**Appendix B Key sites for landscape reconstruction in the Oer-IJ region**

Since the 1980s geological and palaeoenvironmental observations have been made in archaeological excavations in the Oer-IJ region. Nine of these key sites in the landscape reconstruction are presented in this appendix. For the location of the sites, see App. Fig B.

[Fig. App. Fig. B near here]

**Appendix B1 Uitgeest–De Kleis**

During excavation work for the construction of the railroad tunnel De Kleis at Uitgeest in November 2003 a canoe of oak wood was discovered (Fig. App. B1). The approximately 20 m long canoe lay in a silted-up tidal channel which in the Iron Age formed the connection between the main channel of the Oer-IJ (west of Assum–Uitgeest) and the salt-marsh creek systems in Uitgeesterbroekpolder. The canoe was salvaged in a steel box (Fig. App. B1) and, along with the surrounding soil, taken to the Nederlands Instituut voor Scheeps- en onderwater Archeologie (NISA – Dutch Institute for Ship and Underwater Archaeology) in Lelystad. There the surrounding soil was removed and examined, and the canoe was conserved. The canoe is on display in the Huis van Hilde exhibition space (Home of Hilde, the exhibition area of the archaeological storehouse of Noord-Holland in Castricum).

[Fig. App. B1 near here]

Prior to the recovery of the canoe, a geological survey was carried out to determine the stratigraphic position of the canoe in the subsurface and make a palaeo-landscape reconstruction of the circumstances in which the canoe had sunk. The field survey consisted of a recording of the ring profile around the canoe (Fig. App. B6) and the recording of the profile wall about 30–40 m north of the canoe (Fig. App. B6). To determine the ages of the layers in the profile walls, marine shells from the clastic strata and organic samples from the peat layers were sampled for 14C investigation (Table A2.1a). The canoe has been dated using the 14C method (UK-1, Table A2.1a) and dendrochronologically (Table A2.1b; Koehler, 2004). The research has been reported in De Koning & Vos (2007).

In the tunnel pit wall exposure (Fig. App. B6), the basal unit consists of the Wormer Member (Ca unit). The lowest layers in this unit are tidal flat deposits of grey, clayey, bioturbated, very fine sand with *Scrobicularia plana* shells in life position. On top of these tidal flat sediments salt-marsh deposits with bluish-grey clays with crinkly sand laminations occur. On top, a rooted clayey layer with thin sand layers (Tl 1 unit) forms the transition layer to the Holland Peat layer above. Aeolian deposits of the beach ridge of Uitgeest (Tl 2 unit) are sandwiched between the Holland Peat layers (Hv 1 and 2 units). The Holland Peat layers consist of amorphous reed beds. The top of the beach ridge and part of the upper layer of the Holland Peat had been eroded by the Oer-IJ tidal channel so that only the base of the eastern part of the ridge is still present. The Oer-IJ channel deposits (Oij unit) consist mainly of slightly humic clays in which thin sand layers and *Scrobicularia plana* shells in life position occur. At the base of these channel deposits many peat and clay lumps occur (Fig. App. B6), which indicates that the channel eroded peat and clay layers in the hinterlying coastal marshes.

The 14C dates of the *Scrobicularia plana* shells (UK-7; Table A2.1 a) in the top of the Wormer tidal flat deposits indicate that the last stage of intertidal deposition took place around 4000–3800 BC. The top of these sand flats lay at a depth of c. 5 m –NAP. In the subsequent period, between c. 3800 and 3365 BC, the sand-flat environment evolved from a salt-marsh landscape into a coastal peat land (base Hv 1; UK-6, Table A2.1a). Around 3365 BC a coastal peat bog developed near Uitgeest. This implies that at that time in the area west of the study site a beach barrier had developed that shielded the area from the open sea. Coastal peat development at the site continued until about 3040 BC (top Hv 1; UK-5, Table A2.1a), when the peat was covered by salt-marsh deposits of layer Tl 1. In the next stage, between about 2800 and 2500 BC, aeolian deposits of layer Tl 2 were formed, which indicates that the beach ridge of Uitgeest shifted towards the position of the De Kleis site. The basis of the beach barrier lies at a depth of 4.1 m –NAP. East of the exposed pit wall the beach ridge sands were grown over by peat (Hv 2 layer). The peat growth at this side started around 2500 BC (base Hv 2; UK-4, Table A2.1a). Because of erosion of the uppermost part of the peat layer by the Oer-IJ channel, it cannot be determined how long peat development east of the beach ridge continued. Erosion at least occurred after about 2020 BC (top Hv 2; UK-3, Table A2.1a).

