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# MONITORING PROGRAMME FOR THE MV2, PART IV – ARCHAEOLOGICAL AND PALAEOLOGICAL FINDS

## ABSTRACT

This is the fourth and last of a series of articles describing the extensive monitoring related to the construction of Maasvlakte 2, Port of Rotterdam, the Netherlands. As far back as the 1990s during the first studies by the Main Port Rotterdam (PMR) project organisation for Maasvlakte 2 (MV2), archaeology was recognised as a subject of high importance. When the studies for MV2 were restarted in 2004 by the Port of Rotterdam Authorities (POR) a decision was made to tackle this subject as a “risk” item.

The Treaty of Malta (1992) makes it compulsory to look for archaeological remains in or on the seabed. In the Netherlands, this led in 2007, to the (revised) Archaeological Heritage (Management) Act (Wamz). Following this, in 2007 POR signed an archaeological agreement (covenant) with the Cultural Heritage Agency of the Netherlands (RCE) for assistance and guidance during construction. In the covenant the responsibilities and tasks of RCE and POR were specified as well as the protocols and the budget reservation.

At the start of the construction, an archaeology task group was installed. Based on a guiding paper from RCE, this group, with representatives of POR, RCE and the

Rotterdam Bureau of Archaeological Research (BOOR) prepared what the procedure would be depending on location and type of archaeological find.

The interdisciplinary approach sought after by the POR and RCE in which many scientists from different fields and disciplines have worked together, has provided very exciting results. Next to bones also fossil shells, gravel and other specific geological features were sorted out. The natural history museum organised a public friendly weekend in September 2010 during which youngsters under supervision of researchers joined professional and amateur palaeontologists and geologists.

## INTRODUCTION

As far back as the 1990s, during the first studies by the Main Port Rotterdam (PMR) project organisation for Maasvlakte 2 (MV2), archaeology was recognised as a subject of

high importance. When the studies were restarted in 2004 by the Port of Rotterdam Authorities (POR) it was decided to tackle this subject as a “risk” item. Meetings were organised with the municipal and national responsible archaeological authorities, i.e., the Rotterdam Bureau of Archaeological Research (BOOR) and the Cultural Heritage Agency of the Netherlands (RCE) respectively.

The Treaty of Malta (1992) makes it compulsory to look for archaeological remains in or on the seabed. In the Netherlands, this led in 2007 to the (revised) Archaeological Heritage (Management) Act (Wamz). At the start of the project it was clear that the RCE would be the competent authority for the archaeology at sea during construction of Maasvlakte 2. This study concerned two aspects: wrecks and drowned landscapes. Both were believed to be present at the Maasvlakte 2 location and possibly in the borrow areas offshore.

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Above: Overview of the crane ship at work in the Yangtze Harbour, Port of Rotterdam. Using multibeam bathymetry and sonar equipment, a search was made for objects of historical importance and in particular of shipwrecks and drowned landscapes.

At the same time a fair amount of money was “reserved” by POR in case archaeological finds did emerge. Thus instead of creating a project budget, a budget reservation was booked. From this reservation, money would be spent only if deemed necessary by the archaeology task group, with a fixed maximum. Based on a desktop study into available data of the larger Maasvlakte area, it was already clear that the likelihood of finding a drowned landscape under or next to Maasvlakte 2 was a real possibility. A special study, followed by an excavation (if possible) would be initiated to tackle this special subject.

The archaeological protocols became part of the tender documents and by doing so they were treated by the companies bidding for the works during the tender period as a “risk” item for which they could make a financial assessment.

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The archaeological agreement (POR and RCE) and the protocols are part of the contract between POR and PUMA, the contractor for Maasvlakte 2. Implementation protocols state how archaeological finds must be treated during construction: Within 24 hours of an archaeological find, the Contractor must inform POR and RCE. Then the archaeology task group, in which now also PUMA was represented, decides what will be done with it.

### AREAS OF INTEREST

The archaeological investigation for MV2, which started in 2004, indicated that the investigation should focus on (Figure 1):

1. The location where MV2 was to be built;
2. The place where the Yangtze Harbour was to be widened and deepened;
3. The sand borrow area 10-15 kilometres off the coast, southwest of Maasvlakte 2.

### MARITIME ARCHAEOLOGY

Before the start of the construction work, the seabed of the sand extraction area and the construction area were investigated. Using multibeam bathymetry and sonar equipment, a search was made for objects of historical

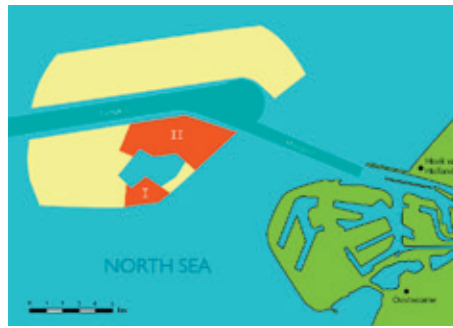


Figure 1. Maasvlakte 2 with (1) the beach area, (2) the location of Yangtze Harbour and (3) the offshore sand borrow areas I and II.



Figure 2. Wooden beam with kegs.

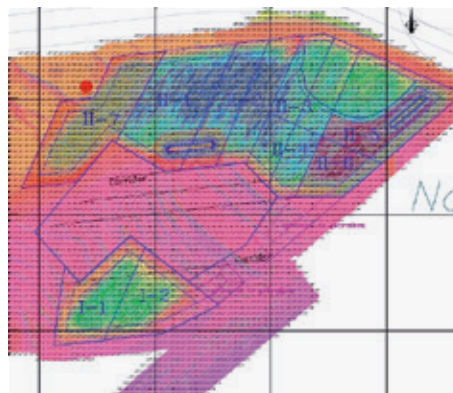


Figure 3. Bathymetric chart of western part of sand borrow area, with location of archaeological find (the red dot) that is to be preserved.

importance and in particular of shipwrecks or parts thereof. General practice is that prior to the start of a dredging work, bathymetric survey in combination with side scan sonar and magnetometer are carried out – often at high speeds (sailed at 20 knots) which in general is all right for volume assessment and permit requirements.

