VOLUME 1

A GIS based framework for historic landscape design analysis as a support for future interventions

a case study of Castle Rosendael, Velp

A GIS based framework for historic landscape design analysis as a support for future interventions: a case study of Castle Rosendael, Velp

L.H.M.A. Joosten

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Supervisors:

Erik de Jong
Culture, Landscape and Nature
University of Amsterdam

Ron van Lammeren
Laboratory of Geo-Information Science and Remote Sensing
Wageningen University

Paul Roncken
Landscape Architecture
Wageningen University

Abstract

A GIS based framework for historic landscape design analysis as a support for future interventions: a case study of Castle Rosendael, Velp

The field of landscape architecture becomes more and more confronted by a research and design task it is thus far poorly equipped to handle: the preservation and continuation of historic landscape designs into the future. A task which becomes increasingly important as many seventeenth, eighteenth and nineteenth century landscape architectural works reach the end of their natural life span and questions of a social kind, tourism, financial remunerability and ecology ever more explicitly call for physical interventions. Existing research on the topic is however scattered, commonly has a random character, is often not scientifically grounded and is troubled by a poor integration of (historical) research and design. This research is an attempt to contribute to this challenge by exploring and testing the use of Geographic Information Systems (GIS) both as an instrument to research historical landscape designs and as a supportive framework for the integration of historical analysis and landscape design using the case of Castle Rosendael, Velp, the Netherlands. Central to it was the setting up of a historical geo-database, which collects all spatial information, modern and historical, into a GIS. With the help of this system, following an extended and adapted version of the historical framework methodology, the object itself was researched and suggestions were given to retain and strengthen the landscape's cultural significance. The methodologically constructed geo-database added to the transparency and credibility of the research results obtained by various GIS operations, which in their turn helped to integrate and visualise the site's morphological composition and the changes therein. By offering an unbiased platform for discussion GIS is furthermore likely to facilitate social negotiation between research and design.

Keywords: geographic information systems, landscape architecture, historic landscape, cultural heritage, preservation, design

Preface

This booklet is volume 1 of 2 of my Master thesis project landscape architecture. It is the result of an explorative study on the use of Geo-Information Systems (GIS) to study historical landscape designs and to facilitate the generation of management, maintenance and development measures to sustain them into the future.

The thesis is spread over two volumes to allow the reader to comprehend text — this booklet — and image — mainly booklet 2 — simultaneously and to stress the equivalence of image and text as the results of this study.

The combination of historical landscapes, GIS and landscape architecture studied in this thesis originates from my fascination for historical landscape designs and the complex problems they face today, my indignation over the way their generally handled, and my interest in the use of analytical techniques outside the traditional realm of landscape architecture. My interdisciplinary team of supervisors was selected accordingly.

My thanks first of all go to my tutors Erik de Jong (University of Amsterdam), Ron van Lammeren (Wageningen University) and Paul Ronken (Wageningen University) for their invaluable criticism, inspiration and help. I also thank Ronald van Soest for writing me a small computer program.

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I

Introduction

Garden, park and landscape are places of change (Schmidt, 2006; Sigel et al., 2006). On the one hand radical changes fuelled by stylistic, socio-political and technological innovations, on the other hand gradual and small changes by the inherent growth of plants and its continuous maintenance (e.g. Sigel et al., 2006). The present landscape is the result of all these changes and as such contains the complex historical traces of its development (Corboz, 1983; Scazzosi, 1993a). Preserving these traces, whilst facilitating the living, process-based character of gardens, parks and landscapes is currently the task of green heritage conservation (ICOMOS, 1964; 1981; Schmidt, 2006).

In the near future, however, this task might shift in the direction of the landscape architect if the recent and thus far controversial philosophy to embrace green heritage's continuous process of change and to consider its essential characteristic and continuable force continues to gain prominence within the field of heritage conservation (Sigel et al., 2006). According this philosophy it is an illusion to take garden, park or landscape out of time, to freeze it, by separating past from present and future (Scazzosi, 1993b; Kolen, 2007). Instead green heritage should be considered as opera aperta — work that is never finished (Scazzosi, 1993b). For the practice of green heritage conservation this implies that besides conserving the existing historic fabric it also has to think about suitable future-oriented solutions to steer and continue this force (Schmidt, 2006). Herewith, it moves onto the terrain of the landscape architect, who, although this task was already pointed to the 1990s (Baljon, 1992; De Jong, 1997), sees himself challenged by a barely explored research and design task.

This task becomes increasingly important as many seventeenth, eighteenth and nineteenth century landscape architectural works reach the end of their natural life span and questions of a social kind, tourism, financial remunerability and ecology ever more explicitly call for physical interventions (Hennebo, 1985; De Jong, 1993; Ruyten, 2005; De Jong, 2006). Witnessing the recent increase in research and design projects considering the green heritage (e.g. H+N+S and Karres and Brands recently embarked on the research and design of Estate Windesheim (Zwolle) and Trompenburg (Rotterdam), respectively), already more and more landscape architects and landscape architectural bureaus seem to lay this task to heart.

If landscape architecture, however, wants to integrate this task into its curriculum it will have to study the cultural- and design history of garden, park and landscape more deeply: continuity in the landscape can after all only be achieved by an understanding of what preceded (De Jong, 2005). Such research would not only offer an enormous amount of information that is particularly important for future cultural-historical preservation and design, but might also help in solving present-day spatial issues by distilling and reconsidering design-principles from past practice (De Jong, 1993). Research into the existence, the development, the historical and the planological significance of green heritage is, however, by far common in the Netherlands (De Jong, 2005). Existing research is fragmented, commonly has a random character, is often not scientifically grounded (De Jong, 2009) and is troubled by a poor integration of (historical) research and design (e.g. Bosma and Kolen, 2010).

This thesis wants to contribute to this research and design challenge by developing and testing an analytical framework that produces credible, transparent and reproducible information and thereby aids historical research and the integration of research and design to sustain historic gardens, parks and landscapes into the future. Starting point for this research is the hypothesis that a Geo-Information System (GIS) is the appropriate instrument to achieve so as it is able to archive, combine, analyse and visualise all different kinds of spatial information in a scientifically sound, exchangeable and easy to update framework (Knowles, 2002; Gregory, 2003; Gregory and Ell, 2007; Gregory and Healy, 2007; Longley et al., 2011) and is proven to facilitate social negotiation (e.g. Harvey and Chrisman, 1996). In addition, GIS might produce new results and insights compared to more traditional landscape architectonic research techniques as it offers a suit of new analytical possibilities and instruments (Nijhuis, 2011).

And although GIS is increasingly applied in for the historic research of landscape change at the wider landscape scale (Knowles, 2002; Ardissone and Rinaudo, 2005; Madry, 2006; Gregory and Ell, 2007; Gregory and Healy, 2007; Heere, 2008) and very limited also for the analyses of architecture (e.g. Batty, 2001), landscape (e.g. Weitkamp, 2010) and the designed landscape (Nijhuis, 2011) at the larger scale, we face here a barely explored research domain. A domain which I will further explore with using the case of Estate Rosendael.

The study area: Castle Rosendael, Velp

Geological and topographical setting

Castle Rosendael is located in the Veluwezoom, a transition zone between the Veluwe and the rivers IJssel and Rijn (Figure 1.1). Its main fysical landscape structure is shaped during the Saalien, when the progressing land ice pushed the older river deposits up to heights 100 meters above sea level; and during the Weichselien, when an interplay of melting water streams and gelifluction shaped several valleys intersecting these ice-pushed ridges, the so-called dry valleys (Dutch: droogdalen) (Berendsen, 2005). Characteristic for these valleys is their asymmetrical shape with relative steep west-facing slopes and flatter east-facing slopes due to differential permafrost thawing. During the second, drier and colder part of the Weichselien this effect was further strengthened by the partial infill of the valleys by fine aeolian deposits (i.e. loss) with thicker deposits at the western hill sides (lee side) and at the lower valley parts (Berendsen, 2005). The valley bottoms are moist till wet and seepage is common; water is generally drained off by a brook. Castle Rosendael and its park are situated within a classic example of such a valley, drained by the Rozendaelse Beek (Figure 1.2).

Origins of the designed landscape

Rosendael's history dates back to the fourteenth century when Reinald I, count of Gelre, choose to build his castle within the dry valley. For its defence it was surrounded by an artificially impounded moat, supplied with water from several, possible pre-existing, oozing wells (Dutch: sprengen). Few generations later, under Reinald IV (circa 1404), additional ponds were dug and even a fountain would have been installed (Van Hasselt, 1808). These were also fed by the seepage water attained from the oozing wells and served a defensive as well as an economic function with a double-use as mill and fish-pond.
Further information on the landscape is sparse until 1667 when Jan van Arnhem (1632-1721) started the construction of his garden. It is however likely that the site's general out-

line shaped by a sequence of ponds and a structure of avenues already existed (Bierens de Haan, 1994).
Jan van Arnhem, counsellor and friend of King-Stadholder Willem III, included the existing mill ponds (propelling seven watermills!) into the larger garden layout and over a period of fifty years restlessly improved the gardens with waterworks, parterres and other garden ornaments (Bierens de Haan, 1994).
The Van Arnhem's died without issue and their nephew Lubbert Adolf Torck inherited Rosendael in 1721 (Bierens de Haan, 1994). As a worthy successor he spared neither expense nor trouble and embarked on a radical renovation and modernisation of house and garden. Very likely he charged Daniel Marot with the garden works (Bierens de Haan, 1994). Marot left the basic lines lain out by Van Arnhem in principal form unaltered, but changed its content drastically: new parterres, a maize and several garden ornaments were added resulting in a rather complex, rich and surprising whole. The still extant shell gallery, the trick fountains (Dutch: Bedriegertjes), the summerhouse, and the cascade with river gods date from this period (Bierens de Haan, 1994)(check Figure 1.2 for all toponyms).
Torkck's successor, his nephew Assueer Jan Torck (1764-1793) heralded a quieter period that lasted until Assueer Lubbert Adolph Torck (1830-1843) drastically modernised the park. Assueer charged few minor changes that involved the modernisation of some garden elements in landscape style by the Stadholder's architect Philip Willem Schonck (1735-ca.1823)(Bierens de Haan, 1994). Also his son Reinard J.C. Torck (1793-1830) changed little, even although his diaries point at a clear interest in gardens in general and in the new garden taste in particular. Their changes left the main garden structure untouched.
The next generation imposed drastic changes. A.L.A. Torck considered the garden old-fashioned and metamorphosed it by the hand of Jan David Zocher the Younger (1791-1870) into the landscape style it now stands in (Bierens de Haan, 1994). Zocher preserved some of the eighteenth century garden ornaments, but otherwise changed the layout drastically. The six polygonal ponds were remodelled in three ponds with fluent contours; winding paths were constructed; the former parterres were transformed in rolling grass fields; and an orangery and, just outside the park, a school and inn were built.
In the second half of the nineteenth century, successors Ada C. Torck and Reinhard J.C. Van Pallandt (1843-1902) made further alterations and issued garden architect Dirk Wattez (1833-1906) for the construction of the now disappeared English Garden; the planting of several exotic tree species; and the reorganisation of the Koningsberg and its surroundings. Their son Frederick Jacob Willem van Pallandt (1860-1932) and his wife Constantina Alexine Loudon (1859-1948) were the last to put their mark on castle and garden. A few years after Van Pallandt moved in he added a rose garden to the park (circa 1904). The garden was situated between castle, orangery and drive and was probably designed by himself and his head gardener Schreurs (Bierens de Haan, 1994). In front of the shell gallery also a pattern of flowers was reinstated.
During the Second World War house, orangery and garden became heavily damaged. The last heir Willem Frederik Torck van Pallandt (1892-1977) restored the castle and the damaged shell gallery (1972).
After his death house and park, including the Koningsberg, were assigned to the Stichting Het Gelderslandschap (1978). In the following years Gelders Landschap restored the gardens: arrears of maintenance were cleared, water ways were restored and ponds were cleaned; both the rose garden (1985) and the orangery (1990) were reconstructed. Res-

toration activities continued with the shell cave and the Bedreigertjes (1995); the latter's planting (1997); the orchard was reconstructed (2003); and finally also Marot's pavilion was restored (Figure 1.3).

Policy framework and legal status

Rosendael is considered to be of national cultural-historic interest and is therefore designated the statutory status of national monument. According the governmental department of cultural heritage, RCE, Rosendael earns this status for (RCE, 2011):

- the very high quality layout and architecture of all its parts and their mutual relationships
- being a clear example of an estate with a pronounced historic layering in which both the formal and landscape style are represented and conserved.
- the large influence of this complex on the layout of other Dutch estates in the seventeenth, eighteenth and nineteenth century
- its uniqueness as an estate with a several waterworks propelled by naturally flowing water
- being part of Zocher the Younger and Wattez' oeuvre
- its unimpaired status
- its age
- its aesthetic value

Apart from being protected as an ensemble ('complex historische buitenplaats' Rosendael, complex number 528473), 21 individual parts (monument numbers: 528472, 528474, 528475, 528476, 528477, 528478, 528479, 528480, 528481, 528483, 528484, 528485, 528486, 528487, 528488, 528489, 528490, 528491, 528492, 528493, 528494) are also protected as national monuments in their own right. This protection entails that for every change to the monument a permit is to be requested.

For part of Rosendael also the Natuurschoon wet 1928 (NSW) is still valid. Note that the NSW is a tax regulation and not a protective law.

Besides its cultural-historic values Rosendael also represents important ecological values. The total terrain, including the Koningsbergs, is part of the Ecological Main Structure (EHS) and Natura 2000, represented by the habitat-directive (Veluwe) and the birds-directive (Veluwe), the latter is not operative for the Koningsberg (Provincie Gelderland, 2012). The goal of the EHS is to protect, connect and develop nature areas in order to turn the decline of nature and biodiversity in the Netherlands.