The dendrochronological date of the oak-wood canoe at the base of the Oer-IJ channel gives information about the age of the channel. The outermost tree rings of the canoe wood were dated to between 617–600 BC (UKa1 –a4, Tab. A2.1b). Given the limited lifetime of a canoe, it probably sank between 600 and 550 BC. The eroded peat lumps and clay balls below the canoe (Fig. App. B1B, B1E) were deposited in a short period before the canoe sank, so the erosion phase of the channel is dated around 650 and 600 BC.

Where and why the canoe sank cannot be answered. Tidal currents may have moved the canoe over tens of metres or more after sinking.

[Fig. App. B1 near here]

**Appendix B2 Klein Dorregeest**

In November 2004 important archaeological finds were made by the Archaeological Regional Workgroup Oer-IJ during the construction of a residential basement at Klein Dorregeest (Fig. App. B2). This location is situated on the eastern flank of the Uitgeest–Akersloot beach barrier. The find report concerned a culture layer from the Neolithic (Beaker culture). The culture layer was well preserved because it is situated >1.4 m below ground level and therefore the archaeological layers had not been disturbed by agriculture and other developments.

The north, west and south profile walls of the construction pit were archaeologically and geologically investigated (Fig. App. B2). The organic and sandy layers in the profiles were dated with 14C and OSL. The results of this study have been reported by Vos (2007a). The archaeological and archaeo-botanical research in the Neolithic culture layer in the pit walls was carried out by the Rijksdienst voor het Cultureel Erfgoed (RCE, State Agency of Cultural Heritage, formerly Rijksdienst voor Archeologie), Cultuur-historie en Monumentenzorg (RACM, State Agency of Archaeology, Cultural-History and Conservation) and the de Rijksdienst voor het Oudheidkundig Bodemonderzoek (ROB, State Agency of Archaeological Heritage). The results of this study are reported in Müller et al. (2008).

[Fig. App. B2 near here]

In the excavation pit only the top of the beach ridge deposits was exposed. In the aeolian beach ridge sands a culture layer (layers 4 and 25, Fig. App. B2) was present in which plough tracks and shard material from the Beaker period were found (archaeological date about 2300–1900 BC). The layer units above the culture layer consist of organic-rich levels (peats, sandy peats and strongly humic sands) and drift sand layers (dune sands). The dating study revealed that it is likely that the culture layer on the underlying dune sand of the beach barrier was formed around 2100 BC, and that it was overgrown by peat in the subsequent period (from about 2100 to 1850 BC and onwards; KD-3 and KD-9, Table A2.6a).

Windblown sand layers (sand drifts), and the soil/peat levels which butt against the eastern flank of the beach ridge, arose between 1650 and 800 BC (Middle and Late Bronze Ages; KD-1, KD-4 up to KD-8, Table A2.6a). After 800 BC a big sand drift occurred and the covering sand layer was formed (layer 13/24, Fig. App. B2). It cannot be ruled out that Bronze Age aeolian activity was partly caused by humans. However, archaeological proofs in the form of, for example, plough marks were not observed in the profiles.

***Appendix B3 Heemskerk – Hoogdorperweg***

On the construction location of two new houses at the Heemskerk – Hoogdorperweg, in April 2004, a small archaeological excavation was carried out by Hollandia Archaeologists (Vaars, 2004). For palaeogeographical reasons it was an interesting excavation because of its location on the easternmost and oldest beach ridge of Heemskerk. In the top of the beach-ridge sediments artefacts were found which could be dated from the Middle Bronze Age to the Early Iron Age (Fig. App. B3). In addition, plough marks were found, the oldest of which might date from the Late Neolithic period. The presence of these archaeological traces on top of the beach ridge sediments indicates that the ridge was formed at least before about 2000 BC. It might possibly be older and of the same age as the remnant of the beach ridge sediments at the locations Uitgeest – De Kleis.

[Fig. App. B3 near here]

***Appendix B4 Assum –Waldijk***

In 2005 Hollandia Archaeologists conducted a large excavation at Assum-Waldijk, south of Uitgeest (Koning, 2007). Because of a new housing development at this location excavations were necessary to rescue archaeological features. Besides traces of Medieval houses (1200–1350 AD), older settlements from the Late Bronze Age (about 950–750 BC) were found. The Bronze Age settlements were constructed on dune sands on a beach ridge and were covered at the lower eastern side by salt-marsh deposits of the Oer-IJ. Shells and peat layers above and below sand dunes have been 14C dated in a geological profile (Fig. App. B4).