In archaeological investigations, however, the emphasis is different and so is the order of the surveys. First of all, high definition side scan

sonar is sailed, in combination with magnetometer (search for metallic objects) and (if possible and required) shallow seismic. On those locations where anomalies or clear objects are found, high definition fullcover multibeam bathymetry at low speed is sailed to allow an assessment of the object. If still unclear, diver inspection might be needed.

During this investigation, 94 observations were made, which finally led to 9 possible sites of historical wrecks. At these spots, divers looked for anything of archaeological value. At one location in the construction area this resulted in an archaeological field investigation. A wooden shipwreck from the 19th century was excavated (Figure 2).

The contours of the sand extraction area were modified on the basis of investigations, so that another shipwreck could be preserved. The slope stability around that location was monitored throughout the project (Figure 3).

The MS. Cornelia Maersk, built in 1925, sunk in 1942 in front of the entrance to Rotterdam. The wreck was situated in the area where the new wet infrastructure of Maasvlakte 2 was projected. This wreck was not of archaeological importance, but needed to be removed (Figure 4).

### DROWNED LANDSCAPE: ARCHAEOLOGY AND GEOLOGY IN THE YANGTZE HARBOUR

In order to make the new wet infrastructure of MV2 accessible for ocean-going ships, the Yangtze Harbour had to be widened, deepened and dredged through. The bottom of the Yangtze Harbour was initially dredged to –17 metres NAP, but in the final configuration needed to be deepened to almost –21 m NAP. This deepening and widening was envisaged to take place at the end of 2011.

However, based on a 2004 desk study and the available geological data, it was believed that the area where the Yangtze Harbour now lies was inhabited by humans in the Middle Stone Age (8800 to 4400 BC). The area from the North Sea to beyond present-day Rotterdam once formed part of a large river delta that was rich in food, with aeolian river dunes, river channels, natural levees and swamps. The river





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received a MSc, Civil Eng, at Delft University of Technology in 1974 and joined De Weger International, followed by Svasek BV. In 1987 he took over Netherlands Dredging Consultants. From 1991-2002 he lectured part-time at the Groningen State Polytechnic. He is a founding member of Blue Pelican Associates. In 2005 he joined the Maasvlakte 2 organisation to draft the EIA for the project and is now responsible for monitoring the possible effects on the marine environment.



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#### ANDREA OTTE

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## FORMATION OF RIVER DUNES

During the last Ice Age, 100,000 to 11,700 years ago, it was bleak and cold. During the coldest period, between about 25,000 and 15,000 years ago, the landscape was bare, with sparse vegetation. Strong winds blew the sand on the surface away and deposited it elsewhere. During the Ice Age, the rivers were of the braided type: they had a wide multiple channel bed which was only completely filled with water in spring when the snow melted. In the summer and autumn, the bare bed was largely dry. The sand of the dry bed was blown by the wind and deposited on to the vegetated low terrace next to the bed which was sparsely vegetated. Here the sand became trapped in the vegetation. In this way, up to 20 m high dunes (donken) were formed. These dunes stood out as dry hills in the delta that formed here later.

## PREHISTORIC HABITATION ON RIVER DUNES

The river dunes were found in the drill cores of the fieldwork. The stratigraphy of the soil consists of a thick layer of (sub)recent North Sea bed, made up of sand and shells. Below this, Middle Stone Age layers of clay and peat have been preserved. Below the peat lies the river dune, the top of which is recognisable by its dark, medium grained sand. This means that sections of the surface on which people walked in the Middle Stone Age, are still intact and well preserved.

This is one of the most important discoveries and allows researchers to form a good picture of this period. Where the North Sea and the port of Rotterdam now lie, there was a fluvial delta formed by the Rhine and Maas 9,500 to 9,000 years ago. The rich flora and fauna made this area very attractive to hunters and gatherers. In the Middle Stone Age, these hunters and gatherers lived in families, in small groups of about ten people. They moved through the region, with the higher river dunes (donken) serving as 'camping sites', as they were safe from floods there. There was also sufficient food in the area, such as fish, meat, berries, nuts and fruit. The excavations are providing more information on their way of life.

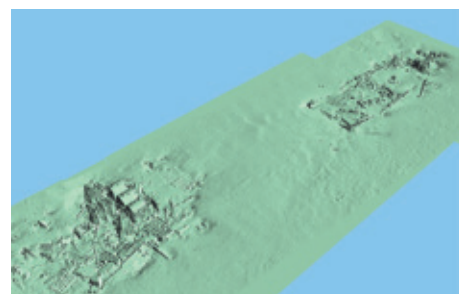


Figure 4. Above: MS Cornelia Maersk. Above right: Two pictures of the multibeam echo sounder surveys. Below right: Salvage of the wreck.



Figure 5. Yangtze Harbour in 2008, accessible for Euromax container ships only.

dunes, also referred to as ‘donken’, were high and dry sandy spots in the wet river delta. These river dunes were ideal places to spend night and live for a short time. Here, the hunters and gatherers once lived high and dry in temporary encampments. Carefully planned fieldwork in the Yangtze Harbour revealed the presence of these sandy dunes located at levels between –17 and –20 m NAP.

UNIQUE ARCHAEOLOGICAL UNDERWATER RESEARCH

Systematic research, desk studies followed by field surveys, was carried out investigating the buried former land surface and the possible traces of hominin occupation. This research was unique as it was in the Netherlands the first time that research was done at such a depth (about – 20m NAP) and so far to the west of the country. The research was directed in such a way that the scientists used the (assumed) knowledge of how these people would have lived in such an environment in

combination with a staged approach zooming in on the most promising results of the previous surveys.

On the basis of existing borings, seismic measurements and Dutch cone penetration tests, an area of approximately 120 hectares was charted. Of the three ‘archaeologically promising’ zones which emerged from these initial investigations, two were looked at in more detail: a buried river dune (donk) and a silted-up channel, where people in the past possibly sailed in their canoes. These two areas were studied more thoroughly by means of highly detailed seismic research and vibrocore sampling. On the buried river dune, archaeological remains were found in three vibrocores. This led to the decision to excavate three small sections (pits) around the location of the cores.

