WATER QUALITY DISTRIBUTION IN THE EASTERN COASTAL PLAIN OF BELGIUM: INFLUENCE OF INTERCALATED PEAT BEDS.

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ABSTRACT

The unconfined aquifer of the Belgian coastal plain consists mainly of quaternary sands which are intercalated by peat and in lesser extent clay layers. These quaternary deposits are approximately maximum 30 m thick and are situated above Tertiary clay, sandy clay and sand, dipping gently in north-eastern direction. The intercalated peat layers, the so called surface peat, influence importantly the ground water flow and the water quality distribution. During the Dunkirkian, salt water infiltrated the aquifer. Later replacement by fresh water is highly influenced by the distribution of the intercalated peat layers. This water quality distribution and the relation with the location of the peat layers are considered here by re-evaluating data gathered extensively in the past and is supplemented by new observations.

INTRODUCTION

From the end of the Atlantic period (7800 – 5000 BP) and during the Subboreal (5000 – 2800 BP), extensive peat growth occurred in the Belgian coastal plain. With the Dunkirkian transgressions (2800 BP – recent), this peat growth ended. The coastal plain was inundated and the peat bogs and fens were covered with clay and sandy clay deposits. Creeks and gullies cut in the peat layers were filled with sandy deposits. This differential sedimentation gave rise to the typical geomorphology of the region. By differential settling of the peat, clay and sandy deposits, the old creeks and in lesser extend the old gullies are set partially higher in the relief than the more compaction sensitive peat and clay layers. These recent geological developments results in clay-covered peat areas which are intersected with sand filled creeks and gullies. The surface level of the creeks and gullies (3-4 mTAW) is now slightly higher than the surface level of the clay covered peat areas (2-3 mTAW). During the Dunkirkian transgression, salt water infiltrated the aquifer. By development of the recent dune belt and the extensive land reclamation, this salt water was partially replaced by fresh water. Obviously, there is an important difference in hydraulic resistance of the peat-clay deposits and the sandy creek and gully deposits. The pattern of creek ridges, old gullies and areas with surface peat has herewith a large influence on this replacement and hence on the water