[Fig. App. B4 near here]

The dune sands (Dune A and B, Fig. App. B4) were formed on top of tidal deposits of the Wormer Member. A double-valved shell dating from a shell layer in the top of the Wormer clay indicated an age of c. 2940 BC (AW-7; Table A2.2.). Dune sands A and B were separated by a layer of Holland Peat. In the profile, at 2.55 m –NAP the base of the peat layer on Dune A has been dated at about 2390 BC (AW-6; Table A2.2) and at 2.0 m –NAP around 2245 BC (AW-3; Table A2.2.). The top of the peat layer at 2.22 m –NAP has been dated at about 1890 BC (AW-5; Table A2.2) and at 1.84 m at 1700 BC (AW-3; Table A2.2.). These dates indicate that the sand drift and the formation of Dune B took place after 1900 BC. Dune B is certainly older than the 7th century BC, given that Late Bronze Age settlements have been constructed in the dune.

The flanks of Dune B, including the Bronze Age traces in it, have been silted over by a sandy clay layer, which was formed during the active marine phase of the Oer-IJ between about 650 and 400 BC.

West of Assum-Waldijk in a geological profile at Waldijk I (Dautzenberg & Kluiving, 2004) aqua-aeolian sands were observed. These sands have an erosive contact with the dune and peat layers below, on the east side of the profile. The dune and peat sequence in the profile of Waldijk I has not been dated, but based on stratigraphic similarities it is likely that the erosive aqua-aeolian deposits of Waldijk I were also formed between c. 1950 and 1550 BC. Erosion and sand transport around Assum in the Early and Middle Bronze Age are associated with the major breakthrough of the beach ridge between Heemskerk and Assum, when a new tidal inlet of the Oer-IJ developed and the new tidal channel connection was formed in the direction of the Wijkertunnel.

***Appendix B5 Broekpolder***

The archaeological Project Wetland West of the Amsterdams Archeologisch Centrum (Amsterdam Archaeological Centre) of the University of Amsterdam (AAC, as from 2012 called DIACHRON) made excavations at the new housing (VINEX) Iocation at Broekpolder in an area of 150 hectares in the period 1998– 2001 (Therkorn et al., 2009.). In the subsurface of this polder archaeological values from Bronze Age–Roman times were present. During the archaeological research a west–east profile was geologically recorded (Vos, 2000; profiles 1A and 1B in Fig. App. B5). The aim of this study was to investigate the relationship between the archaeological culture layers and the main channel of the Oer-IJ east of the site. In the geological profile, from bottom to top, the layers shown in Table B5.1 were distinguished.

[Fig. App. B5 near here]

*Table B5.1. Lithostratigraphic description and age of the layers shown in profile of Fig. App. B5*

