# After the deluge, a palaeogeographical reconstruction of bronze age West-Frisia (2000-800 BC)

Zijverden, W.K. van

**Author**: Zijverden, W.K. van
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# 4 Reconstructing the surroundings of a Bronze Age farmstead in a wetland environment

## 4.1. Introduction

In the previous chapter a palaeogeographical reconstruction for West-Frisia has been presented for three time frames on a small map scale. These reconstructions explain the long term changes in the (in)habitability and general geography of West-Frisia. Questions like: "Which parts of the environment were suitable for arable land or pastures?" or "Where and what kind of forests and timberland were present in the environment?" could not be answered with these reconstructions. Therefore, these reconstructions fail to present information about the appearance and exploitation possibilities of the area which has been exploited on a daily basis, the catchment area. For this purpose, palaeogeographical reconstructions on a large map scale of the environment of settlement sites are necessary. In this chapter a method for the construction of this kind of palaeogeographical map will be presented. First a short overview of palaeogeographical reconstructions of wetland sites on a large map scale is presented and the elements needed for a reconstruction and the principles are discussed. These will be applied to the land consolidation area of Westwoud (figure 4.5), resulting in a palaeogeographical map which presents the appearance of the landscape during the Middle and Late Bronze Age.

## 4.2. Palaeogeographical reconstructions of wetland sites: an overview

Many palaeogeographical reconstructions have been made within the framework of archaeological projects in the Netherlands. Only few reconstructions concern the catchment area of a wetland. Different approaches have been used in these maps to reconstruct the palaeogeography of wetlands at a specific moment in time. The publication of Thoen *et al.* (2013) incorporates a number of recent case studies of coastal wetlands in relation to human exploitation of the North Sea basin. This publication focuses on the influence of man in the past on the development of coastal landscapes in this region (Thoen *et al.* 2013). In this publication a concise overview of published palaeogeographical maps for the southwestern coast of the North Sea basin is presented by Weerts (2013, 45-176).

This overview and the previously mentioned reconstructions have been the starting point for the exploration of methods for the making of palaeogeographical reconstructions, together with the publications of Vos *et al.* (2011) and Vos (2015). In table 4.1. an overview of the reconstructions used is presented. In the palaeogeographical studies presented in the overview, the subsurface is mostly represented by geomorphological units like creeks, creek ridges, salt marshes,

| Toponym | Publication | Units legend | | | | | | | | Area (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Relief | Topographic | Geomorphologic | Lithologic | Lithogenetic | Environment | Vegetation | Soil | |
| De Bogen (NL) | Van Zijverden 2002b; Van Dinter and Van Zijverden 2010 | x | x | x | | | | | | ±225 ha |
| De Bruin (NL) | Mol 2001b | x | x | x | | | x | | | ±100 ha |
| De Horden (NL) | Steenbeek 1990 | x | | | x | x | | | | ± 30 ha |
| Dithmarshen (D) | Meier 2004 | | x | x | x | | | | x | ±90.000 ha |
| Dodewaard-Hiensche Veld (NL) | Steenbeek 1990 | x | | | x | x | | | | ± 30 ha |
| Eigenblok (NL) | Van Zijverden 2002a; Van Beurden 2008 | x | | | x | x | | x | | ±400 ha |
| Hattemerbroek (NL) | Lohof *et al.* 2011 | x | | x | x | x | | | | ±300 ha |
| Huis Malburg (NL) | Van Dinter 2000 | | | | | x | | | | ±100 ha |
| IJzer valley (B) | Baeteman and Declercq 2002 | | | x | | | | | | ±20.000 ha |
| Jade Busen (D) | Behre 1999 | | x | x | | | | | | ±20.000 ha |
| Katwijk-Zanderij (NL) | Van Dinter 2013 | x | x | x | | x | | | | ±8000 ha |
| Kesteren-De Woerd (NL) | Van Dinter 2002a; Van Dinter and Van Zijverden 2010 | x | x | x | | | | | | ±100 ha |
| Lage Blok (NL) | Van Zijverden 2002c | | x | x | | x | | | | ±100 ha |
| Leidschendam-Voorburg (NL) | De Kort and Raczynski-Henk 2014 | | x | x | | | | | | ±600 ha |
| Lienden-Woonwagenkamp (NL) | Van Dinter 2002b; Van Dinter and Van Zijverden 2010 | x | x | x | | | | | | ±100 ha |
| Linge-Steenen Kamer (NL) | Van Dinter 2005 | | x | x | | | x | | | ±100 ha |
| Molenaarsgraaf (NL) | Van der Woude 1987 | | | x | | | | x | | ±400 ha |
| Peins (NL) | Bazelmans *et al.* 1999 | | x | x | | | | | | ±7500 ha |
| Polderweg (NL) | Mol 2001a | x | x | x | | | x | | | ±100 ha |
| Romney Marsh (UK) | Waller *et al.* 2007 | x | | | | | x | | | ±30.000 ha |
| Serooskerke (NL) | Bos and Zuidhoff 2011 | | | x | | | | | | ±600 ha |
| Severn (UK) | Rippon 2000 | | x | | | | x | | | ±1600 ha |
| Swifterbant (NL) | Dresscher and Raemaekers 2010 | | x | x | | | | | | ±1600 ha |
| Texel (NL) | Woltering 1997 | x | | | | x | | | | ±50.000 ha |
| Vergulde Hand (NL) | Eijskoot *et al.* 2011; Vos 2015 | | x | x | | x | x | | | ±40 ha |
| Wijk bij Duurstede (NL) | Vos *et al.* 2011 | | x | x | | | | | | ±2500 ha |
| Yangtze harbour (NL) | Vos 2015 | x | | x | | | x | | | ±10 ha |
| Zijderveld (NL) | Van Beurden 2008 | x | | | x | x | | x | | ±400 ha |

*Table 4.1: Overview of palaeogeographical reconstructions of wetlands at a large map scale.*

floodplains, tidal flats and so on. Apart from geomorphological units, lithogenetical, lithological and soil units are used to describe the nature of the subsurface. Different types of units are often combined. For example in the reconstruction of the site *Eigenblok* the geomorphological unit floodplain is subdivided, based on lithological characteristics into a floodplain with humic clay and a floodplain with clay (Van Beurden 2008). Often the geomorphological unit peatland is subdivided into lithogenetical units to distinguish different types of peatland (Lohof *et al.* 2011; Van Dinter 2013; Vos 2015). Alongside the subsurface most palaeogeographical maps present topographical elements like settlement sites, roads, allotments and so on. Often relief units are added to distinguish relatively low and high parts of for example tidal marshes, levees, crevasses, etcetera. Relief is also used to differentiate Pleistocene outcrops or dunes in these coastal landscapes.

The palaeogeographical map of the Severn (UK) is a rare exception in the presented overview. This map does not present information on the subsoil at all but presents solely environmental units like fen sedge and marsh (Rippon 2000). Surprisingly, only less than half of the reconstructions present some sort of information on the environment or vegetation. This is rather odd considering the purpose of the construction of these maps. For example, a differentiation into freshwater, brackish water and salt water environments would be relevant


*Figure 4.1: Three types of floodbasins in the Danube delta, Romania (Photos: Farmers of the Coast).*

for coastal environments. The only reconstruction in this overview with such a differentiation is the reconstruction of the site *Vergulde Hand* (Eijskoot *et al.* 2011; Vos 2015). Only a few reconstructions in the overview provide detailed information on vegetation units (Van Beurden 2008; Van der Woude 1987). For example, the reconstruction of *Eigenblok* presents vegetation classes like wet grassland and willow shrub, herbs and grasses, alluvial hardwood forest and alder carr (Van Beurden 2008).

