Appendix A – Supplement to chapters 2, 3, and 6 in

Past human-landscape interactions in the Netherlands

Reconstructions from sand belt to coastal-delta plain for the first millennium AD

Harm Jan Pierik

Utrecht 2017

Utrecht Studies in Earth Sciences 139

A1 Input materials to the reconstructions

In this appendix, more background information is given on the datasets discussed in Chapter 2 and used in Chapters 3 and 6. While integrating existing datasets into new geomorphological reconstructions a set of priority rules was followed (e.g. which dataset provides the best information on age or extent?). This was based on their coverage, aims, and quality of the studies (described in Chapter 2 and this Appendix). Geological maps have the largest spatial coverage on deeper features and are therefore mostly used in the coastal plain (Figure A1). This data was supplemented with LiDAR data and information from local studies on age. In the fluvial area, existing natural levee reconstructions were refined using borehole and LiDAR data and local soil maps if available (Figure A2).

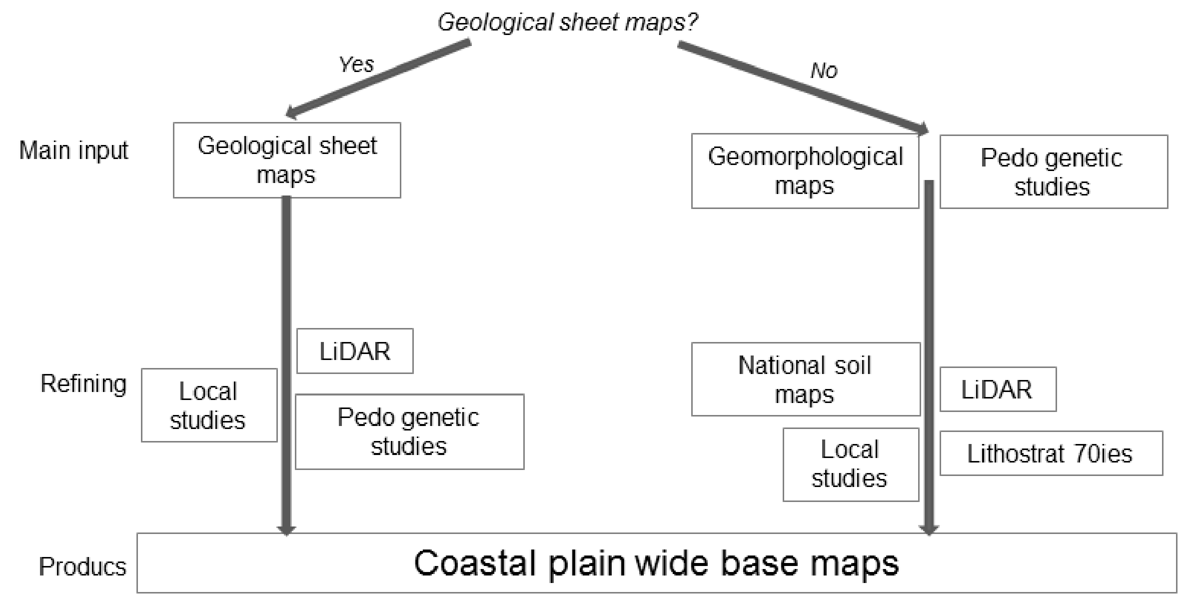

Figure A1 | Priority on data intake coastal plain GIS.

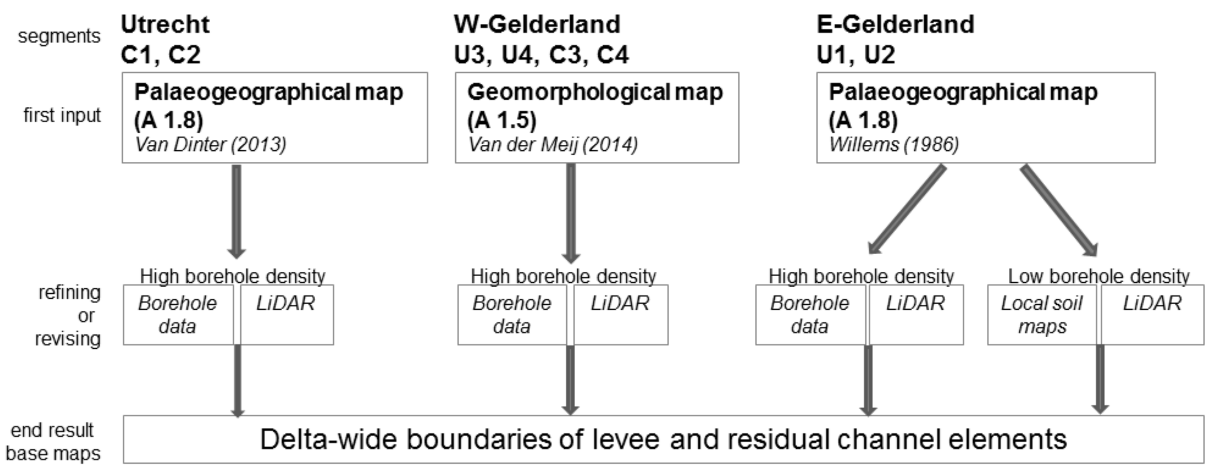

Figure A2 | Priority on data intake Rhine-Meuse delta geomorphological reconstruction maps.