Thesis outline

The text in this volume is structured as follows. The second chapter describes the procedures followed for setting up of a historical GIS (HGIS) aimed at the analysis of landscape designs using the Rosendael case; its resulting geo-database is provided on DVD. The third chapter introduces the GIS based historical framework model for the analysis and evaluation of historical landscape designs and practically executes it for Rosendael. All inventorying and analytical imagery of this chapter are presented in volume 2 of this thesis. Chapter four lists the main conclusions and discusses them.

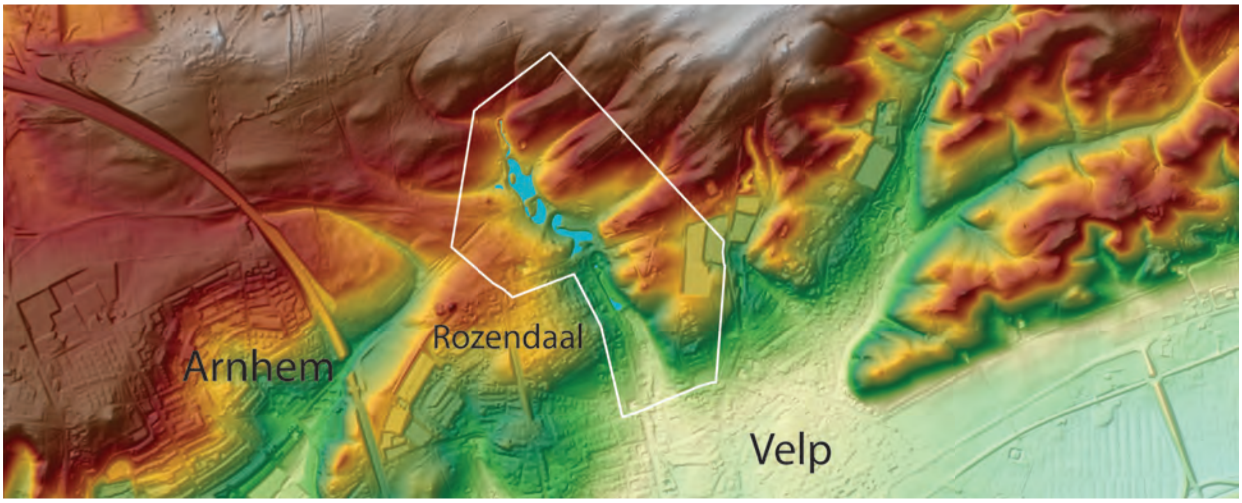

Figure 1.1 Rosendael's landscape context.

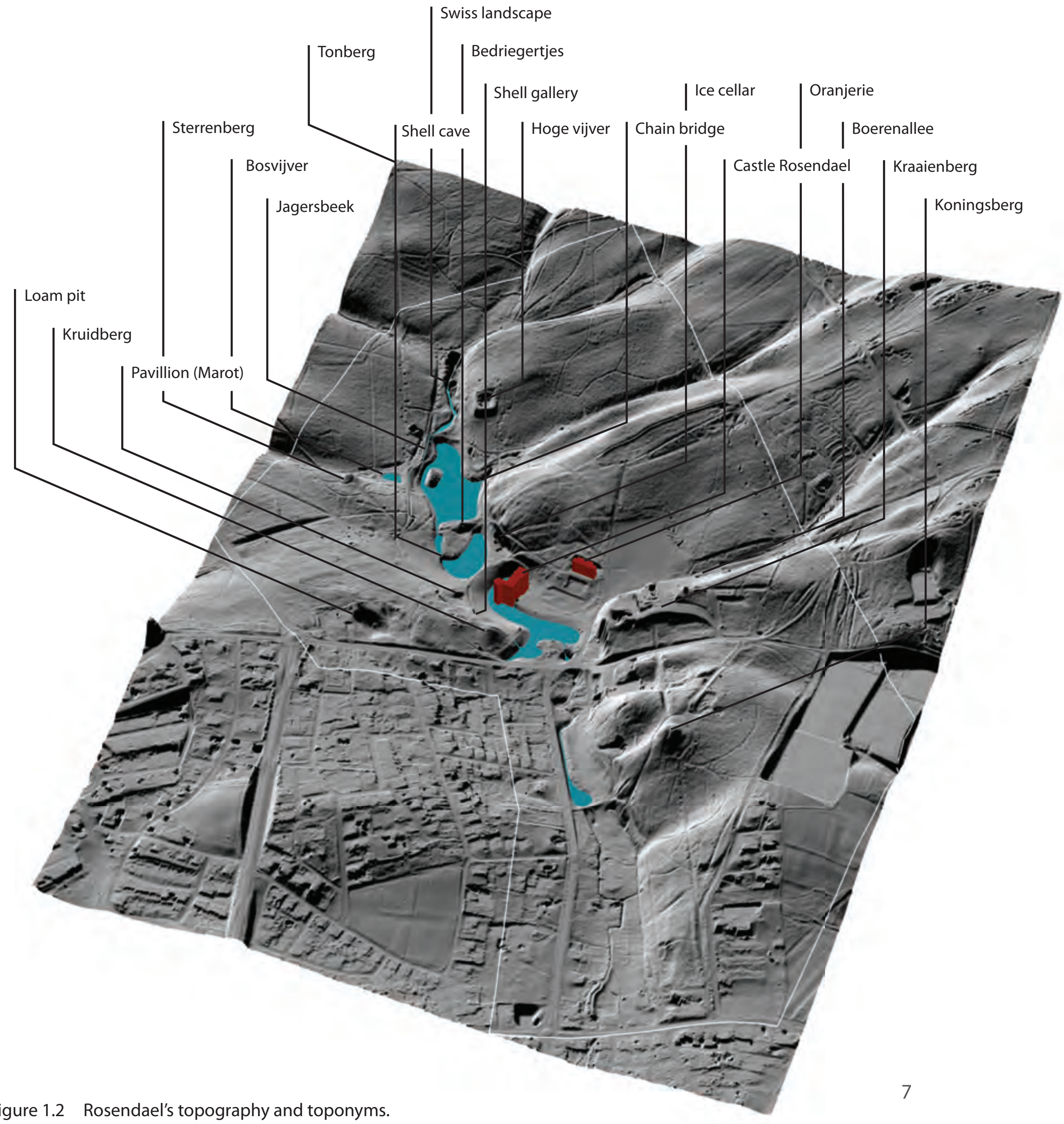

Figure 1.2 Rosendael's topography and toponyms.

Figure 1.3 Map of Rosendael 2011

II

Setting up a GIS for historic design analysis

This second chapter literally sets the stage for the chapters that follow. It describes the construction of a basic historic geographic information system (GIS) and as such forms the basis for all work in the remainder of this thesis. The work presented below can be regarded as a basic methodological template for the construction of a historical design geo-database.
The text is structured as follows. First, all basic data, modern and historic, are described briefly (section 2.1). Secondly, the incorporation of these data in a GIS is discussed in section 2.2. Thirdly, the temporal aspect and its incorporation in a GIS are elaborated (section 2.3) and section 2.4 , finally, discusses how data quality and uncertainty are dealt with.
All basic data discussed here are recorded on the accompanying DVD; copies of the original historical data are also presented as an integral part of this text.

2.1 THE DATA

This section briefly describes the basic data that were used during this thesis. First the modern data are described, thereafter the historical data.

2.1.1 Modern data

This section lists the modern data used in the GIS.

Vector data

- Topographical data (TOP10NL), version 2010, 1:10 000
  The TOP10NL is currently the most detailed and up to date topographical dataset available for the Netherlands. The data model is based on aerial photography, field surveys and existing cartographic information and covers all general topographical categories.
- Geomorphological map (Geomorfologische Kaart Nederland (GKN)), version 2008, 1: 50 000
  Nationwide digital file displaying the Dutch geomorphology. Most map sections are updated versions of the original paper geomorphological maps made between 1960 and 1990. For the study area's largest extent the map contains 22 geomorphological classes.
- Soil and groundwater map (Bodem- en grondwatertrapkaart (BodGwt)), version 2006, 1:50 000
  Digital survey showing the soil and groundwater units' spatial patterns and variations within. The map sections are generally updated, digital versions of the analogue soil maps from the 1980s. The map distinguishes 16 soil classes for the total study area.

Raster data

- High resolution aerial picture, version 2010, 0.4m resolution
  Highly detailed and up to date airborne aerial pictures of the Netherlands.
- Digital Elevation Model (Actueel Hoogtebestand Nederland (AHN2)), version 2011, 0.5m resolution

Raster file representing continuous elevation values over the area's topographic surface. The AHN's height values are collected by LiDAR (light detection and ranging), filtered and interpolated to construct the very detailed 0.5m resolution height file.

2.1.2 Historical data

Below the historical maps depicting Castle Rosendael and its immediate surroundings are briefly described and discussed in chronological order. Considering my limitions in time and the purpose of this study the inclusion of historic data is restrained to those materials that depict garden and park in detail. For future purposes other smaller scale data such the Kaart van de IJssellinie (1783) by Herman van Hoof; the Topografische kaart van de Veluwe en Veluwezoom (1810) by Maximiliaan Jacob de Man; and the Dutch sequence of (chromo) topographical maps (±1850, ±1910, 1927/31, 1953/58, 1964/66, 1969/72, 1974/77, 1980/85, 1987/90) might be added. Most of the data were already digitally available, only the designs by Wattez were scanned by the author using a common flat-bed scanner at 300 dots per square inch (dpi).

- 'Platte Grond van de Heerlykheyt van Roosendaal buyten Arnhem' by Jan Smit after Berend Elshof, circa 1718, 51.5·58.5cm, ±1:240, 75dpi (Figure 2.1)
  The first surviving map that depicts the total of castle, gardens and park (including part of the Koningsberg) is an engraving in oblique projection by Jan Smit I (ca. 1663 — after 1719) or Jan Smit II (worked between 1713 and 1748) after an initial drawing (probably made between 1702 and 1713) by land surveyor Berend Elshof (Bierens de Haan, 1994). This engraving, together with the images of Schenk and a prosaic description by d'Outrein, give a good topographical description of the garden at the beginning of the eighteenth century.
  The engraving can likely be considered to be a documenting plan (Seiler, 1985), which was often made after the closure of a construction phase to 'portray' the finished garden. The plan is well detailed and even depicts the partly invisible water supply system. Since the work is based on a land survey by Elshof, it can be considered relatively accurate, although possible manipulations of the image for drawing technical or artistic reasons should not be excluded. I, however, did not found clear evidence for that.
- Map of Rosendael's gardens, probably by Daniel Marot, circa 1722, 65·106cm, ±1:840, 600dpi (Figure 2.2)
  Although Elshof made two overview maps of Rosendael (*Geometrise caart van de vrije Heerlijkheijd Roosendael* (1721) and *Geometrise caart van de Rosendaelse Plantagie* (1723)) there is only one plan, known from a photograph, that depicts the central part of garden and park in detail; the original's abode is unfortunately unknown. The plan, probably a design, is unsigned, but can likely be ascribed to the prominent French engraver and designer Daniel Marot (1661-1752) as payments and drawings confirm his involvement at Rosendael during that period and because the design's style corresponds to some of his other works (Huis ten Bosch and Meer en Berg, both not executed) (Bierens de Haan, 1994).
  The map is almost as detailed as the Smit/Elshof map, it, however, lacks a legend. It is unknown on what measurements the plan is based or what map underlay may have been used. The maps medium is regrettably damaged, folded and wavy.
- Minuutplan sectie C, Rosendael (land registration plan), 1817, ??·??cm, ±1:2900, 300dpi (Figure 2.3)

The Minuutplan Rosendael only records buildings, main roads and water structures; other landscape features are not depicted. The plan, nonetheless, offers the possibilty to orientate otherwise non-orientable plans, especially because of its reliability and accuracy (Seiler, 1985; Benavides and Koster, 2006).

- 'Park behorende bij het huis Rosendaal' (Park belonging to Rosendael) by Jan David Zocher jr., 1836, 88.2·63.2cm, ±1:1800, 240dpi (Figure 2.4)
  The plan Zocher jr. drew for the transformation of park Rosendael should rather be considered a design concept than a design drawing/blue print (Bierens de Haan, 1994). Few of his proposals are carried through as drawn and overall the park's transformation is executed much less radically then Zocher envisioned.
  The map's original is well preserved and in good overall condition. It is not known on what measurements or earlier maps the drawing was based.
- Design for the re-organisation of the Koningsberg ascribed to Dirk Wattez, circa 1874, 115.4·67cm, ±1:3700, 300dpi (Figure 2.5)
  The plan Wattez made for the re-organisation of the Koningsberg considers the Koningsberg itself as well as the parcelling of the land along the Rozendaelselaan and the Ringallee. The plan is likely a design and is partly executed as such.
  The water-colour is well preserved. Also for this map it is not known based on what measurements or earlier maps the plan was made.
- Design for the re-organisation of the park between the Bedriegertjes and the Sterrenberg ascribed to Dirk Wattez, circa 1875, 71·54cm, ±1:2200, 300dpi (Figure 2.6)
  Wattez also made a design for the area between the Bedriegertjes and the Sterrenberg. From this design only the 'English garden', between the Bedriegertjes and the small cascade with shell cave, was constructed. The maps is well preserved; its geometric origins are again not known.

2.2 INCORPORATING HISTORICAL DATA IN A GIS

Whereas the modern data are ready to use in a GIS environment, the historic data require two additional steps to be incorporated: geo-referencing and digitising.