Apparently the appearance of the landscape at a specific moment in time is reconstructable in abiotic, geomorphological elements like creeks, levees and so on. These units are helpful in understanding the landscape in terms of possibilities for transportation and so on. But do these palaeogeographical maps provide answers to the questions previously asked? For example the geomorphological unit floodbasin can represent environments with obvious distinct exploitation possibilities (figure 4.1). Floodbasin A provides reed, which can be used amongst others for roofing. Floodbasin B is an ideal location for fowling. Floodbasin C is ideal for fishing with weirs and fykes. Therefore lithogenetic or geomorphogenetic units seem to be more appropriate for presenting such information. For example floodbasin A can be represented by peaty floodbasin deposits, B by humic floodbasin deposits and C by clayey floodbasin deposits.

The palaeogeographical map of the site *Vergulde Hand* is a good illustration of a palaeogeographical map with lithogenetical units (Eijskoot *et al.* 2011; Vos 2015). Figure 4.2 presents the palaeogeography of this site around approximately 250 BC. The reconstruction displays two lithogenetical units, eutrophic peat (reed-sedge peat) and oligotrophic peat (mosaic of *Sphagnum* and heather). The location of creeks and settlements are also depicted in this palaeogeographical map. In the map description it is explained that during the exploitation of this area there is no active peat formation around 250 BC, but that the substrate consists of peat which has been formed within a fen or bog. According to the description, the research area became inhabitable just before 250 BC as a result of extensive drainage. This lithogenetic

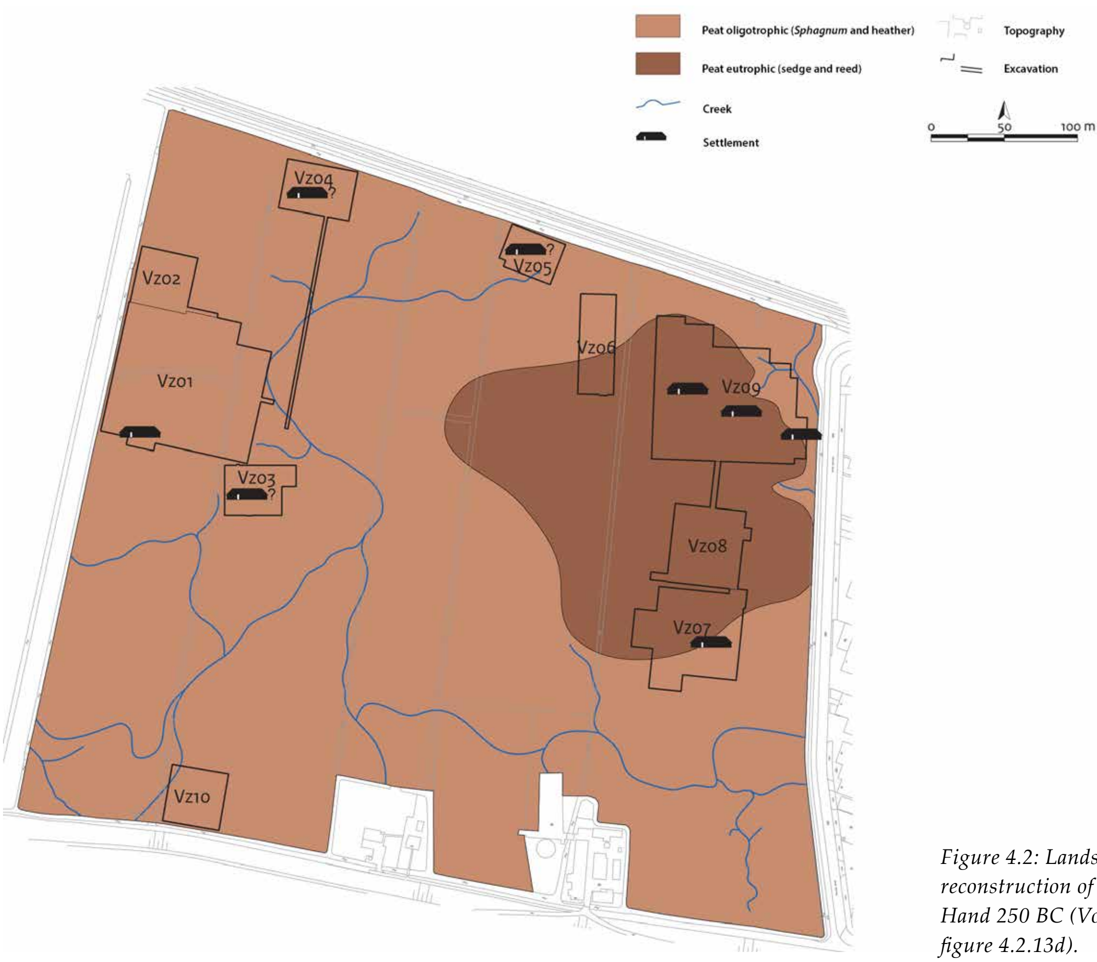


*Figure 4.2: Landscape reconstruction of Vergulde Hand 250 BC (Vos 2015, 285, figure 4.2.13d).*

information is very useful to understand the origin of this specific landscape. However, questions regarding the suitability for agricultural use or the location of forests and shrubs cannot be answered using these lithogenetic units in a palaeogeographical map. In this specific reconstruction, knowledge of the palaeohydrology is essential to understand the possible development of the vegetation and the exploitation possibilities in this area.

The abiotic environment as presented in the analyzed palaeogeographical reconstructions, is relevant to some extent. But it has been the vegetation that was noted by and mattered to prehistoric communities (Arnoldussen 2008, 48). Therefore, insight into the appearance of the landscape including vegetation is crucial to understand the different possibilities and use of the landscape around settlement sites. The elements needed for a reconstruction of such a palaeogeographical map at this scale are: topography, relief, information of the subsurface and hydrology.

## 4.3. Methods

In upland environments the aforementioned elements: relief, information of the subsurface, hydrology and vegetation, are relatively "easily" obtained (figure 4.3). Sources like LIDAR-data, soil maps and historic maps usually provide the necessary ingredients for a reconstruction of the subsurface, relief and hydrology. The vegetation in uplands is commonly reconstructed by using palynological data. A problem with vegetation reconstructions in upland environments is the overrepresentation of wet contexts (Gaillard *et al.* 2008; Groenewoudt *et al.* 2008). The study by Gaillard *et al.* (2008) presents promising results to overcome this problem. In wetland environments palynological data is easily obtained and can be completed with macrobotanical remains, but the other sources are not sufficient. Weerts (2013) notes several problems that hinder an easy application of these sources. First of all, the reconstruction of the groundwater level is not only influenced by the sea level rise, but also by the estuary effect, floodbasin effect, river gradient effect and avulsion effect (Weerts 2013, 157-159). Secondly, periods of erosion, sedimentation and non-sedimentation alternate in wetlands through space and time (Weerts 2013, 166). LIDAR-data, soil maps and historical maps only represent the result of these processes and are therefore not applicable. Thirdly, wetland environments are liable to differential subsidence (Weerts 2013, 166). The present day height differences as shown in LIDAR-data are therefore not applicable. Due to these three factors (water dynamics, sedimentation history and differential subsidence), the aforementioned sources are of limited use in palaeogeographical reconstructions of wetlands. In the following paragraph an alternative method will be presented in order to obtain the necessary elements for a palaeogeographical reconstruction of a wetland.

### 4.3.1. Hydrology

In order to obtain information about changes in hydrology over time, three types of indicators are usually used: sediment, botanic remains (pollen, spores and macrobotanical remains) and archaeological features (water pits and ditches). Sediments indicate changes in water conditions by the presence of several organisms. Organisms like diatoms, ostracods, forams, amoeba and molluscs present detailed information on water depth, salinity, stream velocity, temperature and so on. Combined with micromorphological analyses, a well-argued typification of the environment at a specific location at a specific time can be made. Botanical remains like pollen, spores and macrobotanical remains preserved in mires and moors can deliver information on general changes in water conditions over time (Lowe and Walker 2003, chapter 4). It is important to note that short events are sometimes not registered by these proxies due to the relatively long reaction time of plant communities (e.g. § 3.5.3). Archaeological features related to water management like canals, ditches and water pits can provide information about changes in the local hydrology. Remains of organisms from the infill of these features, for example molluscs, can provide information about the groundwater level and fluctuation at a specific moment in time. Furthermore it is thought that the depth of these features is related to the groundwater level (Buurman 1996, 187).