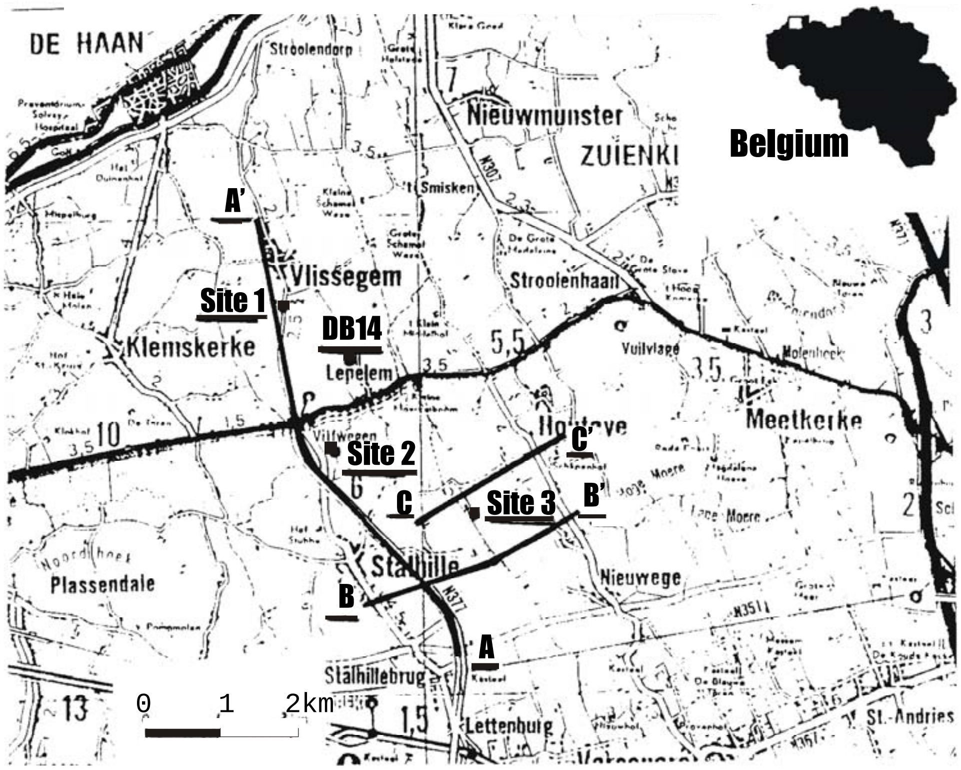

Figure 1. Localisation of the study area (inset) and of the different cross-section and sites, used in this paper.

quality distribution in the region. The infiltrated water can barely penetrate through the peat and clay layers and is almost continuously evacuated by drainage. Hence, the saline water beneath this areas is not replaced. Contrary, the highly permeable creek ridge allows a strong replacement (De Breuck & De Moor, 1975).

The region between Brugge and De Haan was selected as study area (fig. 1) due to the large amount of data collected in previous studies. These data consist of bore hole logs, geo-electrical survey results, geophysical bore hole measurements and water analyses available in the archive of the LTGH. A major creek ridge, the Stalhille creek ridge, makes up the central part of the study area. A clay on peat area is situated west of the Stalhille creek ridge. The eastern part of the study area is complex due to interaction with gullies and extensive peat cutting.

GENERAL PICTURE

First, a general view is obtained by means of three cross-sections through the study area on which the lithology and fresh-salt water interface is depicted (fig. 2, 3 and 4). The locations of these cross-sections are given in fig. 1. The cross-sections are based on a number of drilling logs and the location of the fresh-salt water interface is derived from a combination of geo-electrical surveys and bore hole observations (De Breuck & De Moor, 1975).

Cross-section A-A' (fig. 2) is north-south orientated through the study area and crosses the Stalhille creek

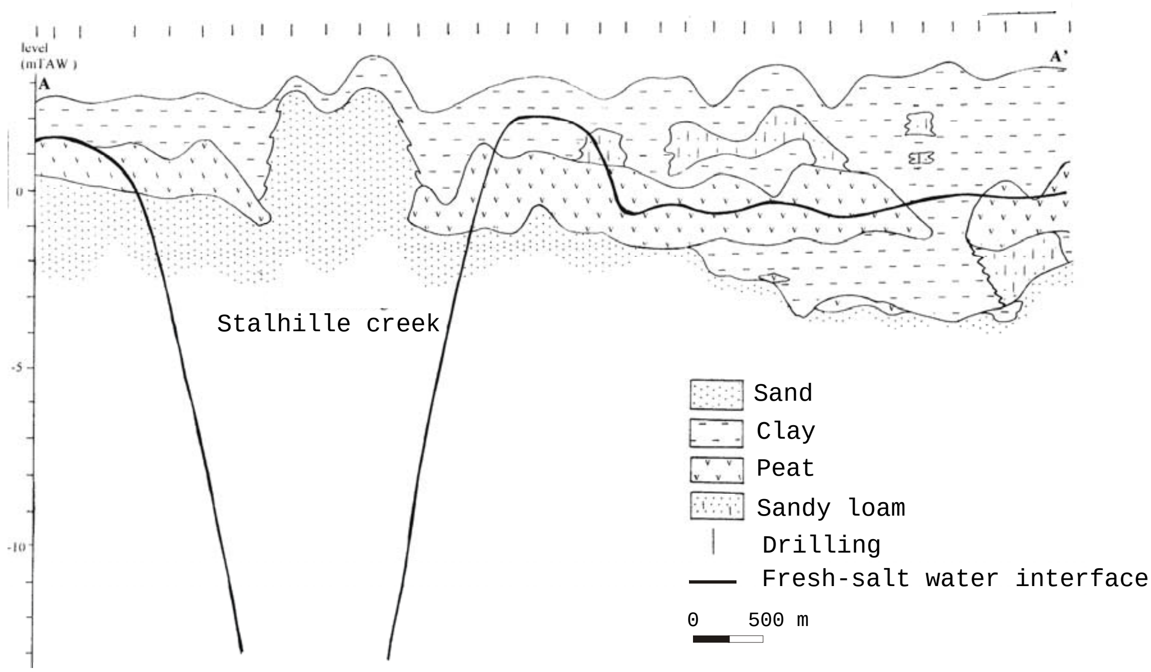

Figure 2. Cross-section A - A'.

