

Reconstructing the Military Infrastructure of Curaçao in the Late 18th Century

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For the island Curaçao in the southern Caribbean Sea, the defense infrastructure played an important role in the 17th and even more so in the 18th century. After the Dutch had conquered the island in 1634, they immediately started constructing the first fortification. According to our research based on the book by Hartog (1997), historical reports and a large set of historical maps, 34 fortification sites were established until 1801, some of these lasted only a few days. Several site locations were extended, rebuilt, or moved in the course of time. Most of these sites were located close to bays and natural harbors that allowed landing of smugglers or enemy boats. The remnants of some of these forts can be visited today, but a large proportion of the forts disappeared from the modern maps. Based on the sources mentioned above we were able to narrow down the location of 21 out of 27 disappeared fortresses with an estimated accuracy of 200 m or less. The paper also investigates location factors for the reconstructed fortification locations, i.e. the viewsheds within the cannon ranges. These suggest that some of the fortification positions initially chosen should be moved in order to generate larger viewsheds. The tentative results presented could be improved if high resolution aerial photographs, altitude and topographical data become available.

Key words:

Curaçao; forts; historical sources; viewshed analysis; cannon range.

CHNT Reference:

Irmela Herzog and Vincent Mom 2019. Reconstructing the Military Infrastructure of Curaçao in the Late 18th Century.

INTRODUCTION

Curaçao is located in the south of the Caribbean Sea, about 70 kilometers north of the coast of Venezuela (Fig. 1). Nowadays, Curaçao is a well-known tourist island famous for its sunny beaches and mild tax regime, but mostly in its capital Willemstad, well-preserved fortresses remind visitors of the turbulent past.

The original inhabitants of Curaçao were Arawak Indians. Their ancestors had migrated to the island from the mainland of South America, probably from the Amazon Basin. In 1499 the island was "discovered" by Alonso de Ojeda from Spain. Impressed by the size of the Indian inhabitants, the island was named "Isla de los Gigantes" (Fig. 2). In 1515 the Spanish deported a large part of the population as slaves to the nearby island of Hispaniola.

As Curaçao lacked silver and gold resources, the Spaniards did not have much interest in the "Islas inútiles" as they called the Caribbean islands. The first Spanish map of Curaçao was not drawn before 1634, after the Dutch West India Company (DWIC) had conquered Curaçao. The resistance was low, and all the Spanish (about 30) and many of the Indian population were brought to Venezuela. A number of Indian families were allowed to stay on the island [Wright 1934; Hartog 1961].

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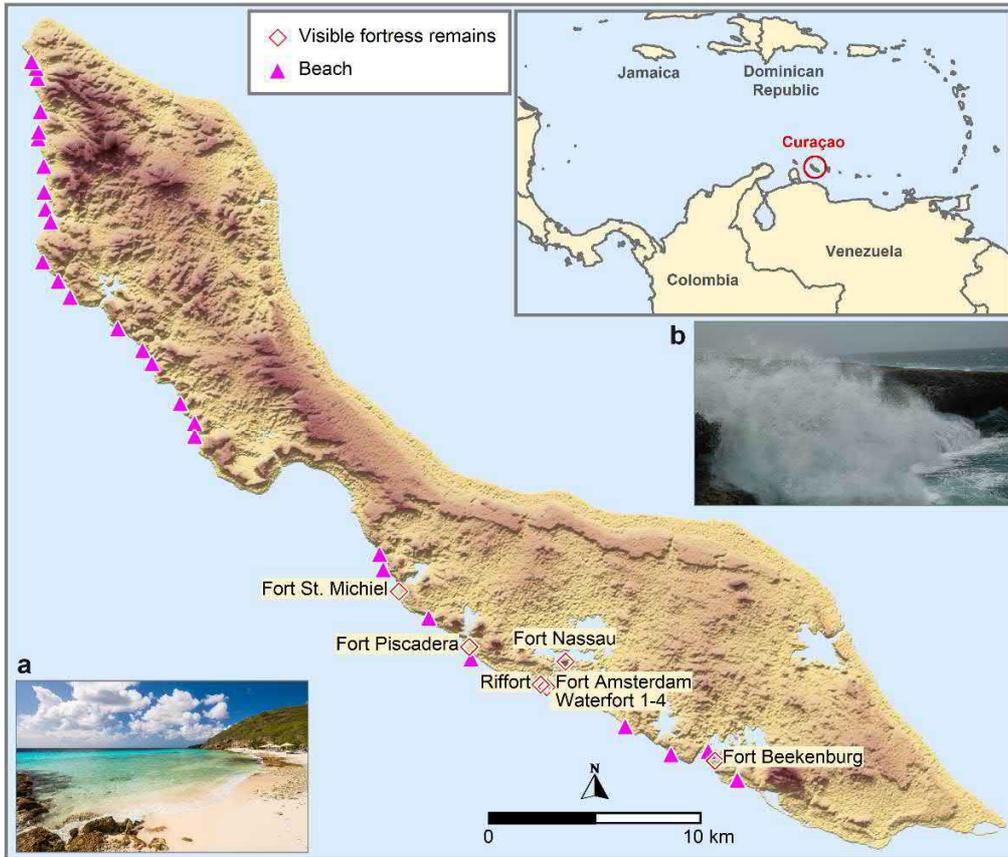


Fig. 1. Location and topography of the island with two inset images of (a) the south and (b) the north coast respectively. The digital elevation data shown is derived from 1" SRTM data. The beach symbols were digitized from a tourist map.



Fig. 2. Alonso de Ojeda and his conquistadores meet the indigenous people of Curaçao. [Herrera 1706]

The 17th and 18th centuries were turbulent times and it was important to defend a newly obtained property against its former owners, but also against other parties like privateers, pirates and smugglers. And an appreciated ally could easily turn into an enemy. After fighting Spain until 1648, the young Republic of the Seven United Netherlands were engaged in four Anglo-Dutch wars (1652-54, 1665-67, 1672-74 and 1780-84) and the Franco-Dutch war (1672-78). From 1701-14 they were a party in the Spanish Succession War.

The DWIC had turned the island into an important transition hub for the slave trade and other trading activities, but nevertheless went broke in 1791. After that, Curaçao became a full colony, but was occupied twice by the British in the early 19th century for several years. Nowadays, the island is still part of the Kingdom of the Netherlands.

Currently, the most important and prominent example of the old defense works is Fort Amsterdam (initial fortifications dating back to 1635 AD) with the adjacent Waterfort (1830 AD). This area is part of the UNESCO World Heritage Site “Historic Area of Willemstad, Inner City and Harbour, Curaçao”. Today, the massive walls of the fortification are in contrast with the brightly painted buildings used by the government, a museum and a church (Fig. 3).



Fig. 3. Fort Amsterdam, Willemstad Curaçao.

Additional fortresses in Willemstad shown on tourist maps are Fort Nassau (1796 AD), Riffort (1828 AD, with predecessors dating back to 1701 AD), and Fort Waakzaamheid (1803 AD). The latter is not depicted on the map Fig. 1 because our focus is on the fortifications created in the year 1800 or before.

Remains of three other fortresses are still visible today: Fort Beekenburg (1703 AD, Fig. 8), Fort St. Michiel (1701 AD, Fig. 4) and Fort Piscadera (1701 AD). In the late 18th century, the number of fortifications was considerably higher, and our aim is to identify their location as exactly as possible. We have limited our study to fortresses built before 1800, because of the relative detailed information from the 18th century reports, such information lacking from later periods. Moreover, the attacks and occupations by different nations in the early 19th century caused the local government to change frequently, including their politics concerning the island's defense.

Most of these fortresses are discussed in some detail in the book by Hartog (1997). This information is supplemented by two reports on the defense infrastructure of Curaçao written in the second half of the 18th century [Rodier 1774; Kreefts 1783]. Jean Rodier was a French trader who was appointed Governor of the island in 1758, and held this position until 1761 and again from 1762 to 1781. Daniel Kreefts was an army engineer who worked on the island from 1782 to 1787. In 1776 Governor Rodier also wrote letters to the Chamber of Amsterdam, accompanied by maps of the fortifications drawn by lieutenant-engineer C.G.F. Serz. These maps are depicted in the

book of Renkema (2016, pp. 286-300) as well as the maps included in Kreefts' report (pp. 309-313). This is only a subset of more than 100 historical maps created before 1800 showing the island or parts thereof presented in Renkema's book along with transcriptions of the texts on each map and descriptions of the map elements (pp. 139-319; 604-624). Many of these maps have been digitized and are available in open access archives.



Fig. 4. Fort at St. Michielsbaai

Another aim of our research is to analyze the location factors for the fortifications. Obviously, positions with large viewsheds covering the area to be defended were preferred. A location on steep slopes towards the sea provided natural protection against unwanted visitors coming ashore and increased the cannon range. Viewsheds and cannon ranges of the fortresses are investigated in the final part of this paper.

DEFENDING THE ISLAND

In times when attacks and invasions were to be expected by ships, only the south coast needed fortifications, because the bays and natural harbors of the south coast allowed anchoring ships. The north coast was 'self-defendant': according to the text on one of the first historical maps dating back to 1634 (Fig. 5), the north coast of the island is wild ("brava") and lacks harbors. Governor Rodier's report about the defense infrastructure of the island mentions that the north side of this island defends itself; there are no bays, and its coastline is very high and steep, so at that side it is not possible to come ashore [Rodier 1774, Fig. 6]. This is also illustrated in Fig. 1.

When the Dutch had conquered the island in 1634, they immediately started building a fortification north-east of the island's main natural harbor St. Anna bay, which nowadays is surrounded by the different quarters of Willemstad. This location, about 2.5 kilometers north-east of the hill where later Fort Nassau was built, was near a water well, access to drinking water was a matter of life or death [Hartog 1997, p. 22]. Hartog gives a detailed description including a map of this location [Hartog 1997, p. 33]. Modern construction work destroyed all visible remains of this and all other short-term fortifications in the Willemstad area. This fortification lasted about a year. Two days after its construction started, it was decided that a larger fortification was required, at the entrance of the bay. This would become the first Waterfort which was destroyed in 1681 by a hurricane ("Fortificacion" on map Fig. 5; "Waterfort 1-4" on map Fig. 1). Three more fortifications would follow on the same location [Hartog 1997, pp. 34-52]. Currently the fort buildings contain a number of small restaurants.