### 4.3.2. The subsurface

The properties of the first 50 centimeters of a soil are for most plants one of the determining factors if they will be able to grow at a specific location, besides the climatological conditions (De Bakker and Locher 1990, 218). Therefore a map presenting the soil properties to a depth of at least 50 centimeters is needed. Ellenberg (1979) describes the soil preferences for phytosociological vegetation classes by the following soil characteristics: acidity (pH), nutrient availability, moisture content and salinity. If these soil characteristics are known for a specific location, the natural vegetation that will develop and the different succession stages can be more or less predicted. The suitability of a soil for agricultural use is usually described by a different set of soil characteristics: natural drainage, field capacity, crumbling and

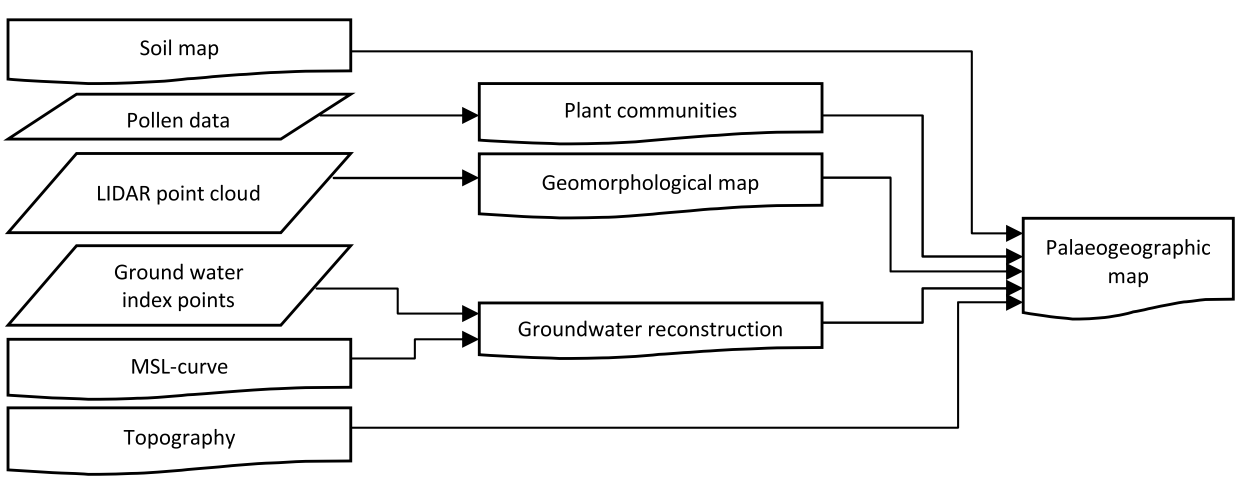


*Figure 4.3: Flow chart for a conventional palaeogeographical reconstruction for an upland location.*

sensitivity for slaking and aeolian erosion (De Bakker and Locher 1990, 216). These characteristics, needed to make an estimate of the vegetation and soil suitability for agricultural purposes, are relatively easy to obtain by manual corings and it can often be deduced from coring databases.

For instance, the soil suitability for agricultural purposes depends heavily on the lithology. Soils with a lutum content smaller than 8% are sensitive to aeolian erosion and are susceptible to drying (De Bakker and Locher 1990, 218). Drying can be prevented to a certain extent by enlarging the organic matter content. Soils with a lutum content smaller than 25% are susceptible to slaking, but do have a high capillary fringe and are therefore less susceptible to drying (De Bakker and Locher 1990, 220). Slaking can also be prevented by enlarging the organic matter content. Soils with a lutum content larger than 25 % do have a low capillary fringe and are difficult to work due to a low crumbling rate (De Bakker and Locher 1990, 219). The crumbling rate can also be enlarged by adding organic matter. Soils with a lutum content larger than 25% are not susceptible to slaking or drying. From an agricultural point of view, the crop failure risk is smallest in the 8-25% and highest in the <8% lutum zone. The suitability for crop cultivation of the different soil types depends largely on the groundwater level. Soils with a groundwater depth less than 15 cm during winter season are thought to be unsuitable for arable land (De Bakker and Locher 1990, 218).

The soil characteristics used in vegetation research can also be partly deduced from these coring databases. The acidity of a soil is usually expressed in pH-values however it can also be roughly estimated from the $CaCO^3$-content. Since 1966 $CaCO^3$-content has been estimated with a 10% HCl solution as a standard during soil surveys in the Netherlands (De Bakker and Schelling 1966). This standard has been used in all available databases for West-Frisia as presented in table 2.1. The availability of nutrients is usually expressed by the C/N-ratio, $CaCO^3$-content and P-value. A high $CaCO^3$-content often coincides with a good C/N-ratio and P-value. The reverse is untrue, for example an oxidized peat usually has a high C/N-ratio but a low $CaCO^3$-content. Moisture content and salinity are difficult to obtain. The moisture content depends on the groundwater level and capillary fringe and thus lithology and hydrology as described before. The salinity of soils at a certain moment in time is difficult to estimate due to the mobility of salt in a soil. The original salinity can be obtained by an analysis of fossil organisms like molluscs, ostracods, forams and diatoms (Lowe and Walker 2003, chapter 4). Pollen and macrobotany can be used to describe the salinity of an environment at a specific moment in time in general terms (Lowe and Walker 2003, chapter 4).

### 4.3.3. Relief

The original morphology of a wetland is difficult to reconstruct due to differential subsidence, erosion and sedimentation. Soils exploited during a specific period in the past are, when non erosively covered, often well visible in wetlands. For example the dark fossil A-horizons representing the surface of the landscape during a specific period (figure 5.20) of sites like *Noorderboekert* and *De Rikkert* can be traced over extensive areas. The relief of these horizons can be mapped easily using hand coring equipment or digital coring databases. The mapped relief of these horizons can be represented with a digital elevation model (DEM). This mapped relief differs from the original relief due to differential subsidence. Several methods have been applied in the past in order to create an educated guess for the original relief. A first method which has been used by many authors is a correction based on the thickness of sand bodies (Van der Woude 1987; Steenbeek 1990; Van Dinter 2002a; 2002b; Van Dinter and Van Zijverden 2010). In this method the amount of sand present in a soil section is used to estimate the compression factor. A second method is the measurable compressibility of the subsoil. This type of correction is only possible for locations with detailed and reliable knowledge of local soil properties and compressibility of the sediments (Koster *et al.* 2012). This kind of information is often available in a high density from cone penetration tests for construction sites, railway-tracks and highways. Although, outside the perimeters of the actual construction sites little to no information on compressibility is available. A third approach is the use of modern analogies. A DEM of the surface can be corrected with a well-considered compression factor based on maximal height differences in an analogy.

### 4.3.4. Vegetation

In order to reconstruct the vegetation at a specific location and moment in time archaeobotanists use several proxies. Palynological data (pollen and spores), macrobotanical data (seeds, leafs and stems) and analysis of wood are widely used for this purpose. Traditionally palynological research is used to gain insight into the wider environment of archaeological sites and changes over time in these environments. This type of research has been criticized in the past two decades. Studies, especially of the relevant source area of pollen (RSAP), prove that traditional archaeological contexts like water pits and ditches are often too small to gain insight into the wider environment (Sugita 1994; Sugita *et al.* 1999; Groenewoudt *et al.* 2008; Van Beurden 2008; Lohof *et al.* 2011, 437). Furthermore wet contexts are overrepresented due to their relatively good preservation conditions. The frequent analysis of these wet contexts and on-site contexts resulted in a biased image of the natural vegetation in the past (Groenewoudt *et al.* 2008; Schepers 2014). Samples obtained from intensively used areas like settlement sites and arable fields present almost a reverse image of the environment which has been exploited by man (Van Amerongen 2016, 17). Finally palynological data represent vegetations of the past, but quite different vegetations can result in strikingly similar palynological records (Vera 1997, 73). The interpretation of these records is a specialism and sometimes leads to heated debates (Louwe Kooijmans 2012).