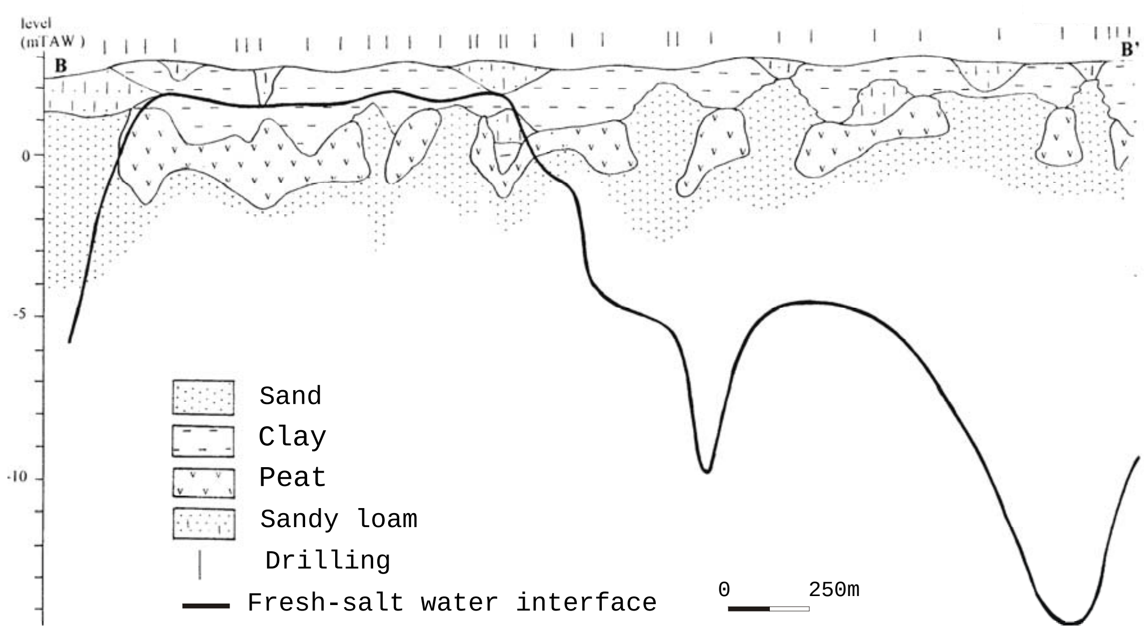

Figure 3. Cross-section B - B'.

ridge. In the southern part, the fresh-salt water interface is very shallow (less than 5 m deep). The top of the aquifer consists of peat and the Dunkirkian clay. In the Stalhille creek ridge, which consist mainly of sandy deposits, a fresh water lens develops. This pushes the fresh-salt water interface deeper in the aquifer (20-25 m deep). In northern direction, a lagoon clay is found under the peat. The Dunkirkian clay occurs again