RECONSTRUCTION OF STONE AGE FLUVIAL AREA

The last obtained vibro soil corings (2010) and the samples obtained from them, combined with all the other field studies and measurements, provided the scientists with a detailed picture of the substrate. In the



Figure 9. Burned and unburned animal bones from vibro cores Yangtze Harbour (proof of human activity).

laboratory, the soil samples are examined further, for example to work out from pollen (paleo-botanic study) what plant growth was like in the past. The biggest surprise (and reward) was that based on the small fragments of unburned and burned animal bone which were found in three samples, it became immediately clear that humans had lived in the area. These finds date from about 7,500- 7,000

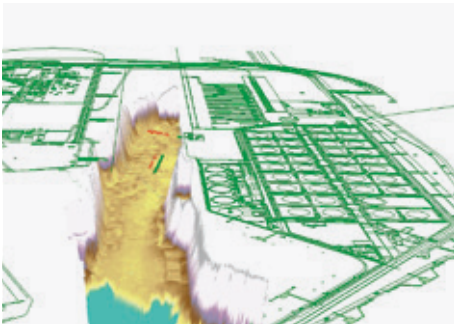


Figure 6. Left: Layout of Yangtze Harbour, with location of borings: 2nd stage.

Figure 7. Below left: Geological cross section of Yangtze Harbour, 3rd stage, showing drowned landscapes (dunks in orange).

Figure 8. Below right: Detailed geotechnical and geophysical data: seismic lines, borings and Dutch CPT's, part of the 3rd stage investigations

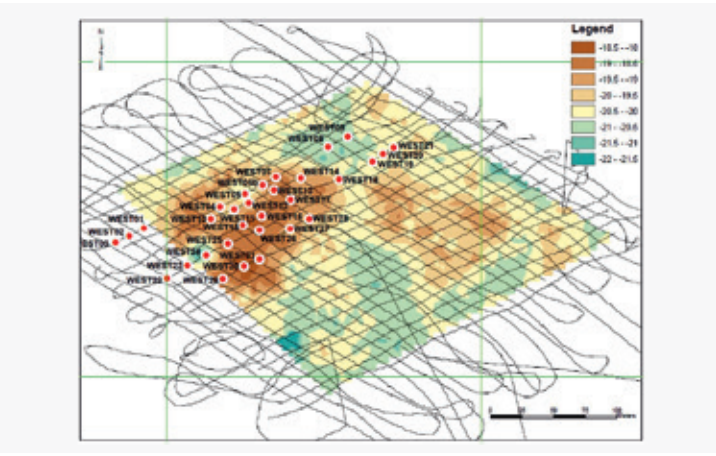
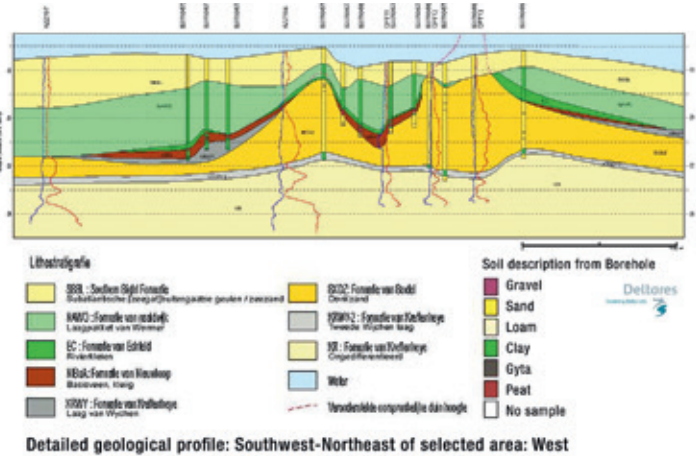






Figure 10. Location of excavation pits in Yangtze Harbour.

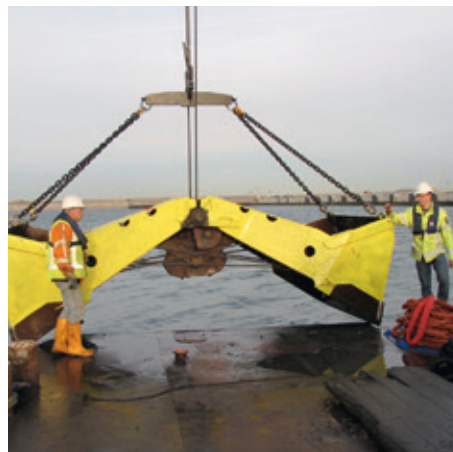


Figure 11. Horizontal closing wire operated grab, footprint 2 x 5 m<sup>2</sup>.

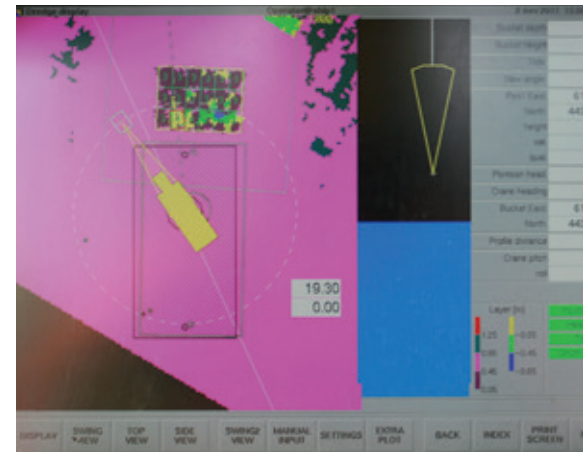


Figure 12. Computer screen of crane operator, digital logging of data.

B.C., providing the first scientific proof that people lived at this spot in the Early-Middle Stone Age. Up to now, very little was known about this period so far west in the Netherlands. The research done here is unique: the depth, the techniques and the exceptionally well-preserved remains.

### EXCAVATION AND FILLING OF BIG BAGS

At the Maasvlakte 2, the construction progress prescribed a very tight time window for the actual excavation in the field. Construction could not be delayed by the archaeological excavation. The period in which the site was accessible for the archaeologists and the field operations was limited to October and November 2011 only. The designated

excavation areas were in front of one of the largest and busiest container terminals in Rotterdam's Yangtze Harbour basin. After all the preparatory works and contracts were in place, the removal of the overburden, the non-archaeological layers, started at the end of October 2011. In two weeks' time, 27 October till 9 November 2011, the whole archaeological excavation was completed.