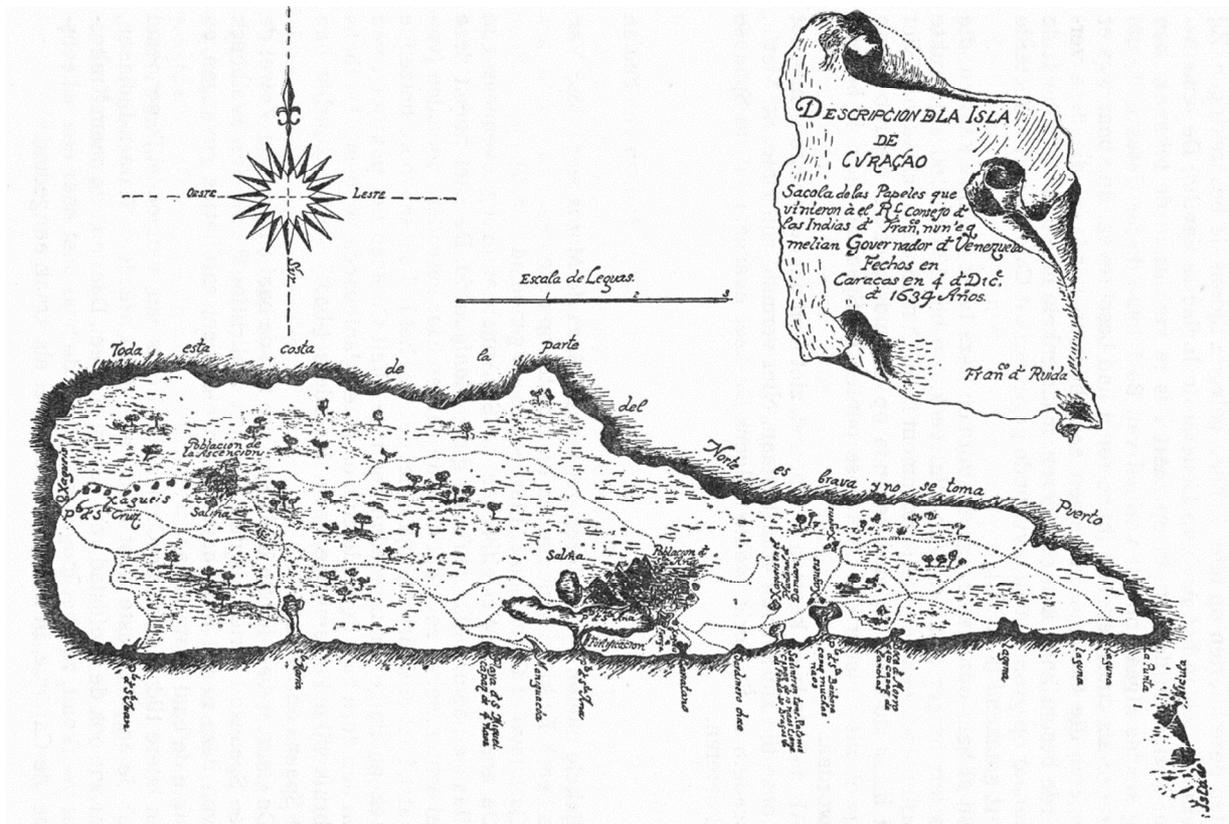


Fig. 5. One of the first maps of Curaçao, dated 4th December 1634. From the Archivo General de Indias (Sevilla, Spain). Reprinted from Hartog 1961 p. 69.

<p>Inventaris van het Fort gelegen aan de Craij St. Cruis, sub L. J.</p> <p>Inventaris van het Fort gelegen aan de Craij Baay, sub L. K.</p> <p>Inventaris van het Fort gelegen aan de Krijp Baay, welke drie distincte Batterijen heeft, sub L. L.</p> <p>Inventaris van het Fort gelegen aan de Craij de West Point, sub L. M.</p> <p>Inventaris van het Fort gelegen aan de West Ophel, Eylant Bonaire, sub L. N.</p> <p>Inventaris van de Wapenkamer, sub L. O.</p> <p>Liste van de Publicque Gebouwen, sub L. P.</p> <p>Wel nu aangaat de defensie, die alle dezen Forten, en tijt van noodtijde kunnen doen, sal de Eer. u. l. de Graaf de Witte, als so veel mogelijk, detailleeren, en ten dien Eijde van de Boovenkant van het Eylant aan des Zuidzijde, beginnen, en dus aflopen tot beneden den Noordzijde, van die Eylant de ferdere af wijf de Natuur, alsoe daar geen Baijen sijn, en dat steilhoog en loof is, so dat aan die zijde, geen mogelijchheid is te landen.</p> <p>De West. Tuinch. is de wijterste hoek van het Eyl lant van de boven kant, en loof vlak oostwaerts aan, dan dees punt is een binnen waater,</p>	<p>Inventory of the fortress lying on the bay St. Kruis (St. Cruis, Santa Cruz) (Doc. J)</p> <p>Inventory of the fortress lying on the Crabbe bay (Doc. K)</p> <p>Inventory of the fortress lying on the Krijp bay, which has three distinct batteries (Doc. L)</p> <p>Inventory of the fortress lying on the bay the West Point (Doc. M)</p> <p>Inventory of the fortress lying on the anchorage on the island Bonaire (Doc. N)</p> <p>Inventory of the weapons room (Doc. O)</p> <p>List of Public Buildings (Doc. P)</p> <p>Related to the defense which all these fortresses in time of danger could do, I will have the honor You Great Almighty as much as possible to give details, and so from the upper side of the island on the South side to begin and so to run down until down The North side of this island defends itself from the Nature; and there are no bays, and is very high and steep, so that that side there is no possibility to come ashore. The East Point is the ultimate corner of the Is land at the upper side, and lies at the east at this point is a backwater</p>	<p>Folio 2 / 41 Inventaris</p> <p>265</p> <p>Uitgebreid overzicht van de toestand van de forten door mevrouw J. Rodier 15-1774</p> <p>Bonaire Fort van Craij fort aan St. Krijpbaai fort aan de Hoofdzijde de Oostzijde de Wapenkamer de Westpunt fort aan de Zuidzijde</p> <p>Gebouwen publieke</p>
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Fig. 6. Page 3 from the report of Governor Jean Rodier to the Chamber Amsterdam about the status of the defense on the island [Rodier 1774].

FORTIFICATIONS

Hartog (1997) describes 31 fortifications that were constructed on the island up to the year 1800. Some of these had predecessors at the same location such as the Waterfort in Willemstad. Apart from the two fortresses mentioned above, two short-term fortifications were created during the 17th century in the Willemstad area as well as the first Fort Amsterdam, the most prominent of the fortresses on the island. Plans (including plans for conversion) showing details of this citadel fortress (Fig. 7) can be found on numerous historical maps created before 1800 [Renkema 2016, pp. 147,153, 154, 156, 158, 160, 164, 166, 176, 178, 179/183-185, 188, 199, 234-239, 240-252, 257/258, 263, 277, 278, 280, 281, 283/285, 287, 301, 305/306, 315; see also Ozinga 1959, pp. IV, XIII-XX, XXVII]. Some of these also show images of the fort (e.g. Renkema 2016, the 1711 AD map on p. 178).

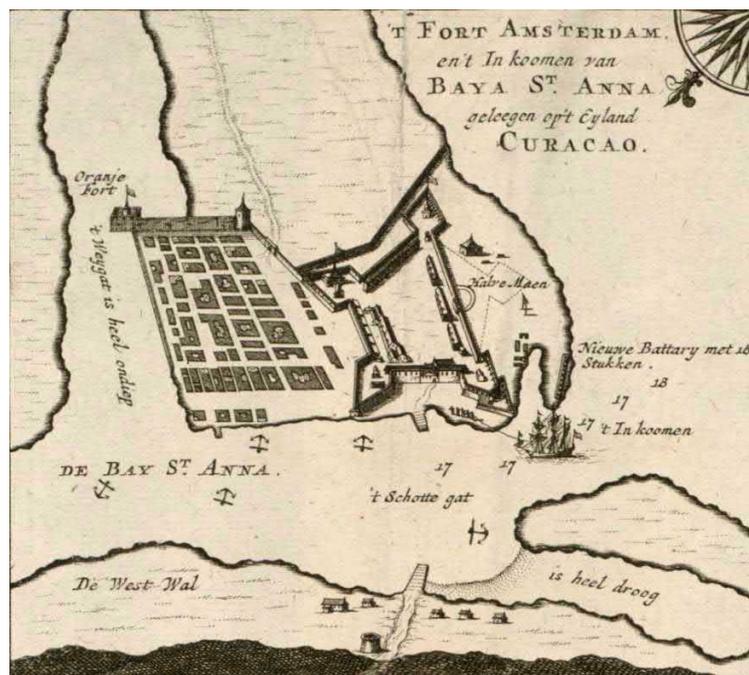


Fig. 7. Plan of Fort Amsterdam. Detail from a map of Curaçao by Gerard van Keulen [Van Keulen 1728].

Hartog (1997, pp. 82-94) records another two locations where fortifications were established for some period of time during the 17th century: the natural harbor nowadays known as “Spaanse Water”, where the Spanish administration set up the first colonial settlement after taking the island into possession [Hartog 1997, p. 82], was protected by Blokhuis (1639/40 AD) and its successor Batterij Uitkijk (1702 AD) as well as the Tolcksburg (1639 AD) and the later Fort Beekenburg.

On Fig. 5 this bay is labeled “Puerto de Santa Barbara capaz muchos naos”, i.e. the Spanish spies drawing this map were aware that this natural harbor could accommodate many ships. Initially this natural harbor had two inlets, one of them was blocked by a sunken ship in 1639, afterwards the harbor could only be entered by passing Caracas bay.

Hartog (1997, pp. 53-122) describes 18 additional locations of fortifications that were established in the years until 1801. Fortresses were mainly situated close to natural harbors or bays in defense of naval attacks. Nearly all fort locations allowed watching large parts of the sea and shooting at approaching ships; no measures were taken to hide the fortifications [Hartog 1997, p. 18].