A1.1 Utrecht University LLG Borehole data

Primary information: Detailed lithological description per 10 cm interval logged in the field using the De Bakker & Schelling (1989) system for the lithological description. The logs were compiled using hand corings of typically 2-3 meter deep. Descriptions also contain a genetic facies interpretation, separating channel deposits, natural levee deposits, flood-basin deposits, etc.

Coverage: Holocene wedge of the entire delta plain.

Scale/resolution: 125,000 high-quality borehole descriptions digitally available and 90,000 non-digitised descriptions. Coring density of 30 to 200 boreholes per km^2. In the study area, the borehole density varies between 30/km^2 to 200/km^2. The lithological descriptions have 10 cm intervals and contain facies interpretation (e.g. natural levee, residual channel, dike-breach deposits).

Use in the coastal plain

No coverage, not used.

Use in the Rhine-Meuse delta

Usage: Queries on lithology from this database were the primary source for mapping the extent of the natural levees and other architectural elements (section 3.2.1). The surface elevation (in meters relative to the Dutch NAP datum: m OD) as recorded in the borehole database, was verified with the LiDAR national DEM (A1.3).

Note: -

Main references: Berendsen (1982); Berendsen & Stouthamer (2000; 2001).

A1.2 TNO Geological Survey of the Netherlands DINO borehole data

Primary information: Lithological descriptions of (the upper meters of) boreholes, logged at varying intervals. The descriptions in the database are standardised (Bosch, 2000) and meta-information on its source, type of equipment and descriptive quality is maintained. The bore logs have a stratigraphical subdivision to Formation and Member level. Facies (e.g. flood basin, levee and channel deposits) are distinguished on lithology only.

Coverage: National

Scale/resolution: coring density varying between 5 – 20 boreholes per km^2

Use in the coastal plain
Not used.

Use in the Rhine-Meuse delta
Usage: Used in addition to the LLG dataset, especially in areas with a lower density borehole coverage in the latter source. Hereto, the data was resampled to regular 10 cm intervals and the surface elevation was corrected using the LiDAR DEM.

Note: Used in areas with lower data density

Main references: www.dinoloket.nl/en; Stafleu et al. (2012); Van der Meulen et al. (2013).

A1.3 LiDAR AHN
Primary information: LiDAR elevation set, processed into a DEM of ground-surface elevation.

Coverage: National

Scale/resolution: 5 x 5m footprint, cm vertical resolution, 10-cm elevation accuracy.

Use in the coastal plain and the Rhine-Meuse delta
Usage: This dataset was used to refine the extent of geomorphological units (e.g. natural levees, tidal ridges, and channels), inferred from other maps. In the delta it served for checks and corrections of absolute surface elevation recorded for borehole locations. Here, it was also used in tracing the boundaries of natural levee elements and residual channels between borehole sections.

Note: Geomorphological interpretations based on LiDAR data need confirmation checks, based on borehole data. The AHN2 dataset replaced AHN1 in 2013 (0.5 m x 0.5 m x 5 cm resolution).

Main references: Berendsen & Volleberg (2007); De Boer et al. (2008); Van der Zon (2013); www.ahn.nl

A1.4 National geological map series
Primary information: Geological profile type map, with sequence of tidal deposits and their presumed absolute age. The geological maps compiled during the 1960s and 1970s (SW Netherlands) in the coastal areas show a strict chronostratigraphical division, whereas later mapping campaigns also included facies and environmental interpretation as a subdivision (e.g. Dunkirk I: supratidal deposits).

Coverage: Most of the southwestern coastal plain area, part of western and northern coastal plain for the entire Holocene sequence

Scale/resolution: 1:50,000; 9 borings per km^2

Use in the coastal plain
Relevant units: Dunkirk I-III deposits. Channel and tidal flat facies.

Usage: Most important input for architectural element extent intake into the GIS (Figure A1). The maps provide a consistent dataset with planform geometry and attributed relative ages to subsequent generations of tidal architectural elements. Their intake in the GIS worked particularly well for the areas where facies (channel deposits, tidal flat deposits etc.) were separately mapped (the younger map sheets).

Note: Absolute chronology based on now abandoned assumptions on synchronous sea level controlled development (Weerts et al., 2005). Because in the original publication, the chronostratigraphy was used for relative dating, instead of absolute dating. Age-attribution was rechecked by verifying the originally used dates (^{14}C, archaeology) and where available also newer additional dating evidence. Parts of the coastal plain that have not been mapped are filled in based on additional datasets.

Main references: General: Dubois (1924); Tavernier (1946); Hageman (1969); de Mulder & Bosch (1982); Oele et al. (1983); and Table A1.

Table A1 | Geological map sheets 1:50,000 used in the coastal plain.