The excavation was contracted to PUMA and supervised by BOOR. The archaeological excavation was based on a programme of requirement that was worked out by the archaeological task force. The starting point was to treat the excavation as an environmental dredging project with high accuracy excavation and digital logging

techniques. The contractors' equipment consisted of: the "Triton", a floating pontoon with spuds and a fixed crane on a turntable, a large flat working pontoon with a receiving container and two small hydraulic cranes to fill and move big bags.

The excavation was done with a horizontal closing grab operated by wire, as the excavation depth was too deep for a hydraulic grab on a long stick. Positioning was done by dGPS and all data was logged on board of the Triton. The footprint of the grab, in open position, was 2 x 5 m<sup>2</sup>. The excavated layer thickness was limited to 0.15 - 0.20 m, resulting in 1.5 to 2.0 m<sup>3</sup> of sediment for each grab. First the overburden, the non-archaeological layers were removed. What remained



Figure 13. Crane ship and receiving container.  
Insert, Figure 14. Inspection of content: archaeological or not?



Figure 15. Filling: from receiving container into numbered big bag.  
Insert, Figure 16. Layout of working pontoon, with storage area at the back.



Top row, left to right:

Figure 17. Transport of big bags from Yangtze Harbour working pontoon to the onshore sieving station at the end of each day.

Figure 18. Storage area of the big bags at the onshore sieving station.

Figure 19. Onshore sieving station.

Figure 20. Second stage sieving over 2 mm mesh.

Lower row, left to right:

Figure 21. Sorting of dried sieve samples at BOOR offices.

Figure 22. Example of sorting result looking for animal bones and mouse teeth from a dried sample.

Figure 23. Example of sorting result looking for flint stone tools from a dried sample from a particular big bag.

Figure 24. Individual experts inspect the preliminary results from BOOR's sorting.

was the archaeological layer (sandy topsoil of the river dune) underneath 0.4 to 0.8 m peat and fluvial clayish material. This sequence was excavated in 4 to 5 steps of 0.2 m each. Because the subrecent marine sand had not been removed completely, every grab was checked on the pontoon. Grabs of the subrecent sand were temporarily stored in a dump barge lying next to the dredge pontoon. Grabs with the peat, clay and dune sand were released in a storage container placed on the large work pontoon.

The storage container was emptied by a small hydraulic excavator standing next to the container. From each grab, the excavator filled 2 big bags (size 1 m<sup>3</sup>) being labelled A and B plus a number. After being filled and labelled they were placed at the end of the work pontoon by the other hydraulic crane. At the end of the day, the bags would be transported to the quay of the Yangtze Harbour approximately 1500 m away from the excavation where they were temporarily stored on land. To double-check on the progress of

the excavation, a bathymetry in-survey was carried out by POR's hydrographic unit at the start of the excavation. At the end of every excavation day, an intermediate survey was carried out with multi-beam equipment. At the end of each excavation a final out-survey was done in the same way.

From the 3 areas thus excavated 316 big bags were recovered, each labelled and assigned X, Y and Z coordinates. The sieving on site at the quay of the Yangtze Harbour took from 1 November till Christmas 2011. The bags were sieved with water from the harbour over a 10 mm and a 2 mm mesh sieve installation. The residues were collected and stored on site in a hot room to dry. Once dried they were dispatched to BOOR's offices for sorting out of the obvious archaeological and botanical remains (see Figures 17-20).

## FINDS FROM HUNTERS AND GATHERERS

The first coarse sorting of the material coming from site and worked over in BOOR's

laboratory resulted in some 46,000 small remains of charcoal, wood, bones, burnt bones, fish, (worked) flint, natural stone, bone adze (tool used for working wood) and scrapers (skins). The bone remains are small particles, not bigger than 1 cm, burnt and unburnt animal bone. The unburnt bone demonstrates the presence of animals in the area. The burnt bone is burnt in such a way that it must be the result of human action. Together with the charcoal finds, this is evidence of food preparation, such as the grilling of meat. Charred tuber remains of several plants, amongst which pilewort, were also abundant (see Figures 21-24).

The flint fragments and the minuscule splinters of flint prove that flint was worked in situ to make implements (tools), such as arrowheads, knives and scrapers for cleaning animal skins.

The unique thing about the site in the Yangtze Harbour is that it is the first time in the Netherlands that a complete package of material of this age has been found, including



well-preserved plant and animal remains that give a good indication of these people's diet. Many known sites in the Netherlands exist where flint of this age and slightly older has been found, but the organic material (wood, berries, tubers and so on) was always missing because it had decayed through time. Here everything was found together because of the excellent preservation conditions. This yielded spectacular new knowledge about how people at the time lived.

All the sieved material was investigated by specialists, i.e., on charcoal, paleo-botany, flint, animal bones (terrestrial and fish) for in-depth studies. Preliminary (partial) reports are now available and the final reports (in English) with all the combined results put in perspective, will be available mid-2014.

A three-dimensional image of the submerged landscapes and what life looked like there and then has been created. The finds and method have been presented internationally at scientific conferences both at home and abroad. The project as a whole has already led to various scientific publications in the field of archaeology, underwater archaeology, and palaeontology and landscape reconstruction.

### LESSONS LEARNT SO FAR IN THE YANGTZE HARBOUR

Treating the archaeological excavation as an environmental dredging project was the 'right choice' given the local circumstances. All other techniques that experts proposed were not feasible in view of the boundary conditions: limited time available, excavation depth 17-20 m underwater, high turbidity in tidal water (no

visibility for divers), no congestion/delays of ongoing work allowed, deep drafted container terminal next door, and more.

Another lesson learnt dealt with the underwater excavation method. The special grab that was used had proven itself in environmental dredging projects. Here, a heavy grab will sink easily in the 'soft contaminated' sediment layer(s). In this case, the archaeological layers contained consolidated very stiff peat that was very difficult to penetrate or break through. Having a grab on a wire, compared to one on a hydraulic stick, means that no extra force for penetration is available. The grab, being prevented to sink into the layer at one side, will no longer excavate horizontally anymore and make a slight hollow. The small dimensions of the pits, with the stiff peat protruding at the sides at some locations resulted in a slight twist of the grab in the horizontal plane (Figures 25 and 26).

All of these were visible in the daily bathymetric surveys and with the help of the electronic logging (X, Y, Z) of each grab, could be dealt with – although it was quite a puzzle in the end.