When considering the number of depictions on historical maps created until 1800, the citadel fortress Fort Amsterdam takes the lead (see above), Fort Beekenburg and the Collenburg at Fuik bay (south of the “Spaanse Water”; “Boca de Mooros” in Fig. 5) come second. The visible remains of Fort Beekenburg show that it has a round tower structure (Fig. 8). Already the earliest historical plan of Beekenburg dating back to 1701 depicts a round tower [Renkema 2016, p. 168]. This structure is also recorded in the historical documents of 1754, and on nearly identical maps of the Caracas bay created in the years 1737 to 1780 [Renkema 2016, pp. 204-205, 269-271; see also Ozinga 1959, pp. XLIX-LI].



Fig. 8. Fort Beekenburg

Most of the 18th century fortresses had a very simple structure consisting mainly of a battery on a stone platform, the battery's breastwork formed a polyline with one or two obtuse angles. Apertures of the fortifications known as embrasures through which cannons were directed at their targets, allowed the soldiers behind the fortification to remain under cover but also limited the firing directions. Rectangular buildings were situated behind the batteries, parallel to the area they had to defend [Hartog 1997, pp. 18-19]. Examples for these simple fortifications are depicted on the maps created by engineer Serz for Vaersen Bay, Bullen bay, Porto Marie, St. Kruis bay, Krabbe bay, Knippe bay, and Westpunt bay in 1776 [Renkema 2016, pp. 292-296, 298, 300]. Behind the fortress usually the gunpowder storage was situated, at some distance to prevent casualties in case of an explosion. Often, forts were located on steep slopes towards the sea so that they were defended by nature against people coming ashore. The land part of most forts was hardly fortified at all.

At least three short-term improvised batteries were set up on the island at some time before 1801, Hartog includes two of these in his fort list (see below). Of course, it is even more difficult to detect remains of such a fortification than of the forts on stone platforms with a simple structure.

Building a fortress is one thing, but to man it and keep it in proper shape was a recurring problem. The soldiers on the island were often mercenaries, badly trained and without much enthusiasm for fighting. For operating a cannon, 2 gunners, 6 soldiers and 4 officers were required [St. Germain 1996]. Maintenance cost of the fortifications had to be provided by the civil population and the DWIC, whose main goal was making profit.

Several historical sources record these shortcomings as well as plans for improvements. These documents include the 40 page report by Governor Rodier mentioned above [Rodier 1774]. He wrote to the board of the DWIC in Amsterdam listing each fort and pointing out deferred maintenance and inadequacy of the defense infrastructure. Nine years later inspector Daniel Kreefts judged only Fort Amsterdam with the adjoining batteries well, all other fortifications required serious upgrades or were completely defective [Kreefts 1783].

The data provided by the historical sources are very useful for our research, but sometimes it is difficult to decide if new fortifications were constructed at the proposed locations or upgrades suggested in the documents were carried out. For instance, Kreefts (1783) refers to the Marseline bay battery ("believes this battery must be built on the height"); according to Renkema (2016, p. 309) just a dam is depicted on the map accompanying Kreefts' report; but we think that in addition a battery is shown south of the bay on this map (see Fig. 13); yet Hartog does not mention Marseline bay; therefore this location was not included in our list of fortifications.

GEOGRAPHICAL DATA OF THE ISLAND

For mapping the disappeared fortifications we tried to find a proper base map with high accuracy and high resolution. Google maps and Google Earth are obvious choices but these do not integrate as well with our GIS software as we had hoped for, though exchanging point location data using the Keyhole Markup Language (KML) format worked well. An incomplete vector data set of OpenStreetMap (OSM) data covering the island was used as well (<http://www.geominds.de/downloadcenter.html>).

The modern topographic data is not perfect for our purposes because of the industrial activities and the increase of the population resulting in substantial landscape modifications. Hartog (1997) mentions this issue several times when discussing the location of disappeared fortifications (e.g. p. 34, p. 81). Therefore we decided to use the map set known as "Werbata map", published in 1911 [Werbata 1911] as a basis for georeferencing disappeared fortification locations. The Werbata maps are not only considered to be the first reliable topographic map set of the island, but they are also said to be as accurate and at least as detailed as the topographic maps created later using aerial images [NAAM 2004; Renkema 2016, p. 19]. The maps depict details such as buildings down to the size of mud brick shacks, footpaths, and wooden quays. The measurements for this map set are based on 45 triangle points that were placed across the island. These triangle points can still be seen today [Renkema 2016, p. 18], but unfortunately, no open access list of their coordinates could be found.

The Werbata map sheets were stitched together resulting in one big map file covering the whole island. For the Werbata sheets the geographical coordinates are given, but the projection used is unknown. This fact along with the substantial changes of the road system led to the decision to georeference only parts of the map set when needed. The results were not quite as accurate as we had hoped for (see e.g. Fig. 9). Moreover, in the early 20th century natural resources extraction was already a major industry on the island as can be seen in the map section Fig. 9. Many of the industrial facilities depicted have disappeared today, but they may have destroyed or reused military buildings in their active days. An example is Fuik bay shown in Fig. 9: opposite to the entrance of the bay some detailed historical maps (creation dates: 1737 to 1780) focusing on this bay depict a fortification [Renkema 2016, pp. 206-208, 232, 272-273, 289]. On the Werbata map several industrial facilities are shown at this location including an ore tramway starting at the bay. This tramway is no longer depicted on Google Earth.

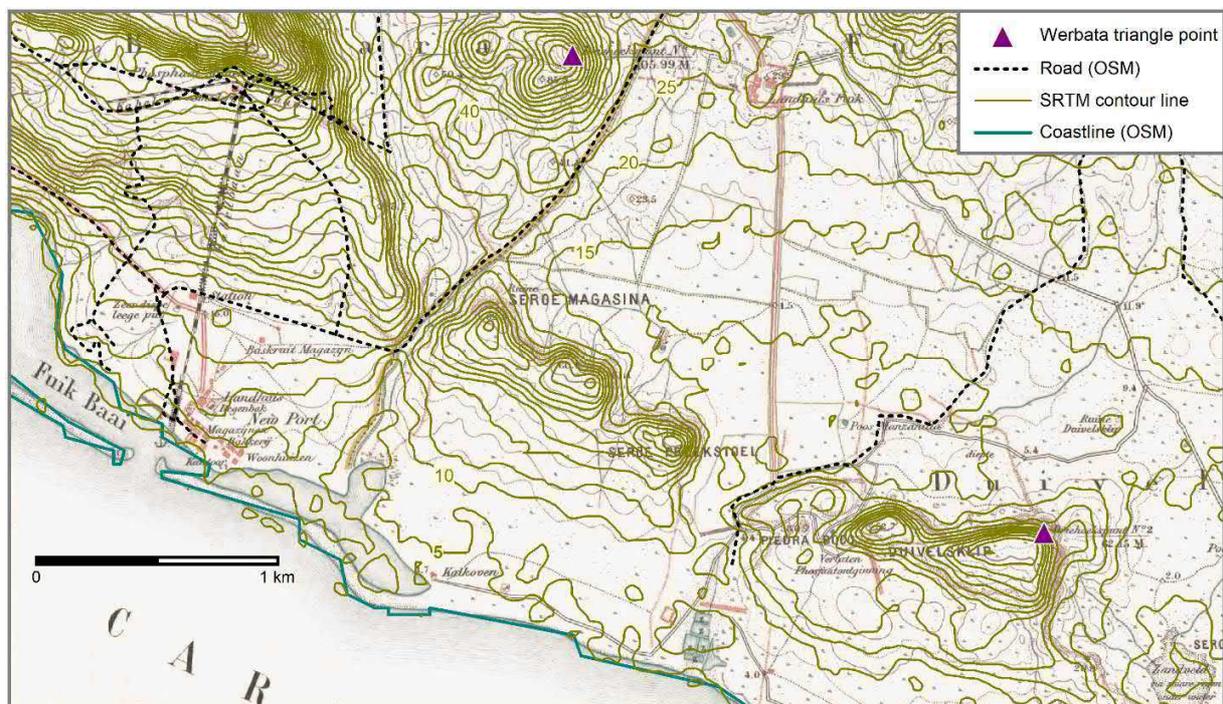


Fig. 9. Part of Werbata map sheet 17 showing Fuik bay in the south of the island, overlaid with some modern topographic data. On the map dating back to 1634 (Fig. 5), this bay is labeled «Boca de Mooros, solo capaz de lanchas», i.e. it is indicated that this bay is only suitable for small boats.

Archaeological landscape analysis mostly relies on digital elevation models (DEMs). Unfortunately, the open access repository of the Netherlands provides only high resolution airborne laser scan (ALS) data for the European part of the Kingdom (<https://www.pdok.nl/nl/actueel/nieuws/artikel/06mrt14-actueel-hoogtebestand-nederland-voor-iedereen-vrij-toegankelijk>). Therefore, two well-known globally available DEM data sets were downloaded: (i) The Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM2, web site: <https://asterweb.jpl.nasa.gov/>) developed jointly by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA) and (ii) the elevation data recorded by the Shuttle Radar Topography Mission (SRTM) resulting from the collaboration between NASA and the National Geospatial-Intelligence Agency (<https://www2.jpl.nasa.gov/srtm/>). Both ASTER GDEM2 and SRTM store elevation raster data at 1 arc-second resolution corresponding to a cell size of about 30 m. Comparison of hill-shading images for the two DEMs shows that the SRTM data of the island provides a more realistic surface (Fig. 10). This notion is confirmed by a better fit to the coastline downloaded from the OSM archive mentioned above. But at some locations the shoreline derived from the SRTM data deviates 150 m or more from the OSM coastline. Deviations exceeding 200 m can be seen at some inlets and large bays. According to the SRTM data, the highest point of the island is at 337 m (ASTER GDEM2: 342 m), but a tourist map printed in 2005 depicts the mountain top of the Sint Christoffelberg in the northern part of the island with an altitude of 375.4 m. These observations show that more accurate elevation data, if possible high resolution ALS data, is badly needed for a reliable landscape analysis.