Coverage	Reference
Southwestern coastal plain	
Goeree & Overflakkee	Hageman (1964)
Zeeuwsch-Vlaanderen West/Oost	Van Rummelen (1965)
Schouwen-Duiveland	Van Rummelen (1970)
Walcheren	Van Rummelen (1972)
Beveland	Van Rummelen (1978)
Western coastal plain	
Rotterdam West (37W)	Van Staalduinen (1979)
Alkmaar West/Oost (19W/O)	Westerhoff et al.(1987)
Rotterdam Oost (37O)	NITG-TNO (1998)
Northern coastal plain	
Sneek West/Oost (10W/O)	Ter Wee (1976)
Heerenveen West/Oost (11W/O)	De Groot et al. (1987)

Use in the Rhine-Meuse delta
Not used, newer and more accurate datasets are available.

A1.5 Digital base map for delta evolution and palaeogeography
Primary information: Age and extent of the channel belts in the Rhine-Meuse delta, palaeogeography of the network of channel belts, with extensive documentation of the ages. The documentation separates dating of begin and end of sedimentary activity, and described the considered radiocarbon datings).
The first version of the basemap (Berendsen & Stouthamer, 2001), was based on detailed geomorphogenetic field survey maps (section A 1.8: Fs units, except Fs5: alluvial ridge levee slopes flanking the channel belt) and geological information. Later releases

verified the mapping of alluvial ridges versus LiDAR elevation data and by direct confrontations with the LLG borehole data (besides the revising ages of channel belts; Berendsen et al. 2007; Berendsen & Volleberg, 2007; Cohen et al. 2012).

Coverage: Entire Rhine-Meuse delta plain and upstream valleys.

Scale/resolution: On-screen digitised map, positioning of boundaries based on LLG and DINO borehole data (typical spacing in sections: 100 meter), AHN1 (5x5m footprint), field mapping at scale 1:10,000 – 1:5,000 (production scale).
Publication / intended reproduction scale: 1:100,000 – 1:25,000.
Digital usage zoom scale: same as production scale.

Use in the coastal plain
No coverage, not used.

Use in the Rhine-Meuse delta
Relevant units: Active channel belts and crevasse splays.

Usage: The active channel belts age at 1950, 1500, and 1150 BP and the position of older channel belts were directly incorporated in the reconstructions. The documentation provided and extensive overview of datings used to assign an end age of activity to the levees.

Note: The dataset provides the channel belt sand body extent below the natural levees.

Main references: Berendsen & Stouthamer (2000; 2001); Berendsen et al. (2001); Cohen et al. (2012; 2014).

A1.6 National Geomorphological map
Primary information: Interpreted geomorphology, based on criteria established by Maarleveld et al. (1977). After the introduction of LiDAR DEMs a national coverage digital geomorphological map was released (Koomen & Maas, 2004), produced by verification against earlier soil mapping and underlying shallow borehole data (mostly from other databases than UU-LLG and TNO-DINO).

Coverage: National / Updated version: fluvial area in Gelderland (roughly covering the sections U1-U4, C3 and C4).

Scale/resolution: On-screen digitised map, positioning of boundaries based on topographic features AHN1 and 2 (5x5m footprint), and past detailed soil mapping using field maps at scale 1:10,000 to 1:5,000 (production scale). The publication scale and digital usage zoom scale is 1:50,000.

Use in the coastal plain (national map)
Relevant units: Supratidal levees, silted up tidal channels

Usage: Used where late Holocene pre-embankment geomorphology has been well preserved (mainly northern Netherlands).

Note: Only information of the surface morphology, no age information. More detailed information was obtained from LiDAR DEMs.

Main references: Maarleveld et al. (1977); Koomen & Maas (2004).

Use in the Rhine-Meuse delta (update of the national geomorphological map)
For the Rhine-Meuse delta, a regional revision was performed by Van der Meij (2014) using the AHN2 LiDAR dataset corrected for the river plain gradient.

Relevant units: Van der Meij (2014) identified amongst others alluvial ridge slopes ('stroomrughellingen'), crevasse splay ridges ('crevasseruggen'), residual channel depressions ('restgeulen'), floodplain / flood basin ('Rivierkomvlakte').

Usage: The flood basin to levee boundaries were imported, verified and edited using borehole information.

Note: The revised map was based on geomorphological criteria only and not verified with lithology (Van der Meij, 2014).

Main references: Van der Meij (2014).

A1.7 National Soil map
Primary information: Soil maps compiled by STIBOKA (Wageningen) from surveys in the 1960-1990-ies. Mapping based on soil-formative properties, including the lithological composition of the upper ca. 1.20 meter. Natural levees were mapped as soils of lighter texture, more suitable and hence in longer use as arable land and orchards than flood basins. Reports that accompany the maps include sections on geology, geomorphology and land-use history.

Coverage: National, see Table A2.

Scale/resolution: Publication scale: 1:50,000.

Use in the coastal plain
Relevant units: Clay soils, sandy soils

Usage: Local substitution where national geological maps are less detailed. Clay soils indicating tidal flats, sandy soils indicating channels or proximal tidal flats.

Note: Mapped boundaries have not been synchronised with geomorphology, geology maps, LiDAR data.

Main references: De Bakker & Schelling (1989); STIBOKA maps 1:50,000

Use in the Rhine-Meuse delta
Relevant units: Crevasse splay soils; young natural levee soils, channels.