Analyses of macrobotanical remains are often used to gain insight into the use of domesticated and gathered plants by communities in the past. Furthermore, these are also used to gain insight into the biotopes represented by these plants. In this way the study of macrobotanical remains contributes to the analyses of the environment outside the settlement, for example distinctions are made between different types of pastures and meadows. Macrobotanical remains from natural contexts have not been used in order to reconstruct the palaeovegetation with the exception of the study by Schepers (2014). A special class of macrobotanical remains is wood. Wood from archeological sites is often used for obtaining dendrochronological dates. It is rarely used to obtain information on woodland types in the vicinity of sites. A few studies in Dutch archaeology of large samples of wood provide information about the composition and maintenance of woodlands in the past (Koot and Vermeeren 1993; Bulten *et al.* 2002; Van Dinter 2013). Contexts with well preserved sub-fossil woodlands are rare, but provide detailed information about the composition of woodlands in the past (Kooistra *et al.* 2006; Bouma 2011).

Schepers (2014, 30-33) distinguishes two research strategies for the reconstruction of plant communities of the past. Plants can be differentiated into ecological groups, groups with more or less similar demands to pH, nutrient availability, light, salinity and so on. Secondly plants can be differentiated into syntaxonomic groups, that is to say, groups of plants which form a plant community under certain

*Figure 4.4: Yard of a house in Letea (Romania) showing straw for cattle, reed for roofing, assembled wood for fire, wood for timber and locally grown pumpkins.*

preconditions. Every plant community is represented by one or more indicator species, which is typical for this plant community. Based on the presence of indicator species in a macrobotanical analysis the presence of specific plant communities can be deduced. For example, *Calamagrostis Canescens*, *Ribes nigrum* and *Carex elongata* are the indicator species of a specific type of alder carr. One or more of these indicator species in combinations with remnants of *Alnus glutinosa* indicate the presence of this type of woodland. The combination of these types exclude other types of alder carr. The principle of actualism is an important condition for the application of both approaches. Schepers (2014) uses in his study samples from channel lags and other remains assembled in natural secondary contexts. Based on an analysis of indicator species he presents a plausible vegetation reconstruction of the wider environment. This idea should also be applicable to macrobotanical and zoological remains from settlement sites. Man assembled material in his catchment area. The finds on-site are therefore a representation of the exploited off-site environment and the on-site environment, which is well-illustrated in figure 4.4.

### *4.3.5. A method for the reconstruction of a wetland environment*

In order to create a reconstruction of the environment, information on the subsurface is needed regarding lithology, organic matter content and $CaCO^3$-content of the upper 50 centimeters of the surface. Furthermore a reliable set of groundwater index points is needed in combination with a reliable DEM of the former surface. For reconstructions in (near-) coastal environments information on the salinity of surface water is needed. The palaeovegetation can be reconstructed using these characteristics, because plants arrange themselves in plant communities based on the previously mentioned characteristics. Plant communities and the succession of plant communities are therefore more or less predictable in composition and structural appearance.

A man-made selection of macrobotanical remains is available at every excavated site. This selection is not at all a complete representation of the exploited environments but more or less a jig saw puzzle with lots of missing pieces although the individual species can be organized in plant communities based on the indicator species which are present in the samples. These plant communities can be compared with the based on the soil properties predicted plant communities. If there is a match the communities can be distributed in space based on their preferred habitat. Information derived from remains of wild fauna can be used to complete the environmental picture but can also be used to evaluate the reconstruction.

## 4.4. Case-study Westwoud

Westwoud is a land consolidation project situated in West-Frisia (figure 4.5). The Westwoud land consolidation project was carried out in the mid-eighties preceded by a soil survey (Bles and Rutten 1972). The original 1360 core descriptions from the soil survey could be obtained for this study from Wageningen University.[66] The surface height measurements of the original survey were not available. To create a valid reconstruction of the surface level for the seventies a set of 4047 height measurements dating from 1971 has been used.[67] In advance of the land consolidation project an extensive archaeological field survey was carried out. The original data and finds from this survey could be obtained for this study from the Provincial Archaeological Depot Noord-Holland.[68] Based on the results of the soil survey and the archaeological field survey, four small-excavations were carried out (figure 4.5: site 1-4). Since 1984 several small-scale excavations have been carried out within the Westwoud land consolidation area (figure 4.5: site 5-7). Recently, in advance of the construction of a road, several small scale excavations were conducted (figure 4.5: site 8 and 9). Just outside the borders of the land consolidation area the large scale excavations of *Hoogkarspel* were carried out as well as a small scale excavation (figure 4.5: site 10-12).

The landscape in the Middle Bronze Age of the Westwoud land consolidation area can be characterized as a former tidal marsh area. The subsurface is therefore characterized by the presence of tidal marsh deposits, creek deposits and peat. In the top of the tidal marsh deposits a distinct A-horizon of 10-15 centimeters has developed. This A-horizon is

66 Thanks to Fokke Brouwer for making available the original data (Alterra Wageningen UR) and Renate de Boer (Leiden University) for digitizing the data.

67 The vertical datum used is the Amsterdam Ordnance Datum (NAP).

68 Thanks to Martin Veen and Jean Roefstra (Provincial Archaeological Depot) and Esther Eilering (Saxion University) for digitizing the data.