|  |  |  |
| --- | --- | --- |
| Layers  (field names) | **Lithology** | **Period of deposition** |
| Pikklei | This pedological name was given in the 1950s to the heavy, stiff, greenish grey, non-calcareous, clay layer at the surface. The clay was deposited during occasional floods when the polder was inundated (e.g. by dike breaches). | Middle Ages to Modern times |
| Peat | The peat layer was found only in the lower eastern channel part of the profile. The peat is brown and consists mainly of reed. The top of the peat is oxidised and black (oxidation layer). | Roman Period to Early Middle Ages (BP-1; Table A6.1) |
| Blub | ‘Blub’ is the field name for the brown organogenic/humic clay that – to the east of the salt-marsh ridge – was present in an elongated strip in the excavation areas. At the base of the Blub, imprints of cow legs were found. | Early and Middle Roman Period |
| Sand layer | This is an abbreviation for the non-calcareous, yellowish grey, moderately fine-grained sand layer in the top of the lower lying eastern channel part of the profile. The sand is locally displaced sand that probably originates from nearby dune sands. The cattle trail (blub) lies stratigraphically above the sand layer. | Late Iron Age to Early Roman Period |
| Layer I | Non-calcareous, moderately sandy and extremely silty clay. The layer contains a lot of brownish-black iron-manganese concretions. Sedimentary structures were not observed in this layer. The layer was deposited in a salt-marsh environment. The traces of habitation in this layer indicate that the site was not often flooded anymore. | Middle to Late Iron Age |
| Layer II/*Scrobicularia* layer | Calcareous, sandy to silty grey clays, with iron discoloration. In the eastern side of the profile, layer II merges into the *Scrobicularia* layer with bivalved shells in life position and fine sand laminations. This layer was deposited in the intertidal zone. | Middle to Late Iron Age (BP-2 to BP-6; Table A6.1) |
| Layer III | Dark, dirty grey, strongly silty and calcareous clay. The layer is subdivided based on humusness. Eastwards, in the direction of the channel, the layer becomes less humic and thin layers of sand occur in the deposits. In the transition to the channel at the east side of the profile, reed stalks and land snails (*Vallonia pulchella* and *Succinea elegans*) were found. In the western humic part of the layer, plough traces were observed. | Late Bronze Age (BP-7; Table A6.1) |
| Layer IV | Calcareous, sandy to silty clays. The layer contains small shell fragments and one thin humus layer. The layer is subdivided into sub-layers based on sandiness and humus laminations. The western part of the layer consists of salt marsh and salt-marsh ridge deposits with crinkly sand laminations. Eastwards it grades into sand-laminated channel deposits. These deposit lay erosively on the older layers VII–V. | Probably Middle to Late Bronze Age |
| Layer V | Dark/dirty grey, silty and calcareous clay. The sublayers are divided based on humousness. The excavated surface of this layer showed plough marks, which indicates that the marsh was not frequently flooded. | Middle Bronze Age (BP-8; Table A6.1) |
| Layer VI | Calcareous, grey, silty clay with crinkly sand layers indicative of a salt-marsh environment. | Probably Early to Middle Bronze Age |
| Layer VII | Calcareous grey clay with thin sand layers. The sand layers consist of very fine sand, are light grey and are horizontally laminated. Downwards the number of sand layers increases. The layer was deposited in the intertidal zone (tidal flat environment). | Probably Early Bronze Age |

In Fig. 11 a profile reconstruction has been made for the period between 1000 BC and 50 AD, based on the lithostratigraphy of the geological profile (Fig. App. B5) and on the palaeoenvironmental and age information in Table App B5.

Layers IV–VII were formed in the western part of the profile in an intertidal to salt-marsh environment before 1000 BC. On the east side of the profile the main channel of the Oer-IJ was located. The channel accretions in layer IV indicate that the channel at that time migrated eastward. After that time tidal activity decreased. The observations that the upper layer III has been rooted by reed stalks and that land snails and plough marks are present in this layer, are arguments for a reduction of the tidal regime in the Late Bronze Age. Between 650 and 400 BC the tidal energy in the estuary increased again. The formation of the relatively sandy layer II and – at the channel side of the Oer-IJ – the *Scrobicularia* layer (intertidal sediments) are indicative of this. The tidal range and storm surge levels in those days were higher than in the preceding period. Shells from the upper part of the tidal flat deposits are dated between about 500 and 280 BC (BP-2/6; Table A6.1). Between 400 and 200 BC tidal activity decreased again and salt marsh deposits were formed (layer I). The permanent Late Iron Age settlements in the top of layer I demonstrate that around and after 200 BC the salt marshes were not flooded anymore and that tidal activity had been reduced to zero.

The palaeotidal levels (MLW, MHW and EHW) in the reconstruction of Fig. 11 are based on the sea-level curves that have been made for the coastline area of the western Netherlands (Plassche & Roep, 1982; Roep & Beets, 1988). However, when the tidal wave penetrates estuaries – such as the Oer-IJ – these tidal levels are distorted by factors as refraction of the tidal wave in a funnel-shaped basin, by bottom resistance and by resonance. The transformation of the incoming tidal wave is reconstructed – hypothetically – on the basis of the reconstructed palaeoenvironmental sequence of the Broekpolder (Fig. App. B5): during ‘quiet periods’ (800–650 BC) the tidal range was reduced in the hypothetical curve, and during the active phase (650–400 BC) the tidal range and the EHW level increased. In the Late Iron Age, tidal activity had disappeared in the estuary and a non-tidal water table was reconstructed for the palaeochannel.

***Appendix B6 Uitgeest – Benes***

The archaeological site Uitgeest – Benes is located northwest of Uitgeest along the former tidal channel of the Oer-IJ (Fig. App. B6). Because the site was threatened by removal of the top layer, related to water retention works, an emergency excavation was carried out by Hollandia Archaeologists in April 2014. For the palaeogeography, the site was of special interest because at this location the last stage of marine sedimentation in the central part of the Oer-IJ has been registered.