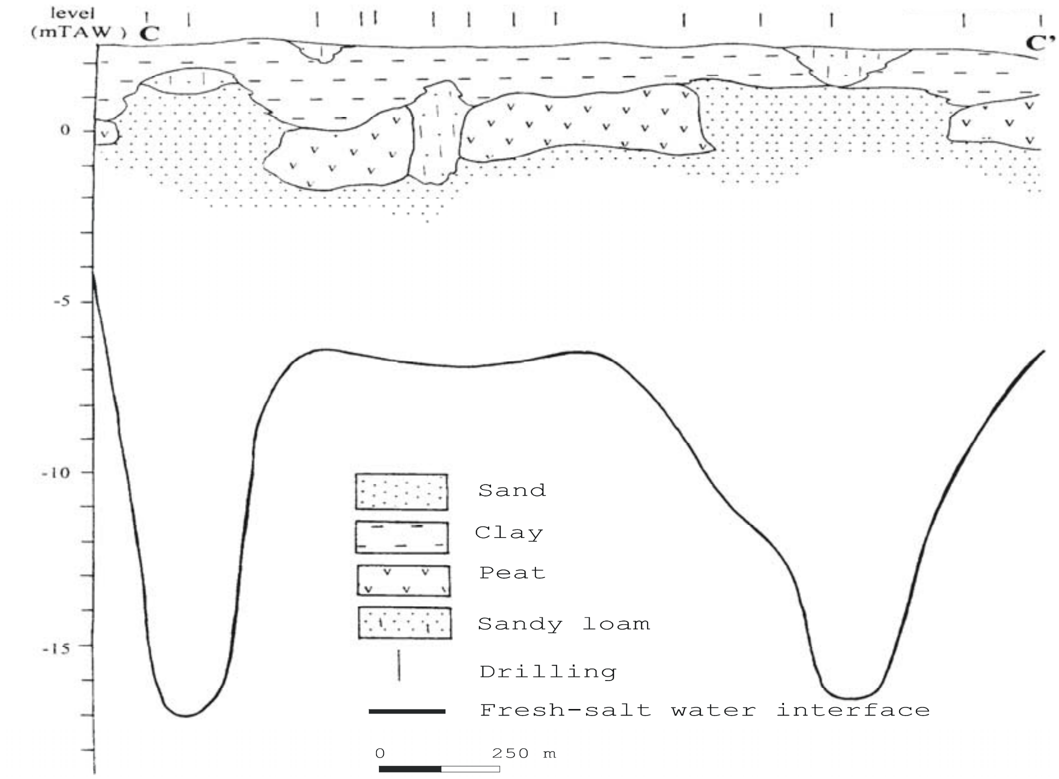

Figure 4. Cross-section C – C'.

above the peat layer. A creek further north is completely filled with clayey deposits. In these deposits, the fresh-salt water interface is again very shallow and is situated in the low permeable peat and clay sediments.

Cross-section B-B' (fig 3) is an east-west section located east of the Stalhille creek ridge. The peat layer is intersected by gullies and historic peat cutting. In the gullies, sandy deposits are present. After anthropogenic peat excavation, the slits are filled with loam and/or clay. The profile starts in Stalhille creek ridge (B), which explains the deep fresh-salt water interface. East of the creek ridge, the interface is situated in the less permeable peat and clay deposits. More east, the fresh-salt water interface is found progressively deeper (15–20 m). The peat layer is more cut up laterally than in the western part of the profile and the clay layer becomes less thick and more loamy.

Cross-section C-C' (fig. 4) is also an east-west section, situated more north than section B-B'. Here also, the peat has been cut up and sandy or sandy-loamy sediments are intersected in the peat layer. A fresh water lens is developed under these sand filled intersections in the peat layer, the fresh-salt water interface is approximately 15-20 m deep. The fresh-salt water interface under the peat covered area in the profile is relatively deep (5-10 m). This freshening is partly due to more rapid infiltration through the clay and peat layers. There is one sand/loam filling found in the peat layer but other smaller ones could also be present.

The cross-sections illustrate clearly the interaction between sediment and water quality distribution. Where the peat layer is still present, the water table is relatively low due to intensive drainage. The hydraulic conductivity of the sediment (peat and clay) is low. In the creeks and gullies the water table is higher then in the surrounding clay-covered peat areas. The sandy deposits have a higher hydraulic conductivity. These relative positions of the water table and the different hydraulic conductivities, influence the regional ground water flow and the distribution of the fresh and salt water. In agreement with the Badon Ghyben-Herzberg principle a fresh water lens develops under the permeable creek ridges whereas salt or brackish water occurs under the surface peat .