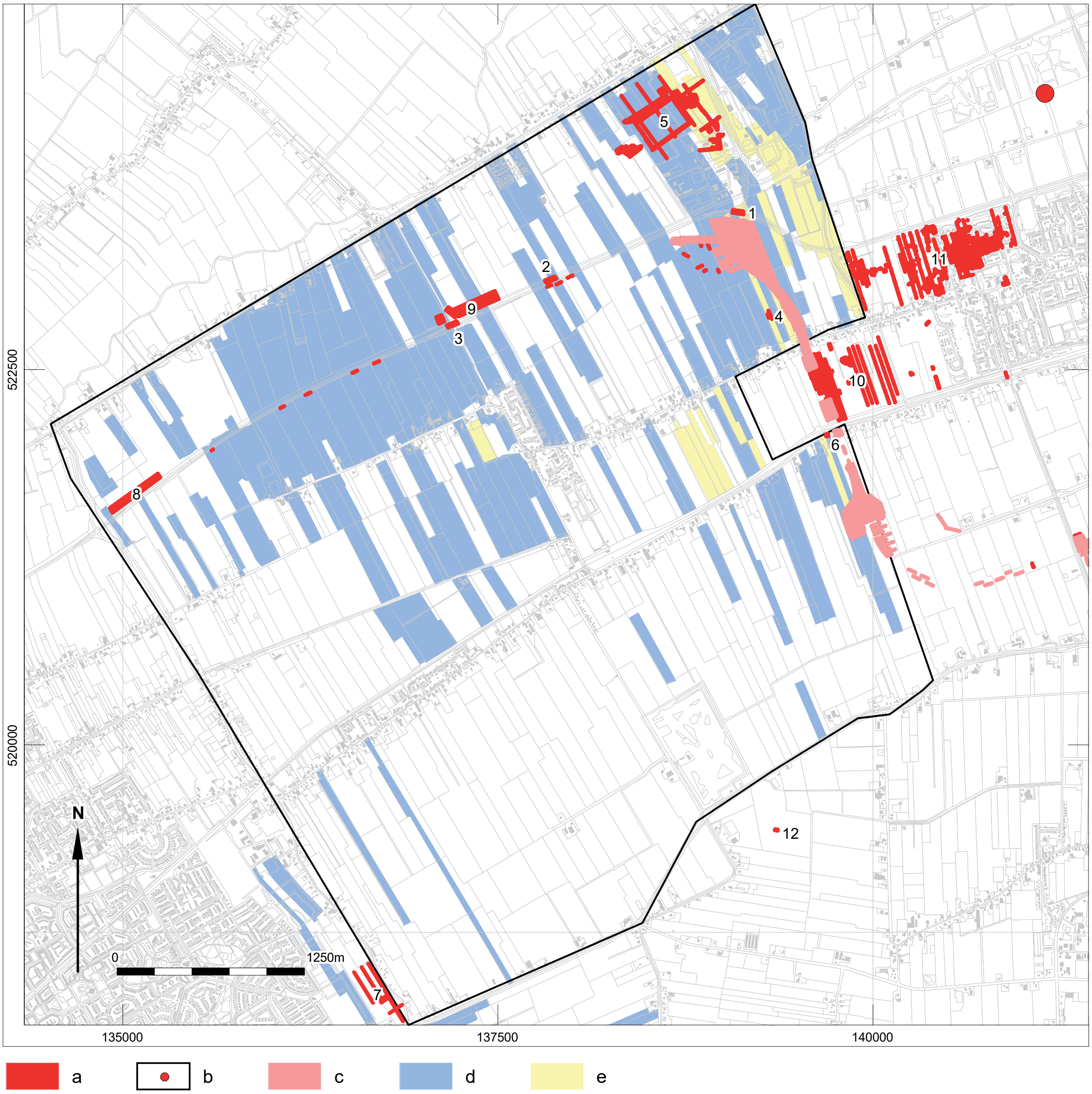


*Figure 4.5: Excavations and field survey within the Westwoud land consolidation area. Legend: a sites: 1 Westwoud I, 2 Westwoud II, 3 Westwoud III, 4 Westwoud IV, 5 Zwaagdijk-Oost, 6 Binnenwijzend 100, 7 Zuiderdracht, 8 Rijweg, 9 Noorderboekert, 10 Hoogkarspel-Tolhuis, 11 Hoogkarspel-Watertoren and Tumuli, 12 Blokdijk, b Klokkeweel, c Excavations in advance of construction works N23, d parcels included in field survey without finds dating to the Middle or Late Bronze Age, e parcels included in field survey with finds dating to the Middle or Late Bronze Age.*

covered with a thin layer of younger sediments dating after approximately *c.* 750 BC (Buurman 1996, 112). The A-horizon was mostly still present during the soil survey carried out between June 1970 and March 1971 (Bles and Rutten 1972).

### 4.4.1. Construction of the subsurface model

The original top of the Bronze Age surface is well visible due to a distinct dark colored A-horizon. In the set core descriptions, dating from the seventies, this A-horizon is easily identified. The lithology is described in centimeters below the surface level. In order to reconstruct the Bronze Age relief the depth


*Figure 4.6: Reconstruction of the relief and soil properties.*
*A. Palaeorelief, a 4.00-3.25 m-OD, b 3.25-2.50 m-OD, c 2.50-1.75 m-OD, d 1.75-1.00 m-OD.*
*B. Adjusted palaeorelief, a 1.25-1.50 m-OD, b 1.50-1.75 m-OD, c 1.75-1.00 m-OD.*
*C. Soil properties, e 8-25% lutum in top and subsoil, f >25% lutum in top soil and 8-25% in subsoil, g 8-25% lutum in top soil and >25% in subsoil, h >25% lutum in top and subsoil.*

of the soil horizon in centimeters O.D. was calculated with a DEM based on a set of height measurements dating from the seventies (figure 4.6A). The height differences within this A-horizon are approximately 3 meters. This is a high relief difference which is unlikely for this type of landscape. Modern analogies like "*Het Verdronken Land van Saefthinge*" and "*De Slufter*" show maximal height differences of approximately 75 centimeters. Therefore the DEM has been adjusted in proportion to this maximum difference (figure 4.6B).

To reconstruct the soil properties, the lutum content of the distinct A-horizon and the first layer beneath this horizon have been mapped resulting in four lithological classes: 8-25% lutum in top and subsoil, >25% lutum in top soil and 8-25% in subsoil, 8-25% lutum in top soil and >25% in subsoil and >25% lutum in top and subsoil. Apparently a class vulnerable to aeolian erosion and susceptible to drying is absent within this particular area. In addition a distribution map of the $CaCO^3$-content has been made as well as a distribution map of the organic matter. Within this research area these factors show little to no variation. Therefore these classes are not incorporated in the subsurface map. Peat is absent in the upper 50 centimeters within the research area. All factors are presented in a soil suitability map (figure 4.6C).

In order to obtain an idea of the rise of the groundwater level, an analysis of features like pits, water pits and ditches from sites in the region has been conducted. Comparing these features in relation to the original top soil, a clear trend is visible (figure 4.7A). Water pits become shallower over time, indicating a rising groundwater level as expected. Although the function of the pits is unknown these also tend to become shallower over time. Within the category ditches, a difference between house ditches (ditches surrounding a house plan) and terp ditches (ditches surrounding a terp mound) has been made. The terp ditches dating to the Late Bronze Age are clearly deeper compared to the house ditches dating to the Middle Bronze Age.

A confusing image arises when the depth of the previously mentioned features is compared in meters O.D. (figure 4.7B). The house ditches of *Hoogkarspel* are approximately 1 meter less deep compared to the house ditches of *Andijk* and *Enkhuizen*. If these ditches have been dug into or close to the groundwater level, these ditches should have a different depth with respect to the Bronze Age surface, which is obviously not true (figure 4.7A). More confusing is the depth of the terp ditches. The terp ditches of *Hoogkarspel* are slightly deeper compared to the

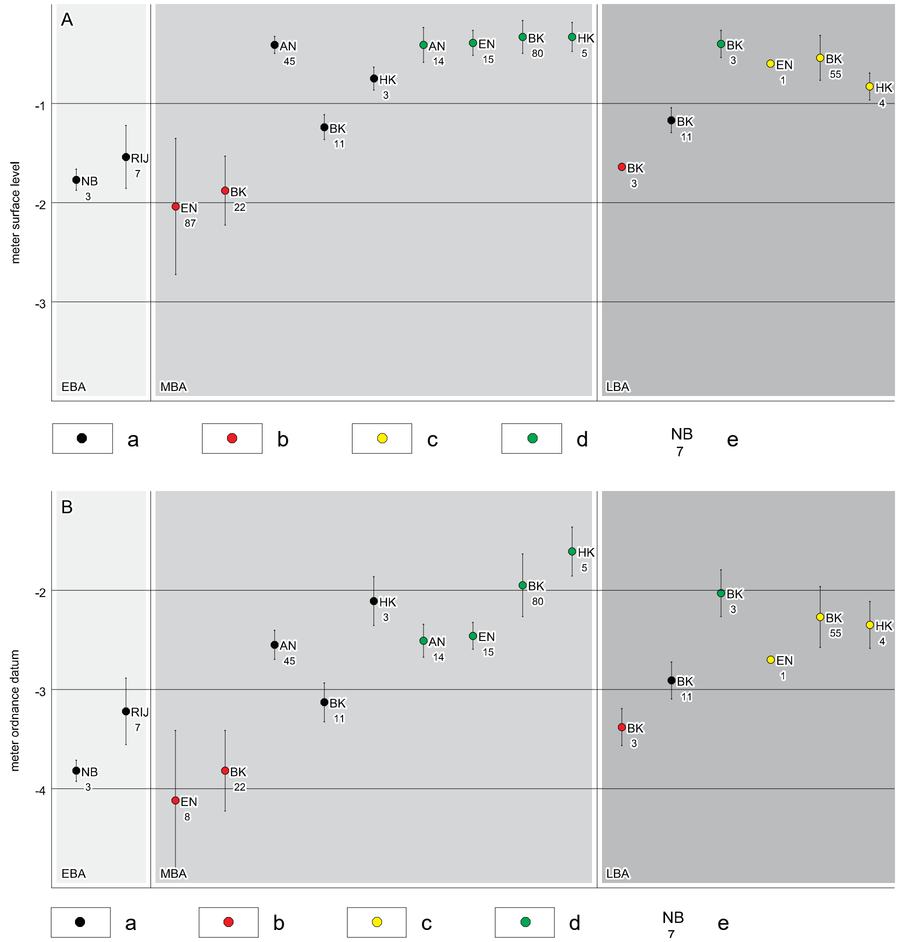


*Figure 4.7: Mean depth of features with variation. Legend: a pits, b water pits, c terp ditches, d house ditches, e site name and number of features: NB Noorderboekert, RIJ Rijweg, EN Enkhuizen-Kadijken, BK Bovenkarspel-Het Valkje, AN Andijk, HK Hoogkarspel.*