Fortunately the site stratigraphically consisted of only one archaeological layer with a thickness of 40–80 cm and covering a time span of some thousand years as the drowning of the landscape at the time was quite rapid. This was the result of sea level rise caused by the melting of the ice caps above North America and Scandinavia. Dating took place on samples from the vibrocores taken before

## ARCHAEOLOGY, PALAEOLOGY AND GEOLOGY IN THE SAND BORROW AREA

### Cold Serengeti in the North Sea

The bed of the North Sea is a rich and internationally important underwater site for prehistoric fossil mammals. Until about 12,000 years ago, the southern North Sea basin was dry and formed an expansive cold steppe, referred to as the Mammoth Steppe. It was inhabited by woolly mammoths 100,000 to 25,000 years ago, along with rhinos, steppe wisents, hyenas, reindeer, Irish elk, as well as many other smaller mammals.

Palaeontologists study the past on the basis of fossil remains, such as teeth, bones and vertebrae, or traces of plants and animals. They are interested in such things as their origins and relationship with plants and animals living today. The finds alone tell only one part of the story; to complete it the geological context is needed – for instance which layers contain the fossils and how old are these layers.

the excavation. They had a very precise vertical accuracy, and yielded excellent results.

### PALAEOLOGY: 'BY CATCH' FOR SCIENCE AND THE PUBLIC

There are in the Netherlands to date, no legal obligations regarding palaeontological finds. However, because geologists and archaeologists can gain new insights into the submerged landscapes and their possible inhabitants on the basis of these finds, POR decided to handle all palaeontological finds, such as bones and fossils, with care during the dredging operations. During various Ice Ages, the sea level was so low that what is now the North Sea was dry land. The many finds led to a covenant with the Natuurhistorisch (Natural History) Museum Rotterdam (NMR), which was signed on 16 February 2010.

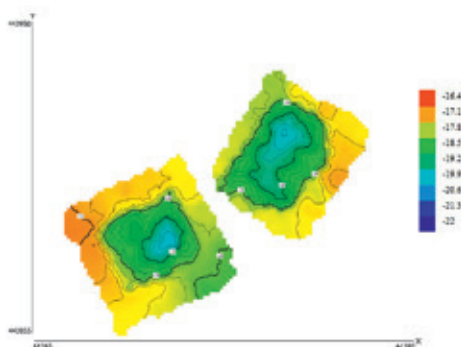


Figure 25. Bathymetric recordings of pit 1 (left) and pit 2 (right) in Yangtze Harbour.

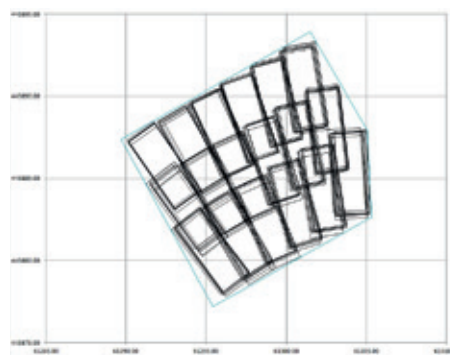


Figure 26. Footprints of the grab positions at pit 2.

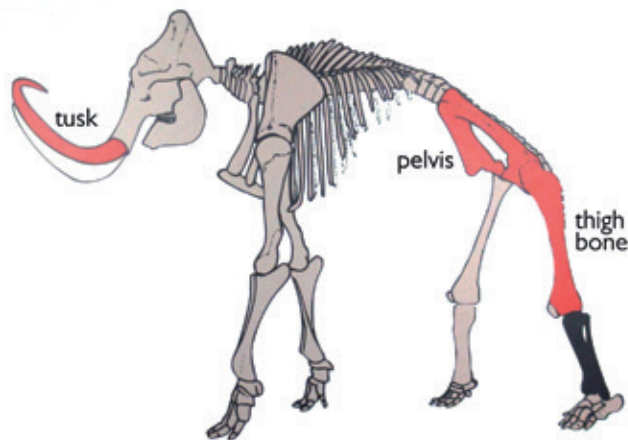


Figure 27. In October 2009, a 133 cm long thigh bone of a woolly mammoth was dredged up. This is to date the largest fossil bone found in the North Sea in the Netherlands.

Figure 28. Drawing of a woolly mammoth with the tusk, pelvis and thigh bone indicated in red.

The POR ensured that all bones from mammoths and other fossil mammals found during the sand extraction on the trailing suction hopper dredgers (TSHDs) and on the new reclamation of MV2 go to the NMR. Thanks to the meticulous records kept by PUMA, the 'exact' sand extraction locations and depths are known for most of the finds. Partly as a result of this, the new material is of great scientific value. The palaeontological objects are accessible for scientists and the public; the most beautiful and scientifically interesting specimens are exhibited in the NMR as referred to above, but also in the Port's FutureLand information centre on Maasvlakte.

### Two hundred and more mammal remains

During dredging, a number of larger objects were caught in the 'bomb grate' of the drag

head of the TSHD, including palaeontological finds. As a result, the POR decided, in consultation with RCE, to organise several specific fishing trips for palaeontological finds in the sand extraction area. In the earlier mentioned protocols such a fishing expedition was referred to as a "Cerpolex" survey in the Netherlands and geared at looking for archaeological and at the same time palaeontological finds.

In October 2009, the fishing boat OD7 spent two days in the borrow area trawling for finds. This trip was so successful that it was decided to carry out some more trips. For the in-situ silt (SPM) measurements that were required for environmental reasons, the POR used a fishing boat BRA-7 which was at sea for a week for each campaign. Consequently, in 2010 the BRA-7 was chosen to fish for

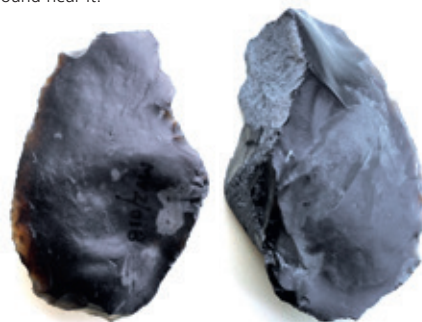
mammoth fossils and archaeological finds on six Saturdays at the end of the silt measuring week. Thanks to the TSHDs, which kept exposing new and deeper parts of the borrow area, the fossil finds in particular were spectacular: over two hundred top-quality mammal remains, such as teeth, vertebrae and bones, have now been added to the collection of the NMR.