Usage: The delineation of the peat extent were taken from this dataset. Furthermore it gave a first indication for the presence of levee and dike-breach deposits**.**

Note: Mapped boundaries have not been synchronised with geomorphology, geology maps, LiDAR data.

Main references: De Bakker & Schelling (1989); STIBOKA maps 1:50,000 (Table A2)

Table A2 | The national soil maps used in the Rhine-Meuse delta. The segments used in this thesis that they (partly) cover in this study are indicated.

Coverage	Reference	Scale
's Hertogenbosch West *(U4)*	STIBOKA (1969)	1:50,000
Rhenen East/West *(C3, U2)*	STIBOKA (1974)	1:50,000
Arnhem East/West *(U1-U3)*	STIBOKA (1975)	1:50,000
Utrecht East *(C1, C2)*	STIBOKA (1979)	1:50,000
Gorinchem East *(D)*	Harbers et al. (1981)	1:50,000
Oosterhout West *(D)*	Damoiseaux et al. (1987)	1:50,000
Oosterhout East *(D)*	Harbers (1990)	1:50,000

A1.8 Detailed older soil maps (pedogenetic)

Primary information: Original soil maps, from surveys in the 1940-1960-ies (school of Edelman, Wageningen), were made prior to major rationalisation and field reorganisation campaigns. The maps were based on soil-formative properties, including the lithological composition of the upper ca. 1 meter. Natural levees were mapped as soils of lighter texture, more suitable and hence in longer use as arable land and orchards than flood basins. Reports that accompany the maps include sections on geology, geomorphology and land-use history.

Coverage: Regional maps: entire coastal plain, Local maps: For specific local study areas in the Rhine-Meuse delta (Table A3).

Scale/resolution: Publication scale: 1:10,000. Field survey scales: 1:5,000. Soil surveys in the Netherlands conventionally strived for an observation density of 0.3 ha^{-1} = 30 boreholes per km^2 (e.g. Kempen, 2011).

Use in the coastal plain

Relevant units: Typical local pedological terms indicating tidal flat extent

Usage: Local substitution where national soil, geomorphological, and geological map series are less detailed or absent. The local pedological units were translated into lithological units and facies (e.g. soil developed in heavy clay formed as a supratidal flat).

Table A3 | Detailed older soil maps used in the coastal plain.

Coverage	Reference
Southwestern Netherlands	Bennema et al. (1952)
Western Netherlands	van Liere (1950); de Roo (1953); Pons & Wiggers (1959/1960); Pons & van Oosten (1974)
Northern Netherlands:	Veenenbos (1949); Cnossen (1958); de Smet (1962)

Use in the Rhine-Meuse delta

Relevant units: Crevasse splay soils; young natural levee soils, channels.

Usage: Where borehole data was not sufficient, these maps provided information on the extent of levees, residual channels, and dike-breach fans.

Table A4 | The detailed soil maps used in the reconstruction maps. The segments that they (partly) cover in this study are indicated.

Coverage	Reference	Scale
Overbetuwe (west) *(U1 and U2)*	Egberts (1950)	-
Wageningen *(U2, northern tip)*	Buringh (1951)	1:10,000
Maaskant *(U4, southern part)*	Van Diepen (1952)	1:10,000
Land van Maas and Waal *(U3 and northern part U4)*	Pons (1957; 1966)	1:10,000
Land van Heusden Altena *(C5)*	Sonneveld (1958)	1:10,000
Vijfheerenlanden *(D, west of C3)*	De Boer & Pons (1960)	1:50,000
Biesbosch *(D, west of C5)*	Zonneveld (1960)	1:10,000

A1.9 Regional palaeogeographical reconstructions for the Roman period

Primary information: Detailed palaeogeographical maps of channel belts, residual channels and levees during the Middle Roman period.

Coverage: Regional to national, distinct time steps in the Holocene / Eastern river area (U1 - U3), Lower Rhine limes region (Utrecht-Leiden C1, C2).

Scale/resolution: Willems (1986) 1:100,000; Van Dinter (2013): 1:50,000.

Use in the coastal plain

Relevant units: Channels, tidal flats, beach barriers.

Usage: Check to our scripted-generated palaeogeographical output, which generally reproduced the featured developments from the basic elements stored in our GIS.

Note: The first maps on a macroregional scale (Netherlands for the Holocene) were compiled by Pons et al. (1963), the second generation was made by Zagwijn (1986). In both publications, the selected time steps coincided with the presumed transgression periods in the coastal and fluvial area derived from chronostratigraphy which was widely accepted at that time. Newest generations are also manually drawn, the maps however do not cover the entire timespan of landscape evolution as only distinct time steps are used. Whereas general decisions behind the series of palaeogeographical maps are documented (Vos, 2015), on the scale of individual elements the workflow has not been outlined. The manually produced map series is only available for fixed time steps based on archaeological periodization considerations (Vos, 2015).

