The HIP as well as the heat extracted with the proposed masterplan for Greenport Westland-Oostland is listed in Table 6. The Nieuwerkerk Formation in this table includes both sandstone layers in the Alblasserdam Member as the Delft Sandstone Member.

The surface of the greenhouses heated is calculated by assuming a yearly gas consumption of 40 cubic meters of natural gas equivalent per square meter. The greenhouses comprise an area of approximately 3,650 ha. Calculations of the percentage of the HIP extracted with the wells placed according to the current pattern of individual claims results in values below 20%. In comparison, results from the masterplan show that a substantial increase in extracted heat (up to 54%) can be achieved when applying subsurface spatial planning.

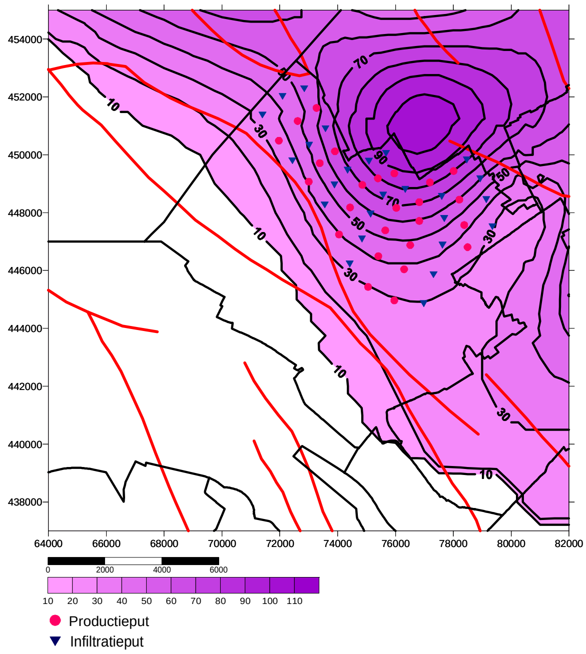

Figure 6: Masterplan in the Delft Sandstone Member in the municipality Westland. Red dots are production wells and blue triangles are injection wells. Faults and municipality borders are also indicated.

Table 6: Analytical results calculation Greenport Westland-Oostland. Besides the HIP and the extracted heat, the number of geothermal doublets and the surface of greenhouses heated by a yearly gas consumption of 40 m^3/m^2 are also given.

	Berkel Sandstone Member	Nieuwerkerk Formation
HIP [TJ]	200,950	506,800
Heat extracted (masterplan) [TJ]	73,500	274,300
Percentage of HIP [%]	37	54
Doublets	39	114
Surface greenhouses [ha]	189	714

3.3 Results of Numerical Modeling

The results from the analytical calculations were corroborated with a numerical modeling exercise. The assumptions made for the analytical calculations are the same as used in the model. Also assumed are a homogenous porosity and permeability. However, variations in thickness and thermal retardation are included in the modeling.

The results for the Delft Sandstone Member in the Municipality Westland are given in Figure 7. In this figure the thermal contours that develop between the injection and production wells at the end of year 30 are shown. Thermal breakthrough has occurred when a thermal contour reaches an production well.

From Figure 7 it can be observed that the well spacing based on the analytical equations (Figure 6) is a good starting point for the configuration of the geothermal wells. Since several wells show a slight thermal breakthrough, further optimization of this well configuration is possible. This will probably result in a larger percentage of extracted heat. This optimization can take place as soon as an extended geological and geophysical investigation has been carried out. In addition, after the first geothermal well has been drilled, the masterplan can be adapted and further optimized on basis of new (geological) information acquired from this first well.