2.2.1 Geo-referencing

Geo-referencing is the process in which the coordinates from a known reference system are assigned to the page coordinates of the scanned maps in order to bring them in accordance with the real-world (Knowles, 2002; Longley et al., 2011). This is done by applying a suitable geometric transformation to a set of homologous points, or control points (CPs) which originate from the scanned maps and a modern reference map, or known xy-coordinates (Balletti, 2006; Jenny and Hurni, 2011). The geometric transformations use the control points to register, i.e. interpolate, the historic map with the coordinate system of the reference map (Jenny and Hurni, 2011). The choice for the kind of geometric transformation depends on the expected characteristics and deformations of the considered map and on the ability to identify control points. In what follows these three crucial steps, (i) the modern reference map; (ii) the selection of control points; and (iii) the choice for a suitable geometric transformation, are discussed in more detail.

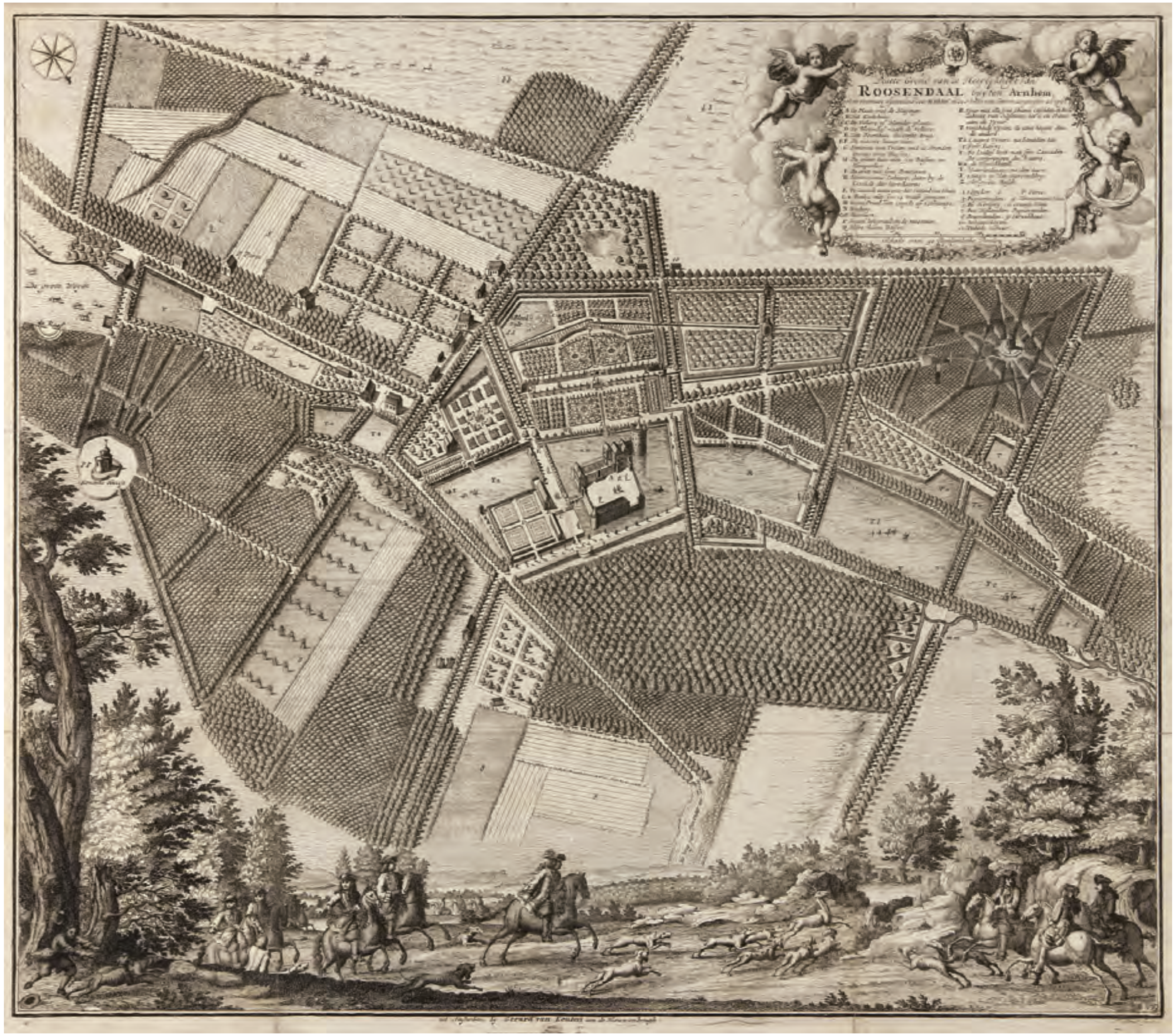

Figure 2.1 'Platte Grond van de Heerlykheyt van Roosendaal buyten Arnhem' by Jan Smit after Berend Elshof, circa 1718

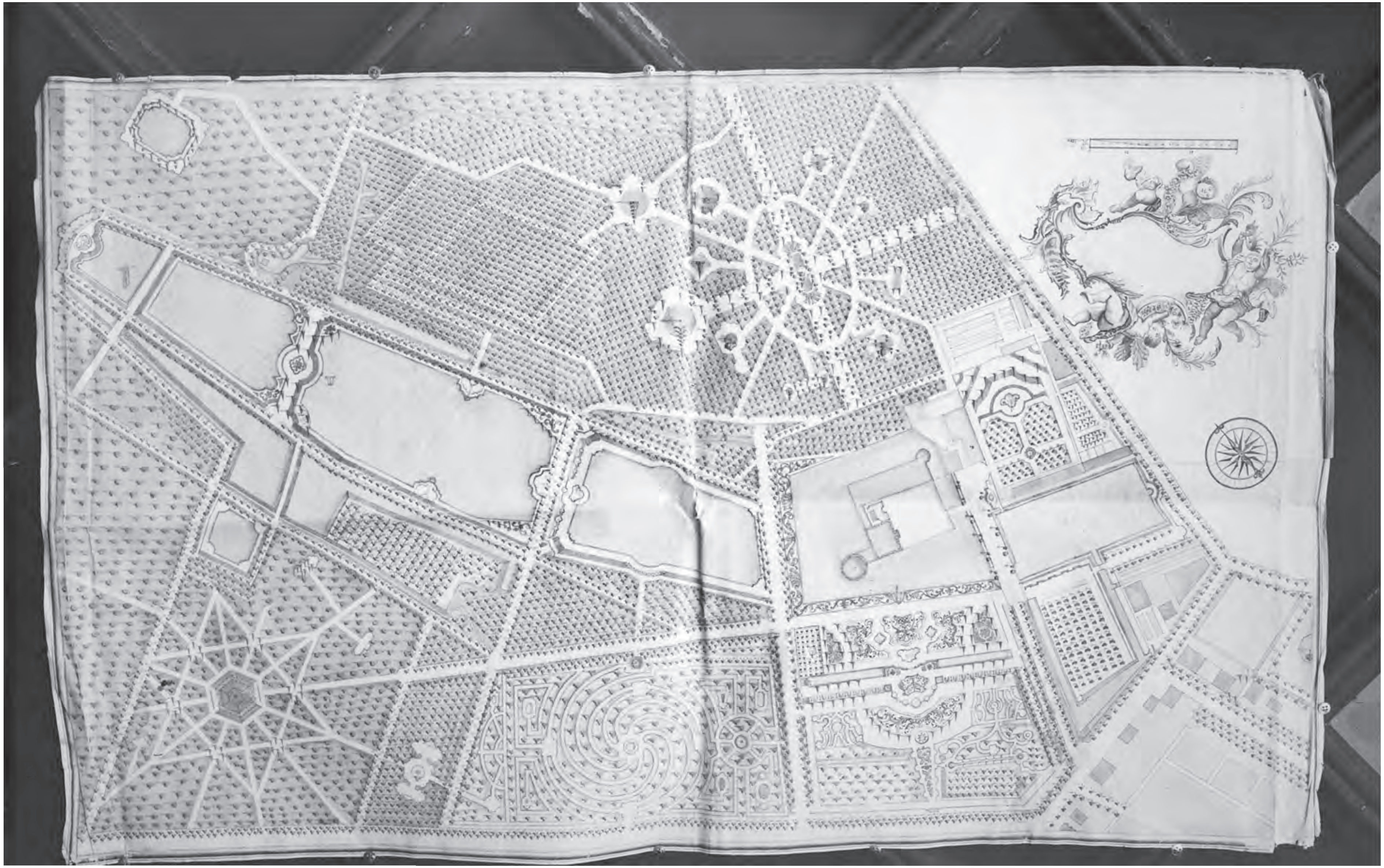

Figure 2.2 Map of Rosendael's gardens, probably by Daniel Marot, circa 1722

Figure 2.3 Minuutplan sectie C, Rosendael (land registration plan), 1817

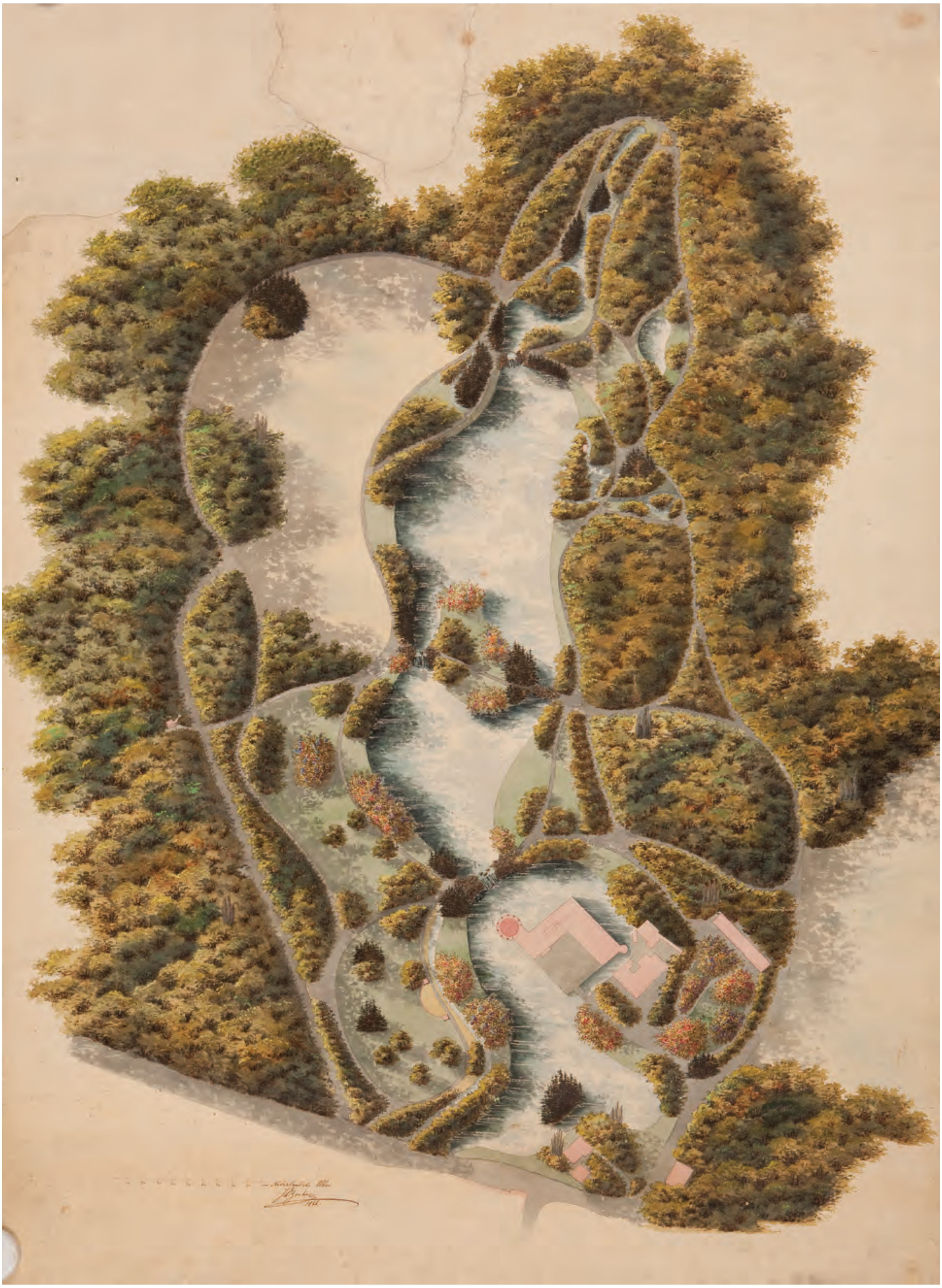

Figure 2.4 'Park behorende bij het huis Rosendaal' (Park belonging to Rosendael) by Jan David Zocher jr., 1836