Main references: National: Pons et al. (1963); Zagwijn (1986); Vos & de Vries (2013); Vos (2015). Southwestern Netherlands: Vos & van Heeringen (1997); Vos & Zeiler (2008). Western Netherlands: Lenselink & Koopstra (1994); Vos & Gerrets (2005); Vos & Eijskoot (2015); Vos et al. (2015a; 2015b). Northern Netherlands: Knol (1993); Vos & Knol (2015)

Use in the Rhine-Meuse delta (only regional reconstructions)

Relevant units: Overbetuwe area, Willems (1986): ‘Levee deposits’, ‘residual channels’
Utrecht area, Van Dinter (2013); ‘Natural levees’ Van Dinter et al. (2017): ‘levee on flood-basin deposits’.

Usage: The maps were used as source map and a check for the reconstructions.

Note: The maps show the situation during Roman Age only, for the Eastern river area reconstruction no LiDAR data was used.

Main references: Willems (1986); Van Dinter (2013); Van Dinter et al. (2017).

A1.10 Lithostratigraphy 70ies

Mapped information: Their studies focused on lithostratigraphy rather than on their spatial extension or exact age. Clastic units were interpreted and labelled as transgressive, vegetation horizons and peat layers were labelled as regressive units. Regressions and transgressions in their deployment only represent lateral facies shifts of marine and coastal deposits and do not directly refer to sea-level fluctuations. Lithostratigraphical schemes divide the substrate into mappable units that have distinct lithological properties and distinct stratigraphical positions.

Coverage: Regional for the northern Netherlands, entire Holocene sequence.

Scale/resolution: -

Use in the coastal plain

Relevant units: Groningen Formation and subunits

Usage: For some units both the extension and assigned age have been mapped (e.g. supratidal levees, transgressive surfaces), which was used for our dataset.

Note: No absolute chronology, very local stratigraphy. Information on chronology and development were taken from additional studies.

Main references: Roeleveld (1974); Griede (1978)

Use in the Rhine-Meuse delta

No coverage, not used

A1.11 Detailed older geomorphogenetical maps

Primary information: Geomorphogenetical maps are profile-type geomorphological maps with legend units based on geomorphological as well and on genetic criteria. The maps were developed by Berendsen (1982) based on borehole descriptions and of the upper 2 m (the UU-LLG dataset above) and geomorphological field observations. The system has been used in Utrecht University academic studies since the 1970ies, and on a small scale in archaeological studies (e.g. Willemse & Verhelst, 2012).

Coverage: Published maps: see Table A5. Further unpublished maps by Utrecht University staff and students (field survey maps) cover the entire study area (Berendsen & Stouthamer, 2001). They have been used to verify accuracy of the LLG database in digitalisation projects prior to this study, as part of the efforts on channel belt mapping see above.

Scale/resolution: Field survey and map production scale: 1:10,000-1:5,000. Publication scale 1:25,000. In cross-sections, minimal borehole distance of 100m, and across boundaries of landforms this was densified. See LGG dataset above.

Use in the coastal plain

No coverage, not used

Use in the Rhine-Meuse delta

Relevant units: Levees covering channel belts (‘Fs1-4’), levees flanking channel belts (‘Fs5’), residual channels within channel belts (‘Fs6-9’), crevasse splays (‘Fc1-4’).

Usage: The dataset gives a good impression of the thickness and extent of both levees and residual channels. We took their boundaries and adapted them using LiDAR, borehole data, and earlier mappings. The depth of the levee and sand below the surface was used as validation of borehole data.

Note: LiDAR data was not yet available when most of these maps were produced, and considerable reinterpretation of pre-LiDAR maps was needed to use them in our maps.

Main references: Berendsen (1982); Berendsen et al. (1986); Bos et al. (2009).

Table A5 | The detailed geomorphogenetical maps. The segments that they (partly) cover in this study are indicated.

Coverage	Reference	Scale
SW Utrecht (C2)	Berendsen (1982)	1:50,000
Bommelerwaard (C4)	Berendsen et al. (1986)	1:50,000
Utrechtse Vecht area (north of C2)	Bos et al. (2009)	1:100,000

A1.12 Large cross-sections

Primary information: Extent, depth and thickness of lithostratigraphical units (e.g. overbank deposits, channel belt deposits).

Coverage: 5 major delta-wide north-south oriented cross-sections every ca. 10 km.

Scale/resolution: Based on borehole data described in A1.1.

Relevant units: Natural levee and crevasse splays or overbank deposits.

Usage: Used for correlating levees to channel belts and to estimate the depth of levees with a certain age.

Note: -

Main references: Berendsen (1982); Törnqvist (1993); Cohen (2003); Gouw & Erkens (2007); Makaske et al. (2007).

References

BENNEMA, J., K. VAN DER MEER, C. DORSMAN & J.P. VAN DER FEEN (1952) *De bodemkartering van Walcheren*, Staatsdrukkierij Uitgeverijbedrijf.

BERENDSEN, H.J.A. (1982) *De genese van het landschap in het zuiden van de provincie Utrecht*. Utrecht University.

BERENDSEN, H.J.A. & E. STOUTHAMER (2000) Late Weichselian and Holocene palaeogeography of the Rhine–Meuse delta, The Netherlands. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 161(3–4), pp.311–335.

BERENDSEN, H.J.A. & E. STOUTHAMER (2001) *Palaeogeographic development of the Rhine-Meuse delta, The Netherlands*, Assen: Koninklijke Van Gorcum.

