# HYDROGEOLOGICAL AND HYDROGEOCHEMICAL INVESTIGATION OF THE DUNE AREA AND ADJACENT LOW POLDERS AT WENDUINE-UITKERKE, FLEMISH COASTAL PLAIN

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ABSTRACT

The hydrogeology and hydrogeochemistry of the dune area at Wenduine and the polders behind it have been investigated. Of special interest are the lowlying polders at Uitkerke, that are situated at the flow lines' end. For the purpose of a nature restoration project, that will be implemented soon, a hydrogeological investigation is currently being carried out in the core of these lowlying polders. Insight in the overal hydrogeological functioning of the system has been obtained beforehand. The general hydrogeological setting will be the subject of this contribution.

The geometry of the groundwater reservoir in the dune area and polders has been established. Groundwater flow has been determined. The groundwater chemistry has been studied by means of resistivity loggings in boreholes and by groundwater analysis. The interpretation of the both vertically and laterally strongly differentiated groundwater salinity is based on the hydrogeological history of the area.

## STUDY AREA: WENDUINE-UITKERKE

### Location and morphology

The study area is situated in the eastern Flemish Coastal Plain (Belgium) and is to be found on map 4/7-8 (1:25.000) of the NGI (National Geographic Institute of Belgium) (fig.1). The study area lies within the municipalities of Wenduine (De Haan), Nieuwmunster (Zuienkerke) and Uitkerke (Blankenberge) and contains the extensive agricultural Polder of Uitkerke.

The dune belt of the North Sea between Wenduine and Blankenberge has a rather restricted width, no more than 50 m. Between Wenduine and De Haan the dune belt is far more developed and reaches a width of 1 km.
Further on, there is a connection with the interior dune belts of Klemskerke and Vlissegem in the south. These dunes have a varied relief of pans and parabole dunes, which are mostly fixated by plantations.

The polders within the study area are of two kinds. First, those which are located on the top of former creeks (the so called "creek ridges"): the

Fig. 1 – Location of the study area with indication of profiles A-A'-A" and B-B'-B"

Dunkirk-clay was deposited on the sand of the creek. Second, the lower clay-on-peat sediments (the so called "pool grounds"). Both types form part of the "Bruges' Old Land".

## Geological setting

Based on well logging and borehole descriptions of DE BREUCK (1966, 1969), DEVOS (1984), VAN HAECKE (1998), CLAYS (1999) and HERMANS (1999), the nature and level of the Tertiary surface and the structure and thickness of the Quaternary deposits in the area of De Haan-Blankenberge were established, which gives us insight in the geological setting.

Tertiary

The Tertiary surface of the Polder of Uitkerke has the form of a bowl, originated by Early Pleistocene erosion (Saalian). Tertiary sediments were eroded in the centre of the bowl just until the clay of the Member of Merelbeke (Formation of Ghent), in its surroundings the clay-loam of the Member of Pittem (Formation of Ghent) was preserved. The glauconite-rich sands of the Member of Vlierzele (Formation of Ghent) form the Tertiary surface in the rest of the study area. The transition from the Formation of Ghent to the underlying Formation of Tielt is to be found between De Haan and Wenduine.

Quaternary

During the Eemian interglacial age, the deposit of Oostende took place. Its top and base are characterized by silex and gravel parts, the deposit itself is mainly sand with shell fragments. Late Pleistocene sediments are, consecutively, the deposit of Uitkerke (sand) and the deposit of Wenduine (sand and gravel) (DE BREUCK, DE MOOR & MARECHAL, 1969).The Pleistocene age was followed by a period of peat-growth. (BAETEMAN, 1987).The latter deposit was eroded during Atlanticum age (Flandrian Transgression; AMERYCKX, 1961) in the centre of the Polder of Uitkerke. The deposit of that transgression, the deposit of Calais, can be divided in the eastern coastal area in two deposits: the sandy deposit of Houtave (base) and the deposit of Zuienkerke (top), which has a sandy character, but also contains some clay (DE BREUCK, DE MOOR & MARECHAL, 1969). At the end of the Atlantic age, the peat of Nieuwmunster was formed behind the dune belt (DEVOS, 1984) which was removed during later transgressions, known as the Dunkirk Transgressions. Of most influence was the Dunkirk II transgression which formed creeks at Wenduine and Blankenberge, where the peat of Nieuwmunster was removed. Nowadays, on these sites remain 'creek ridges' (clay on sand), and sites formerly higher situated, are at a lower level (subsidence through clay on peat). This phenomenon called relief inversion was of a great importance in the study area. More recent relief changes such as peat-digging during Medieval Ages up to the late 19th century and clay-digging for bricks up to the middle 20th century also took place.