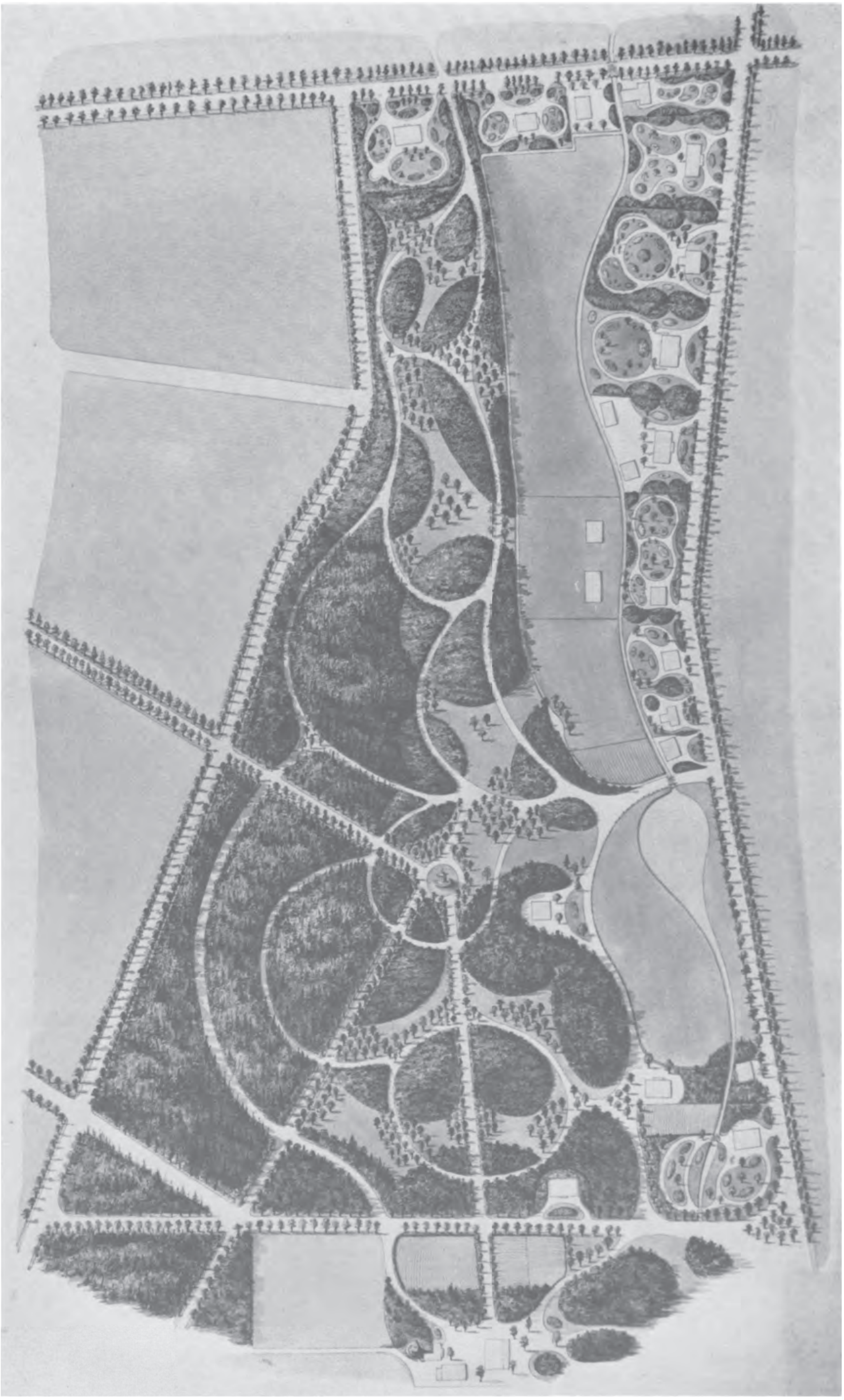

Figure 2.5 Design for the re-organisation of the Koningsberg ascribed to Dirk Wattez, circa 1874

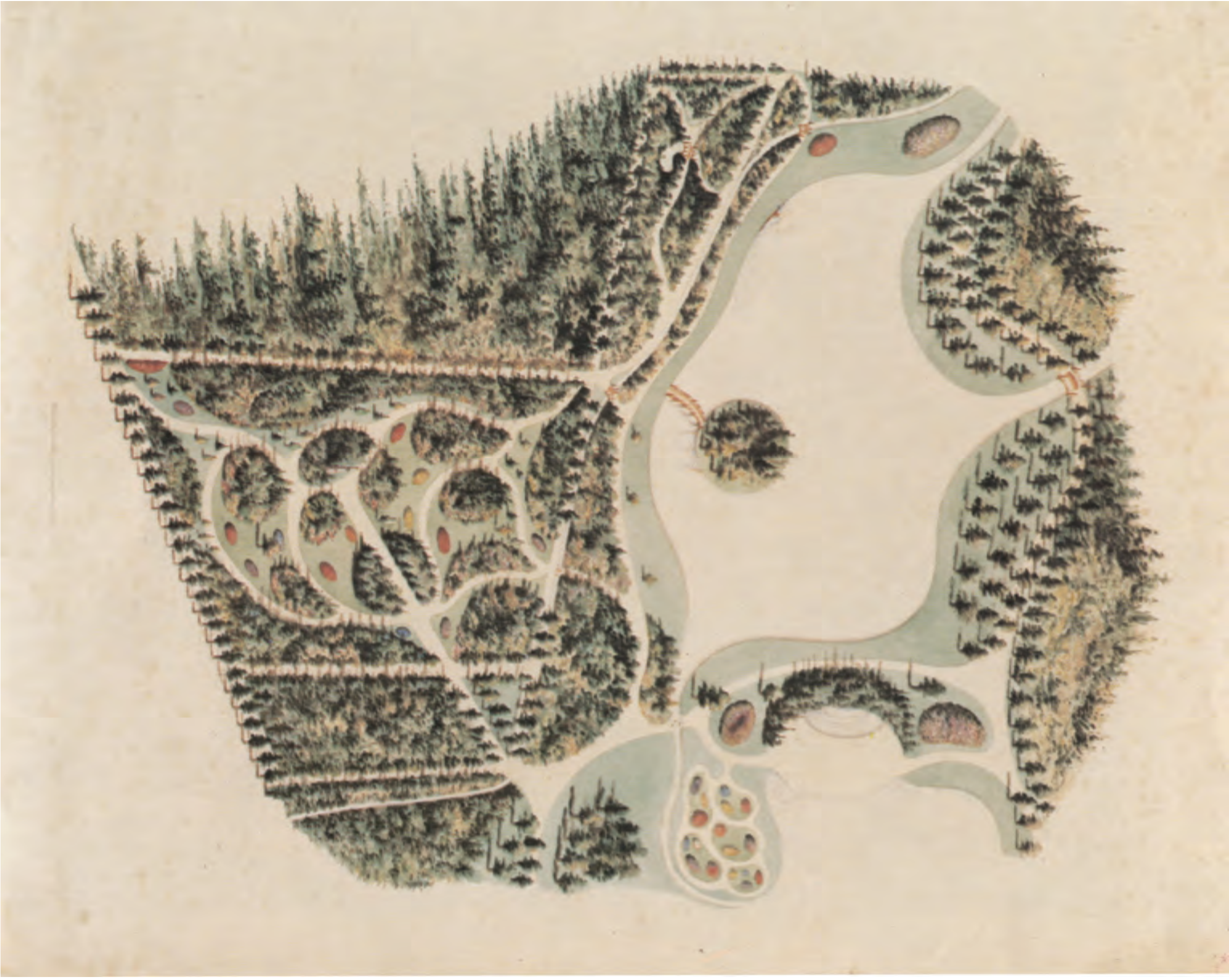

Figure 2.6 Design for the re-organisation of the park between the Bedriegertjes and the Sterrenberg ascribed to Dirk Wattez, circa 1875

The modern reference map. Ideally, the historic maps are geo-referenced to a detailed survey. Given the expense of such surveys these are, however, rarely available. Also for Rosendael a survey has thus far not been conducted. Alternatively, I made a modern reference map (Figure 1.3) by heads-up digitising the area's recent and highly accurate aerial photograph. The areas with obstructed view were mapped using the AHN2 height data and Rosendael's management plan (1984) made by Stichting het Gelders Landschap (1:2500) in combination with several field campaigns. A basic hand-held GPS (Garmin eTrex H) unfortunately proofed unsuitable to register coordinates for mapping.

Selecting control points. Basic to the identification of control points is the allocation of common features on the scanned and modern reference map. This turned out to be a delicate task for three main reasons: (i) the extent of the landscape under study is relatively small and hence the pool of potential control points is also restricted; (ii) the landscape was transformed completely between 1836 and 1838, diminishing the amount of potential control points to geo-reference older maps (<1836) by; and (iii) the site is characterised by its 'natu-

ral' setting with few clearly delineated features which makes the identification of unambiguous control points hard.
Nonetheless, all maps made after 1836 could be geo-referenced using the modern reference map. For best results the least ambiguous control points were selected (i.e. buildings) first. If these proved insufficient for the chosen geometric transformation, or they did not provide a reasonable spread throughout the image they were replenished by more ambiguous points (i.e. road-crossing, using centre lines).
The current landscape did, however, not comprehend enough control points to geo-reference the older maps by (Berend/Elshof, Marot and Zocher). This problem was solved by introducing the land registration map from 1817 as intermediate. This map provided enough control points for geo-referencing, although the point's spatial spread is still not completely satisfactorily.

Choosing the geometric transformation. With the control points identified the old maps were registered with the modern coordinate system (i.e. RD_New, datum Amersfoort) using those geometric transformations that provided reasonable local accuracy for digitising within the limits set by the amount and spread of control points. For most maps (Table 2.1) a simple first order polynomial transformation (affine transformation) sufficed, since the maps did not pose any complex distortions that required corrections beyond shifting, scaling and rotating.
Given the distortions of the two older maps, either due to the drawing perspective used (Smit/Elshof) or due to paper shrinkage and geometric shearing (Marot), a more complex geometric transformation was required. Considering that the digitising process requires local accuracy and that the control points are spread unevenly higher order polynomial functions (2nd or 3rd order) and rubber sheeting algorithms were ruled out. Instead, I used the adjust transformation which combines the merits of both global (polynomial transformations) and local (rubber sheeting algorithms) accuracy by using a combination of polynomial transformations and triangulated irregular network (TIN) interpolation techniques (ESRI, 2010).
For an initial judgement of the transformations' accuracy the root mean square error (RMSE) was used. The RMSE describes the consistency of the geometric transformation between the control points and is calculated by taking the root mean square sum of all the residuals (i.e. measure of error describing the difference between where the point ended up as opposed to the location specified) (ESRI, 2010). Note that the adjust transformation does not provide a RMSE as it is designed to perfectly registers the 'from' and 'to' points. Further caution has to be paid when interpreting the RMSE since it is a measure of transformation accuracy and not directly of registration accuracy.
Although the historical maps' RMSEs by far meet the planimetric accuracy standards set today (FGDC, 1998) (appendix 1) the results can be considered reasonable given the survey methods at the time and the landscape's natural character. The geo-referencing results considering a similar case in Italy (Agosto et al., 2005) further confirm this thought. The issue of spatial data uncertainty is discussed in greater detail in section 2.4.

Table 2.1 Geo-referencing details

Map	*Map type*	*# Control Points*	*Transformation*	*RMSE [m]*
Smit/Elshof (ca. 1718)[1]	documenting plan	46	adjust	-
Marot (ca. 1722)[1]	design	89	adjust	-
Minuutplan (1817)	land register	13	affine	1.67
Zocher (1836)[1]	design	15	affine	2.49
Wattez (ca. 1874)	design	6	affine	2.96
Wattez (ca. 1875)	design	6	affine	1.79

[1] geo-referenced with the Minuutplan Rosendael 1817 as intermediate

2.2.2 Digitising

In order to make use of all basic GIS operations (e.g. selection, overlay, query) the historic data needed to be digitised. I digitised the maps heads-up using the highly accurate drawing software AutoCAD 2012 (Autodesk, 2011). Zocher's design map was not digitised as it was executed with great variety and thus by far resembles the actual lay-out that is almost perfectly preserved today (Bierens de Haan, 1994). Depending on the distortions imposed on the maps by the geometric transformation used during geo-referencing the maps were digitised in full extent — the Wattez maps — or using a smaller extent — the Smit/Elshof and Marot maps — that excluded the heavily distorted peripheral map areas containing non or too few control points (Figures 2.8-2.13 show the control points' spatial spread). During digitising straight and parallel lines on the original map were kept straight or parallel in its digital counterpart to represent the designs as accurate as possible and to preserve topological relations. All geometric deviations between the original and digital maps resulting from this condition were documented in the geo-database by including both the geo-referenced raster image and its vectorised counterpart.

During digitising I used the thematic attribute values (i.e. legend) presented in Table 2.2. All features were classified based on qualitative judgement of the images and, if available, on the maps' legends. All digitised images were imported in ArcGIS10 (ESRI, 2011b) and converted to feature classes using ArcCatalog10 (ESRI, 2011a).

Table 2.2 Thematic attributes and their descriptions used during digitising

Classification	*Description*
Architecture	All constructions, including garden ornaments
Avenue	Road or path border by a regularly spaced sequence of trees along its sides
Roads/paths	All closed, permeable or semi-permeable surfaces made for all kinds of locomotion
Forest	Tree, group of trees or a complex of trees
Shrubbery	A planting or growth of shrubs, includes both shrubs with ornamental and functional purpose

Classification	Description
Hedge	A planting or growth of shrubs, includes both shrubs with ornamental and functional purpose
Ornamental planting	Plantings in an ornamental arrangement, mainly used to indicate parterres or flower beds
Kitchen garden	Garden where vegetables, fruits or herbs are grown for domestic use
Private garden	Garden belonging to, or for the use of one person or a group of people
Arable land	Land used for growing crops
Heathland	Area covered by heath
Water	Water

The modern data, the geo-referenced historical data and the digitised historic data described above together compile a basic geo-database. Time and change over time are, however, poorly incorporated in this database: the data's temporal component is implicit, and change can only be evaluated by exhaustively comparing the time stamped feature classes. The next section addresses these problems and presents a data structure that is able to represent both time and change.