BERENDSEN, H.J.A. & K.P. VOLLEBERG (2007) New prospects in geomorphological and geological mapping of the Rhine-Meuse Delta – Application of detailed digital elevation maps based on laser altimetry. *Netherlands Journal of Geosciences - Geologie en Mijnbouw*, 86(1), pp.15–22.

BERENDSEN, H.J.A., T.E. TÖRNQVIST & H.J.T. WEERTS (1986) De geologisch-geomorfologische kaart van de Bommelerwaard. In *Het landschap van de Bommelerwaard*. pp. 15–20.

BERENDSEN, H.J.A., K.M. COHEN & E. STOUTHAMER (2001) The geological-geomorphological map and palaeogeographic maps of the Rhine-Meuse delta. In H. J. A. Berendsen & E. Stouthamer, eds. *Palaeogeographic development of the Rhine-Meuse delta, The Netherlands*. Assen: Koninklijke Van Gorcum, pp. 49–50.

BERENDSEN, H.J.A., K.M. COHEN & E. STOUTHAMER (2007) The use of GIS in reconstructing the Holocene palaeogeography of the Rhine–Meuse delta, The Netherlands. *International Journal of Geographical Information Science*, 21(5), pp.589–602.

BOS, I.J., H. FEIKEN, F. BUNNIK & J. SCHOKKER (2009) Influence of organics and clastic lake fills on distributary channel processes in the distal Rhine–Meuse delta (The Netherlands). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 284(3–4), pp.355–374.

BURINGH, P. (1951) *De bodemkartering van Nederland - over de bodemgesteldheid rondom Wageningen*, Wageningen.

CNOSSEN, J. (1958) Enige opmerkingen omtrent het ontstaan van het beneden-boornegebied. *Boor & Spade*, pp.24–38.

COHEN, K.M. (2003) *Differential subsidence within a coastal prism - Late-Glacial - Holocene tectonics in the Rhine-Meuse delta, the Netherlands*, Utrecht.

COHEN, K.M., E. STOUTHAMER, H.J. PIERIK & A.H. GEURTS (2012) Digitaal Basisbestand Paleogeografie van de Rijn-Maas Delta / Rhine-Meuse Delta Studies' Digital Basemap for Delta Evolution and Palaeogeography.

COHEN, K.M., S. ARNOLDUSSEN, G. ERKENS, Y.T. POPTA & L.J. TAAL (2014) *Archeologische verwachtingskaart uiterwaarden rivierengebied*, Utrecht.

DAMOISEAUX, J.H., G.A. VOS, G.G.L. STEUR, W. HEIJINK, H.D. BAKKER, O.H. BOERSMA & C. HAMMING (1987) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad 44 West Oosterhout*, Wageningen.

DE BAKKER, H. & J. SCHELLING (1989) *Systeem van bodemclassificatie voor Nederland. De hogere niveaus, 2e gewijzigde druk*, Wageningen: PUDOC.

DE BOER, A.G., W.N.H. LAAN, W. WALDUS & W.K. VAN ZIJVERDEN (2008) LIDARbased surface height measurements: applications in archaeology. In B. Fischer & A. Dakouri, eds. *Beyond Illustration: 2d and 3d Digital Technologies as Tools for Discovery in Archaeology. British Arch. Rep. Int. Series 1805*. pp. 69–77.

DE BOER, T.A. & L.J. PONS (1960) *Bodem en grasland in de Vijfheerenlanden*, Bennekom.

DE GROOT, T.A.M., H.A. VAN ADRICHEM BOOGAERT, M.M. FISCHER, B. KLIJNSTRA, H.M. VAN MONTFRANS, H. UIL, M.W. TER WEE, M.J. VAN WEEPEREN & J.G. ZANDSTRA (1987) *Toelichtingen bij de Geologische Kaart van Nederland 1:50.000, Blad Heerenveen West (11W) en Oost (11O)*, Haarlem.

DE MULDER, E.F.J. & J.H.A. BOSCH (1982) Holocene stratigraphy, radiocarbon datings and paleogeography of central and northern north-holland (the Netherlands). *Mededelingen Rijks Geologische Dienst*, 36(3), pp.111–160.

DE ROO, H. (1953) De bodemgesteldheid van Noord-Kennemerland. *Verslagen van landbouwkundige onderzoekingen*, 59(3), p.202.

DE SMET, L.A.H. (1962) *Het Dollardgebied, bodemkundige en landbouwkundige onderzoekingen in het kader van de bodemkartering. De Bodemkartering van Nederland, Verslagen Landbouwkundig Onderzoek*. Den Haag.

DUBOIS, G. (1924) *Recherches sur les terrains quaternaires du Nord de la France*. Lille.

EGBERTS, H. (1950) *De bodemgesteldheid van de Betuwe*, Wageningen.

GOUW, M.J.P. & G. ERKENS (2007) Architecture of the Holocene Rhine-Meuse delta (the Netherlands) – A result of changing external controls. *Netherlands Journal of Geosciences - Geologie en Mijnbouw*, 86(1), pp.23–54.

