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MEMORANDUM

To: NEDMAG, Veendam

Subject: Blanket diesel dynamics for new caverns VE-7&8

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Introduction

In reference 1, Evaluation of blanket diesel dynamics for new caverns VE-5 and VE-6, it was investigated if blanket diesel trapped in these caverns could potentially reach the biosphere. The focus of diesel dynamics was on trapping, permeation and dispersion in the overburden rocks above the caverns. The overall conclusion was that in this scenario, the use of diesel for developing the caverns VE-5 and VE-6 does not constitute a risk for the regional biosphere, not in the short term (during active mining), nor in the (very) long term after cavern abandonment.

In this memo, the influence of differences in location between VE-7&8 and VE-5&6 concerning diesel migration through the process of permeation to the overburden has been investigated.

The possible environmental consequences of an instantaneous leak to the overburden by one macro-fracture or multiple macro-fractures are not discussed in this memo.

Cavern positions relative to the Veendam Pillow

The positioning of the VE-7&8 caverns is to the SE side of the Veendam pillow (see Attachment A). The following similarities exist between the planned caverns of VE-7&8 and VE-5&6:

- The operating parameters for VE-7 and VE-8 are equal to those of VE-5 and VE-6. During cavern development, the same amount of 2500 m^3 (net) diesel per well is expected to be injected and could conservatively expected to be finally left behind at cavern abandonment. Over time the caverns will become connected, summing the diesel conservatively to 5000 m^3.

- Although the exact geology is unknown above the planned future VE-7&8 cavern, the same formations (lithology and thicknesses) and similar fault systems are expected on basis of high-quality 3D seismic data (ref. 2).

Based on those similarities, the same conclusions can be drawn for the VE-7&8 caverns as for the VE-5&6 caverns:

- The deep, subsurface dynamic process of blanket diesel after cavern abandonment will very likely result in an end-situation of diesel predominantly adsorbed in the Zechstein salt, instead of leaking off into the overburden rock formations. The diesel will be contained in smaller ambient lithostatically pressured pockets outside the brine leak-off point after abandonment and, thus, become geologically immobile. In other words, diesel stays preferentially behind in the Zechstein salts due to capillary pressure effects (ref. 1).

- Even when part of diesel or all diesel (worst-case scenario) would escape from the twin-cavern VE-7/8, the highest possible migration level of permeating diesel is the bottom of the Vlieland claystone, which seals off the Vlieland sandstone. The shallowest bottom of the Vlieland claystone is below 800 m TV. During its way upwards, the diesel is likely

trapped in the hydrostatically pressured overburden by a series of capillary barriers and permeable layers, perhaps in combination with natural fracture systems.

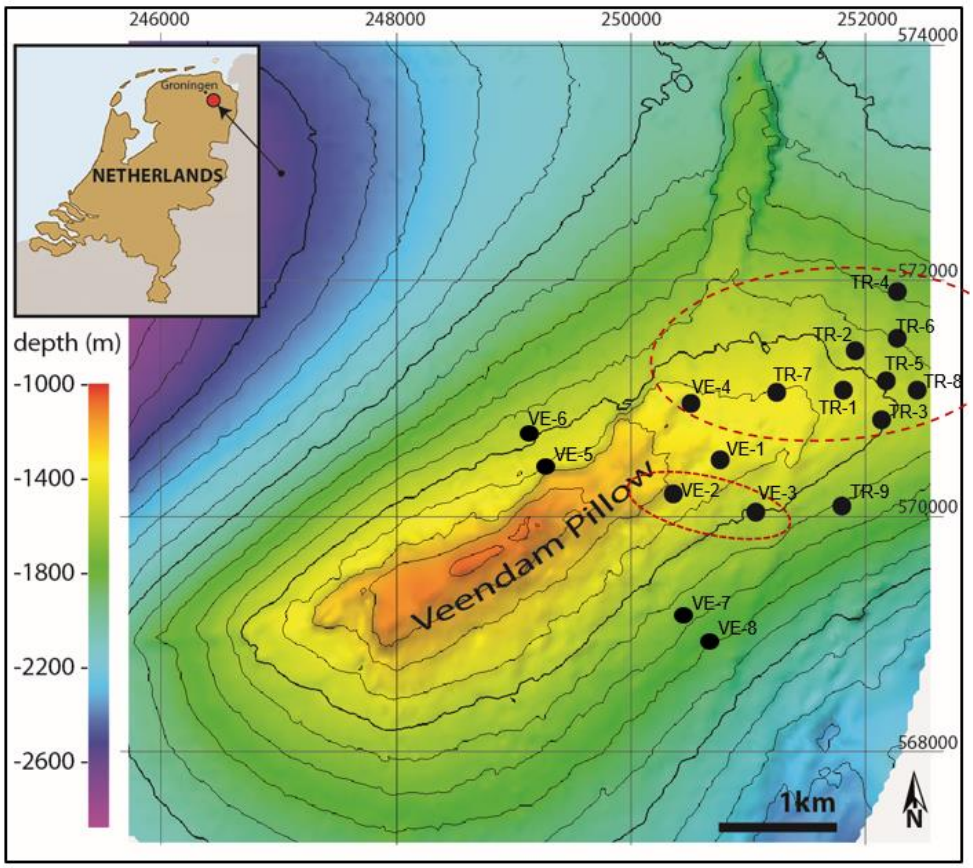
- The Vlieland sandstone will act as ultimate diesel containing reservoir. For a Vlieland migration process to be justified, a permeable fault must exist in the Solling claystone, with sufficiently large offset to be juxtaposed to the permeable Vlieland sandstone. Then, the remaining amount of diesel finally arriving in the Vlieland sandstone will form a small low saturation accumulation, which is geologically stable under the overlying clay-rich seal.