2.3 INCORPORATING TIME IN GIS

The representation of time in GIS proves to be less straightforward as one might superficially think (Langran, 1992; Longley et al., 2011). The concept of time and its incorporation in GIS troubled researchers for considerable time now and despite serious efforts there is as yet no consensus about what 'incorporating time' should mean or how it should be accomplished (Galton, 2004; O'Sullivan, 2005). Current attempts are typically application focused, work for limited data types, are 'add-on' extensions for existing systems or remain conceptual (Freelan, 2003; Pelekis et al., 2004); a generic temporal GIS model still remains to be developed (Abraham and Roddick, 1999; Longley et al., 2011). Nevertheless, several different spatio-temporal models are developed to, at least, incorporate the temporal dimension to some extent. Amongst others, these include the snapshot model, the space-time composite model, event-oriented models, the history graph model, the spatio-temporal entity-relationship (STER) model, the object-relationship model, spatio-temporal object-oriented data models, and moving object data models. For an overview of the models I refer to Pelekis et al. (2004). In what follows I will only discuss those models that build upon the existing GIS functionality and relational database management system (RDBMS), since both the explication of a new spatio-temporal model and the implementation of a conceptual model are beyond the scope of this thesis. Although several different model types are developed that comply to these restrictions, little progress has been made beyond three basic models proposed by Langran and Chrisman (1988): (i) the snapshot model; (ii) the base state with amendments model; and (iii) the space-time composite model (Gregory and Ell, 2007).

The snapshot model
The simplest and most intuitive way of incorporating time is by means of an indexed sequence of snapshots (Langran, 1992; Galton, 2004). A snapshot is a static representation of

the world valid at one moment in time (Galton, 2004) and a sequence of them, let us say, *snap*(t_1), *snap*(t_2), …, *snap*(t_n), incorporates time when $t_1 < t_2 < \ldots < t_n$. The different snapshots are saved as an entirely new copy of the database whenever an update or alteration is made. This implies that the model stores a state and not the changes between states, which makes it difficult to know the state of the world at a time that is not present in our sequence (t_{i-1}), or to know how t_1 changed to t_2, as the pertinent snapshots must be compared exhaustively to find differences (Langran and Chrisman, 1988; Langran, 1992). From a data storage efficiency point of view a further drawback is the storage of redundant data since a complete snapshot is saved regardless of the extent of the change and, as such, also duplicates all unchanged data.

The base state with amendments or versioning model
The base state with amendments or versioning model largely mitigates the snapshot model's main problems. As this model starts with a base state (t_0) for the earliest time to include in the database and only stores the subsequent change data as new overlays, or amendments, in a separate amendment database, it both represents change and reduces the storage needs enormously (Langran, 1992). To recreate the map/event for a given time period, the base state is sequentially altered by including amendments until the required date is achieved (Freelan, 2003).

The space-time composite (STC) model
The base state with amendments model presented above, forms the basis for the space-time composite model. The model is generated by overlapping all time-stamped layers to produce a single space-time composite layer which accumulates the geometry and spatial topology of the studied region (Langran and Chrisman, 1988). Accessing the model's temporal information is conceptually straightforward since beginning and end dates of each feature are recorded as attributes. Querying for change by this becomes a simple attribute query and units with coherent histories can easily be identified.

Given the simplicity of the space-time composite's database structure, especially with regard to temporal querying and display, and its ability to flexibly include retroactive insertions of data, it was selected as basis for the current historical GIS' data model. Rosendael's space-time composite (Figure 2.7) was constructed using basic ArcGIS overlay operations. The composite includes: the digitised versions of the Smit/Elshof map, the Marot map, and the Wattez maps; both Zocher's design and the 20th century additions (i.e. the rose garden and the flower beds in front of Marot's shell gallery) are included as a selection of the modern reference map, since their layouts have either been preserved or reconstructed almost perfectly today (Bierens de Haan, 1994); and the modern reference map. Rosendael's space-time composite and its possibilities will be further addressed the next chapter. Before moving on to this chapter I will first discuss how data quality and uncertainty are dealt with in the geo-database.

OBJECTID	Shape	_1718	_1722	_1836	_1874	_1875	_1904	_2010	Shape_ Length	Shape_ Area
3952	Polygon	water	water	water				water	22,5	20,8
12745	Polygon	grass	forest	forest		shrubbery		forest	23,0	20,8
7208	Polygon	paths	paths			paths		forest	21,5	20,8
5119	Polygon	shrubbery	forest	paths				paths	32,4	20,7
4274	Polygon	avenue	avenue	paths				paths	31,9	20,7
5370	Polygon	hedge	grass	forest				forest	33,1	20,7
4900	Polygon	grass	shrubbery			shrubbery		paths	23,3	20,7
4245	Polygon	avenue	avenue	forest				forest	24,9	20,7
555	Polygon				paths			paths	36,7	20,6

Figure 2.7 Rosendael's space-time composite. The space-time composite's cut-up appearance is the logical consequence of accumulating all geometric changes into one composite layer. The individual time-stamped layers can easily be displayed separately by switching the space-time composite's symbology (ArcGIS) to one of the years. Each polygon, uniquely identified by its own number (OBJECTID), contains all historic information available for the spatial location it denotes. Historic changes or coherencies can thus easily be identified by comparing the attribute values (e.g. water, forest) of the columns representing the different years (e.g. _1718, _1722). Check the corresponding file at the dvd for all details.

2.4 DATA QUALITY AND UNCERTAINTY

Considering that historical cartographic data generally carry a higher degree of uncertainty — herein broadly defined as the acknowledgement and consideration of imperfections in information (Longley et al., 2011) — compared to contemporary cartographic data, it is important to assess their quality before using the information contained in them for further inquiry. Besides their inherent uncertainty as being conscious and unconscious compromises of purpose, generalisation, scale, cartographic accuracy, technology at the time, and cultural context (Madry, 2006), their incorporation in a GIS brings up further issues of uncertainty as geo-referencing, digitising and geo-processing might add additional uncertainty. Although several approaches are proposed to quantify uncertainty (e.g. Goovaerts, 2002; Tucci and Giordano, 2011) or to at least extensively describe its causes, types and nature (Plewe, 2002) little of these works, however, have found their way into mainstream GIS software and their practicality and utility for further research remain to be proven (Gregory and Ell, 2007; Gregory and Healy, 2007). Given that historians are well used to handling these problems though documentation and interpretation, and to avoid lots of effort being put in sources of uncertainty that may not be relevant, work is focussed here at the adequate recording and documenting of uncertainty. Below, uncertainty is recorded and documented according geography's three major domains: space, time and theme. In the geo-database basic considerations regarding data uncertainty such as RMSE values were recorded in the meta-data.

Space: positional uncertainty
With positional, or planimetric uncertainty I here refer to the uncertainty in location measures (Jenny and Hurni, 2011; Longley et al., 2011), more specifically the extent to which distances and bearings between identifiable objects coincidence with their true values (Laxton, 1976; Jenny and Hurni, 2011). Planimetric distortions are inherent in historic maps and might either be introduced during the various stages of map production or by deformation of the map's medium over time (Madry, 2006; Jenny and Hurni, 2011). For a cumulative measure of planimetric accuracy the RMSE was already used (section 2.2), which, however, is unable to express how accuracy varies across the maps. These local variances are a key issue in heritage conservation, since the choice for restoration, reconstruction or adaptation largely depends on the quality and accuracy of the available information (Schmidt, 1985). The recently developed *MapAnalyst* software (Jenny and Hurni, 2011) is equipped with several tools to express these variations visually. In this thesis planimetric uncertainties are visualised using displacement vectors and distortion grids. The first graphically illustrates the accuracy of each pair of control points by drawing a vector connecting the position of the 'from' point with its 'to' point, by which a longer vector indicates a less accurate point. The latter uses a transformed grid to reflect the old map's local distortions and rotations, displaying uncertain areas as rotated, compressed or enlarged grid meshes. In order to evaluate the inherent spatial uncertainty of the Smit/Elshof and the Marot map I geo-referenced these again using a 3rd order polynomial transformation giving RMSEs of 5.1 and 5.3, respectively. The results (Figures 2.8-2.13) of this procedure not only help to qualitatively assess the maps' initial uncertainties and how these might be conveyed during digitising and geo-processing, but also shed light on the individual maps' characters, most notably on their possible ma-

nipulations or unexecuted design proposals. Both might be indicated by structural or unidirectional errors in displacement vectors and/or distortion grids, although caution has to be paid as these might also be the result of structural survey errors.
Whereas most maps show deviations without any clear patterns (Figures 2.8, 2.10-2.13), indicating a regularly spread error, most probable resulting from surveying errors, the Marot map (1722) (Figure 2.9) shows an unidirectional deviation pattern around its central pond. The combined deviations indicate that the central pond was drawn more elongated than its actual extent displayed on the land registration plan from 1817. This either means that Marot manipulated its drawing to suggest longer lines, or, more convincingly considering the maps purpose, that his design was not executed as drawn. Note that such conclusions can only be drawn for individual landscape features when enough control points can be identified during geo-referencing.

Time: temporal uncertainty
Temporal uncertainty is introduced in the geo-database by not knowing the temporal gap between survey time and publication date of the historical maps (Leyk et al., 2005). Additional historical research might clarify these issues, although the limited availability of historical resources might well leave them unresolved. Also for most of Rosendael's historical maps Bierens de Haan's (1994) extensive reserach was unable to date all maps accurately, let alone the situation they depict.

Theme: attribute uncertainty
Attribute uncertainty refers to the uncertainty of all other spatial dataset's attributes (i.e. the non-spatial information about a geographic feature in GIS, such as its name or description (ESRI, 2011c)) other than its positional or temporal attributes. In this case, attribute uncertainty mainly refers to the correspondence of a polygon's semantic attribute description (table 2.2) with that what it is supposed to represent on the map. As most of the historical maps have no legend enclosed, uncertainty might arise about what a polygon represents. Especially for the landscape plans apparent differences in planting on the maps are hard to translate into specific attribute classes. More detailed data such as illustrations, photographs and descriptions might additionally be used to resolve such issues. Considering my limited resources I was unfortunately unable to do so. Instead, I reduced attribute uncertainty by using generally defined attribute classes (Table 2.2); and I added both the original data and the their digital counterparts to the geo-database to allow future users their own (re-)interpretation.