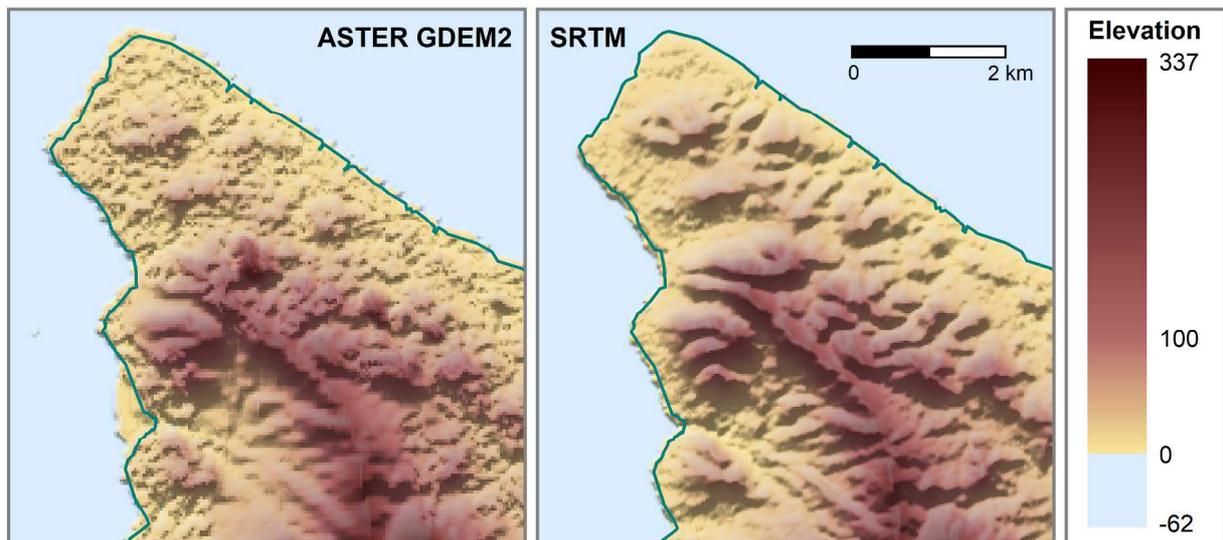


Fig. 10. Comparison of the ASTER GDEM2 and the SRTM elevation data for the northernmost part of the island. The turquoise coastline was provided by OpenStreetMap.

An alternative global DEM data set with a cell size of 12 m was obtained by radar technology mounted on a German Earth observation satellite (https://www.dlr.de/dlr/desktopdefault.aspx/tabid-10378/566_read-426/#/gallery/345). The elevation data is said to be provided free of charge for scientific purposes, but this came to our knowledge only after the deadline of submission. We intend to use this data set for future GIS analysis of the fortress data.

MAPPING THE DISAPPEARED FORTIFICATIONS

The previous section already referred to our attempts to map the disappeared fortifications at Fuik bay that are shown opposite to the entrance of the bay on some historical maps (Fig. 9). A discussion of this example illustrates some of the difficulties encountered during our research: According to Hartog [1997, p. 93] the Collenburg at Fuik bay was built in 1713 and upheld until the early 19th century. The detailed plans created between 1737 and 1780 show a fortification opposite to the entrance of Fuik bay, the floor plan is nearly rectangular with snipped corners on the seaside. On quite a few maps covering the whole island created in the years 1715 to 1823 a castle (indicated by the labels Casteel, Castle or Chateau) is depicted east of the bay [Renkema 2016, pp. 183-187, 301-303, 328, 335-337, 347]. So we tried to find out if there were two or only just one fortification location(s) at Fuik bay. In the end

we decided that only one fortress existed and this is depicted on the detailed plans. Firstly, the name Collenburg contains the Dutch word Burg, which is castle in English. Secondly, the earliest map (1715) showing the castle is a copy of a map created in 1711 [Renkema 2016, p. 178], with some added features including the castle. The incorrect placement of the castle may be due to reports given to the map maker who probably had never visited the island. The only map in Renkema's book that shows both Fort Collenburg opposite to the entrance of Fuik bay as well as the castle is the 1783 overview map by Kreefts [Renkema 2016, pp. 302-303]. According to Renkema, this map is based to a large extent on phantasy and transferring map elements from older maps. But Kreefts stayed for a long time on the island and also created a more detailed map of the coast south of Willemstad in 1785 [Renkema 2016, pp. 312-313] showing only one fortification close to Fuik bay, opposite to the entrance of the bay. According to the legend description of Renkema [2016, p. 620], the map depicts another building "landhuis Fuik" further inland, but the printed map does not allow its reliable identification.

In general we tried to combine the information published by Hartog [1997] and historical maps. Hartog [1997] describes the location of some of the fortresses referring to the Werbata maps or modern maps. In most cases the historical maps created in the second half of the 18th century provide the most detailed information on the fortress locations. Initially we planned rectifying and georeferencing the maps, especially those maps that are available at a high resolution and depict one bay only (e.g. the Serz map in Fig. 11). Nowadays, sophisticated software is freely available supporting several transformation algorithms that allow the rectification of distorted historical maps based on a set of ground control points

(https://docs.qgis.org/testing/en/docs/user_manual/plugins/plugins_georeferencer.html#available-transformation-algorithms). But it turned out that hardly any ground control points could be identified on most of these maps.

Moreover the coastline depicted on these maps varied substantially between the different historical maps and the Werbata map used for reference. Figs. 11 and 12 illustrate the difficulties encountered.

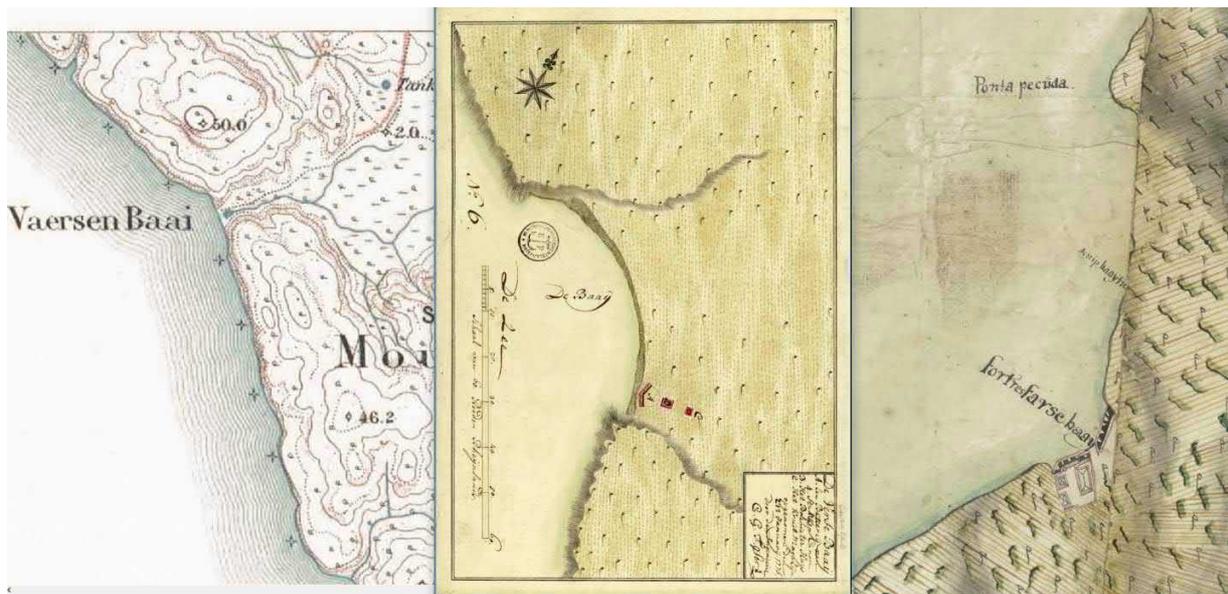


Fig. 11. Maps of Vaersen bay created in 1911 (left: Werbata), 1776 (center: Serz), and 1784 (right: Kreefts). The 18th century maps differ substantially, and it is hardly possible to identify corresponding points both in the Werbata map and the earlier maps.

In Fig. 11, the Vaersen bay is shown on the Werbata map (left) and two different historical maps created in 1776 (center) and 1784 (right). On the Werbata map, a brook bed drained in the dry season is depicted close to the center of the bay. A line with a similar shape is shown on the 1776 map, but ends in the north part of the bay. No such line is present on the 1784 map section of the Vaersen bay. The shape of the bay differs on these maps, and even the structure of the fortifications depicted on the two 18th century maps is not as similar as expected. The fortifications shown on the 1776 maps appear more generalized so the depictions on the later maps are probably more reliable. In both 18th century maps the fortification is situated in the south of the bay. So we mapped this fortification on the

modern map accordingly and tried to estimate the accuracy of the location. In this case, we are confident that the historical location of the battery is within a 150 m radius of the location chosen.

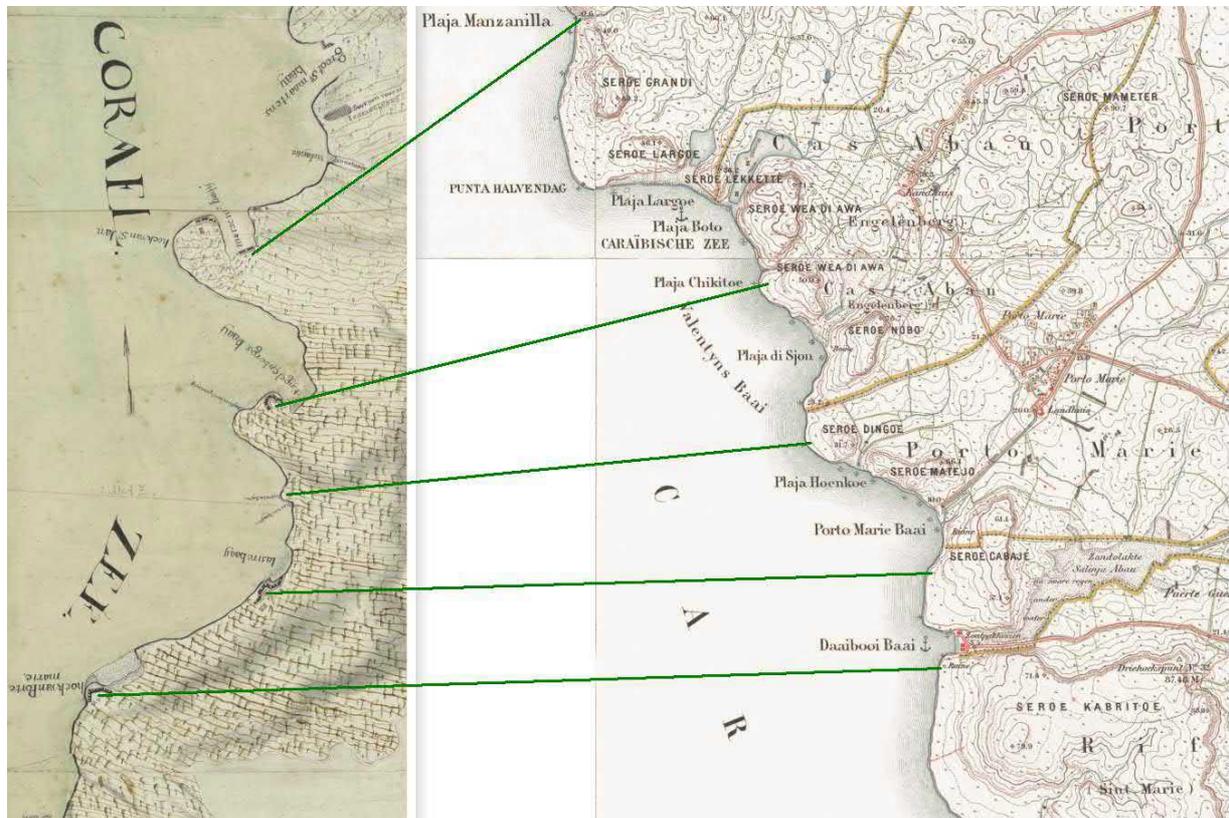


Fig. 12. Result of our attempt to find locations depicted on the 1784 map (left: Kreefts) on the Werbata map, for a coast section in the north of the island.