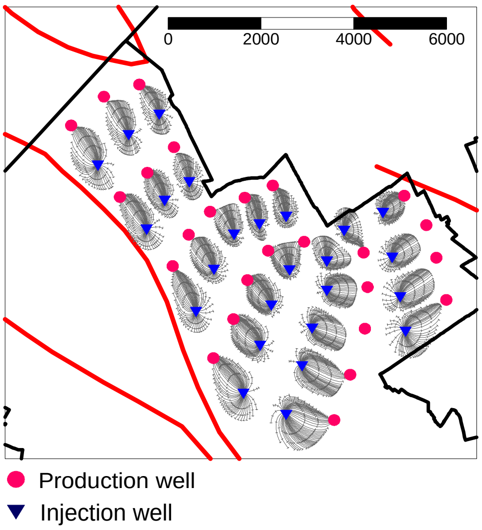

Figure 7: Modeling results of the thermal calculations for the Delft Sandstone Member in the Municipality Westland. Faults are indicated by red lines. Due to the presence of an oil field between the two faults crossing the municipality, no wells are placed here.

4. LEGISLATION

To fit the masterplan within a legal framework an application for an exploration permit for geothermal heat for two municipalities within the Greenport Westland-Oostland was made. Parts of this exploration permit will be transferred to parties willing to realize a geothermal system. This can be fitted into the existing Mining Act, Mining Degree and Mining Regulation by first splitting the permit into parts, and by subsequently transferring these parts to the new permit holders.

This process will take six months to a year and requires the followings steps: (1) A request for an exploration permit (for geothermal heat) will be formulated for the two considered municipalities and submitted to the Ministry of Economic Affairs (EZ). EZ will grant the permit if the applicant is economically and technically capable of drilling the well in a responsible and efficient manner. (2) When the exploration permit for geothermal heat is granted, the holder can split the permit into two or more separate parts. This action will be carried out by EZ on request of the holder of the permit. EZ will not allow a division when the influence (thermal and pressure) of a single geothermal doublet will be spread over several permits. (3) The new exploration permit can be transferred to the new holder. This transfer has to be approved by EZ and the new holder will be judged on the same aspects as the original holder.

5. IMPLEMENTATION

The above chapters show that it is technically advisable to implement a masterplan for the positioning at reservoir level of the geothermal doublets within the Greenport Westland-Oostland. The percentage of the HIP extracted may be doubled when compared to the positioning according to a pattern of individual claims.

Although the Mining Act provides an opportunity to implement a masterplan, practice shows another reality. At the moment EZ seems to prefer concrete projects above the strategic plans of the Greenport Westland-Oostland. A point of view that is supported by the Mining Act. Additionally, EZ does not completely endorse the involvement of other governmental bodies in the legislation concerning the subsurface.

Since the initiators of the current projects were concerned with serious time delays, they weren't immediately satisfied with the involvement of the Greenport Westland-Oostland in the realization of geothermal projects in the region. However, at the moment the initiators within the Greenport Westland-Oostland are, after a promise of financial and technical support, working together with the involved municipalities.

Another recent development is that EZ is currently studying the way the exploration and exploitation of geothermal heat is fitted within the current Mining Act. Partial result from this study is the influence of subsurface spatial planning of the geothermal doublets on the efficiency of the geothermal systems and the heat extracted.

6. CONCLUSIONS

- The rush on exploration permits in the Greenport Westland-Oostland may cause a suboptimal use of the subsurface with respect to geothermal energy. The Greenport Westland-Oostland intends to develop and stimulate geothermal energy as a renewable energy source as well as to provide equal opportunities with respect to the realization of a geothermal project to all interested parties.

- To prevent suboptimal use of the subsurface and to extract the HIP as efficiently as possible, a masterplan which provides a subsurface spatial planning of the geothermal wells should be designed.
- In the Greenport Westland-Oostland two potential reservoirs for geothermal energy are present. The Berkel Sandstone Member and the Delft Sandstone Member.
- Analytical calculations show that at least 49% of the HIP can be extracted when applying subsurface spatial planning. Compared to the current pattern of individual claims, where 20% of the HIP can be extracted, the sweep efficiency is doubled.
- A model of the designed masterplan shows that the masterplan should be adapted and optimized according to the results of an extended geological and geophysical investigation.
- The masterplan is adaptive. This means that after every realized geothermal project the masterplan can (and should) be optimized with the newly gathered (geological) information.
- Although legally possible, the implementation of a masterplan for geothermal energy is not obviously. However, recent developments may change this in the future.

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