[Fig. App. B6 near here]

The exposed sedimentary sequence consists, from the bottom to the surface, of tidal flat deposits, overbank deposits with shell layers and a cover layer of dune sand (Fig. App. B6). The shell layers contain single-valved specimens of *Spisula subtruncata*, a species which originates from the North Sea. This indicates that these shell deposits were formed during storm events when the shells were eroded from the nearshore area and brought into the estuary by storm tide currents and deposited along the main tidal channel of the Oer-IJ. The storm deposits were the last marine sediments formed at the site. The cover layer of dune sands (Fig. App. B6) indicates that aeolian sand transport took place after tidal activity stopped and the Oer-IJ and the tidal flats were not inundated anymore.

The bivalved *Scrobicularia plana* shells occur in the upper part of the intertidal flat deposits of the Oer-IJ (Fig. App B7D). These shell dates (UB-2/4; Table A4.11a) indicate that these sediments were formed between about 390 and 285 BC, that is, during the period that the marine activity decreased in the Oer-IJ estuary. The storm sand layer and the base of the aeolian cover layer – on top of the tidal-flat deposits – was dated around 220 BC (UB-O1 and UB-O2; Table A4.11b). The uncertainty margin of the OSL dates was ±114 and 119 years. Taking this uncertainty margin into account, the tidal activity in the Oer-IJ estuary stopped at least before 100 BC. The traces of Late Iron Age settlements found at this site (Koning, in prep.) and the nearby site Castricum Grote Ven (De Koning, 2013; Fig. 12) correspond well with the change in the landscape.

The disappearance of tidal activity and the formation of lower dunes on top of the tidal sediments can only be explained by a complete closure of the Oer-IJ mouth by a beach ridge system in the Late Iron Age.

***Appendix B7 PWN dune area***

In 2001 and 2002, eight deep excavation pits were constructed in the PWN dune area near Castricum. These pits were dug as part of the removal of redundant water pump and distribution stations in the PWN. As a result of the change in the technique of water refinement (most of the drinking water of Noord Holland nowadays comes from the IJsselmeer area) many of the water installations in the PWN dune area were not necessary anymore and therefore could be removed. The excavation pits for the removal of the buildings provided a unique opportunity to investigate dunes, beach deposits, ancient soils and archaeological culture layers from the pre- and protohistory. The excavation pits were 5–6 m deep and the maximum pit depth was about 2 m –NAP. The study was archaeologically non-destructive since only the walls of the pits were cleaned with an excavator such that ‘readable’ profile walls arose. From each pit one wall was recorded in photographs and profile drawings (Fig. App. B7).

[Fig. App. B7 near here]

The geographic position of the excavation pits was extraordinarily. They were located just across the mouth of the former Oer-IJ estuary (Fig. App. B7). To investigate the dune sequence and the deeper-lying Oer-IJ inlet sediments, eight high-quality drillings were made by TNO in the vicinity of the excavation pit locations. The layers in the pits and the drilling holes were sampled for dating and palaeoecological research (Vos et al., 2010).

Using DINO boreholes data, the new PWN drillings and information from the excavation pits’ lithostratigraphical north–south profile was compiled (Fig. 10a). The lithostratigraphical profile shows the sequence of layers down to the top of the Pleistocene. On the basis of the dates of the Holocene sequence derived from the PWN drillings and excavation pits (Tables A3.5–A3.20) a chronostratigraphic profile with timelines was reconstructed (Fig. 10b). The timelines show the filling history of the tidal basin (deposits of the Wormer Member), the offshore marine deposits (Spisula sands) and the transition to the Oer-IJ inlet sequence (*Spisula* sands and beach and dune sands).

The base of the Older Dune sands, on top of the beach and tidal inlet deposits, occurs at a depth of around 0.5 m –NAP. The relief of the dunes is low, 1 m to at maximum 1.5 m. In dune valleys between the dunes humic to peaty soils occur. Often these soils have been reworked by humans (culture layers). Only at the westernmost located Secundair 3 were no soils/organic-rich layers found, and this can be associated with rapid and relatively large-scale dune formation (large-scale skewed stratification) from the Late Roman Age onwards.

Near the Pompgebouw only one peat layer was present, lying on washover deposits with shells. The washover deposits were not dated but stratigraphically related to washover shell deposits of Castricum – Zanderij (see Appendix B8). In the other PWN pits the Older Dune sands alternated with two or more soil and/or culture layers, for example at Secundairs 5 and G, and the WRK building (Fig. App. B7). This alternation indicates that local sand drifts occurred repeatedly and that in a subsequent period these sand dunes were captured again by vegetation. It is likely that humans played a role in causing the aeolian activity by disturbing the local vegetation, for example by ploughing and treading the vegetation (Fig. App. B7).