Fig. 12 shows part of the 1784 map belonging to the Kreefts report [Renkema 2016, pp. 309-311] on the left and the corresponding Werbata map section (based on combining three map sheets) on the right. Due to the similarity in shape, it seems likely that the Daaibooi Baai on the Werbata map corresponds to the bay shown north of the “hoek van Porte marie” on the 1784 map. Labels with identical text occurring several times on the Werbata map (such as Porto Marie or Engelenberg) complicate the identification of the corresponding locations on the newer map. In Fig. 12, green straight lines indicate the tentative corresponding locations that are also listed in Tab. 1 along with Renkema’s description of the military features shown. It seems that Renkema forgot to mention the feature south of Marsenille bay that may indicate a small battery.

Table 1. The first column lists the labels on the section of the Kreefts map shown in Fig. 12 from north to south. In the second column their probable corresponding location on the Werbata map is given, and the third column shows Renkema’s description of the (military) features depicted on the 1784 map [Renkema 2016, p. 309] if present.

Label 1784	Werbata 1911	Renkema’s description
Marsenille baaij	Plaja Manzanilla	dam
hoek van St. Jan	Punta Halvendag?	
Engelenberg’s baaij	Plaja Chikitoe? Larger Engelenberg label north of Plaja Chikitoe	
loefhoek van Engelenberg	Smaller Engelenberg label south of Plaja Chikitoe	battery
hoenke tuijn/houkebaaijtje	Seroe Dingoe (north of Plaja Hoenkoe)	
Lasire baaij	Porto Marie Baai	battery
hoek van Porte marie	Daaibooi Baai (with ruin in the south)	battery

Using visual comparison of historical maps as described above, we recorded most of the permanent fortifications listed by Hartog. We also mapped some additional batteries not mentioned in Hartog's book but referred to in historical reports and depicted on a 18th century map. These include four fortifications that are listed in Kreefts' report (1783) and the accompanying maps. Two omissions are shown in Fig. 13: batteries at Groot St. Maartens bay and Engelenbergs bay (see also Fig. 12).



Fig. 13. Location of batteries at Groot St. Maartens bay and Engelenbergs bay. Detail of a map, made by D. Kreefts

Some of the fortresses mentioned need further investigation because the different sources are sometimes contradictory. For example, the report by Kreefts on the overall status of the fortifications, suggests that the battery at Groot St. Maartens bay (Fig. 13) should be placed backwards [Kreefts 1783], while Renkema [Renkema 2016, p. 309] interprets the construction on the map as a 'quay'.

Based on historical maps and Hartog's book, counting fortresses is not easy because sometimes different fortresses are very close and sometimes batteries belonging together are at a distance of 500 m or more. Moreover, fortresses were extended, rebuilt, or moved in the course of time. For instance, Hartog (1997) lists four different fortresses at the Waterfort location, three of which were constructed before 1800 AD, and he also dedicates a chapter to another battery at this location (Hartog numbers 4, 5, 6, and 8). Moreover, Fort Amsterdam and the Waterforts had different commands, but are located close to each other. An example of spatially separate batteries that belong together are the three Knippe fortifications, they are discussed in one chapter only [Hartog 1997, p. 101].

Therefore it is quite difficult to clearly point out the omissions in Hartog's publication. Beyond the four fortifications referred to above, another three fortifications were identified on the historical maps, each of which is quite close to a fortress described in a chapter of the book by Hartog, but he does not mention this nearby structure explicitly.

Fig. 14 shows a map of the permanent fortifications that were located as described in this section. In connection with French attacks in 1713 and 1800 three temporary fortifications were set up, and the next section describes our attempts to identify their location.

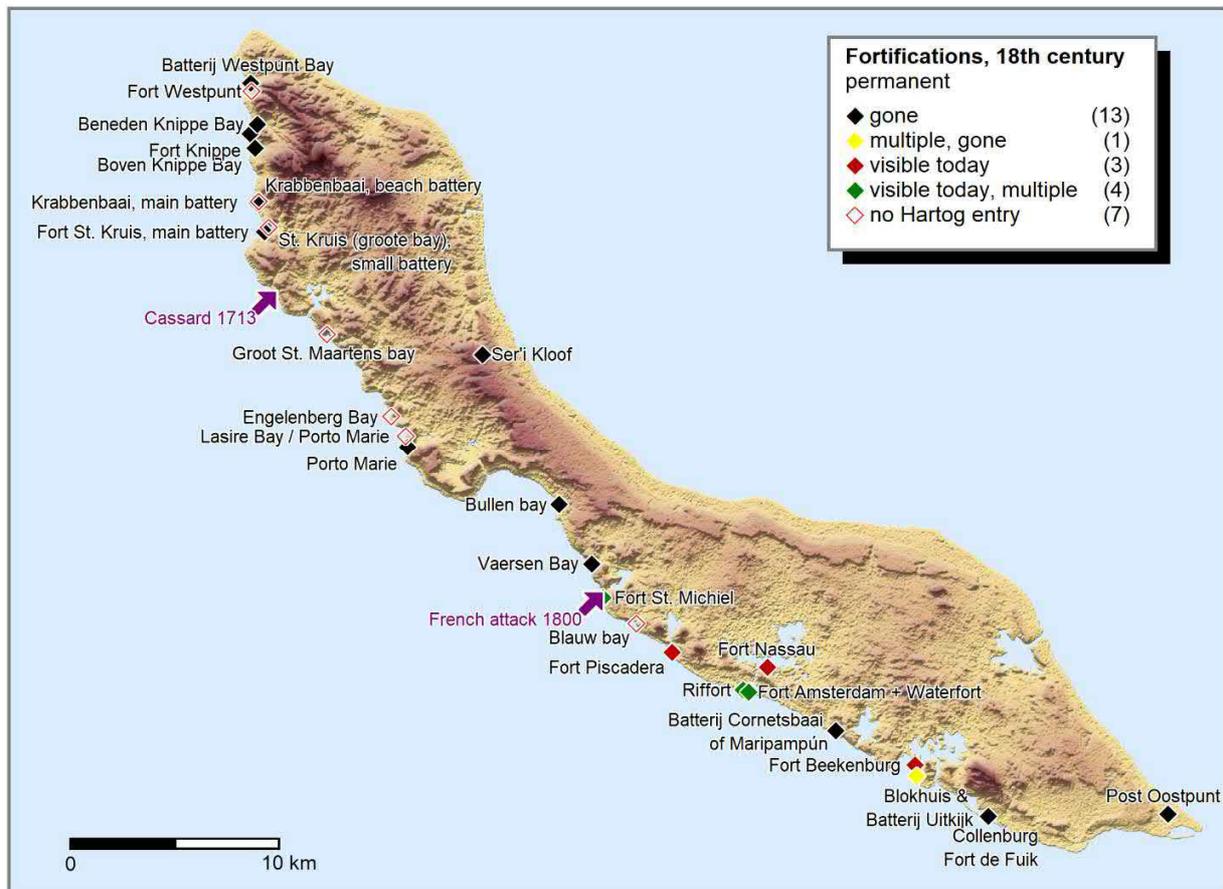


Fig. 14. Distribution map of the 18th century fortifications listed by Hartog (1997). The spots of two French attacks are marked by violet arrows.

MAPPING TEMPORARY FORTRESSES

The historical sources provide information on three locations of temporary fortifications on the island for the years 1713 to 1800. In 1713, more than 500 French soldiers led by Jacques Cassard landed on the island in a very small bay south of Fort St. Kruis known as Spaanse Put [Hartog 1997, pp. 102, 109; Renkema 2016, pp. 180-181; Fig. 14]. The French marched to the outskirts of Willemstad, several battles on their way could not stop them. According to a historical map published by Renkema [2016, p.179], the French invaders set up a temporary battery west of Willemstad and bombed the city. The approximate location of Cassard's mortars is indicated on Fig. 15, the background shows the result of georeferencing a map dated 1912 (also attributed to Werbata) along with some modern data.

Hartog [1997, pp. 116-117] mentions that in this context a temporary battery was put up in the eastern part of Willemstad, in an area known as Fleur de Marie. Based on this place name and Hartog's overview map of fortifications surrounding St. Anna bay, we selected the top of a hill as a probable location for this battery (Fig. 15).

This location was reused in 1800 after another French attack [Hartog 1997, pp. 114-117]. On the 4th of September 1800 the French invaded the island near Fort Sint Michiel and advanced from Fort Blauw to the bay of Piscadera, where they found a number of cannons that were still working properly (Fig. 14). They forced some locals to help them moving the cannons about 3 kilometers to an elevated plateau on the fringe of Willemstad. Protruding rocks protected them against any cannon fire from Fort Nassau. In one night only, 12 to 13 September, the French built a

small fortress with three embrasure apertures, directed to the Willemstad quarters east and west of the St. Anna Bay. The locals coined the name Fort Eennacht (Fort One Night) for this temporary fortress.

Based on the descriptions given by Hartog and the 1912 Werbata map it was possible to reconstruct the approximate location of this temporary fortification. The distance to Fort Amsterdam on the eastern side of the St. Anna Bay located, was approximately 1350 meters (Fig. 14). The French bombed the city during nine days.