Figure 2.8

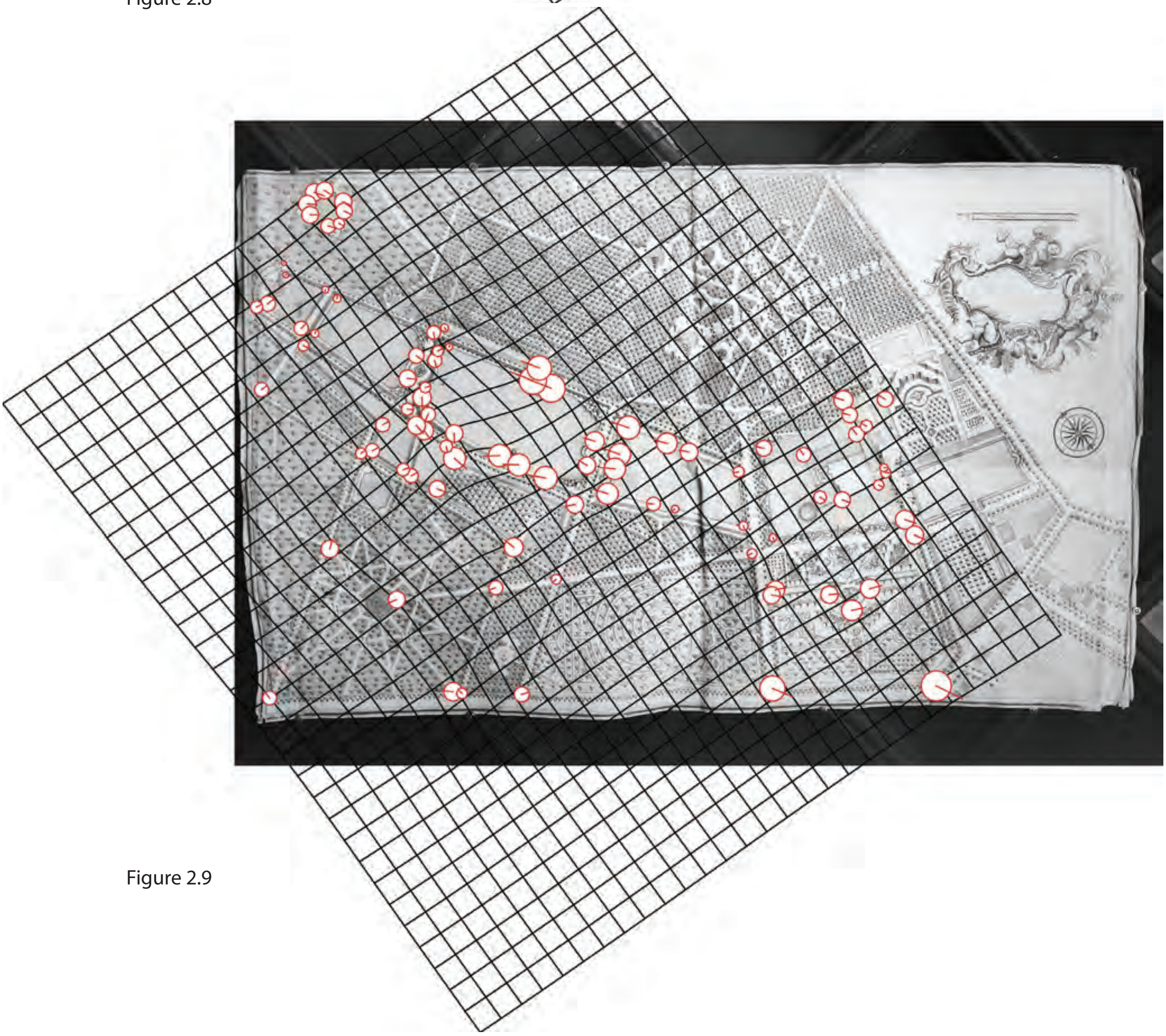

Figure 2.9

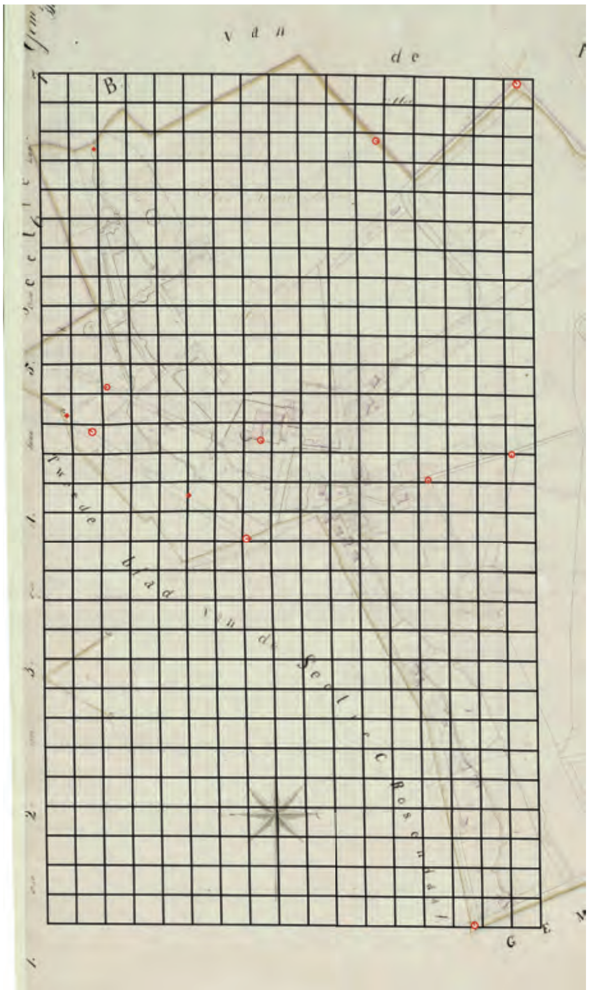

Figure 2.10

Figure 2.11

Spatial uncertainty: displacements and distortions

The images shown on this page, the previous and the next display the original historical maps overlain with the distortion grid and the displacement vectors created with the *MapAnalyst* (Jenny and Hurni, 2011) software. To increase legibility also the circles of displacement (proportional to the length of the displacement vector) are shown. When comparing distortions among the maps it has to be remembered that the Smit/Elshof and Marot map are transformed using a 3rd order polynomial transformation; all other maps are registered using an affine transformation.

In general, the maps produced in the 18th century show largest displacements and thus relatively the lowest planimetric accuracy, especially the Marot map stands out in this regard. The land registration map (1817) is, as expected, accurate with very little displacements, which confirms its legitimacy as an intermediate for geo-referencing. Also the maps made by Zocher and Wattez are rather accurate, although it has to be kept in mind that their 'map interiors' might show larger displacements as no control points could be identified for them.

Figure 2.8: Smit/Elshof map (ca. 1718) with distortion grid (30m mesh size) and displacement vectors.
Figure 2.9: Marot map (ca. 1722) with distortion grid (20m mesh size) and displacement vectors.
Figure 2.10: Land registration (1817) with distortion grid (50m mesh size) and displacement vectors.
Figure 2.11: Zocher map (ca. 1836) with distortion grid (20m mesh size) and displacement vectors.
Figure 2.12: Wattez (ca. 1874) with distortion grid (20m mesh size) and displacement vectors.
Figure 2.12: Wattez (ca. 1875) with distortion grid (15m mesh size) and displacement vectors.

Figure 2.12

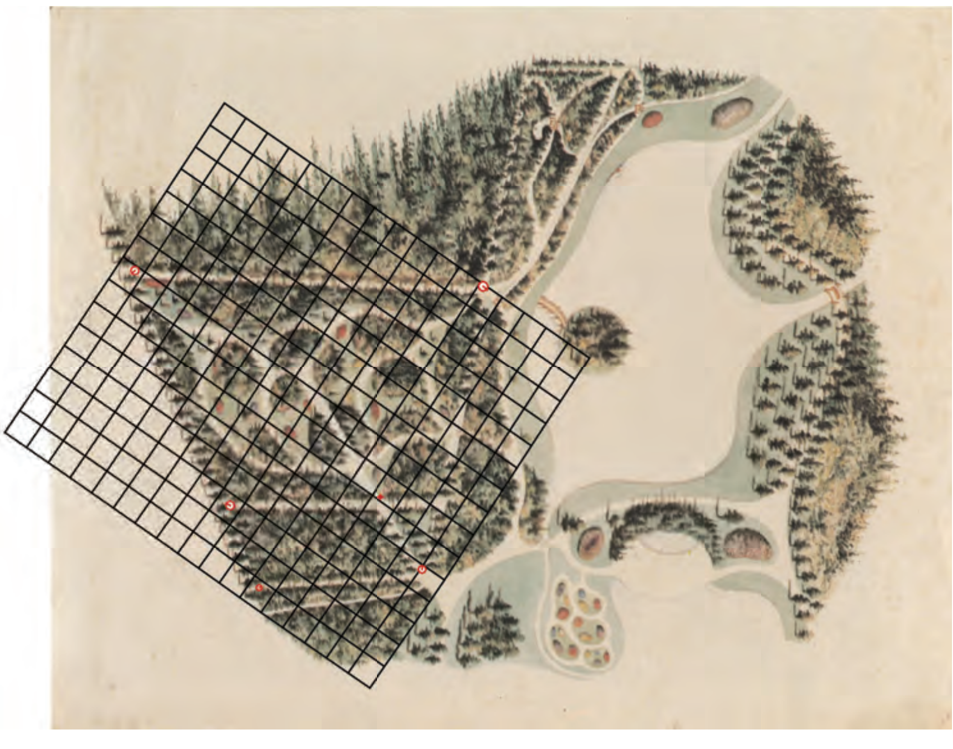

Figure 2.13

III

Using the developed HGIS to design a historical framework for Rosendael

Historic gardens, parks and landscapes are considered to be a valuable part of our cultural heritage[1] and substantial efforts are made to ensure and prolong their existence into the future. There is, however, an on-going debate about how this should be done (e.g. Luiten, 1989; Hajós and Wolschke-Bulmahn, 2011). The general purport of this argument is the old contradiction between building and preserving — archetypically represented by landscape architects and historians, respectively. Already in 1989 Luiten described its extremes, which can still be perceived in today's dispute:

> […] *"expressions that some landscape architects consider vital to their profession are not situated in the concern of what was, but rather in the contribution to the quality of what still has to come. With this professional realisation historical-geographical information is quickly considered ballast that withholds the balloon of the designed future's take off* […]. *According to its advocates, historical consciousness points to a fundamental attitude that despairs civilisation: we all lost our faith in our culture's ability to create, which largely explains our hinge to the culture of our ancestors, graphically lied down in the topographical map of 1850. We can speak of a true polemic since archaeologists and cultural-historicists not only publish their own research, but, in their turn, publically worry about the landscape architectonic threat to the Dutch cultural landscape*"[2] (Luiten, 1989, own translation).

In the extreme this chasm might even end up in court as the Rechberggarten (Zürich) lawsuit showed (Renfer, 2006). Although the issue is rarely forced that far, the relation between landscape architects and historians remains troubled. A substantial part of this resentment can be attributed to the poor integration and communication between both disciplines (e.g. Bosma and Kolen, 2010; Van der Meulen et al., 2011). Practice showed that when these hurdles were cleared, cooperation became possible and even fruitful. A particularly elegant example — one that might well be considered best practice — is the approach used for the renovation of the Vondelpark in Amsterdam (Amsterdam Oud-Zuid, 2001; De Jong, 2002; De Jong et al., 2007a; b). Basic to it is the multidisciplinary development and design of a so-called historical framework, which functions as a new middle ground for discussion as well as a practical guide regarding issues of management, maintenance and development.
In the remainder of this chapter the historical framework model is presented as an integral approach to ensure and prolong the existence of historic gardens, parks and landscapes and their cultural-historical meaning into the future. After an introduction to this model in section 3.1, the model is applied to the case of Rosendael using the HGIS (section 3.2).

1. Historic gardens, parks and landscapes are considered to be valuable because:
(i) they represent an important historical source: they reflect the social and political relations of a time or period (Hennebo, 1985); they are an expression of the constantly changing relation between nature and culture and function as representations of the idealised image of paradise and the philosophical, moralistic and literary movements expressed therein (Hennebo, 1985; De Jong, 1998; Sigel et al., 2006); and they function as witnesses of our territorial and national history and as such shape our collective memory (Hennebo, 1985; Goultry, 1993; Koch, 1998);
(ii) they function as bearers of our national, regional and local identities (Hennebo, 1985; Koch, 1998);
and (iii) they take up important functions in our everyday lives, as places for rest, contemplation and elbowroom, as landmarks, as ecological niches and as educational resource (Hennebo, 1985; Watkins and Wright, 2007)

2. [...] "uitingen die sommige landschapsarchitecten als wezenlijk beschouwen voor hun discipline liggen niet in de bezorgdheid voor wat was, maar veeleer in de bijdrage aan de kwaliteit van wat nog moet komen. Historisch-geografische kennisvergaring speelt in die vakinvulling als snel de rol van (...) aangedragen ballast die de ballon van de vormgegeven toekomst belet op te stijgen, de luis in de pels van het geloof in een maakbaar landschap. In stelling gebracht historisch besef duidt volgens hen op een cultuurpessimistische grondhouding: wij zijn met zijn allen het vertrouwen in het scheppend vermogen van de eigen cultuur verloren, wat het terugvallen in de cultuur van onze voorouders, grafisch opgeslagen in de topografische kaart 1850 grotendeels verklaard. Er is sprake van een heuse polemiek sinds archeologen en historisch-geografen niet meer alleen publiceren over hun onderzoek maar op hun beurt zich openlijk zorgen maken over de landschapsarchitectonische bedreiging van het Nederlandse cultuurlandschap" (Luiten, 1989).

3.1. THE HISTORICAL FRAMEWORK MODEL

This section discusses briefly the theoretical concept behind the historical framework (3.1.1) and defines the practical steps that should be taken for its development in real life (3.1.2). Finally, it is briefly argued how GIS can facilitate and contribute to the development of the historical framework (3.1.3).

3.1.1 Theory

The historical framework model is a specialised variant of the spatial planning based landscape framework concept (Kerkstra and Vrijlandt, 1989; Sijmons, 1991). This concept uses the differences in process dynamics as a main organisation principle. It introduces a spectrum of functions bound to low spatial dynamics and long periods of development (low dynamic functions) and land utilisations which generate higher spatial dynamics (high dynamic functions). According the concept both are ordered in a stable spatial structure that fixates part of the landscape, whilst allowing for flexible development in other parts such that these do not affect the main scheme (Vroom, 2005). The framework's stable part generally consists out of those elements that are characterised by a slow development and is referred to as the low dynamic structure. Those parts that are allowed to meet the short-lived demands form the high dynamic structure (Sijmons, 1991).

The historical framework uses the same principle to preserve those elements, structures and functions that lend the landscape its cultural significance, whilst also facilitating the introduction of elements, structures and functions that ensure its historical continuity. Hereby the first is considered the low dynamic structure and the latter the high dynamic structure. The low dynamic structure thus comprises the whole of landscape structures and elements that are considered essential to the landscape's physical (historic) structure and appearance, and to the cultural-historical meaning conveyed by it. As such these form the basic structure, or skeleton, that in idea and physique, bears the landscape's appearance and identity, and binds its many inextricably related parts in a coherent whole (De Jong and Schreiber, 2007). This framework entails both an abstractly, conceptual description of the idea, or the basic principles, that define the landscape as such, and a physical counterpart that secures the spatially defined structures and elements that express this idea.

The first is defined after a thorough study of the landscape and its evolution and makes up the touchstone by which (i) the existing low dynamic structure is evaluated and (ii) by which every intervention, design, or maintenance measure at the short term is tested (De Jong and Schreiber, 2007). Contrary to popular belief, the filling-in of the high dynamic structure is thus by far free from obligations.

At the heart of the latter are those structures and elements that survived the ravages of time and offer us a glimpse into the past: the existing low dynamic structure. For the works of landscape architecture these usually comprise the less transient, longer-lived elements of a design, i.e. the landscape's topography and its manipulation; ponds and watercourses; paths and avenues; architecture, garden ornaments and other solid elements; and more abstractly the conceptual ordering of space expressed by sightlines, views and visual foci.

These existing structures and elements are evaluated by the conceptually defined historical framework and reparation, reinforcement and addition might be deemed necessary to achieve a more comprehensive spatial framework that better expresses the cultural significance of the landscape.

The definition of the conceptual framework, the judgement on which landscape structures and elements are to be incorporated into the framework and on how the framework is to be completed or reinforced ideally is the result of a close collaboration between all disciplines involved, most notably between cultural-history and landscape architecture. Defined accordingly, the historical framework might not only form a spatially explicit alternative to the traditional cultural-historical landscape valuation which, according to Van der Meulen et al. (2011), many landscape architects are unable to handle, but it also provides a new middle ground for discussion. One in which the landscape architect's urge for modernisation and originality on the one hand and the cultural-historicist's tendency towards preservation and standstill on the other become curbed. Thus finding the balance between flexibility and historical continuity necessary for the preservation of every historic landscape design. This is what this thesis tries to establish.

3.1.2 Practice

Although the historical framework's theory (above) is summarily defined by De Jong and Schreiber (2007) its development in practice is further unspecified. It goes, however, without saying that extensive research into both the current and the past landscape is a prerequisite and the starting point for its development. To do so I propose to follow the three-step scheme concordantly defined in literature (Nehring, 1985; Goultry, 1993; Watkins and Wright, 2007), supplemented with additional requirements to define the historical framework.