WATER QUALITY

The water quality and water types occurring in and around the Stalhille creek ridge at three sites is further illustrated. Geophysical borehole logs and water analyses are used (Vandenbohede, 1998). Two site are located at the transition between the clay-covered peat areas and the Stalhille creek ridge (site 1 and 2). The third site is situated in the complex area east of the Stalhille creek ridge. Data of observation wells on the Stalhille creek ridge (DB14) are also used. Water samples analyses are represented on PIPER-diagrams. The composition based on conservative mixing of salt water and fresh water is calculated (Appelo & Postma, 1993). The watertype is determined following Stuyfzand (1986).

Stalhille creek ridge

DB14 is situated on the Stalhille creek ridge (fig 1). It consists of 4 observation wells (DB14/1: 4.8-5.8m; DB14/2: 12.2-13.2m; DB14/3: 16.1-17.1m; DB14/4: 23-24m) (fig. 5). The two shallow observation wells have both a F3CaHCO_3+ water type. The TDS of both is almost equal (1035 mg/l for DB14/1 and 985 mg/l for DB14/2). DB14/3 has a F3NaHCO_3+ water type with a slightly greater TDS of 1385 mg/l. The deepest piezometer contains a S4NaCl- with a TDS of 27607 mg/l, which is almost pure sea water. So, the fresh-salt water interface is situated around a depth of $\pm$ 20 m deep, which is conform the result obtained in the general study of the ground water quality in the area for the Stalhille creek ridge. The transition between the fresh and salt water is very sharp.

The water analyses are represented on a PIPER-diagram (fig. 6). This shows that besides the obvious mixing of fresh and salt water, cation exchange and chalk solution are two very important factors determining the water quality. Cation exchange is a process in which cations from clay particles are exchanged with cations in the ground water. It starts with Na^+ from the clay which is exchanged for Ca^{2+} from the water. This gives rise to a $NaHCO3^+$ water type, found in DB14/3. Then K^+ and Mg^{2+} from the clay are exchanged for Ca^{2+} from the water. This gives rise to the $KHCO_3$+ and $MgHCO_3$+ water. Afterwards, cations from the clay particles which are exchanged for Ca^{2+} from the water can no longer gain dominance over the Ca^{2+}. The result is a $CaHCO_3$+ water type which is encountered in DB14/2 and DB14/1. No $MgHCO_3$+ water type is found but the Mg^{2+} -concentrations do rise deeper under the creek ridge (from 58 mg/l in DB14/1, over 77 mg/l in DB14/2 to 116 mg/l in DB14/3). This means that the $MgHCO_3$+ water type is already highly mixed with infiltrating $CaHCO_3$+ water so that Ca^{2+} has