Three quarters of the finds are from the woolly mammoth (*Mammuthus primigenius*), including the longest mammoth thighbone (as yet) found in the North Sea, two virtually complete and exceptionally large pelvic bones and a tusk (Figures 27 and 28). Other animal species from the Late Pleistocene fossils which were dredged up from the sand extraction area are reindeer, steppe wisent, aurochs, Irish elk, red deer, woolly rhino, wild horse, cave lion, harp seal and otter.



Figure 29. On 18 August 2010, the BRA-7 dredged up the first fossilised hyena dung ever found in the Netherlands.

Figure 30. Below and right: A naturally backed knife, type 3, (cf. Bordes 1961), known as a 'hand-rug-mes' in Dutch, is an artefact made by a human, probably 30 to 50 thousand years ago. No human remains (bones) were found near it.



Ventral

Dorsal





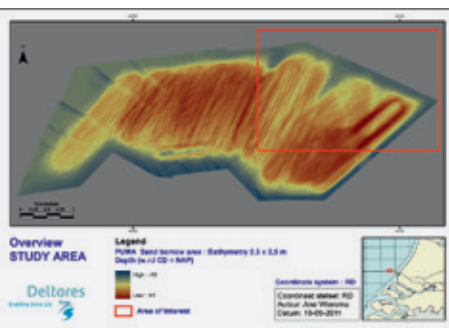


Figure 31. Sand borrow area of Maasvlakte 2 (in 2010/ 2011).



Figure 32. Shallow seismic device 'Boomer' floating on surface towed next to the fishing boat while searching for finds.

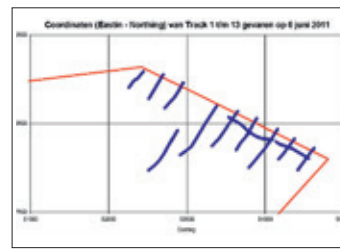


Figure 33. Northern slope of the borrow area, short fishing tracks going up the slope (-40 to -20 m CD) sailed on 6 June 2011.

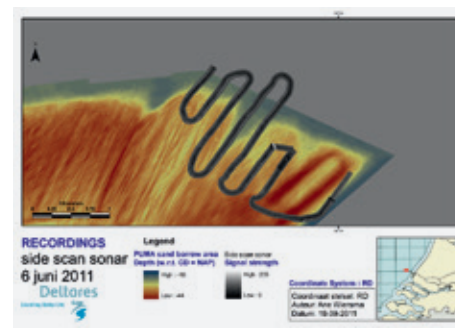


Figure 34. Side Scan Sonar tracks and associated information.

### Special finds

The perfect fossilisation of this relatively young (Late Pleistocene) piece of hyena excrement is exceptional (Figure 29). Research at the NMR revealed that the light brown fossilised dung had been produced an estimated 30,000 to 40,000 years ago by a cave hyena (*Crocota crocuta spelaea*). The so-called coprolite, measuring 55 x 44 millimetres, has been incorporated into the museum's collection and is now exhibited there. The presence of this predator had previously been demonstrated by dredged-up fossilised skeleton parts and, most importantly, by typical signs of a hyena having fed on (mammoth) bones. Other artefacts such as a naturally backed knife were also found (Figure 30).

### GEOLOGICAL CONTEXT, THE "ENVELOPE"

The success of the ad-hoc fishing trips for archaeo- and palaeontological finds of 2010 were discussed in the archaeological task force. It was decided that, if to be continued, a more scientific approach would be appropriate and a budget was made available from the reservation for archaeological research. As an integrated approach with the University of Leiden, NMR, Naturalis Leiden, Deltareis and TNO, a scientific research project was formulated.

The design of this geological-palaeontological search thus differed from that of the earlier fishing trips. Previous results (finds) were looked at in advance in combination with the geological structure of the slopes of the borrow area where most of them were coming from, resulting in short tracks at

predetermined locations and depths. Again, this time the north-western slope of the borrow area would be the target, but with a more systematical and methodological approach (Figures 31 and 32).

### Set-up

The northern slope area in PUMA's sand extraction pit was investigated in depth. Along with the bottom trawl, a Side Scan Sonar (SSS) was used. Use was also made of a shallow seismic profiler (xStar) and a Boomer (sparker). The SSS is used to look sideways along the seabed for objects which protrude from the bed. With the xStar and the Boomer, one can look in the bed at the substrate's structure.

Furthermore, a number of overlapping (in depth level) vibrocore borings were carried out perpendicular and parallel to the northern

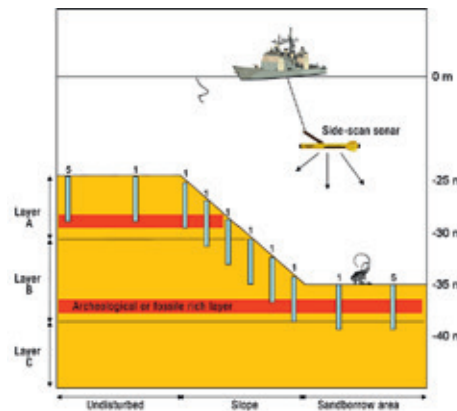


Figure 35. Theoretical sketch showing the row of vibrocore set earlier from original seabed to bottom of sand borrow area with sufficient overlap and the SSS (see also Figure 34).

## YANGTZE HARBOUR AND SAND EXTRACTION OFFSHORE (SUBMERGED LANDSCAPE)

The results already showed that people lived here in the Middle Stone Age, the period after 9,700 BC. From the results of the borrow area, it is now known, partly from the flints and tools found, that people also roamed the cold steppe (what is now the seabed) in the Old Stone Age.

It is important to know if the archaeological and landscape finds at the Yangtze site can be connected with the landscape research in the sand borrow area, some 10-15 km south-westward of the Yangtze site. The scientists, including physical geographers and geologists, were interested in the piling up (sequences) of landscapes. As a section of the bed of the North Sea was dug up in the sand borrow area to a maximum depth of 20 metres below the original seabed, the composition of the layers could be determined and dated. The top layer of the slope in which vibrocores have been placed (see Figure 35) should hopefully coincide with the lowest part of the vibrocore set in the Yangtze Harbour, thus connecting the two sites geologically. This may help with the reconstruction of the landscape sequence. The reconstruction study could produce unique scientific knowledge: A great deal of dredging has been done in the North Sea, but never before was this type of research conducted on such a scale.