GRIEDE, J.W. (1978) *Het ontstaan van Frieslands Noordhoek: een fysisch-geografisch onderzoek naar de Holocene ontwikkeling van een zeekleigebied*. Vrije Universiteit Amsterdam.

HAGEMAN, B.P. (1964) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000. Blad Goeree en Overflakkee*, Haarlem.

HAGEMAN, B.P. (1969) Development of the western part of the Netherlands during the Holocene. *Geologie en Mijnbouw*, 48, pp.373–388.

HARBERS, P. (1990) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad 44 Oost Oosterhout*, Wageningen.

HARBERS, P., G.G.L. STEUR & W. HEIJINK (1981) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad 38 Oost Gorinchem*, Wageningen.

KEMPEN, B. (2011) *Updating soil information with digital soil mapping*. Wageningen University.

KNOL, E. (1993) *De Noordnederlandse kustlanden in de vroege middeleeuwen*. Groningen: Vrije Universiteit Amsterdam.

KOOMEN, A.J.M. & G.J. MAAS (2004) *Geomorfologische Kaart Nederland (GKN); Achtergronddocument bij het landsdekkende digitale bestand*, Wageningen.

LENSELINK, G. & R. KOOPSTRA (1994) Ontwikkelingen in het Zuiderzeegebied; van Meer Flevo, via de Almere-lagune, tot Zuiderzee. In M. Rappol & C. M. Soonius, eds. *In de Bodem van Noord- Holland*. Amsterdam: Lingua Terra, pp. 129–138.

MAARLEVELD, G.C., J.A.M. TEN CATE & G.W. DE LANGE (1977) *Geomorfologische kaart van Nederland schaal 1: 50 000. Toelichting op de legenda*, Wageningen/Haarlem.

MAKASKE, B., H.J.A. BERENDSEN & M.H.M. VAN REE (2007) Middle Holocene Avulsion-Belt Deposits in the Central Rhine-Meuse Delta, The Netherlands. *Journal of Sedimentary Research*, 77, pp.110–123.

OELE, E., W. APON, R. FISCHER, M.M., HOOGENDOORN, C.S. MESDAG, E.F.J. DE MULDER, B. OVERZEE, A. SESÖREN & W.E. WESTERHOFF (1983) Surveying the Netherlands, Sampling Techniques, Maps and their application. *Geologie en Mijnbouw*, 62, pp.355–372.

PONS, L.J. (1957) *De geologie, de bodemvorming en de waterstaatkundige ontwikkeling van het Land van Maas en Waal en een gedeelta van het Rijk van Nijmegen*. Wageningen.

PONS, L.J. (1966) *De bodemkartering van het Land van Maas en Waal en een gedeelte van het Rijk van Nijmegen*, Wageningen.

PONS, L.J. & A.J. WIGGERS (1959/1960) *De Holocene wordingsgeschiedenis van Noordholland en het Zuiderzee gebied.*

PONS, L.J. & M.F. VAN OOSTEN (1974) *De Bodem van Noordholland. Toelichting bij blad 5 van de Bodemkaart van Nederland, schaal 1: 200.000*, STIBOKA.

PONS, L.J., S. JELGERSMA, A.J. WIGGERS & J. DE JONG (1963) Evolution of the Netherlands coastal area during the Holocene. In J. de Jong, ed. *Verhandelingen van het KNGMG"Transactions of the jubilee convention - part two*. s' Gravenhave: Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap, pp. 197–207.

ROELEVELD, W. (1974) The Holocene Evolution of the Groningen Marine-Clay District. *Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek*, 24, pp.1–133.

SONNEVELD, F. (1958) *Bodemkartering en daarop afgestemde landbouwkundige onderzoekingen in het Land van Heusden en Altena*, Wageningen.

STIBOKA (1969) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad 's Hertogenbosch West*, Wageningen.

STIBOKA (1974) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad Rhenen W/O*, Wageningen.

STIBOKA (1975) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad Arnhem W/O*, Wageningen.

STIBOKA (1979) *Bodemkaart van Nederland 1:50.000, Toelichting bij kaartblad Utrecht Oost*, Wageningen.

STAFLEU, J., D.M. MALJERS, F.S. BUSSCHERS, J.L. GUNNINK, J. SCHOKKER, R.M. DAMBRINK, H.J. HUMMELMAN & M.L. SCHIJF (2012) *GeoTop modeling*, Utrecht.

TAVERNIER, R. (1946) L'évolution du Bas Escaut au Pléistocène supérieur. *Géologie: Bulletin de la Société Belge de Géologie*.

TER WEE, M.W. (1976) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000. Blad Sneek (10W, 10O)*, Haarlem.

TÖRNQVIST, T.E. (1993) *Fluvial sedimentariy geology and chronology of the Holocene Rhine-Meuse delta, the Netherlands*. Utrecht: Utrecht University.

VAN DER MEIJ, M. (2014) *De geomorfologie van het Gelderse rivierengebied - actualisering van de geomorfologische kaart*, Wageningen.

VAN DER MEULEN, M.J., J.C. DOORNENBAL, J.L. GUNNINK, J. STAFLEU & J. SCHOKKER (2013) 3D geology in a 2D country : perspectives for geological surveying in the Netherlands. *Netherlands Journal of Geosciences*, 92(4), pp.217–241.