1. A detailed inventory of the site in word and image. The inventory not only maps the landscape and all its elements, but also analyses the elements' spatial configuration.

   This steps makes the researcher acquainted with the object of study and allows him/her to look at the historical material from the object and not vice versa. He or she therewith reduces his/her bias as the risk at clichéd expectations and wishful thinking, often involved when studying the surviving object from its history, is minimised (Schmidt, 1985).

2. A description of the site's life history in word and image based on the available archival sources. It includes descriptions of each of the known construction and design phases' main characteristics and its three dimensional effect; its wider landscape context; its socio-cultural setting; and its immaterial history (e.g. associations, meanings, uses, oral history and their changes over time). All of which accumulates in the formulation of the conceptual historical framework.

   During this step the researcher attempts to scrutinise the history of the object in order to understand through which stages it evolved into its current status. Herewith he or she is able to assess the current landscape from a cultural-historical perspective and can identify the general principles that shaped the landscape throughout its history. These findings lead up to the formulation of the conceptual historical framework.

The additional knowledge attained during this research is an important source of information for the restoration, reconstruction or contemporary completion of the physical framework or elements within, as well as for decisions to continue, modify or reinstate certain aspects of the landscape's immaterial history which might also be part of the historical framework.

3. A synthesis of both: how is the site's anamnesis reflected in the current landscape?

   To understand the historical layering of the landscape and to identify those structures and elements that belong the landscapes historical substance and as such constitute the existing low dynamic structure, the findings from the historical research are tested to the object's current status.

The historical framework model, however, goes beyond mere description and implies a normative stance in relation to the landscape. I would therefore like to supplement the above described steps by two additional ones:

4. An assessment of the existing low dynamic structure in perspective of the conceptual historical framework

   During this step the existing low dynamic structure is critically compared to the conceptual historical framework and areas were reparation, reinforcement or contemporary completion are needed to achieve a more comprehensive spatial framework that better expresses the landscape's cultural significance are identified.

5. A series of proposed measures to preserve, reinforce and complete the existing historical framework such that it is able to retain the landscape's cultural significance for the long term and to withstand and guide the developments at the short term.

3.1.3. The historical framework and GIS

Like the organisation and storage of historical sources (chapter 2), the abovementioned research steps and the development of a historical framework in general would greatly be facilitated by an integration with a GIS, because (i) it adds to the transparency, credibility and reproducibility of the method; (ii) it helps to integrate, analyse and visualise all kinds of spatial information; and (iii) it facilitates social negotiation (e.g. Harvey and Chrisman, 1996). Given my limited resources the next section only explores the first two points for the case of Rosendael. GIS' mediating role might be a topic for future research.

3.2 DESIGNING A HISTORICAL FRAMEWORK FOR ROSENDAEL USING GIS

This section is a practical execution of the theoretical and practical steps elaborated in the previous section and will thus follow the five step scheme defined above. Given my limited resources I will focus here on visualisation and analysis; GIS' mediating role might be a topic for future research. All images and schema are presented in the other booklet so that text and image can be read simultaneously.

3.2.1 Step 1: Detailed inventory of Rosendael

Rosendael's current landscape is well inventoried by a variety of spatial data including highly detailed aerial pictures; precise height data (AHN2); basic geomorphologic and pedologic data; and a detailed modern reference map (section 2.2.1.).
Using basic GIS functionalities these data can be visualised and analysed in a comprehendible manner that contributes to our understanding of the landscape, its morphology and spatial composition. In what follows Rosendael's landscape is concisely inventoried and explored using these techniques and further suggestions are given for additional GIS applications. All text regarding GIS techniques, methodologies and additional applications are set in grey so that they can easily be skipped by the reader only interested in the landscape itself. The inventory is divided into two parts: (i) an inventory and analysis of the landscape's morphology and its spatial composition; and (ii) an analysis of the landscape as it is experienced by the visitor. The first is organised according the three-layered structure — terrain morphology, networks, and volumes — of the landscape-morphological model (Wassink, 1999), specifically designed for the description of a landscape's morphological and compositional set-up (appendix 2); the latter centres around the landscape's visual appearance and tactile experience.

(i) Inventory and analysis of Rosendael's morphology and spatial composition

This section briefly inventories and analyses Rosendael's landscape morphology and its spatial composition according the three layers of the landscape-morphology model (Wassink, 1999). The network layer and the volumes layers are split up in subthemes for a more detailed understanding of the landscape. For the network layer these include the infrastructural network and the network of sightlines and views; for the volumes layer these comprehend planting and architecture and garden ornaments. The results are mainly expressed by images and schema (other booklet) and are only clarified briefly (below). In order for the reader to comprehend how the knowledge contained in the data was singled out and presented here, the data and the manipulative GIS operations applied to them are briefly listed for each theme and subtheme within.

*Terrain morphology (*Figure 3.1 and 3.2*).*

Data used:	Digital Terrain Model derived from AHN2 (0.5m) (appendix 3) and the modern reference map (section 2.2.1)
Operation(s) used:	hillshading and selection

The landscape's main compositional determinant is its natural hilly topography. The valleys overall north-south orientation determines the water's flow direction and its geomorphologic shape — asymmetrical, with steep west-facing slopes and much flatter east-facing slopes — heavily influences the ponds' lay-out and shape and therewith also the site's general layout.
Within this distinct topography local heights such as the Sterreberg, de Koningsberg, de Kraaienberg and to a lesser extent the Kruidberg form important compositional determinants. Local flatter areas at the valley's lower reaches and at the crossing of its largest side-valley shape today's remaining functional spaces of pasture and an orchard, respectively.
The natural topography is manipulated to attain the design's current appearance: oozing wells (Dutch: sprengen) were dug, and ponds were artificially dammed. The thus created differential head between the subsequent ponds is still used to propel several waterworks (i.e. the stream gods, 'de Bedriegertjes', and several cascades). A side branch of the main oozing well in the north, the Jagersbeek, provides the shell gallery's cascade and fountain with water.

Networks
Infrastructural network *(*Figure 3.3).

Data used:	modern reference map
Operation(s) used:	selection and dissolve

Much of the current road and path structure was shaped through the years by building forth on existing structures and adding new ones. This development is elaborated in step two and three.

Network of sightlines and views: visual composition (Figure 3.4).

Data used:	Digital Landscape Model derived from AHN2 (0.5m) (appendix 3)
Operation(s) used:	Observation point, Viewshed, visual assessment (appendix 4)

Sightlines — defined here as the visual connection between a view point and a prominent element or focal point at the horizon or in front of it (Vroom, 2005) — and views are important structural elements that often provide coherence to the landscape as a whole (Broadbent, 1990). Figure 3.4 depicts Rosendael's main sightlines and views as found using the GIS based methodology explicated below. Together with the natural topography, the paths that afford the landscape to be experienced, the placement of visual foci (i.e. castle, orangery, and garden ornaments) and the planting of trees and shrubbery these determine Rosendael's visual composition.

The sightlines between the park's main focal points were assessed using the Observer points function in ArcGIS. This function calculates which observer points are visual from each raster cell of the Digital Landscape Model (DLM)(appendix 3). By calculating this visibility for each of the landscapes presumed focal points (i.e. the donjon, the orangery, the shell gallery, the pavilion, the 'Bedriegertjes', the stream gods, the gardener's house, and the Kraaienberg) and overlaying them, their mutual visibility was assessed. Their interconnecting sightlines were then drawn as the middle line of the total visible area of both features (Figure 3.4, orange lines). For more detailed information on this methodology I refer to appendix 4.
Later all visible fields of each focal point were re-calculated at eye level (average of 1.7m) for each raster cell observed from that point, in order to calculate from which accessible

locations (i.e. locations on a path) one was able to see it. When combining this information for all focal points, it is for each location on a path known whether it has a visual on one or more of the focal points and on which one(s) (appendix 4). Using this information I visually judged which views could be considered compositional sightlines based on the presence of a clear foreground, middle ground and background — a staging often used to compose such views (e.g. O'Malley et al., 2010) — and on whether the path's course purposefully directs the view.

Volumes

Planting (Figure 3.5).

Data used:	Digital Terrain Model and Digital Landscape Model derived from AHN2 (0.5m)
Operation(s) used:	raster calculator and further manual manipulation

Also in Rosendael's planting structure the topography hints through: nearly all steep terrain is forested with a beech-oak mixture, whereas flatter and more undulating terrain is generally planted more sparsely and with more variation including some exotic tree species (e.g. *Cedrus atlantica*, *Thuja plicata*). The Koningsberg is heavily forested with a monotonous mixture of birch, larix and pine trees at its northern part, and a beech-oak mixture in the south. Around the ponds trees, clumps and shrubbery are used to stage an aesthetically pleasing walk with alternating views and scenes. Dense planting is used to obscure certain functional elements, such as the Jagersbeek.

Besides the designed planting structure, Rosendael also has rich 'natural' flora facilitated by the many gradients, clean calcareous seepage water and the loamy substrate. Species, amongst others, include the protected marsh orchid *Dactylorhiza praetermissa*.

Far beyond this very general characterisation of Rosendael's planting, GIS offers the ability to inventory it in the utmost detail. With its location known it is after all possible to store all possible information (e.g. species, age) for each tree, shrub or grouping of them. This not only makes an important historical source easily accessible, but also offers the possibility to include information on the individual plant's condition, thereby making it an important tool for the management and maintenance of historical green (e.g. Morgan, 2011). With the advance in registration techniques such as LiDAR and the progress in developing algorithms to automatically inventory and classify individual trees from their results (e.g. Brandtberg, 2007; Ørka et al., 2009) part of this labour-intensive work might be automated in the near future.

Architecture and garden ornaments *(*Figure 3.6).

Data used:	modern reference map
Operation(s) used:	selection

Besides its picturesque location in the valley, Rosendael is particularly known for its castle and the many garden ornaments. Castle and ornaments have a long history and already in the very first garden designs many of them served as important attractions and focal points. Many of the ornaments (i.e. stream gods, 'de Bedriegertjes', shell cave with cascade, shell gallery, several other cascades) have a close relation with both water and topography, as they use the topographical drop to run cascades and propel fountains. The history of most elements will briefly be considered in the next step. For elaborate descriptions on the castle as well as on the individual garden ornaments I refer to the work of Bierens de Haan (Bierens de Haan, 1994) and to the descriptions made by the Rijksdienst voor het Culturele Erfgoed (KICH, 2008).

Like the inventory of Rosendael's planting, all garden ornaments can be inventoried in detail using GIS. Formal descriptions and images can easily be attached to their geographical location and with a suitable user-interface a publicly accessible, interactive archive can be published quickly.

(ii) Inventory and analysis of Rosendael's experienced landscape

To understand a landscape thoroughly one has to study its abstract, conceptual ordering of space as well as its visual appearance and tactile experience as it is experienced by an observer moving through it. This section briefly explores both the visual form for Rosendael and, be it very confined, its tactile experience, using GIS based concepts and functions. I thereby use and try to build forth on earlier work done by amongst others Llobera (2003) and Nijhuis (2011). Central to this exploration is a circular walk routed by the Geldersch Landschap to display the park and its main attractions (GLGK, 2011).

Visual appearance (Figure 3.7)

Data used:	Digital Landscape Model derived from AHN2 (0.5m) (appendix 2)
Operation(s) used:	Viewshed

One way to grasp the overall visual appearance of Rosendael's landscape with respect to the circular walk is to assess its visual magnitude (Llobera, 2003). Visual magnitude is a measure for the importance each landscape element has within an individual's perception and as such shows how visible each part of the landscape is. The landscape's configuration as experienced during the walk thus becomes described as a visual property.

For Rosendael such analysis (Figure 3.7) reveals its general visual composition within its centre, around the castle, an relative large, open and visually dominant area and further removed from it several parts (e.g. the 'Kruidberg' and the area around the northern pond) that are far less visible and even partially invisible. Within this general structure some elements clearly stand out in terms of visibility, these elements might be considered visually dominant. When speaking of landscape elements rather than of land surfaces, the donjon (n=143), shell gallery (n=92) and the incense cedar at the Kruidberg (*Calocedrus Decurrens*) (n=111) are visually most dominant in terms of times seen.

For the assessment of visual magnitude I used the cumulative viewshed method originally developed by Wheatly (1995). For this method multiple viewsheds from various viewpoints locations — here positioned along the route with a regular interval of 5 meters (n=428) — are added up to generate a cumulative viewshed, or times seen raster which directly provides an indication of visual magnitude (Fels, 1992; Llobera, 2003). The cumulative viewshed was calculated using the Viewshed tool of the Spatial Analyst extension in ArcGIS10 using all viewpoints with a spectator height offset of 1.7 meters and the DLM.

Tactile experience and visual appearance of the landscape along a route (Figure 3.8)

Data used:	Digital Landscape Model derived from AHN2 (0.5m) (appendix 2) Map of the focal's point visibility from the paths (appendix 3)
Operation(s) used:	Viewshed, Slope, Extract values to points, Points Solar Radiation, manual manipulation

Although the cumulative viewshed gives a first impression of how the visual landscape is structured with respect to the route, it does not describe the walk as it is experienced step by step by the observer. To map part of this tactile experience I focussed at (i) the experience of landscape openness together with the visibility of the focal points in relation to the route, and (ii) at the experience of light and shade — an important design technique in the landscape style type of design (Repton and Loudon, 1840) — in relation to the route (Figure 3.8). The resulting graphs show the sequential relationship of path, openness, light, shade and focal points in time based on the walking observer.

Landscape openness and the visibility of focal points along the route. Analogous to the measure of landscape openness in landscape perception research (Kaplan et al., 1989; Weitkamp, 2010) I used the total field of view [m^2] as a measure for landscape openness. Following this approach I calculated the total field of view for every point at a 5 meter interval along the route (n=428) with a height offset of 1.7 meter for the DLM and plotted the results together with the route's heights and with the visibility of the different focal points along the route calculated earlier.