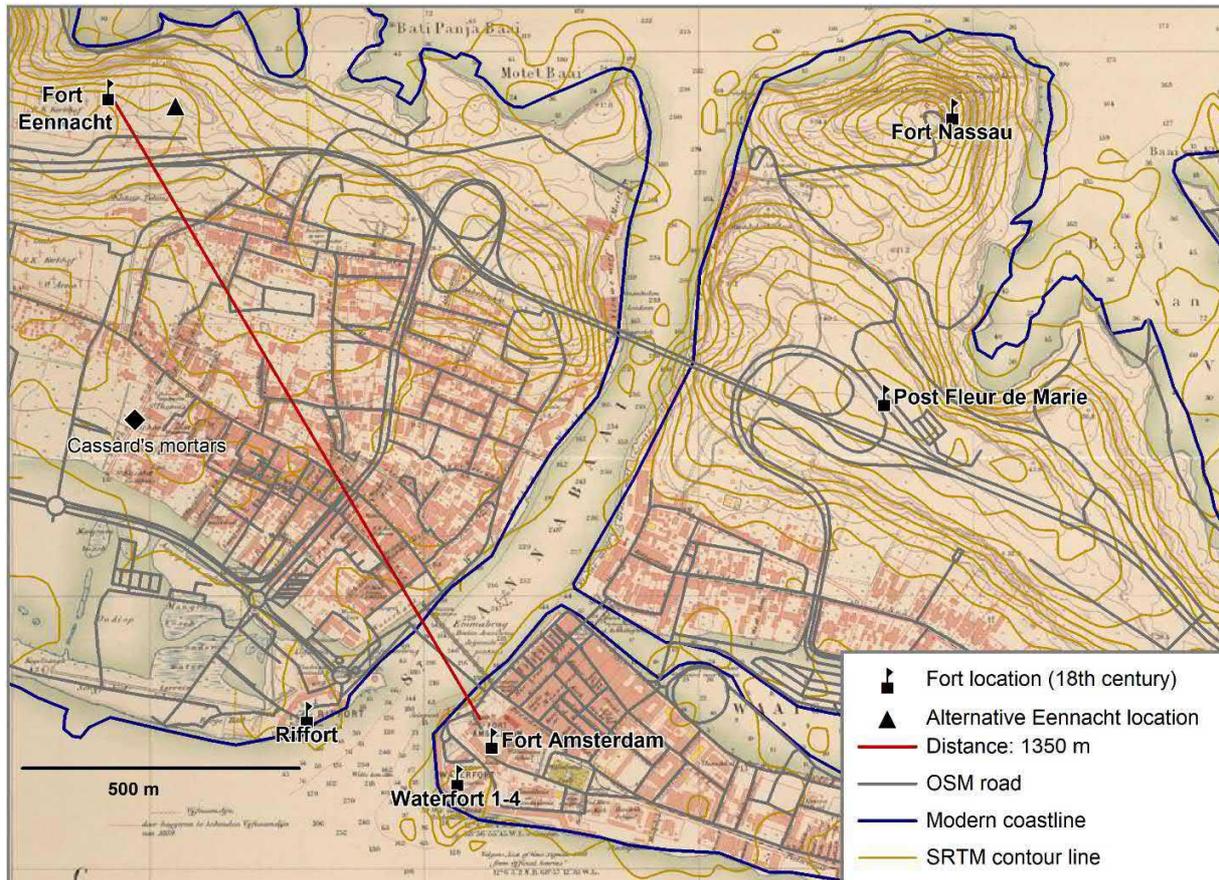


Fig. 15. Approximated locations of fortifications in the Willemstad area that were in operation during a time interval in the period between 1700 and 1801. The historical map in the background is attributed to Werbata (1912) and was georeferenced based on existing fort buildings and the OSM road layer. Unfortunately, the smallest labels are not readable in the scan of this map available in the open access archive (<http://resolver.kb.nl/resolve?urn=urn:gvn:KONB16:41186273>). The modern coastline digitized from Google Earth and the SRTM contour lines with altitude intervals of 5 m allow assessing the georeferencing accuracy and also indicate areas of substantial landscape change.

Governor Lauffer, realizing that the current fortifications were of no use against the cannon fire from Fort Eennacht, immediately started building a bulwark at Fleur de Marie, about half a kilometer south of Fort Nassau. A simple construction only, mainly using cotton bales. It was operational not before the 15th of September because the slaves, who did the actual work, went on strike. On the 23rd of September the fight ended when two American battleships came to the rescue of the island's government. The French fled the island, and Governor Lauffer had both fortifications destroyed.

RESULTS OF THE MAPPING ATTEMPTS

Based on our research, we come to the conclusion that 34 fortress sites were established on the island until 1801. Table 2 lists these fortresses including the sources used for identifying their location and the estimated accuracy of

our mapping. Due to the difficulties in counting fortresses discussed above, some entries in Table 2 are assigned the same Hartog number and for some entries multiple Hartog numbers are listed.

Table 2. List of fortifications constructed until 1801. Dates were taken from Hartog (1997) and converted to numbers (e.g. mid-18th century is converted to 1750) to allow sorting. If the Kreefts report suggested a new location, this is indicated by "n.l."

Hartog no.	Name	first year	last year	accuracy (m)	Sources	Rodier report	Kreefts report
1	Retranchement	1634	1635	50	Hartog 1997, p. 33, map		
2	Wiltschutsburg	1635	1639	100	Hartog 1997, p. 33, map		
3	Het fortje bij Santa Ana/Matancia	1636	0	30	Hartog 1997, p. 33, map		
4,5,6,7 8	1.-4. Waterfort and Batterij Krommelijn	1634	1956	150	Hartog 1997, text p. 35	2 water fortresses	3 water fortresses (main fort), ok
9,10,11	Riffort and predecessors	1701	1928	20	open Street map		
12	Fort Amsterdam	1635	1826	20	open Street map	3 fortresses	
13	Batterij Cornetsbaai of Maripampún	1713	1804	500	Hartog 1997, p. 16		
14	Tolcksburg	1639	1650	300	Hartog 1997, text p. 82		
15,16	Blokhuis & Batterij Uitkijk	1639	1810	500	Hartog 1997, text pp. 83-84; 1754 & 1836 maps	battery (see Beekenburg)	half round battery, to be repaired
17	Fort Beekenburg	1703	1850	10	open Street map	tower, cannon, waterfortress	
18	Collenburg / Fort de Fuik	1713	1805	100	1754 & 1776 map	fortress	half round, breastwork to be repaired
19	Post Oostpunt	1796	1826	1000	Hartog 1997, p. 96, map		3 batteries, under construction?
20	Batterij Westpunt Bay	1750	1822	100	1776 & 1784 maps	?	two batteries
	Fort Westpunt			100	open Street map + 1776 & 1784 maps	fortress	battery
21	Beneden Knippe Bay	1750	1822	100	1784 map	battery	2 entries
21	Boven Knippe Bay, beach, fortifications	1750	1822	100	1784 map		two batteries
21	Fort Knippe	1750	1822	200	1784 map	fortress, three distinct batteries	fort with batteries
22	Fort St. Kruis, main battery	1701	1822	100	1776 & 1784 map	fortress	main fortress
	St. Kruis (groote bay), small battery			80	1784 map		"Baay van het Kruys"? breastwork
	Krabbenbaai, blocked beach (battery)			200	1784 map		battery
23	Krabbenbaai, main battery	1750	1822	200	1784 map	fortress	fortress
24	Ser'i Kloof	1790	0	250	Hartog 1997, p. 105, map + Werbata map		
25	Porto Marie	1750	1822	100	1784 map	fortress	battery, n.l.
26	Bullen bay	1770	0	1000	1784 map	fortress	battery, defective

Hartog no.	Name	first year	last year	accuracy (m)	Sources	Rodier report	Kreefts report
27	Vaersen Bay	1710	1825	150	1784 map	fortress	battery, heavier breastwork required
28	Fort St. Michiel	1701	1816	30	Castle.nl -> Googlemaps	fortress	several batteries, one n.l.?
29	Fort Piscadera	1701	1822	50	Castle.nl -> Googlemaps	fortress	buildings
30	Fort Eennacht	1800	1800	600	Hartog 1997, text p. 116		
31	Post Fleur de Marie	1800	1800	350	Hartog 1997, p. 16		
36	Fort Nassau	1796	1905	30	open Street map		
	Blauw bay	0	0	150	1784 map		two batteries to be repaired
	Engelenberg Bay	1780	0	300	1784 map		breastwork
	Groot St. Maartens bay	0	0	250	1784 map		battery
	Lasire Bay / Porto Marie	0	0	200	1784 map		fortress, defective; n.l.