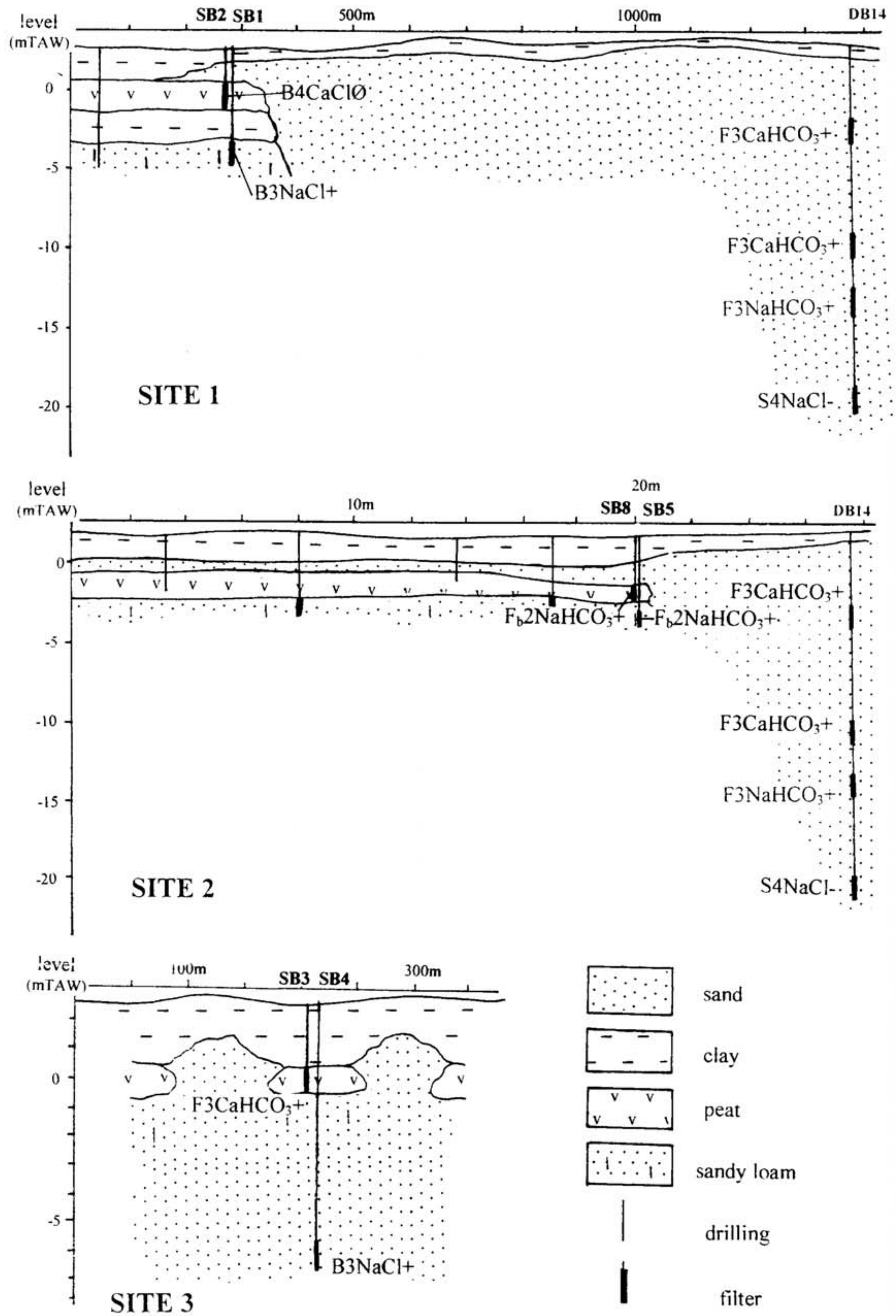

Figure 5. Lithology, location of the observation wells and water quality for site 1, site 2 an site 3.

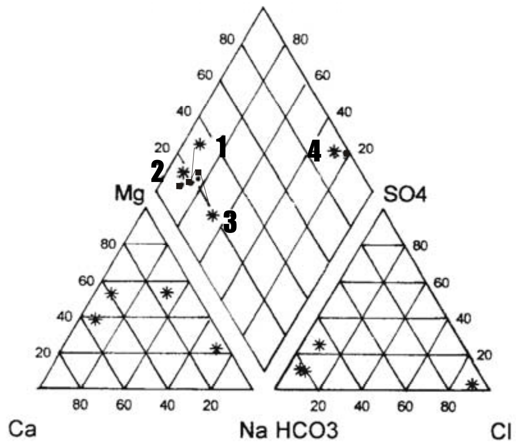

Figure 6. PIPER diagram of water samples from DB14/1 (1), DB14/2 (2), DB14/3 (3) and DB14/4 (4). * water analyses,■ quality of mixing water.

gained dominance over Mg^{2+}.