### Characterization of the groundwater reservoir

The Quaternary sediments in the study area form a layered groundwater reservoir with a thickness of approximately 30-35 m (fig. 2). Three aquifers can be determined (A, B, C), separated by 2 semi-pervious layers (A'/A'' and B'). In the polder area, B cuneates into disappearance. Between De Haan and Wenduine, and in Uitkerke (Blankenberge) the base of the pervious layer also contains the Tertiary sand of the Member of Vlierzele.

Pervious layer A is mainly Pleistocene sand, covered with the Holocene sands of Calais. Its thickness varies between 10 and 25 m. Some local clayey intercalation in this layer cannot be seen as proper impervious layers. Semi-pervious layer A' contains the clayey/loamy top of the deposit of Zuienkerke (deposit of Calais). Locally, the semi-pervious layer A' is thicker due to the existence of the Nieuwmunster peat (A''), that reaches a thickness in polderland of some 2-3 m. Pervious layer B contains the creek sands of Dunkirk, together with reworked parts of the Nieuwmunster peat, eroded by the creeks. Thickness varies up to 6 m. Semi-pervious layer B' is composed by the Dunkirk clay, and also forms the top layer in the polderland, where it forms one layer together with A''. Pervious layer C is the sand of the recent dune belt, where it also forms the phreatic aquifer. The level of the groundwater table is subjected to seasonal fluctuations due to the variations in infiltrated rain water. In the higher dunes which can reach a level of + 20 m TAW, the water table is situated between 5 and 10 m of depth. In the lower and plain polderland the groundwater table is to be situated in B' at approximately 0.75 m of depth (+ 2.5 m TAW).

## METHODOLOGY

### Observation wells

The hydrogeological survey carried out in 1998-1999 was based on the installation of observation wells. Washed borings throughout the study area took place, in order to put up a network of observation wells. In October 1998, this network contained 14 sites where pairs or triplets of observation wells had been installed. The screens of these wells are situated at different depths, in order to establish vertical groundwater flow patterns. Screens were put at the base of the groundwater reservoir (25 to 34 m of depth), at the top of the ground water reservoir (5 to 10 m of depth) and in the polderland at the groundwater table (less than 1m of depth). At the piezometer tube, also miniscreens were installed to enable sampling at various depths.

## Resistivity logging

Long Normal (LN) and Short Normal (SN) resistivity was measured in the open borehole with the equipment constructed at the Laboratory for Applied Geology and Hydrogeology, in normal configuration. A resistivity log gives in fresh water conditions a detailed view of the composition and the thickness of the logged layers. However, in saline circumstances, these lithological properties are overruled by the effects of water quality variations. In these conditions, the information obtained form LN-resistivity can serve in establishing a groundwater salinity log. The salinity of the study area was studied along profiles, in which the information of the LN-resistivity log was used. The LN-resistivity is a good approximation of the true formation resistivity ($\rho_t$).The relation between the formation resistivity ($\rho_t$) and the resistivity of the pore water ($\rho_w$) for the saturated zone of the groundwater reservoir is given by:

$\rho_t = F \,.\, \rho_w$
(in which F = formation factor)

The formation factor is not a constant, but in comparison with the water resistivity it differs little. Assuming a constant formation factor=4, each variation of $\rho_t$ will be interpreted as a variation in $\rho_w$.

## Groundwater analyses

Pumping on filters and miniscreens (using a vacuum pump) until pH and conductivity remain constant, allows to obtain good ground water samples of the study area. Sampling included filtering and fixation. Samples were taken from all screens and miniscreens along the profiles throughout the study area, in order to interpolate the results.

# RESULTS

## Horizontal and vertical groundwater flow

Through monitoring the hydraulic head in the observation wells in the study area, horizontal and vertical groundwater flow was established for both an autumn and early spring situation. The dune area at De Haan-Wenduine is the recharge area and discharge takes place in the lowlying polderland. This trend is most obvious at shallower depths, but also persists at the base of aquifer A. A watershed could be determined which is influenced by seasonal changes. Tidal influence on the groundwater level has been observed inland until a distance of more than 700 m of the high water line.