ditches of *Bovenkarspel-Het Valkje* (figure 4.7A), but do reach to the same depth in meters O.D. This is to be expected when these ditches have been dug into or close to the groundwater level. But why does the terp ditch of *Enkhuizen-Kadijken* reach deeper into the subsurface? The sites *Bovenkarspel-Het Valkje* and *Hoogkarspel* are both thought to be situated on top of a thick sandy creek ridge and *Enkhuizen-Kadijken* on top of a more clayey tidal marsh deposit. Therefore, the groundwater level of *Enkhuizen-Kadijken* in the Bronze Age is expected to be relatively shallow compared to *Bovenkarspel-Het Valkje* and *Hoogkarspel*. Hence the terp ditch should have been shallower in meters O.D. Because of this uncertainty and inexplicable differences in the relative depth of the different archaeological features, these are not used for the reconstruction of the groundwater level.

The site *Bovenkarspel-Het Valkje* is situated on top of a thick sandy creek ridge and is not vulnerable to compaction (Roep and Van Regteren Altena 1988). At the site *Bovenkarspel-Het Valkje* a thorough analysis of 139 mollusc samples from terp as well as house ditches has been conducted. The analysis at this site indicates a different environment within the two types of ditches (Mink 2016, 66-72). House ditches provide a mollusc fauna indicating dry periods during the entire year. Terp ditches provide a mollusc fauna indicating that these ditches contained water throughout the entire year, by the presence of *Anisus vorticulus* and *Planorbarius corneus* and the absence of *Aplexa hypnorum* (Mink 2016, 72). The shallowest terp ditches reach to 200 cm -O.D. The average depth of these ditches is 60 cm. Therefore, the groundwater level in the Late Bronze Age is estimated to approximately 150 cm -O.D. The Bronze Age surface level at this site varies between 90 and 160 cm -O.D. Therefore, the lowest areas of the site will have been regularly flooded which is in agreement with the observation of the local sedimentation of very fine sediments in the Late Bronze Age at for example the nearby site of *Enkhuizen-Kadijken* (Roessingh and Lohof 2011, 46).

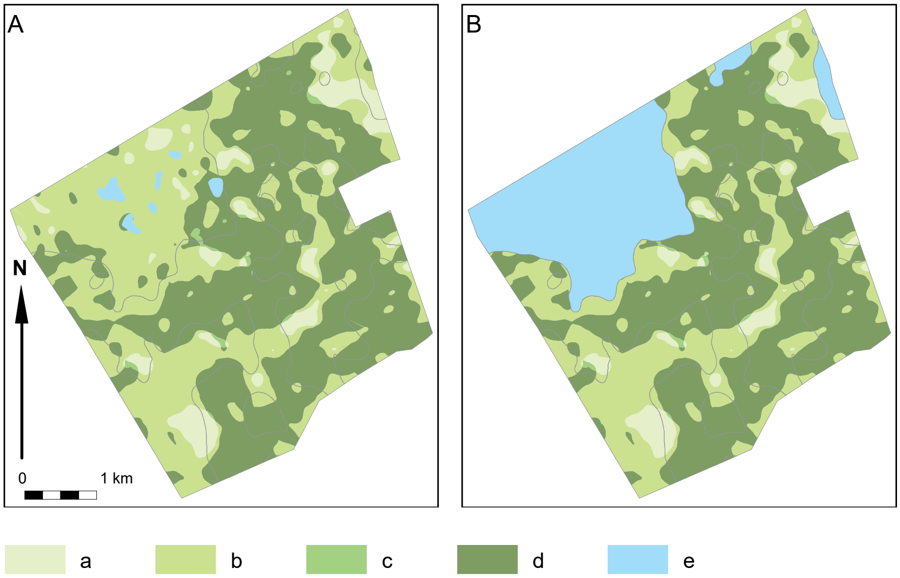


*Figure 4.8: Reconstruction of soil properties for the Middle Bronze Age (A) and Late Bronze Age (B). a 8-25% lutum in top and subsoil, b >25% lutum in top soil and 8-25% in subsoil, c 8-25% lutum in top soil and >25% in subsoil, d >25% lutum in top and subsoil, e freshwater lake.*

On top of the relatively high groundwater level there are also indications for a change in surface water dynamics. An analysis of pollen and macrobotanical remains indicates a significant decrease of *Alnus* and an increase of *Salix* and *Phragmites australis* (Pals *et al.* 1980). This change is dated to around 1000 BC (GrN-7912 2860 ± 30 BP). According to Wolf *et al.* (2001) *Alnus* allows fluctuations in the surface water level up to 30 cm. When fluctuations exceed this value regularly, *Alnus* is replaced by *Salix* and *Phragmites*. Van Beurden (2008, 28) interprets a comparable change in the river area as an enlargement of peak discharges. This explanation of Van Beurden is possibly applicable to the situation in West-Frisia. The idea of larger surface water fluctuations is supported by the erection of small terp mounds, the occurrence of local sedimentation of very fine sediments in the Late Bronze Age at the site *Enkhuizen-Kadijken* and the origination of the Vecht-Angstel system (§ 3.2.2). In figure 4.8B the average water level for the Late Bronze Age is depicted on top of the soil suitability map.

The average MSL-rise for the period Middle Bronze Age to Late Bronze Age is approximately 100 cm per 1000 years (Van der Plassche *et al.* 2010). Therefore the groundwater level for the Middle Bronze Age is estimated at 225 cm -O.D. This value suits very well the observed habitat of molluscs in house ditches, a mollusc fauna indicating dry periods during the entire year (Mink 2016, 66-72). An analysis of fish remains illustrates the presence of open water in this part of West-Frisia (Van Amerongen 2014). Therefore, within the area shallow lakes should have been present. The reconstructed surface level however exceeds the value of the reconstructed groundwater level in the entire area. Due to the absence of a natural drainage pattern and an expected surplus of precipitation, stagnation will occur at the lower locations with a low permeability. Therefore, lakes are depicted in the reconstruction at locations with a low permeability (a lutum percentage of 35 and up) in the lowest relief class (figure 4.8A).