VAN DER ZON, N. (2013) *Kwaliteitsdocument AHN2.*

VAN DIEPEN, D. (1952) *De bodemkartering van Nederland - De bodemgesteldheid van de Maaskant*, Wageningen.

VAN DINTER, M. (2013) The Roman Limes in the Netherlands: How a delta landscape determined the location of the military structures. *Geologie en Mijnbouw/Netherlands Journal of Geosciences*, 92(1), pp.11–32.

VAN DINTER, M., K.M. COHEN, W.Z. HOEK, E. STOUTHAMER, E. JANSMA & H. MIDDELKOOP (2017) Late Holocene lowland fluvial archives and geoarchaeology: Utrecht's case study of Rhine river abandonment under Roman and Medieval settlement. *Quaternary Science Reviews*.

VAN RUMMELEN, F.F.F.E. (1965) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000. Bladen Zeeuwsch-Vlaanderen West en Oost*, Haarlem.

VAN RUMMELEN, F.F.F.E. (1970) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000. Blad Schouwen-Duiveland*, Haarlem.

VAN RUMMELEN, F.F.F.E. (1972) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000. Blad Walcheren*, Haarlem.

VAN RUMMELEN, F.F.F.E. (1978) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000. Blad Beveland*, Haarlem.

VAN STAALDUINEN, C.J. (1979) *Toelichtingen bij de geologische kaart van Nederland 1:50.000 - Rotterdam West (37W)*, Haarlem.

VEENENBOS, J.S. (1949) Bodemkartering van de Friese Wouden. *Boor & Spade*, 3, pp.86–93.

VOS, P.C. (2015) *Origin of the Dutch coastal landscape - Long-term landscape evolution of the Netherlands during the Holocene described and visualized in national, regional and local palaeogeographical map series*, Groningen: Barkhuis.

VOS, P.C. & S. DE VRIES (2013) 2e generatie palaeogeografische kaarten van Nederland (versie 2.0). Deltares, Utrecht.

VOS, P.C. & Y. EIJSKOOT (2015) Palaeo-environmental investigations at the archaeological site Vergulde Hand West in Vlaardingen (Port of Rotterdam). In P. C. Vos, ed. *Origin of the Dutch coastal landscape - Long-term landscape evolution of the Netherlands during the Holocene described and visualized in national, regional and local palaeogeographical map series*. Groningen: Barkhuis, pp. 264–293.

VOS, P.C. & D.A. GERRETS (2005) Archaeology: a major tool in the reconstruction of the coastal evolution of Westergo (northern Netherlands). *Quaternary International*, 133–134, pp.61–75.

VOS, P.C. & E. KNOL (2015) Holocene landscape reconstruction of the Wadden Sea area between Marsdiep and Weser. *Netherlands Journal of Geosciences*, 94(2), pp.157–183.

VOS, P.C. & R.M. VAN HEERINGEN (1997) Holocene geology and occupation history of the Province of Zeeland. *Mededelingen Nederlands Instituut voor Toegepaste Geowetenschappen TNO*, 59, pp.5–109.

VOS, P.C. & F.D. ZEILER (2008) Overstromingsgeschiedenis van zuidwest-Nederland, interactie tussen natuurlijke en antropogene processen. *Grondboor & Hamer*, 62(3/4), pp.86–95.

VOS, P.C., J. DE KONING & R. VAN EERDEN (2015) (a) Landscape history of the Oer-IJ tidal system, Noord-Holland (The Netherlands). *Netherlands Journal of Geosciences*, 94(4), pp.295–332.

VOS, P.C., F.P.M. BUNNIK, K.M. COHEN & H. CREMER (2015) (b) A staged geogenetic approach to underwater archaeological prospection in the Port of Rotterdam (Yangtzehaven, Maasvlakte, The Netherlands): A geological and palaeoenvironmental case study for local mapping of Mesolithic lowland landscapes. *Quaternary International*, 367, pp.4–31.

WEERTS, H.J.T., W.E. WESTERHOFF, P. CLEVERINGA, M.F.P. BIERKENS, J.G. VELDKAMP & K.F. RIJSDIJK (2005) Quaternary geological mapping of the lowlands of The Netherlands, a 21st century perspective. *Quaternary International*, 133–134, pp.159–178.

WESTERHOFF, W.E., E.F.J. MULDER & W. DE GANS (1987) *Toelichtingen bij de Geologische kaart van Nederland 1:50.000 - Alkmaar West/Oost (19O/W)*, Haarlem.

WILLEMS, W.J.H. (1986) *Romans and Batavians. A Regional Study in the Dutch Eastern River Area*. University of Amsterdam.

WILLEMSE, N. & E.M.P. VERHELST (2012) Geologisch onderzoek naar de genese van de Linge in het centrum van Tiel, gemeente Tiel; een geologisch-archeologisch booronderzoek, RAAP-rapport 2646, Weesp.

ZAGWIJN, W.H. (1986) *Nederland in het Holoceen*, Den Haag: Sdu.

ZONNEVELD, I.S. (1960) *De Brabantse Biesbosch*. Wageningen: Wageningen University.