

Supplementary material: Methodology to calculate the porosity and the horizontal and vertical hydraulic conductivity

In this supplementary material, the methodology to obtain the porosity, horizontal and vertical hydraulic conductivity for the different formations, which are not available in the database REGIS is described.

The following information, provided by TNO, is available for the relevant lithologies:

- 1 Composition of the formation , see Table S1;
- 2 The porosity of the formation as function of depth, see Table S2;
- 3 Permeability of the formation [LogmD] as function of the porosity, see Table S3.

Based on these parameters, the porosity and the horizontal and vertical hydraulic conductivity are calculated by the following procedure, described in the steps below. As example to demonstrate this procedure, the Boom Clay is taken:

1. The composition is defined by using the lookup Table S1, which shows the lithology of the geological layers. For the Boom clay it results in 25% siltstone and 75% shale.

Table S1 Composition of the geological layers, provided by TNO

Lithology	Sandstone (%)	Siltstone (%)	Shale (%)	Marl (%)
North Sea Group	50	0	50	0
Lower North Sea Group	50	0	50	0
Dongen Formation	25	0	50	25
Middle North Sea Group	50	0	50	0
Rupel Formation	25	0	75	0
Boom Clay	0	25	75	0
Steensel member	25	0	75	0
Vessem member	33	33	34	0
Tongeren Formation	50	0	50	0
Veldhoven Formation	75	0	25	0
Veldhoven Clay Member	0	0	100	0
Someren Member	75	0	25	0
Breda Formation	75	0	25	0
Kiezelooliet Formation	75	0	25	0
Maassluis Formation	75	0	25	0
Oosterhout Formation	75	0	25	0
Voort Member	100	0	0	0

2. Subsequently the average depth is calculated for each grid cell by calculating the mean of the bottom and top of the geological layer.
3. The porosities for each grid cell can now be found in Table S2, thereby using the combination of the average depth and the compositions of the formation.

Table S2 Porosity as function of depth and lithology, delivered by TNO

Depth(m)	Sandstone	Siltstone	Shale	Marl
0	41	55	70	50
250	38.02	48.54	57.07	44.24
500	35.26	42.85	46.56	39.16
750	32.7	37.84	38.03	34.68
1000	30.34	33.43	31.09	30.72
1250	28.15	29.55	25.45	27.23
1500	26.13	26.13	20.87	24.15
1750	24.25	23.12	17.14	21.43
2000	22.52	20.47	14.12	19.03
2250	20.91	18.14	11.66	16.91
2500	19.43	16.09	9.66	15.04
2750	18.05	14.28	8.04	13.39
3000	16.78	12.69	6.72	11.93
3250	15.61	11.29	5.65	10.65
3500	14.52	10.06	4.78	9.51
3750	13.51	8.98	4.07	8.51
4000	12.58	8.02	3.49	7.63
4250	11.71	7.18	3.03	6.85
4500	10.91	6.44	2.65	6.16
4750	10.17	5.79	2.34	5.56
5000	9.49	5.22	2.09	5.02
5250	8.86	4.71	1.88	4.55
5500	8.27	4.27	1.72	4.13
5750	7.73	3.88	1.58	3.76
6000	7.23	3.53	1.47	3.44
6250	6.76	3.23	1.39	3.15
6500	6.33	2.96	1.31	2.9
6750	5.94	2.73	1.25	2.68
7000	5.57	2.52	1.21	2.48
7250	5.23	2.34	1.17	2.31
7500	4.91	2.18	1.14	2.15

4. The porosity is calculated by multiplying the percentage of each composition times the porosity of this composition at the average depth (calculated in step 2). For the Boom Clay it means for each grid cell: $\text{Porosity} = 0.25 * (\text{Porosity siltstone at calculated average depth}) + 0.75 * (\text{Porosity shale at calculated average depth})$.
5. As the porosity is known, the porosity-permeability relation in Table S3 is used. An interpolation is performed, to get the horizontal and vertical permeabilities at a given porosity.

Table S3 Permeability of typical sandstone, siltstone, shale and marl as function of porosity

Porosity [-]	Permeability [m ²]							
	Typical Sandstone		Typical Siltstone		Typical Shale		Typical Marl	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.01	1.80E-15	1.63E-16	2.75E-17	1.85E-18	1.24E-18	2.18E-19	3.75E-17	6.33E-18
0.25	2.19E-13	1.98E-14	5.40E-15	3.63E-16	1.25E-15	2.20E-16	6.17E-16	1.04E-16
0.41	8.26E-13	7.50E-14	1.85E-14	1.24E-15	1.54E-15	2.71E-16	1.94E-15	3.27E-16
0.5	8.26E-13	7.50E-14	2.58E-14	1.73E-15	1.71E-15	3.00E-16	2.68E-15	4.52E-16
0.55	8.26E-13	7.50E-14	2.99E-14	2.01E-15	1.66E-15	2.92E-16	2.68E-15	4.52E-16
0.7	8.26E-13	7.50E-14	2.99E-14	2.01E-15	2.07E-15	3.63E-16	2.68E-15	4.52E-16

6. Subsequently the hydraulic conductivity is calculated using the following formula:

$$\kappa = K \frac{\mu}{\rho g}$$

Where:

κ = the permeability [m²],

K = the hydraulic conductivity [m/s],

μ = the dynamic viscosity of the fluid [kg/(m·s)], which depends on the depth, according to table S4,

ρ = the density of the fluid, kg/m³, assumed constant at 1000 kg/m³,

g = the acceleration due to gravity and is 9.81 m/s².

Table S4 Depth-viscosity relation of water

Depth [m]	Viscosity [kg/(m.s)]	Temp [°C]
0	0.001306	10
333	0.001002	20
667	0.0007978	30
1000	0.0006531	40
1333	0.0005471	50
1667	0.0004658	60
2000	0.0004044	70
2333	0.000355	80
2667	0.000315	90
3000	0.0002822	100

The outcome of this procedure is for each formation a spatially distributed porosity and vertical and horizontal hydraulic conductivity. As example the hydraulic conductivity for the Boom Clay is presented in Figure 4.