## Salinization

Salinization of the study area took place during the Flandrian and Dunkirk marine transgresions. Due to the infiltration of rain water, freshening of the ground water reservoir occurred, and is most advanced in the recharge area of the dunes. In the polderland, where infiltration is inhibited by the clay-peat-loam sediments, seawater conditions have been largely preserved. Both profiles (fig. 3) illustrate this situation: the dune area has a moderately fresh water body underneath, which saltens inward polderland. In profile A-A’-A’’, this fresh/salt water distribution is disturbed at SB9, at the polder-dunes contact: a tongue of fresher water cones up towards polderland and another tongue with brackish water cones into the dunes. This phenomenon is induced by both the lithological constitution and groundwater flow. Profile B-B'-B'' shows clearly the existence of a moderately to weakly fresh water body underneath the dunes, which runs along two paths toward the polderland: via both aquifers A and B.

### Distribution of groundwater types

Using Stuyfzand's classification (STUYFZAND, 1986) the groundwater type of each analysis was determined. Fig. 4 show the results for the two profiles. These profiles are comparable to the resistivity profiles.

Fresh rainwater infiltration is diluting the salt porewater. In the dunes, this dilution is obvious. On the contrary, in the lowlying polder, almost the whole groundwater reservoir is stil containing salt water of the NaCl watertype. The cation exchange code '+' means that cation exchange as a result of freshening took place. Cation exchange is stronger in the shallower layers of the groundwater reservoir. The $Na^+$ of the clay is exchanged with the $Ca^{2+}$ of the water, which renders a $NaHCO_3$ watertype (WALRAEVENS, 1990). In the recharge area, where freshening has progressed further, the $CaHCO_3$ type of the infiltrating water is preserved. This freshening process can be seen very well in both profiles along the flowlines. While in the dunes the process has already been terminated, the freshening in the polder only started at its edges. In profile A-A'-A'' there is a clear upconing towards the polders of water in the first phase of freshening, in profile B-B'-B'' the two tongues of fresher water are also present. In the core of the lowlying polders, a negative cation exchange code is still pointing towards the salinization of the groundwater reservoir that resulted from the marine transgressions.

## CONCLUSIONS

The hydrogeological history of the study area began with the transgressions (Flandrian, Dunkirk) that salinized the ground water reservoir due to the infiltration of seawater. At present time, this salinization has already been reduced to a large extent underneath the dunes, but still persists in polderland. Flowlines run from the recharge area of the dunes in two directions: towards the sea (rather restricted) and towards the polderland, which is the main discharge area. The groundwater quality distribution confirms this situation.

## REFERENCES

AMERYCKX, J. (1961). La genese des poldres maritimes belges. De Aardrijkskunde, 13, pp. 5-18.

BAETEMAN, C. (1987). Ontstaan en evolutie van de kustvlakte. In: Thoen H. De Romeinen langs de Vlaamse kust, Gemeentekrediet van België, Brussel, pp. 181.

CLAYS, S. (1999). Hydrogeologisch en hydrogeochemisch onderzoek van het westelijk deel van de Uitkerkse polder bij Wenduine. M.Sc. Thesis, RUG, Ghent, pp. 125

DE BREUCK, W., DE MOOR, G. & MARECHAL, R. (1969). Lithostratigrafie van de Kwartaire sedimenten in het Oostelijk Kustgebied. Natuurwet. Tijdschr., 51, pp. 125-137

DE MOOR G. & DE BREUCK. W. (1969). De freatische waters in het Oostelijk Kustgebied en in de Vlaamse Vallei. Natuurwet. Tijdschr., 51, pp. 3-68 + ann.

DEVOS, J. (1984). Hydrogeologie van het duingebied ten oosten van De Haan. Ph.D. Thesis, RUG, Gent, pp. 219.

HERMANS, A. (1999). Hydrogeologisch en hydrochemisch onderzoek van het duingebied te Wenduine - De Haan. M.Sc. Thesis, RUG, Gent, pp. 92.

STUYFZAND, P.J. (1986). A new hydrochemical classification of watertypes: principles and application to the coastal dunes aquifer system of the Netherlands. Proceedings of the 9th Salt Water Intrusion Meeting, Delft, 641-655.

VAN HAECKE, K. (1998). Hydrogeochemisch onderzoek naar de zoet-zoutwaterverdeling langs een profiel loodrecht op de kustlijn (Wenduine – De Haan). M.Sc. Thesis, RUG, Gent, pp. 98.

WALRAEVENS, K. (1990). Hydrogeology and hydrochemistry of the Ledo-Paniselian semi-confined aquifer in East- and West-Flanders. Acad. Analecta 52, 3, 11-66.