Overall conclusion
Although it may not be possible to accurately predict the precise distribution of the diesel fluid with time after cavern abandonment, the presence of potential hydrocarbon traps and seals *in series*, combined with the geometry and thickness of the Veendam overburden, make it extremely unlikely that fresh groundwater contamination can occur by upward migration of the Veendam diesel blanket.

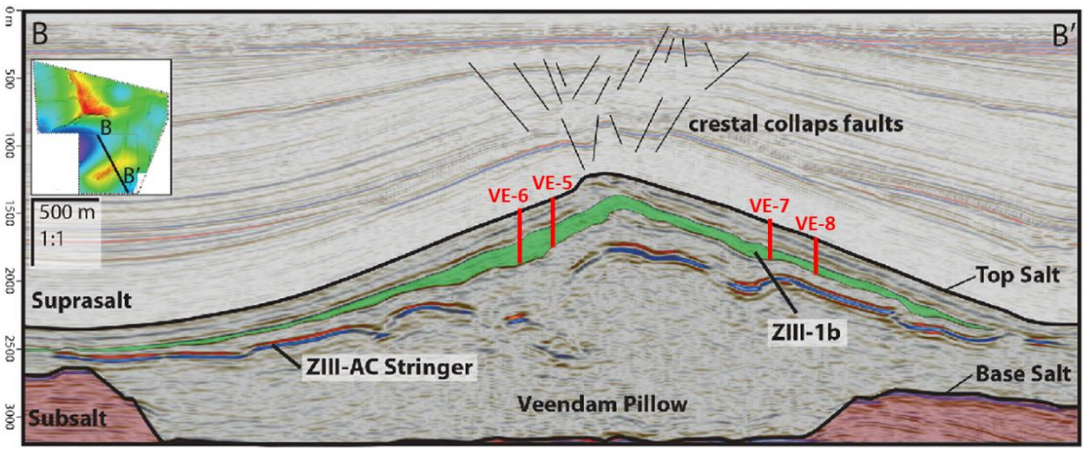
References

1. Evaluation of blanket diesel dynamics for new caverns VE-5 and VE-6 v3, Well Engineering Partners, October 18th 2017.
2. Evolution of rheologically heterogeneous salt structures: a case study from the NE Netherlands, A.F. Raith, F. Strozyk, J. Visser and J.L. Urai, Solid Earth, 7(1), 67, 15 January 2016.
3. Structural and microstructural analysis of K–Mg salt layers in the Zechstein 3 of the Veendam Pillow, NE Netherlands: development of a tectonic mélange during salt flow, A.F. Raith, J.L. Urai and J. Visser, Netherlands Journal of Geosciences 96.4: 331-351 2017.

Attachment A: Location VE-7/8 with respect to Veendam pillow



Positions of the 4 VE-wells (WHC-1) and 9 TR-wells (WHC-2), projected on top of the Zechstein (ZE) structure. Furthermore, planned targets for VE-5, VE-6, VE-7 and VE-8 are shown. Thicker isolines show 1500 and 2000 mTV depth contours respectively. Top of the pillow is somewhat below 1000 mTV (adjusted from ref. 3).



Projection of the VE7&8 cavern positions (and VE-5&6) in the seismic section of the Veendam Pillow (seismic section adjusted from ref. 2).