In the PWN study area, the top of the Older Dunes reached a maximum elevation of 4–5 m +NAP. The parabolic dunes of the Younger Dunes (e.g. Zuidernollen and Papenberg) are much higher and reach as high as 15–25 m +NAP. The Younger Dune formation started around 950 and 1000 AD (e.g. SG-O1; Table A3.9b; WRK-1; Table A3.10a). This age is consistent with the general picture of the Younger Dune formation in the Western Netherlands (Jelgersma et al., 1970; Zagwijn, 1986). At the base of the Younger Dune deposits horizontally layered dune deposits occur which cover the Older Dune relief (e.g. in the pits of WRK and Secundair 5, Fig. App. B7). The flattening and erosion of the Older Dunes is caused by the migration of ‘walking’ parabolic dunes, the so-called ’equalisation phase’ (Jelgersma, 1970; Pruissers et al., 1991).

The oldest archaeological pottery remains are found in the culture layers within the Older Dune deposits and date from the Middle and Late Iron Age (Secundair 5, the WRK building and Secundair E, Fig. App. B7). In the excavation of Secundair G the finds are a little younger and date from the Late Iron Age. Pottery from the Early Middle Ages was found in the culture layers of the pits of Secundair E, D and G. The archaeological datings of the culture layers are in good agreement with those of the dune sand (OSL) and the organic layers (14C) from pits.

Traces of prehistoric settlements were not found in the profile walls, but ploughing marks were encountered frequently in the culture layers (Secundairs 5, G, E and the WRK building, Fig. App. B7). The pottery from pre- and protohistory indicates that settlements were present in the vicinity of these sites. The archaeological observations in the 1950s and 1960s at Secundair H and the Watervlak also point to this (Duinker, 1955; Van Deelen, 1954, 1962; Van Deelen & Schermer, 1963).

Archaeological traces or pottery were not found in the exposed Younger Dune deposits. Because in general no archaeological remains occur in the Younger Dune deposits, these were not expected.

**Appendix B8 Castricum-Zanderij**

In November 2004 the Archeologische Regiowerkgroep Oer-IJ (Archaeological Working Group of the Region Oer-IJ) discovered an archaeological site in the building pit of a private house at location Castricum-Zanderij, south of the railway. Pottery and plough marks from the Roman and Medieval Periods were found. The western profile of the pit was examined and photographed (Fig. App. B8; Vos, 2007a).

[Fig. App. B8 near here]

The Medieval archaeological layer (9) was found covered by a dune sand layer (10). Below Medieval layer 9, which has been intensively ploughed, a remnant of Older Dune sand (layer 8) was preserved. In these sands potsherds from the Roman period were present. The Medieval and dune sand layers were formed on washover deposits (layers 6 and 7). The washover sediments consist of shell layers (layer 6) and shell-bearing fine sands (layer 7, Fig. App. B8) in which *Spisula subtruncata* was the most abundant species. The age of the washover shell bank was determinate by dating of the underlying beach sands (layer 3) and the overlying dune sand layer (layer 8, Fig. App. B8) with the OSL method (CZ-O1 and O2; Table A4.3b). These dates are c. 165 and 300 AD. On the basis of these OSL dates, the formation of the shell layer is placed in the second half of the 2nd century AD/early 3th century AD.

The results of the 14C dating of the single-valved Spisula shells of the washover layer (dates between 895 and 355 BC; Table A4.3a) did not match with the OSL results. Considering the age (too old) and the long time range between the individual 14C dates, the dated washover shells were reworked from the coastal zone and therefore not reliable.

The presence of washover deposits at Castricum-Zanderij shows that around 200 AD the closed beach ridge was incidentally flooded during extreme storms. Westward, at Pompgebouw in the PWN dune area a comparable shelly washover deposit was found, probably of the same age (Appendix B7). From about 250–300 AD the washover deposits at Zanderij were covered with a sheet of aeolian sands and no indications of marine activity were found from this period.