### 4.4.2. Furnishing of the environment

In the previous paragraph the indicator values for phytosocial vegetation classes have been reconstructed for two specific moments in time: approximately 1500 BC and 800 BC. Using the reconstructed indicator values it is possible to predict the succession in phytosocial vegetation classes and, if possible, plant associations, for a specific place and moment in time (figure 4.9). During the Middle Bronze Age habitats with a high morphodynamic are absent. In the lowest areas with stagnant water, a groundwater level almost reaching the surface and a eutrophic environment, a forest of the class Alnetea glutinosae, will develop within several years. Within this class, two associations can develop: Thelypterido-Alnetum, an alder carr with an undergrowth characterized by ferns and a permanent groundwater level less than 20 cm below the surface, or Carici elongatae-Alnetum, an alder carr with an undergrowth characterized by sedges (Stortelder *et al.* 2008). In pollen spectra from the sites within the Westwoud land consolidation area, spores of ferns are rare. Remnants of ferns are

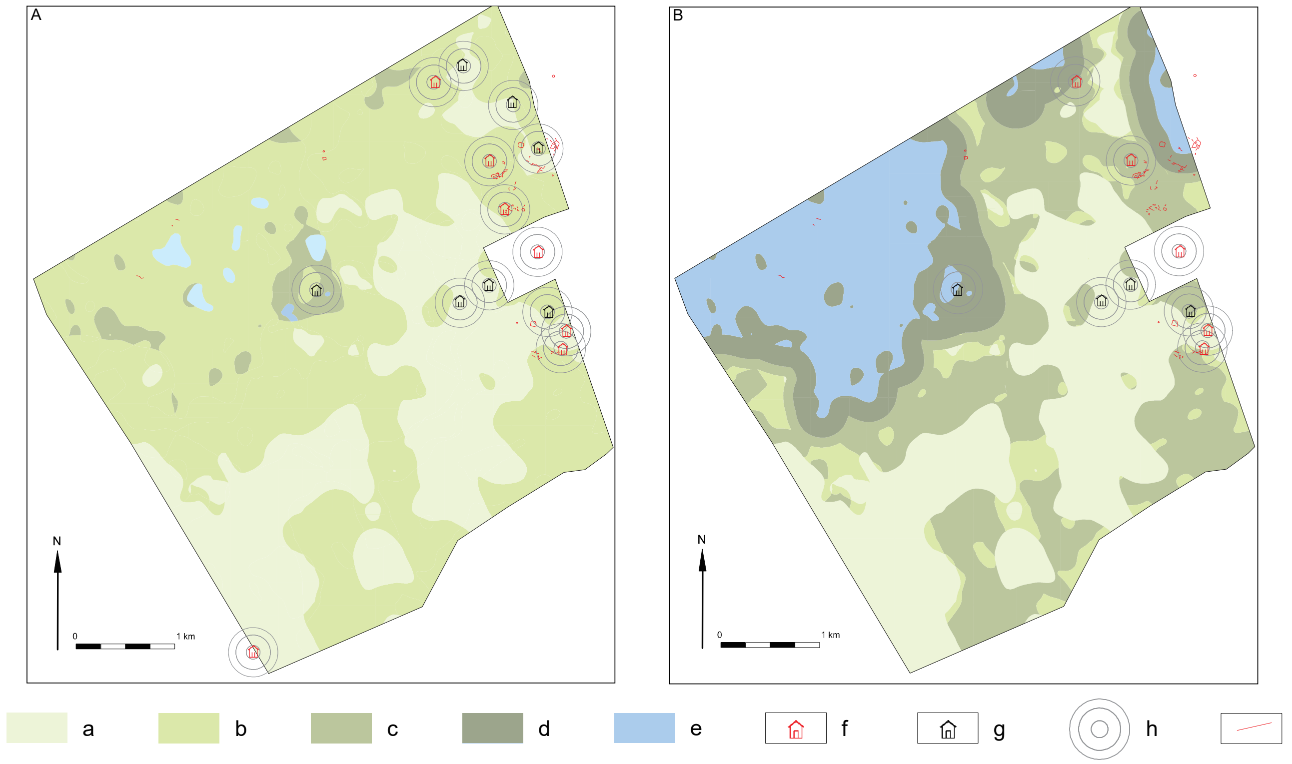


*Figure 4.9A: Palaeogeographical reconstruction of the Westwoud land consolidation area for the Middle Bronze Age (ca. 1500 BC. a Molinio-Arrhenatheretea, b Fraxino-Ulmetum, c Alnetea glutinosae, d Artemisio-Salicetum albae, e open water and or, f settlement site excavation, g settlement site field survey, h vegetation influenced by man Salsolion ruthenicae, Fumario-Euphorbion and/or Polygonion avicularis, i Bronze Age structures from photographs.*

*Figure 4.9B: Palaeogeographical reconstruction of the Westwoud land consolidation area for the Late Bronze Age (ca. 800 BC). a Molinio-Arrhenatheretea, b Fraxino-Ulmetum, c Alnetea glutinosae, d Artemisio-Salicetum albae, e open water and or, f settlement site excavation, g settlement site field survey, h vegetation influenced by man Salsolion ruthenicae, Fumario-Euphorbion and/or Polygonion avicularis, i Bronze Age structures from photographs.*

absent in the macrobotanical samples. Pollen and macrobotanical remains of sedges are, in contrast to ferns, abundant. However, the indicator species *Carex elongata* is absent. Therefore, a more specific subdivision is not possible.

At the drier surfaces a forest of the class Querco-Fagetea could develop. Within this class, a subdivision in orders and alliances is made, based on, amongst others, the nutrient availability of the soil. Due to the local high groundwater level and high calcium carbonate content, a forest of the Alno-Padion alliance is expected. Species belonging to this alliance, like ash (*Fraxinus excelsior*) and elm (*Ulmus*) in the pollen data suggest the presence of a hardwood alluvial forest of the Alno-Padion.

At the driest soils, a forest from the class Querco Fagetea can also be expected. Based on the nutrient availability of the soil and deep groundwater level, a forest of the Carpinion betuli alliance would be expected. However, some important indicator species like lime (*Tilia cordata*) are absent in the macrobotanical data. Lime shows low values in the pollen spectra. Indicator species of the expected associated edges of the forest (class Rhamno-Prunetea) like sloe (*Prunus spinosa*) are absent. Especially the stones of sloe plums are usually widely found in Bronze Age settlements (RADAR 2010). Within the rich botanic data these stones should be present, if the sloe plum has been collected. Indicator species for outer edges and clearances of the class Gallio-Urticetea are present, although common nettle (*Urtica dioica*) and cleavers (*Galium aparine*) are also very common in settlement areas. Where woody vegetation has disappeared completely the class Molinio-Arrhenatheretea is considered to be present. Indicator species of this class are clearly visible in the macrobotanical data, like *Ranunculus acris, Rumex acetosa, Prunella vulgaris, Taraxacum* *officinale* and *Phleum pratense pratense*. Apparently the grazing pressure was high and prevented the succession to woodland. Finally, the influence of man is clearly visible in the presence of indicator species of the ruderal biotopes like Artemisietea vulgaris, arable biotopes like Stellarietea mediae and medium nutrient rich grasslands like Plantaginetea majori.

By the Late Bronze Age the groundwater level had gradually increased by approximately 1 meter compared to the Middle Bronze Age. Apart from this gradual rise of the groundwater level, the seasonal fluctuation of the surface water level had strongly increased as well. These two factors caused a gradual change in the biotopes within the study area. In the enlarged surface of the shallow lakes a reed swamp (Phragmitetea) of the order Sparganio- Glycerion and/or Oenanthion aquaticae developed. Along the borders of the lakes a soft wood willow shrub (Salicetea purpureae) developed. For both biotopes the indicator species are present in high numbers (Appendix 2). The other biotopes are still present in the study area, but at different locations compared to the Middle Bronze Age.

Cronau (2016) used a comparable strategy to reconstruct the appearance of the landscape of West-Frisia in the Middle Bronze Age by an analysis of zoological remains. An important premise in his analysis is the idea that all zoological remains found during excavations represent species which were present in the environment surrounding the settlement sites. Therefore, Cronau deliberately uses the counts of species, instead of the counts of individuals. He argues that all species represent healthy reproducing populations. With the zoological database of the sites of eastern West-Frisia, Cronau calculates different surfaces of preferred vegetation for all species. He also takes the surface used by man and his domestic animals into account, based on an estimated value by Van Amerongen (2016). Cronau concludes that the carrying capacity of the eastern West-Frisian landscape has been sufficient for healthy reproducing populations of game, man and his domestic animals. He also concludes that the grazing pressure was high, which probably affected the vegetation at the richest soils, resulting in a more parkland like vegetation. Based on his analysis he expects the following types of woodland present during the Middle Bronze Age: Fago-Quercetum, Thelypterido-Alnetum, Carici elongatae-Alnetum and Artemisio-Salicetum albae, which corresponds very well with the previously presented results.