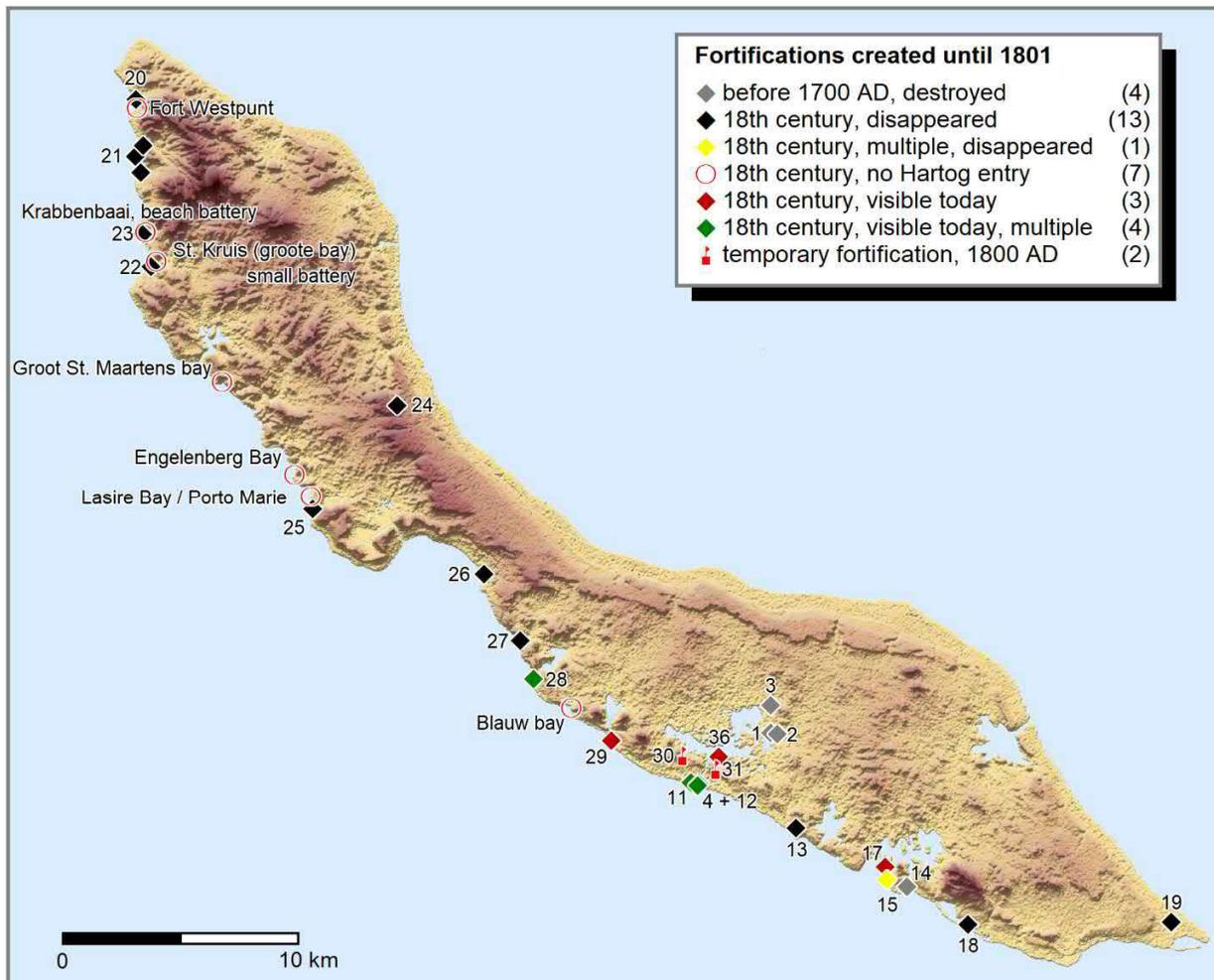


Fig. 16. Map of the fortresses listed in Table 2. Fortification locations mentioned in Hartog's book are labeled by the Hartog number, text labels indicate additional locations of fortifications.

For 21 out of 27 disappeared fortresses, we were able to pinpoint their location with an estimated accuracy of 200 m or less. Fig. 16 shows a map of the fortresses listed in Table 2.

The GIS layer of the probable fort locations was transferred to Google Earth Pro with the aim of checking their vicinity for remains of these features. Some blurred structures were identified that might indicate such remains, but the resolution of the Google Earth images is too low for reliable results.

GIS ANALYSIS BEYOND MAPPING

GIS analysis might assist decreasing the search radius for the site of a disappeared fortification by analyzing location factors. One of the most important location factors for fortifications is a large viewshed covering the area to be defended. The potentials and limits of viewshed calculations [Conolly and Lake 2006, pp. 225-228] for identifying possible fortification locations are illustrated in Fig. 17. The viewsheds shown are based on the SRTM grid projected to a UTM coordinate system, with a cell size of 22 m. The Fort Eennacht viewshed does not include the St. Anna Bay area, and therefore we checked another possible position, about 120 m to the east. The viewshed of this alternative location covers the 18th century settlement area of Willemstad quite well. The results of the viewshed calculations suggest that an alternative Post Fleur de Marie position is north west of the selected location. The position closer to the bay is also closer to Fort Eennacht.

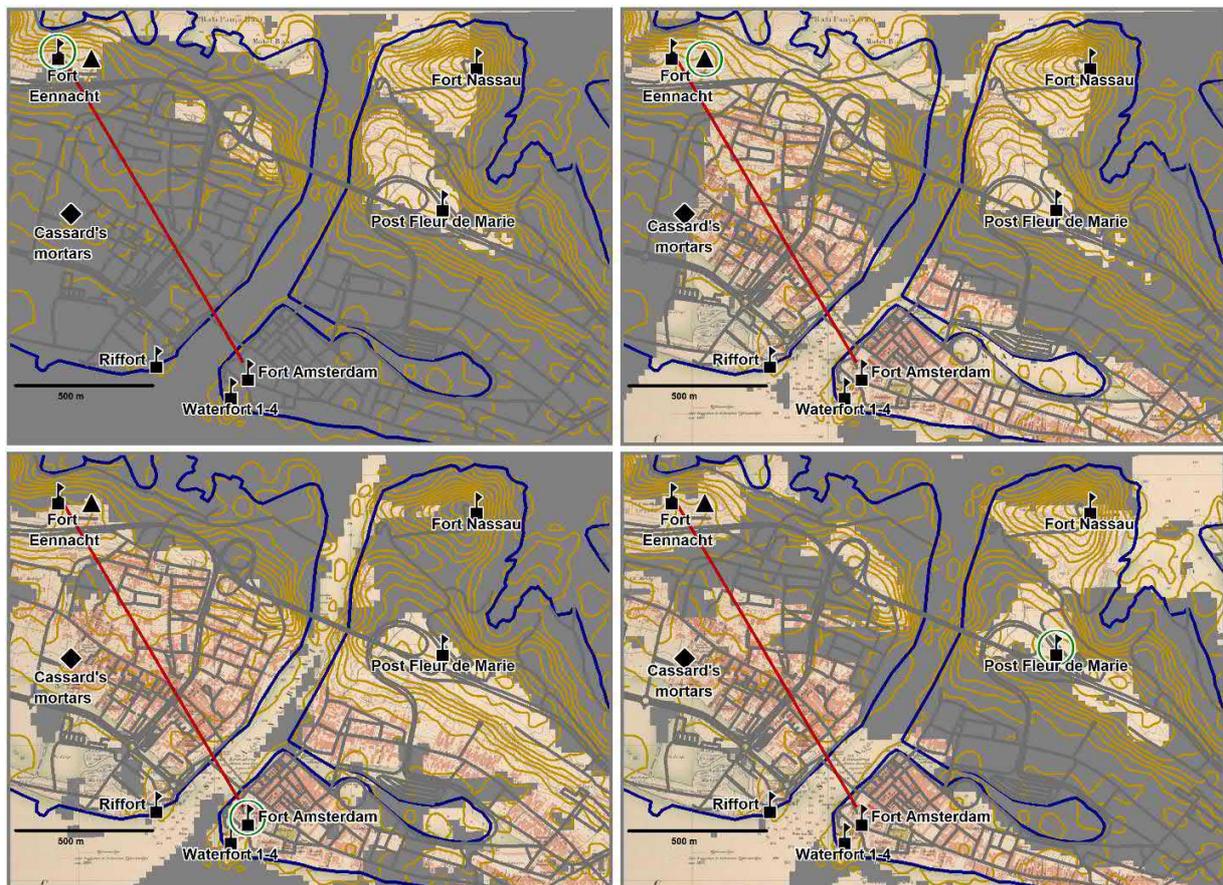


Fig. 17. For the area depicted in Fig. 15, four simple viewsheds were calculated, invisible areas are grey. The viewpoint origin marked by a green circle was assigned a height of 2 m above ground for Fort Eennacht, the alternative position (black triangle), and Post Fleur de Marie, but is 3 m for Fort Amsterdam. The height of the object to be observed was set to 3 m for the two Fort Eennacht alternatives, for the other viewsheds an offset of 2 m was chosen.

Unexpectedly, the Fort Willemstad viewshed includes also the initial Fort Eennacht location. Therefore we have to check the calculations with different software; probabilistic viewsheds would be nice [Conolly and Lake 2006, p. 231]. Substantial landscape modifications during the 20th century in the Willemstad area can be assessed by comparing the modern and the 1912 coast line as well as the contour lines. These changes along with the low resolution of the SRTM data are serious issues that cannot be addressed easily.

We also tried to identify criteria for adequate fortification positions using geographical data: As mentioned above, most fortifications are close to beaches, but prefer steep slopes towards the sea. Steep slopes save the efforts of constructing walls against people coming ashore and the elevated position increases the viewshed and to a minor extent, also the cannon range (see below). The cannon range was important for the effective placement of a fortification and will be discussed in the next section.

CANNONS

The efficiency of a fortification for defending a nearby bay depended on the cannons. Often the same cannons were used on ships and on the island [Hartog 1997, p. 118], but targeting with a stationary cannon is easier, of course.

The number of embrasures, their width, orientation and distance to other structures determined the adequacy of the fortress for an important part. Cannons mounted on carriages were the main weapons used, mortars do not appear on the inventory lists.

The effectivity of the cannon fire depended on a number of parameters [St. Germain 1996]:

- Size of the cannon: there was a variety of sizes, 8 pounders and 12 pounders being the dominant types in the 17th and 18th century.
- Amount of gunpowder used. For bronze cannons, the maximum amount of gunpowder per shot was about a quarter of the shot weight. Using less powder would decrease the range.
- Type of ammunition used: cannon calibres became relatively standardized during the 17th century, and cast-iron spheres, cannonballs, were the standard. But "shells" (hollow projectiles filled with explosives) and "Canister" and "Case" shot (cylinders filled with metal balls) or "Langridge" (loose metal and stones) were effective alternatives.
- Firing angle: at 45 degrees the shot would reach its maximum distance. To point the cannon a quadrant with plummet was used (Fig. 18).
- Height above the target: The elevation has some impact on the cannon range, but the firing angle is more important, so that no construction work was carried out to increase the elevation of the batteries.



Fig. 18. Pointing a cannon with a quadrant and plummet [Ryff and Petrejus 1547]

In the early 17th century, Diego Ufano, a Spanish military engineer, published a treatise on artillery, translated into several languages. From this publication we know that maximum cannon ranges were about 8000 'pas' (2560 m) [Ufano 1613]. More than 70 years later his cannon range tables were still in use (e.g. Blondel 1685). According to Manucy, the maximum distance covered by 18th century cannons was about 1 mile [Manucy 1949]. There are also 19th century military handbooks with information on cannon ranges. For example, a 12 pounds cannon 'Napoleon', shooting at a 5 degree angle, would cover a distance of 1680 yards (1536 meters) [Corgas 1863]. The Artillerist's Manual [Gibbon 1860] mentions comparable data. This allows calculating the initial velocity of the projectile (293 m/sec) using the formula

$$\text{Range} = 2 * v_0 * \sin(\theta) * \cos(\theta) / g$$

in which v_0 is the initial velocity, θ is the firing angle in degrees and g is the gravitational acceleration (9.8 m/sec). This formula results in a range of more than 8 kilometers for a cannon tilt of 45 degrees and a v_0 of 293 m/sec.