Figure 36. Outer contour of the sandy beach of Maasvlakte 2.



Figure 37. Beach cleaning machine, used as mechanical aid in combination with hand picking.



Figure 38. Amateurs and professional palaeontologists looking for finds at the beach (January 2010).



Figure 39. Results of the beach cleaning operation, each big bag represents approx. 400 m<sup>2</sup> of beach area.

slope (Figures 33, 34 and 35). Using these data, the geological structure and stratigraphy of the pit was mapped in detail. With the aid of samples from the borings, the age of the various differentiated layers will be ascertained. Dating results of the samples by Optically Stimulated Luminescence (OSL) are expected to become available later in 2014. The OSL method allows sand grains to be dated. In this way all palaeontological finds from the fishing trips can be placed in their geological and temporal context. The beds have been “dated” indirectly by looking at their heavy mineral composition. From this, a maximum age of 250,000 years is expected for the deepest bed.

During the fishing trips, the catches from the two bottom trawl nets were looked at separately, systematically and sorted into, among other things, bone material, flint, stone, gravel, fossil shells and wood. Also, a general characterisation was given of, for example, the presence of lumps of clay, chunks of peat, residues of wood and the

quantity of serpent stars and starfish. The data gathered also allowed a more statistical evaluation of the find in relation to their geological context.

### DATING SAND LAYERS

Under the guidance of TNO I Geological Survey of the Netherlands, the age of the samples from the layers from the vibrocores is determined via Optically Stimulated Luminescence (OSL) dating and the sediments are carefully analysed. OSL is a relatively new dating technique. Some minerals emit a small light signal when they are heated or a light is shone on them. This light, or luminescence, can be used to date sediments, pot fragments and a number of other artefacts.

Luminescence dating has a longer measuring range (250,000 years) than the commonly used <sup>14</sup>C or carbon dating method (approx. 50,000 years). The OSL dating takes a long(er) time to carry out, i.e., from 9 to 12 months and is not yet a common exercise. The results at MV2 will become available later in 2014.

### PUZZLE: WALKING WHALE OR SWIMMING MAMMOTH?

Palaeontological research on the whale and mammoth bones dredged up using the popular <sup>14</sup>C dating method produced a striking result: both heavyweights apparently lived in the same place between about 32,000 and 38,000 years ago.

Shells were also dated to about the same period. But did the whales walk on the steppe then or, did the mammoths swim in the sea?

It seems that the method for <sup>14</sup>C-dating shell and bone material of this age and older found underwater has some problems. It looks like the shells and bones are contaminated by fresh carbon material that is added to the shells and bones through the recrystallisation of calcium carbonate from the groundwater by bacteria which live in this porous material.

As a result of this ‘contamination’ with young carbon, the <sup>14</sup>C method seems to yield an age of 32,000 to 38,000 years for all shells and bones of this age and much older. By comparing the OSL dates with the <sup>14</sup>C ‘age’ of the fossils from the sand, new light will be shed on this problem later in 2014.



Left, Figure 40. Visitors (children and parents) helping the researcher at Naturalis as part of a public friendly event.

Right, Figure 41. The ‘professionals and amateurs’ at work at Naturalis.





Figure 42. Part of a human skull, 9600 years old, found at MV2. This piece links the three scientific programmes: geotechnical and palaeontological work at the borrow area and on the sandy beach and the Yangtze Harbour archaeology.

### ARCHAEOLOGY AND PALAEOLOGY ON THE OUTER SANDY CONTOUR OF MV2

Simply speaking: the sand taken from the offshore borrow area is put “up-side” down on the Maasvlakte 2 seabed by dumping, rainbowing and pumping ashore. So all the remains of previous life gathered with the paleo-fishing trips can be found in the sand on the surface of Maasvlakte 2 as well. The newly created beach protection (the outer contour with sand dunes) of Maasvlakte 2 was searched three times by a group of palaeontologists, geologists and archaeologists before it was opened to the public. PUMA willingly assisted in providing search areas with exact X, Y and Z coordinates. Through PUMA’s meticulously held logs of the dredging locations, these areas could be linked to the area of origin in the borrow area (Figure 36).

The beach was worked over systematically,

and archaeological and palaeontological finds and stones and gravel were safeguarded in two ways: mechanically and hand-picked. As a result of time constraints and the fact that the accessibility of an active working site is difficult, it was investigated if other “gathering” techniques could be employed.

An often-heard shortcoming of the fishing trip with a trawling net was that small animal remains were hardly found. The idea was to use a conventional beach cleaning machine that would be compared with hand picking. The beach cleaner used was 2 m wide, depth of the knife-conveyor belt variable (up till 15 cm) and a sieve mesh # of 20 mm. The test was done twice: once in February 2010 and once in June 2010. In total 16 Big Bag (~1 m<sup>3</sup> volume) were filled by the beach cleaner, covering an area of approx. 16,000 m<sup>2</sup>. One bag from each of the predetermined and stacked out areas on the beach was sorted out at the natural museum Naturalis in Leiden (Figures 37, 38 and 39).

The sorting out was a huge job. The natural museum organised a public friendly weekend in September 2010 during which youngsters under supervision of the researchers participated next to professionals and amateur palaeontologists and geologists (Figures 40 and 41)

Next to bones also the fossil shells, gravel and other specific geological features were sorted out. This was done to see if correlations could be made related to the geological layers in the borrow area and whether or not a statistical analysis was feasible on the finds and these associated constituent parts.

Many remains of animals from the mammoth group from the Pleistocene and archaeological artefacts from the Late Pleistocene and Holocene have been found. Finds include teeth from a white shark, a beaver and a rhinoceros.

A lot of unique fossil shells were also found, and a large number of fossil marine animals and flints. Some remains proved to be between 50,000 and a million years old. The white shark tooth must definitely be a couple of million years old. The shark did not live here; the tooth has been transported here by the palaeo-Scheldt river that cut through Tertiary deposits in Belgium that are famous for these shark teeth.