***Appendix B9 Middensluiseiland***

Prior to the adjustment of the sluice complex of IJmuiden in 2007, an archaeological investigation was carried out in the western part of the breakwater dam of Middensluiseiland in December 2006 (Fig. App. B9). For the construction of a new lock bay, the western dam was shortened by removing over 550 m (Fig. App. B9). The inner core of this dam consisted of Older Dune sands and therefore might contain archaeological remnants, especially within the humic palaeosols. These remains would have been lost when the lock bay was made. For that reason, an archaeological trench survey was conducted (Vos, 2007b, 2008). Prior to these excavations, georadar recordings were made to create a full picture of the subsurface below the dunes down to a depth of 5 m below ground level (Fig. App. B9). The surface of the dam was about 5 m +NAP. The northern profile section of the trench was recorded and 14C and OSL samples were taken to determine the ages of the dune sands and of the underlying beach sand layer (Table A3.4a and A3.4b). Samples of pollen and macro remains (plant material and seeds) were also taken from the organic layers to reconstruct the vegetation at the time of dune formation and human presence (Vos, 2008).

[Fig. App. B9 near here]

The top of the beach sands, at a level of c. 0.5 m +NAP, was dated on the basis of a bivalve *Macoma baltica* shell at around 45 AD (ME-20; Table A3.4a). Dune formation started in the 1st century AD and embryonic (or pioneer) dunes developed. During the 2nd and 3rd centuries AD the dunes were raised by drifting sand (up to a maximum high of c. 3–4 m). In these dune deposits no soil layers were observed, indicating that at that time the dunes had not yet been fixed by vegetation. In the 5th and 6th centuries AD soil formation began and the dune vegetation largely fixed the dunes (ME-17 and 19; Table A3.4a). Although the sand drifts had remained limited, some windblown sand transport took place, as indicated by the sand/thin sand layers in the organic peaty soil layers of the dune valleys (ME-17 and 19; Table A3.4a).   
Local wind erosion and dune formation, alternating with periods of sand fixation by dune vegetation, occurred between 650 and 950 AD (Fig. App. B9). The maximum height of these dunes was probably 6–7 m +NAP. However, these Older Dune tops were eroded and flattened during the equalisation phase between about 950 and 1000 AD, related to the formation of the Younger Dunes (ME-3 and 4, Table A3.4a; ME-O3 to O5, Table 3.4b). Between 1000 and 1150 AD a large parabolic dune migrated into the direction of the Breesaap area. After 1200 AD parabolic dunes were formed over the equalisation deposits of the walking dune. These parabolic dunes, however, have not been preserved because they were excavated during the construction of the sluices complex of IJmuiden at the end of 19th and beginning of the 20th century. The parabolic dunes at the location of Middensluiseiland can still be seen on the lithograph by J.C. Greive from 1876 AD (Fig. App. B9) and indicate that these dunes may have reached a maximum height of about 15–20 m +NAP.

In the trench survey of Middensluiseiland no settlements or pottery were found, which could indicate that the location was inhabited in the Early Middle Ages. However, humans were present in the area, as shown by the traces of a fire pit, cattle and plough tracks (Fig. App. B9) and a bovine jawbone, an indication of stock-breeding, and, to a limited extent, agriculture in the area. The Early Medieval people probably lived in the more eastern Breesaap area.

Fig. App. B. Location map of the key sites discussed in Appendix B.

Fig. App. B1. Geoarchaeological survey in the tunnel pit De Kleis (2003), below the railway Uitgeest – Zaandam. For 14C, dendrochronologic and OSL ages of the canoe and sediment layers, see Appendix A2, Tab. A2.1. Location (UK) is shown in Fig. App. B. A. Outline of the canoe in front of the northern profile wall of the tunnel pit. The Oer-IJ channel deposits are incised in the underlying sediments (detail in C); B. Ring profile around the Early Iron Age canoe at the base of the Oer-IJ tidal-creek deposits. Holland Peat lumps are indicative of the erosive character of the creek while active in the Early Iron Age (detail in E); C. Channel incision in the underlying deposits (beach-ridge sand of Uitgeest, Holland Peat and Wormer deposits); D. Sedimentary sequence in the northern wall of the tunnel pit; E. Detailed picture of channel sequence in B; F. Transport of the canoe in a box of steel to the Dutch Institute for Ship and Underwater Archaeology (NISA).

Fig. App. B2. Geoarchaeological survey in the building pit Klein Dorregeest, located in the eastern part of the beach ridge Uitgeest–Akersloot. Location (KD) is shown in Fig. App. B. A. Geological cross-sections of the building pit Klein Dorregeest; B. Plough marks in the excavation plane adjacent to the northern profile (layer 4a; hammer for scale).