So the distance of 1350 meters derived from the historical data for the Fort Eennacht cannons (Fig. 15) falls amply within the physical possibilities. The cannon ranges shown for the fortresses between the "Spaanse Water" in the south and Piscaderis bay in the north on a map created in about 1809 are somewhat smaller, about 1 kilometer [Renkema 2016, p. 332]. Of course, reliably targeting a ship is a different thing than shooting at a densely-populated city. Although the range of cannons was quite considerable, for fixed artillery it was not always the best tactic to go for the maximum distance: waiting until a ship was closer to the shore made the pointing easier, and the possible damage larger. Besides, the ship's artillery (especially pirate ships and privateering ships) was often lighter because its main purpose was to damage other ships, not to sink them. Moreover, a ship suffers more from a shot's recoil than stone fortifications.

COMBINING CANNON RANGES WITH VIEWSHEDS

The previous section showed that a cannon range between 1000 and 1500 meters is realistic. But could a cannon operator at one of the fortresses detect enough detail of an approaching sailing ship at such a distance to decide if this was an enemy vessel? The formula published by Ogburn (2006) provides an answer for human vision without a telescope: The minimum size for an object to be clearly seen and recognized at a distance of 1000 meter is 29 cm, whereas at a distance of 1500 meters, a minimum size of 44 cm results. This means that within this distance range, cannon operators on the island could recognize simple flags. Also the colors of the dresses of the people onboard and the mast(s) might be visible.

Of course, the approaching vessels were visible at a larger distance, mainly the distance to the horizon was the limit. This distance depends on the altitude of the fortifications above sea level. According to the SRTM elevation data, the 18th century fortifications protecting beaches were situated at an altitude of 5.3 to 30.1 meters above sea level, with an average of 10.7 meters. For an altitude of 6.7 meters above sea level (5.3 m + 1.4 m height of the observer's eyes above ground) the distance to the horizon is approximately 9.2 km taking atmospheric refraction into account, according to a formula published in Wikipedia. In the average case (10.7 m + 1.4 m) the distance to the horizon amounts to more than 12.4 kilometers. As mentioned above, most of the fortifications on the island were visible at a distance; no measures were taken to hide them. So the approaching ships could detect them at a similar distance.

Fig. 19 shows the 18th century fortifications and a 1000 m as well as a 1500 m cannon range for each of them. Also the viewsheds within a radius of 1500 m for each fortification are displayed delimiting the area that could be protected by the cannons. In most cases modern beaches were possible locations for anchoring ships in former times, except for some areas that underwent substantial change such as the Bullen bay, where nowadays the harbor of the Curaçao oil terminal is situated. So it is no surprise that today's beaches are mostly within the viewsheds and cannon ranges of the fortresses at the coast. Moreover, the fortifications protected the natural harbors, the main harbor St. Anna bay and also minor harbors such as Fuik bay.

Ser'i Kloof is the only fortification with a large distance to the coast or a natural harbor. The viewshed of this fortress is very small, and this does not change when moving the tentative location within a radius of 250 meters. Hartog (1997, p. 104) assumes that this fortification consisting of two parts was set up to control an important road, so its function differed substantially from those of the beach fortresses.

Another special function is attributed to Fort Oostpunt situated close to the eastern most coast of the island [Hartog 1997, pp. 94-95]. The task of the staff of this fortification was to observe the surrounding coast and inform the

Willemstad military on approaching ships. The intermediate signaling stations were set up later. Unfortunately, our attempts to find a position on the island that (i) roughly agrees with the fort's location on an overview map published by Hartog [1997, p. 96] and (ii) has a large viewshed in eastern direction was not successful. If we trust Hartog's map, the viewshed is very small (Fig. 19). The closest position with a substantial viewshed in eastern direction is about 850 meters to the west of the location indicated by Hartog. This is why the accuracy entry for this fortification is 1000 m in Table 2. However, checking the reliability of the viewshed calculations is an important task for future research.

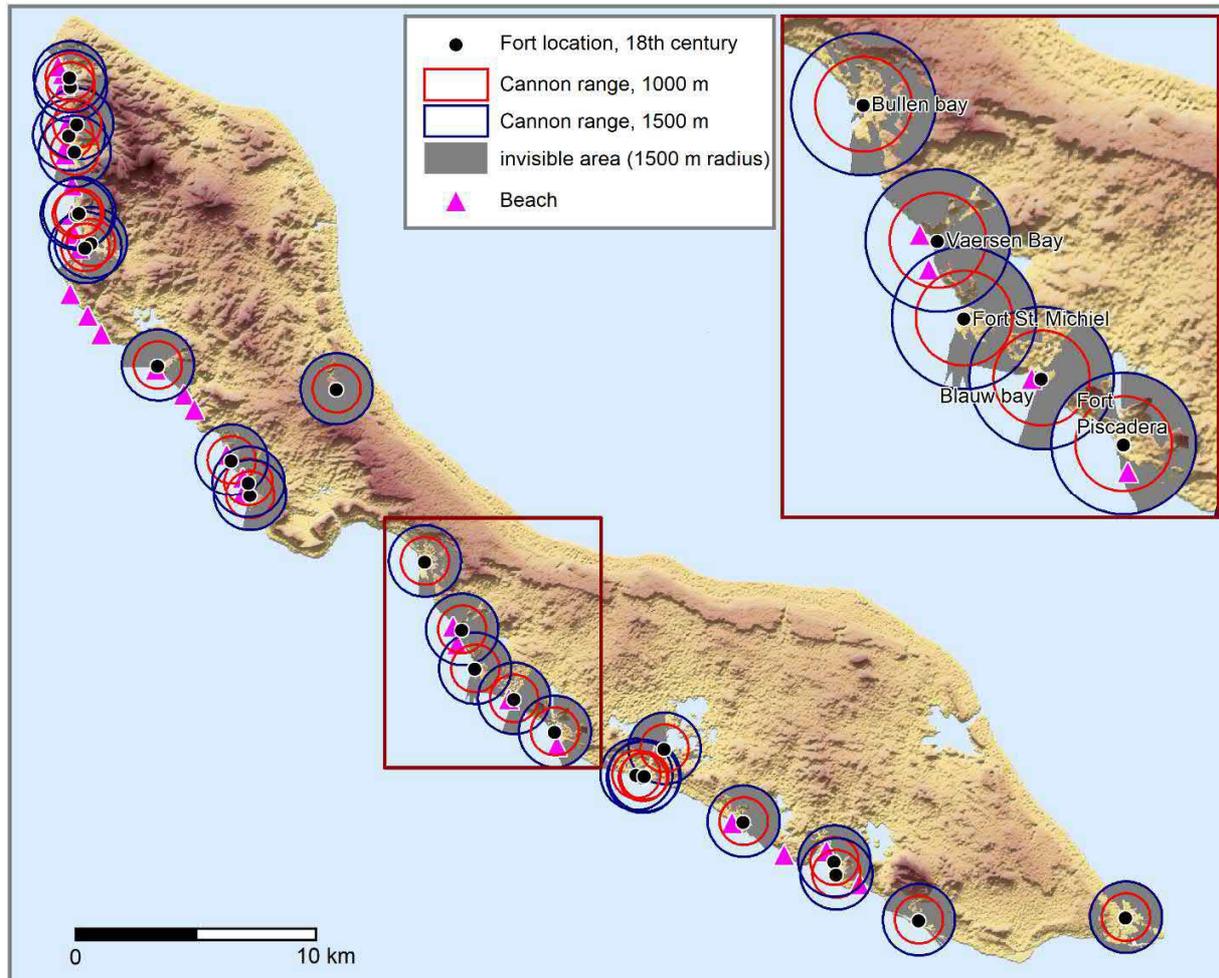


Fig. 19. 18th century fortifications, cannon ranges and visibility within the cannon range.

DISCUSSION AND CONCLUSIONS

In this paper we give a brief overview of our research on the military infrastructure of Curaçao in the late 18th century. And although many historical documents and maps are available it is not easy to reconstruct the exact locations of the fortifications. The coastline of Curaçao is a dynamic entity that changes constantly, and the quality of the historical maps is such, that regular georeferencing is a technique that cannot be used. Moreover, the resolution of the satellite images of Google Earth is not sufficient to detect remains of the forts in the heavy overgrown landscapes. Nevertheless we were able to pinpoint the location of 21 disappeared fortresses with an estimated accuracy of 200 m or less (Table 2).

Approaches to analyze the location factors for the fortifications are presented. To our knowledge, this is the first study combining cannon ranges and viewsheds in a GIS analysis. In future, the research could be extended to include the fresh water resources. For people living on the island, access to fresh water is vital because the island has

a long dry season from January to September. The average temperature throughout the year varies only moderately between a minimum of 25 and a maximum of 31 °C. In the wet season quite some rain may fall, but high temperatures and the never ceasing north-east trade winds cause fairly quick evaporation. Evidence of the importance of access to fresh water is one of the earliest maps drawn by Willem Hondius in 1635 [Renkema 2016, p. 145]. This map includes a detailed legend listing 21 locations, and for 16 of these the absence or presence of fresh or salt water is recorded. The island has no rivers, but Hondius mentions some lakes providing fresh water. Outside the wet season, the drinking water mainly came from water wells, which are susceptible to poisoning and destruction in times of war.

The GIS analysis presented mainly relies on elevation data. Unfortunately, no ALS data is freely available for this island. Due to the resolution of the open access elevation data used in this study, the reliability of the derived fortification location attributes is limited. If it is possible to get hold of the new global DEM data set with a cell size of 12 m, the quality of the GIS analysis results can be improved. Currently, validating our results concerning the locations of disappeared fortifications is only possible by surveys on the island.

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Imprint:

Proceedings of the 22nd International Conference on Cultural Heritage and New Technologies 2017. CHNT 22, 2017 (Vienna 2019). <http://www.chnt.at/proceedings-chnt-22/> ISBN 978-3-200-06160-6

Editor/Publisher: Museen der Stadt Wien – Stadtarchäologie

Editorial Team: Wolfgang Börner, Susanne Uhlirz

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