The shells could help with the reconstruction of the landscape. Furthermore, the shells and shark teeth provide indications of the origin, i.e., brought in from the north or south by ice sheets or rivers. Researchers are now busy investigating how old the shells are.

### A HUMAN FIND AFTER ALL

After the beach was opened to the public many enthusiastic amateurs began searching daily for fossils and archaeological stuff. On 19 March 2013, one man, Walter Langendoen, who already had found some 30 hyeana coprolites, was lucky and found two small pieces of bones that later on proved to be human. With the permission of the finder POR had the pieces investigated by experts and after <sup>14</sup>C-dating they proved to be ~7,600 BC, the same age as the site of the Yangtze Harbour dune. Mr. Langendoen also found two spear points made of bone most probably from the “same” humans. <sup>14</sup>C-dating for those finds is still in progress.

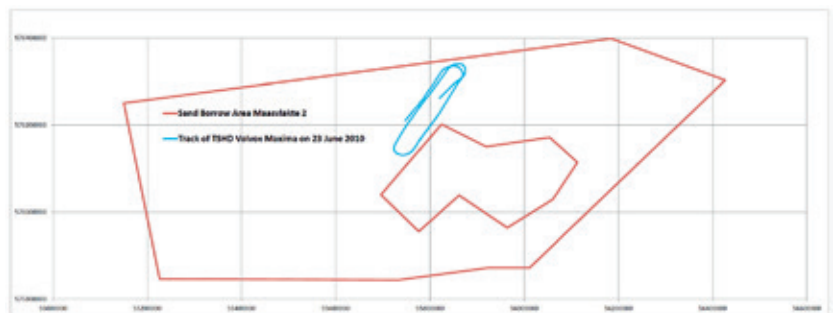
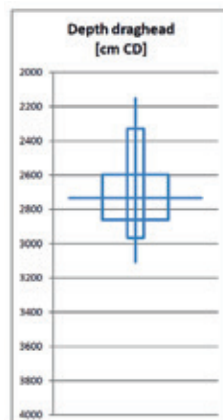
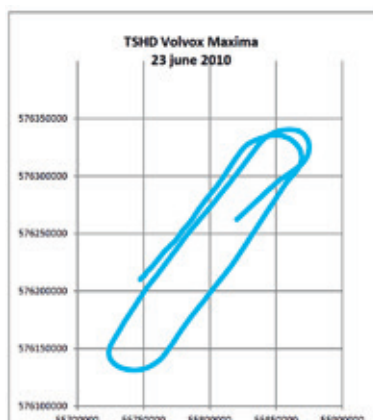


Figure 43. The track of TSHD Volvox Maxima on 23 June 2010 (X,Y plot).

Figure 44. Box plot showing the draghead depth along the track of Figure 43, in percentiles.

Figure 45. Track plotted in the borrow area.

## The geological envelope "reconstructed"

POR has access to the "book keeping" of PUMA during the construction of Maasvlakte 2. In order to comply with the dredging permit regulations, the position of each dredger is continuously logged, as well as the status signals of the complete dredging cycle over the whole day. Furthermore each load brought to shore is guided and registered to a specific placement location that is also logged. Using these data in a reversed mode it is possible, in principle, if the exact coordinates of a find on MV2 are known, to 'look-up' which dredger was the last one that delivered a load of sand at that particular area. Once the name of the dredger and the data and time of delivery are known the path in the borrow area can be reconstructed.

Of course it is unknown where exactly the bones have been picked up by the dredger, but the wishkerplot gives a fair indication of the average depth along the track and the variations (percentiles) around it. The most probable layer(s) where the bone fragments could come from fall within the <sup>14</sup>C date.

A web-based application (App) has been developed on the basis of the above procedure. Any enthusiastic amateur can report archaeological and palaeontological finds on the beach through this App. This will yield a unique database of finds with exact X, Y and Z coordinates, which will help scientists to analyse the gathered information. In return, the amateurs get back a possible date of how old their find is and what type of find it is. This approach has led to the development of a web-based checker for finds on the outer perimeter of MV2: see website [www.oervondstchecker.nl](http://www.oervondstchecker.nl). This application which works on a smartphone, laptop or PC, was launched on the 25 January 2014.

For the skull fragments found on the outer perimeter this yield the following: Coordinates: N 51 57'45.761" & E 003 57'38.698". The placement area that contains those coordinates lists the TSHD Volvox Maxima as last dredger bringing sand on 23 June 2010. Based on this information the track of the Volvox Maxima can be reconstructed from the black box data and is shown in Figure 43.

The depth percentiles are shown in Figure 44, with a median depth of 27.5 m NAP (CD) lying in deposits of the Early Holocene. The depth information from the box plot is matched with the geological information obtained by the

TNO/Deltares surveys into the composition of the geological layers in the borrow area. The track is plotted in the borrow area in Figure 45. The earlier mentioned web application is based on the same procedure and principle.

## CONCLUSIONS

By identifying the archaeology as a normal project "risk" at a very early stage of the project, it could be successfully integrated into the Maasvlakte 2 construction project. Because of the joint efforts of the contractor PUMA, the archaeological task force and the (geo)archaeological and palaeontological specialist, all the desired research could be carried without interfering with the harbour construction. It did not delay the works at any moment.

The interdisciplinary approach sought after by the POR and RCE in which many scientist of different fields and disciplines (geology, archaeology, palaeontology, paleobotany, malacology, and so on) had to work together, provided very promising results. The reports of the research described above are in their final stages and will be available mid 2014 (in English, Moree and Sier).

With the human bone found on the outer contour, mid-2013 and dated ~7000 B.C., the link between the three different projects described in this article, was closed. The humans that lived at the Yangtze Harbour 9000 years ago could be linked to the borrow area, as the remains of a human from that period was found on the Maasvlakte 2 brought there by the TSHD bringing sand from the borrow area.

On 25 January 2014 a public friendly book on the archaeology, drowned landscapes and palaeontological findings related to the construction of the Maasvlakte 2 was released by POR in their information Centre Futureland as part of the archaeo-palaeontological exhibition showing the finds from Maasvlakte 2. POR and RCE, in collaboration with the participating parties, will organise an International Symposium in 2015 to present the final results of the Yangtze Harbour excavation and the findings of the projects.

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