Site 1

Site 1 is situated on the border of the peat-covered area west of the Stalhille creek ridge (fig. 5). Lagoon clay is found under the peat layer. Two observation wells are made. SB1 has a screen under the clay-peat complex, SB2 in the peat layer. On figure 5, the result for the water analyses on the creek ridge are also included. In the peat layer, a B4CaCl∅ with a TDS of 3180 mg/l is found. The water just under the peat-clay complex is of the B3NaCl+ type and has a TDS of 6908 mg/l. The water analyses are plot on a PIPER-diagram (fig. 7). The water in the peat layer even as close to the creek ridge, is still very brackish. For some reason, no major cation exchange or chalk solution has taken place. The water is just the result of the mixing of fresh and salt water. The water under the peat-clay complex is also still very brackish. From the PIPER-diagram, it can be seen that besides mixing of fresh and salt water, cation exchange and chalk solution are important factors, determining the quality. Cl^- is still not replaced by HCO_3^- as the dominant anion. This gives the B3NaCl+ water type.

Site 2

Site 2 is also situated on the border of the peat covered area west of the Stalhille creek ridge (fig. 5). Two observation wells (closer to the border of the creek ridge in comparison with site1) are installed. SB5 has the screen under the peat layer, SB8 in the peat layer. On figure 5, the result for the water analyses on the creek ridge are also represented. In the peat layer, a $F_b2NaHCO_3$+ water type with a TDS of 1402 mg/l is found. The water just under the peat layer is also a $F_b2NaHCO_3$+ water type and has a TDS of 1202 mg/l. The TDS of the water under the peat layer is slightly smaller than of the water in the peat layer. This is probably due to lateral flow under the peat layer of fresh water from under the creek ridge. The water analyses are also plot on a PIPER-diagram (fig. 7). With respect to site 1, the water quality in and under the peat layer is already brackish to fresh water. Ca^{2+} cations of the water are exchanged for Na^+ from clay particles, which give rise to the $NaHCO_3$ water type.

Site 3

Site 3 is situated in the area west of the Stalhille creek ridge (fig. 5). Two observation wells are installed, SB3 in the peat layer and SB4 under the peat layer. In SB3, a $F3CaHCO_3$+ water type is found with a TDS of 1324 mg/l. SB4 has a B3NaCl+ water type with a TDS of 2372 mg/l. The peat layer stretches laterally for approximately 100 m and is flanked by sandy deposits, also approximately 100 m width (Franceschi, 1975). Here important mixing of the salt water with fresh water has occurred due the extensive cutting up of the peat layer. This illustrates the situation found in cross-section C-C' and in the western part of cross-section B-B'.

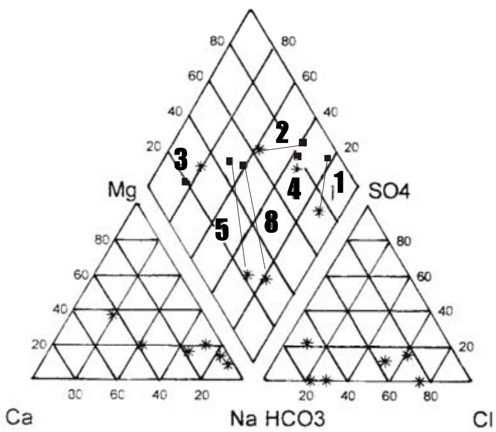

Figure 7. PIPER diagram of water samples from SB1 (1), SB2 (2), SB3 (3), SB4 (4), SB5 (5) and SB8 (8). * water analyses, ■ quality of mixing water

CONCLUSIONS

From the above general study and the case studies, it is illustrated that lateral changes of the lithology influence the water quality distribution. The salt water under the Stalhille creek ridge is replaced by fresh water. In most of this fresh water lens, the seawater is replaced by fresh $CaHCO_3$+ water. Water analyses show also that the interface between fresh and salt water is very sharp (order of meters) which means that the dispersivity must be very small. Under the clay-covered peat areas, salt water is still present. The interface between fresh and salt water on the transition between clay-covered area and creek ridge is clearly observed on site 1 and 2. On Site 1, approximately 250 m from this border, brackish NaCl+ water, with a intermediate TDS between fresh and salt water is present. Close to the creek ridge (approximately 5 m on Site 2), fresh $NaHCO_3$+ water is observed.

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