Fig. App. B3. Excavation Hoogdorpweg (Heemskerk) on the oldest beach ridge Beverwijk – Uitgeest. Location (HH) is shown in Fig. App. B. A. Overview excavation pit 1; B. Plough marks visible in excavation pit 2 and the flint artefact find of the Middle Bronze Age.

Fig. App. B4. Geoarchaeological survey in the Assum-Waldijk I excavation. The layer succession of the west side, shown without vertical exaggeration, two episodes of aeolian activity, as well as several habitation horizons. Location (AW) is shown in Fig. App. B.

Fig. App. B5. Geoarchaeological survey in the Broekpolder (Beverwijk/Heemskerk in 1999/2000). Location (BP) is shown in Fig. App. B. A. Location map of examined sections in the geological profile. B. Geological survey of profile section E. C. Geological profile; the base of the profile reconstruction in Fig. 11.

Fig. App. B6. The Late Iron Age sites Uitgeest Benes and nearby Castricum Grote Ven in the Castricummer Polder, the former tidal area of the Oer-IJ estuary. Location (UB) is shown in Fig. App. B and B6A. A. Location map of the Late Iron Age sites in former Oer-IJ intertidal area (for legend see Fig. App. A);.SV, Location Schulpvaart; GV, Location Grote Ven; UB, Location Uitgeest–Benes; B. View in the southern direction. In the background is the former main channel of the Dye and the village of Heemskerk; C. Sandy overbank deposits with marine shells (mainly *Spisula*); D. Section of the intertidal deposits. E. Detail of intertidal deposits with *Scrobicularia plana* in live position.

Fig. App. B7. Geoarchaeologal survey in the PWN dune area. Locations (S5, WRK, SG and B45) are shown in Fig. App. B. A. Cross-section at Secundair 5, west profile without vertical exaggeration (see D and E); B. Cross-section at WRK building pit, southwest profile (see H and IL); C. Cross-section at Secundair G, north and east profile (see F and G); D. Overview of the pit at Secundair 5 (November 2002), on the left-hand side is the west profile (see A); E. Southwest corner of Secundair 5, lower dune, formed in several stages of aeolian activity; F. North profile of the Secundair G (March 2002), at the base a Middle/Late Iron Age plough layer (detail in G). The plough zone is covered by a sequence of alternating dune sands and humic culture layers dating from the Roman Period up to the Early Middle Ages (see C); G. Detail of the plough layers in G; H. Southern profile of the WRK pit (June 2002); I. Geoarchaeological survey of the southwest corner of the WRK pit (February 2002; see B); J. Large lacquer peel made in June 2002; K. Middle/Late Iron Age culture layers at site WRK (layer 5 in B); L. Fixation of the lacquer peel on a chipboard panel (plough marks are part of layer 5); M. Hoof imprint in a culture layer of the Iron Age; N. Sediment cores of borehole B19C0945, with the lithostratigraphic units and 14C ages (Table A3.20). Depth intervals above each meter-long section denoted in metres below surface level (surface level is 3.78 m +NAP). O. Coring at site of borehole B19C0947 (November 2002).

Fig. App. B8. Geoarchaeological survey in the pit Castricum – Zanderij. Location (CZ) is shown in Fig. App. B. The cross-section shows an early prominence of over-wash activity and subsequent dune development during two phases, separated by a period of stability. Two lacquer peels highlight details of overwash deposits, including a shell layer, thin dune sand and a culture layer with plough marks.

Fig. App. B9. Geoarchaeological survey at Middensluiseiland (for profile reconstruction, see Fig. 14). Location (ME) is shown in Fig. App. B. A. Location map of the geoarchaeological survey in December 2006; B. Painting by J.C. Grieve (1876) of the construction of the sluices in IJmuiden. Middensluiseiland is located at the position of the dune line behind the sluices under construction. The painting gives an impression of the dune landscape of Middensluiseiland before the dune tops were levelled off in the early 20th century, when the sluice complex was enlarged; C. Geoarchaeological survey at section 24. In the background, the Noordzeekanaal and the buildings of the Tata steel factory (formerly Hoogovens) are visible; D. Cross-section of section 20 (at no vertical exaggeration), showing a bowl-shaped organic horizon following the surface of a former dune valley; E. Georadar survey by Marcel Bakker (Geological Survey of the Netherlands – TNO); F. Georadar survey and profile section 20. a Georadar survey from section 20 collected one week before the trench excavation. The dark reflections in the profile showed the dune valley in the image of F–B. b, Drawing of the profile section 20.