### 4.4.3. Topography

A last element which has to be added to the palaeogeographical reconstruction is the topography (figure 4.9). Settlement sites are represented based on the results of excavations and a field survey. Locations where a (part of a) house plan or terp ditches have been excavated are represented as settlement sites. Interpretation of the results of the field survey is less simple. During the eighties a field survey was carried out (De Vries-Metz 1993). During this survey many finds dating to the Bronze Age were found. The pottery is divided into Hoogkarspel Oud (Middle Bronze Age) and Hoogkarspel Jong (Late Bronze Age). The pottery dating to the Middle Bronze Age has a coarse temper and is vulnerable to mechanical weathering, contrary to the pottery dating to the Late Bronze Age. Therefore it is thought that Late Bronze Age pottery is overrepresented in field surveys (Roessingh in prep.; IJzereef and Van Regteren Altena 1991, 65). It appears that finds of Late Bronze Age pottery always coincide with Late and Middle Bronze Age features contrary to the reverse (IJzereef and Van Regteren Altena 1991; Roessingh in prep.). Clusters of Late Bronze Age pottery are therefore mapped as settlement sites in the 1500 and 800 BC reconstruction. Clusters of Middle Bronze Age pottery are only represented in the 1500 BC reconstruction. Loose finds are plotted on the map as well. It is very important to note that the numbers of finds are highly dependent on local visibility of archeological remains. Furthermore it is important to note that the field survey of the northern part was far more detailed compared to the southern part of the land consolidation area (figure 4.5).

Extensive ditch systems are known from all excavations. The detail of these systems is too much to present at this map scale. Sometimes these field systems are visible in aerial photographs. During the period of the land consolidation projects aerial photos were taken by Willy Metz (1993). She kindly gave access to her extensive photo archive with over 4000 (!) analogue photographs of the eastern part of West-Frisia.[69] These photographs are a great resource for the recognition of field systems, burial mounds and even a few settlement sites in the land consolidation area *De Streek*. There were two problems, however, in using the photographs. First the topography

69 Thanks to Carla Soonius, the community archaeologist for West-Frisia, all photographs have been made digitally available.

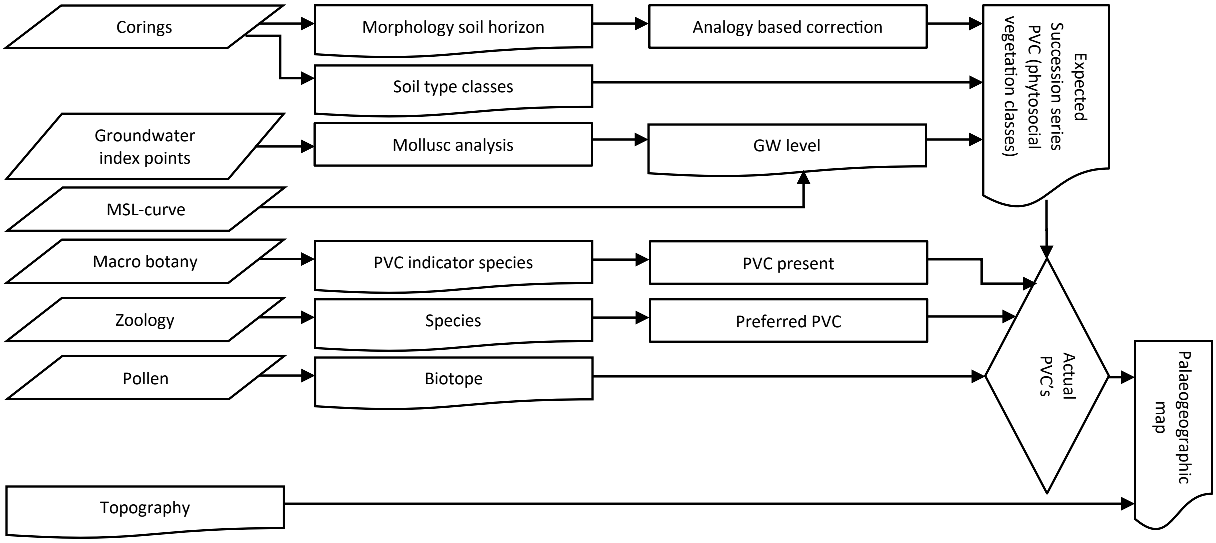


*Figure 4.10: Flow chart for the palaeogeographical reconstruction of Westwoud.*

has greatly changed (see figure 2.4), therefore it is difficult to georeference the photos. Second, all photographs are oblique and therefore difficult to use in a GIS. With a lot of effort all available photos (26) for the land consolidation area *Westwoud* have been incorporated in a GIS.[70] All visible ditch systems have been depicted in figure 4.9.

West-Frisia was a vast tidal marsh in the Early Bronze Age. Such marshes should be (based on modern analogies) intersected by creeks. Therefore, the absence of residual gullies is remarkable. During excavations in the recent decades, only at two settlement sites dating to the Bronze Age in eastern West-Frisia was a residual gully found, *Bovenkarspel-Het Valkje* and *Noorderboekert*. At both locations the gully was active in the Late Neolithic and had been silted up completely at the start of the Middle Bronze Age. In the aerial photos residual gullies are absent within the Westwoud land consolidation area. In the excavated areas the farm yards are surrounded by arable fields. In the palaeogeographical reconstruction the settlement sites are surrounded by arable fields and pastures. It is thought that the arable fields can be expected on the rich soils, the same part of the landscape which apparently had a high grazing pressure preventing the succession of Fagetalia sylvaticae. Van Amerongen (2016) estimated a surface needed for a single farm for a sustainable production of crops, pastures and woodland. The area needed for arable fields and pastures is represented by a circle of *c.* 19 hectares around the settlement sites.

70 With many thanks for the accurate processing and georeferencing of the photos by Esther Eilering.

## 4.5. Concluding remarks

Constructing a palaeogeographical map for a wetland is always a laborious task (figure 4.10). Each project has its own challenges. The construction of a reliable subsurface model is difficult and the quality depends largely on the distribution and quality of the available or collectable data. The conversion from lithological information to meaningful soil type classes in order to predict the succession of plant communities is relatively easy.

The reconstruction of the palaeorelief of a wetland is an educated guess independent of the chosen method. The drainage situation of the subsoil at the start of the exploitation and changes of the drainage situation over time are unknown factors. The influence of man on this process is an unpredictable factor, even for prehistoric times. For example, it is known that artificial drainage of peat and clay soils in Walcheren (the Netherlands) caused subsidence leading to a large impact of floods at the end of the Iron Age and in the Early Roman period (Vos and Van Heeringen 1997). The amount and depth of the ditches in Bronze Age West-Frisia will certainly have contributed to local subsidence. Due to the variation in lithology and unknown parameters for the starting point, it is impossible to estimate the actual impact. Subsidence of clayey soils due to artificial drainage can reach a substantial part of its original volume (De Bakker and Locher 1990, 312-316). Historic and modern water resource management combined with lithological variation influence the local subsidence rate and can cause large differences in the relief of former landscapes (Borger 1975, 74).

Traditional groundwater index points are hard to obtain in a wetland area due to compaction and local influences as noted by Weerts (2013, 166-167). Feature-depths of water pits and/or ditches are unsuitable for constructing reliable groundwater index points. In the case of Westwoud an estimation of the groundwater level could be made using molluscs sampled from features. Not only molluscs but all kind of water organisms like ostracods, diatoms and forams can be useful in the construction of groundwater index points. During excavations one should be aware of the importance of obtaining high quality samples from suitable locations in order to provide reliable groundwater index points.

With the combination of soil suitability classes, a relief model and a groundwater model, a natural succession can be predicted for each unit. An analysis of on-site assembled macrobotanical remains on indicator species unveils the presence of different phytosocial vegetation classes within the catchment area. In this way the classes can be placed in geographical space. The influence of man, which blurs most vegetation reconstructions based on (on site) pollen analysis, can be evaded this way. In a similar way zoological data can be used to evaluate the reconstruction (Cronau 2016).