Experience of light and shade in relation to the route. With the Points Solar Radiation tool of the Spatial Analyst in ArcGIS10 (ESRI, 2011b) in combination with the DLM it can be calculated how much solar radiation in Watt hours per square meter [WH/m^2], direct and diffuse, each point along the route receives. By performing this calculation for the summer solstice, equinox and winter solstice some of the seasonal variation in light and shade was accounted for. It has to be noted that the extra information of this analysis is limited compared to a visual assessment of light and shade along the route, since the calculation is performed for a limited set of dates and does not consider daily variations in light and shade. Nonetheless, it provides consistent results and with the onset of 3D technology it will likely become an efficient tool to assess the density and translucency of trees and shrubs along a route.

3.2.2 *Step 2: Rosendael's anamnesis and the formulation of its conceptual historical framework*

In this section Rosendael's life history is studied and described. As a conclusion of this study's results Rosendael's conceptual historical framework is formulated.

Rosendael's anamnesis

Rosendael's anamnesis is described here in two different manners. First, as a chronology of historic developments depicting the past's main construction and design phases according the earlier defined morphological layers, i.e. (i) terrain morphology, (ii) networks, and (iii) volumes using the same GIS manipulations as described in the previous step (Figures 3.9-3.38). Secondly, as the actual change between each of these successive phases for each of the layers (Figures 3.39-3.48).

Considering the additional historic research needed to reconstruct (2.5D) each of the individual historic layers I did not analysed the landscapes' network of sightlines and views nor its visual appearance and tactile experience as was done above. Which, however, does not alter the fact that these techniques might well be applied to the historic situations and that their results might be of importance for the establishment of the historical framework. To still get an idea of the past landscapes' three dimensional effect I included a virtual landscape reconstruction — in terms of mass-space volumes— for each design phase[3].

All descriptions are chronological and use the patrons' life-spans as demarcations. Since Bierens de Haan (1994) already elaborately discussed the garden's historical elements, their history and meaning, and the changing socio-cultural setting; and a further study into its immaterial history is beyond the scope of this thesis the focus is here is at the landscape's morphology and its spatial composition. The results are mainly presented in image and scheme (other booklet); clarifications are brief (this booklet).

Before 1667

Little is known about the landscape's lay-out before 1667, when Jan van Arnhem initiated the construction of his garden. At least the topography would barely have changed; the castle's donjon (fourteenth century) would have stood there; some ponds were already dug (circa 1404) (Bierens de Haan, 1994) and also several roads probably already existed. Further particularities about the lay-out are not known, although it can be assumed that the castle was at least surrounded by a defensive moat and that the main oozing well was probably already dug to supply its water. Sparse archival evidence (1644-1706) further implies that a series of ponds, propelling six paper mills and one flourmill, existed before Jan van Arnhem commenced the works (Bierens de Haan, 1994). Also the irregular pentagon, which forms the contours of the lay-out's core, can barely be explained other than being an already existent structure.

Jan van Arnhem (1632-1716) (Figures 3.9-3.13)

For his garden design Jan van Arnhem kept the irregular pentagon at the heart of his design and extended the overall lay-out by including the ponds and their watermills. This existent structure and the topography its was shaped after made it nearly impossible for Van Arnhem to build a grand geometrical system of avenues, parterres, and ponds around a central

1. With the aid of more advanced visualisation software and additional historic information these reconstruction might be made more realistic as, for example, Paar and Blaik (2008) and De Boer et al. (2011) showed.

axis, fashionable at the time. Instead, he laid-out a series of enclosed gardens separated by avenues. The thus created 'garden rooms' were to be experienced as individual spaces, but could be viewed from the two belvederes at the Sterreberg and at the Koningsberg. In the absence of a main axis directed at the house, the imaginary line between these two belvederes functioned as a main axis for the whole lay-out (Bierens de Haan, 1994).
Many of the 'garden rooms' were enriched with a variety of garden ornaments, of which the many naturally propelled cascades and fountains showed off Rosendael's principal merit: its naturally flowing water. No expenses were spared to use this water to its fullest potential: special canals (including the predecessor of the Jagersbeek) were dug to lead the water over both the longitudinal and latitudinal axis of the terraced parterres and several mills were demolished in order to safeguard sufficient water flow to propel the water works. Also along side the ponds several cascades and fountains could be found.
The cultivated landscape of these gardens was consciously contrasted with the uncultivated wilderness of the 'Hooge Bosch' at the steeper northern slope to further accentuate its splendour. Similarly as was done at earlier Italian examples (e.g. Villa Lante). This splendour was, however, best experienced from the belvedere at the Koningsberg (built by Willem III), which offered an extended view over most of the garden's layout. From there also nearby places such as Arnhem, Nijmegen and Elst could be seen. The total design was most likely experienced during a circular walk, similarly to the one described by d'Outrein.

Lubbert Adolf Torck (1616-1764) (Figures 3.14-3.18)
Ever since Lubbert Adolf Torck inherited Rosendael (1721) he further embellished its gardens. He thereby kept the structure, as lain down by Van Arnhem, basically as it was, but changed its contents drastically. He redesigned the terraced parterres, which became to function as a garden theatre; constructed a maize; and added several garden ornaments. Archival evidence showed that most of these additions and alterations were likely done after plans made by Daniel Marot (Bierens de Haan, 1994).
The changes to the park's main structure of avenues and ponds were small. Assuming that the radical design for Rosendael's northern slope, with its system of four avenues crossing a star-shape, was never executed (Bierens de Haan, 1994), changes to the avenues were limited to the addition of some side-avenues and at pronouncing their intersections at the Sterreberg. Also the pond's principal shapes were barely altered. The small alterations — filling in corners, adding arched bulges and set-backs — nevertheless both streamlined and livened up the total sequence. A pond, the 'Hoge Vijver', was added to sequence in order to propel the Colonade's cascade (ca. 1740-1837), a half-round gallery that formed the visual closing of the sequence of ponds and the park.
Besides the Colonade several more new garden ornaments were added, many after the designs by Daniel Marot (Bierens de Haan, 1994). Several of these disappeared (e.g. the pavilion at the entrance of the labyrinth, several cabinets, a new orangery, twenty four marble vases), others we can still find at their original locations (i.e. the shell gallery, the 'Bedriegertjes' and the pavilion, originally called het salon) and one was moved to a new location (i.e. cascade with river gods; moved from its location at the southern bank of the castle's pond to its current location at the highest pond). To provide all these works with water, parts of the artificial channels were repositioned and the pipe system was expanded (Bierens de Haan, 1994).
Torck apparently directed his attention fully to the gardens as he left the Koningsberg as it was; he even broke down its belvedere (1721).

Assueer Jan Torck (1764-1793) and Reinhard J.C. Torck (1793-1830)
Although the garden lay-out A.J. Torck inherited was already forty years old and became gradually old-fashioned, he issued no substantial modernisations. He left the main garden structure intact and only ordered the modernisation of a few parts, most drastically at the so-called English Garden/Forest. The English Garden/Forest was built at the maize's location and consisted out of an artificial island, surrounded by a re-routed Jagersbeek (recognisable on the minuutplan, Figure 2.3), and additional planting along the avenue that closed off the whole in the west; further details are unfortunately not known. The plans after which the garden was made were probably drawn by Philip Willem Schonck (1735-c.1823). Judging from Herman van Hooff's Kaart van de IJssellinie (1783) further experiments with the early landscape style were undertaken at the Koningsberg, detailed maps or other concrete evidence however lack.
Also A.J. Torck's successor, R.J.C. Torck, changed little. Nonetheless, his replacement of some old-fashioned elements, such as the parterres, by more 'natural' elements such as tree clumps, shrubbery and grass; and the addition of winding paths around the main oozing well and at the northern slope made the whole park feel and appear more like a landscape style park (Bierens de Haan, 1994). By then also the star-shaped structure at the Sterreberg likely disappeared and according to one account the hill was by 1820 covered with grass (Bierens de Haan, 1994).
Unfortunately, neither detailed maps nor many illustrations depict these efforts. Therefore these are only described here and no inventories or visualisations of this period are presented in the other booklet.

Assueer Lubbert Adolph Torck (1830-1843) (Figure 3.19-3.23)
A.L.A. Torck was the first since the eighteenth century to modernise the whole central layout according to one concept. He therefore hired Jan David Zocher the Younger (1791-1870) who metamorphosed the still largely geometric landscape into a landscape style park (1836-1838). Although the original design (figure 2.4) was executed with great variety and preserved more of the seventeenth and eighteenth century's elements than intended, the change was still drastic.
Zocher transformed the sequence of six ponds into a series of elongated ponds with flowing contours; adapted the Jagersbeek; designed winding paths; made rolling grasslands; used several eighteenth century ornaments as follies; and devised sightlines and views. Now the landscape was to be experienced as a whole and not as separate 'garden rooms'. During this period also a new orangery, also designed by Zocher, and the now disappeared lodging at the Kraaienberg were built.

*Reinhard J.C. van Pallandt (1843-1902) (*Figures 3.24-3.33)
Also during the second half of the nineteenth century few changes were made to parts of the park. Most likely after the designs of Dirk Wattez (1833-1906). These include the construction of the English Garden; a re-design for the Koningsberg; and the addition of several exotic tree species at the Kruidberg.
For the area between the shell cave with cascade and the 'Bedriegertjes' Wattez designed the so-called English Garden, in which a diversity of plant- and shrub species was alternated with a dense pattern of paths. This design was originally part of a larger proposal that also included a reorganisation of the Sterreberg (Figure 2.6). The English Garden is not included in the figures as it could not be geo-referenced properly.

The design Wattez made for Koningsberg (Figure 2.5) provided not only for the reorganisation of Koningsberg itself, but for the whole area between the Rosendaelse laan in the east, the Kleiberglaan in the west, the Beekhuizenseweg in the north and the Ringallee in the south. For the Koningsberg itself Wattez maintained the two eighteenth century avenues to the top, but changed the composition otherwise in mixture of open and enclosed spaces, planted with forest, loosely grouped trees and shrubbery, criss-crossed by the many winding paths. Of this plan only the area north of the Koningsberg's top is known to be executed. Also his plan to parcel out part of the valley for the construction of luxurious residences was not carried through (Bierens de Haan, 1994).
At the Kruidberg Wattez planted several exotic species of which the cone-shaped Thuja plicata and the impressive *Calocedrus Decurrens* (1866; >20m) immediately catch the eye (also Figure 3.7).

Frederik Jacob Willem van Pallandt (1902-1932) (Figures 3.34-3.38)
F.J.W. van Pallandt was the last to add something new to Rosendael's gardens. Around 1904 he and his head gardener Schreurs designed and constructed a rose garden. They devised a geometrical lay-out of rose beds, grass field and straight paths around two axes: one aimed at the coach house and one perpendicular to it directed to the orangery. The whole was fringed by several kinds of conifers and taxus species (Bierens de Haan, 1994).

Willem Frederik Torck van Pallandt (1892-1977)
W.F. Torck van Pallandt restored the castle and the shell gallery (1972) which were heavily damaged during the Second World War.

Stichting het Gelderslandschap (1978-present)
After W.F. Torck van Pallandt died house and park, including the Koningsberg, were assigned to the Stichting Het Gelderslandschap (1978). For the first time the estate became managed and maintained by a foundation and not by one person and its personnel. A fact that confronted many estates in the second half of the twentieth century.
In the following years Gelders Landschap restored the gardens: arrears of maintenance were cleared, water ways were restored and ponds were cleaned and both the rose garden (1985) and the orangery (1990) were reconstructed. Restoration activities continued with the shell cave and the Bedreigertjes (1995); the latter's planting (1997). Fairly recently the orchard was reconstructed (2003); and Marot's pavilion was restored.

ADDITIONALLY
As became apparent during a quick-scan of the AHN2 (0.5m) some bygone historical structures and elements left their topographical traces. To better be able to fully assess these potential archaeological relicts I manipulated the AHN2 by exaggerating its topography (hill shaded relief map) and accentuating its height differences in terms of slope, similarly as done by Hesse (2010) and Werbrouck et al. (2011). By this method I was able to discern several remains of which the majority could be dated by overlaying them with the historic information contained in the digitised maps (Figure 3.49-3.51).

Rosendael's conceptual historical framework

With the knowledge contained in the historical maps, brought forward by the manipulative qualities of GIS, and with the information presented in other historical sources nicely assembled by Bierens de Haan (1994) and summarily described above, I conclude that the basic principles that define the Rosendael's landscape, and thus its conceptual historical framework, are as follows. Note that the immaterial history of the estate was not studied and is thus not incorporated into the framework yet.

Rosendael's conceptual historical framework is defined by:

Its topography and natural setting:

- the position in a north-south sloping asymmetrically shaped valley with steep west-facing slopes and much flatter, more undulating, east-facing slopes

- the presence of distinct local heights, i.e. the Sterreberg, the Koningsberg, the Kruidberg and the Kraaienberg, and flats, represented by several side-valleys, within this general morphology

- the presence of an apparent ground water table near the ground's surface (Dutch: schijngrondwaterspiegel)

The successive manipulation of topography and nature to create an illusionary space:

- the system of oozing wells and artificial channels to attain the water from the apparent ground water table and to supply it through the park

- the dammed and dug ponds which create an artificial staircase topography at the valley bottom, which in turn provides enough differential head for the waterworks to run

- the total layered historic composition, starting with the work of Jan van Arnhem successively completed, changed, transformed and adapted by the following generations of owners, landscape architects and gardeners, which reveals itself each time differently, but should always be considered as one coherent spatial unity.

- The ponds and watercourses; the paths and avenues; the trees, clumps, shrubbery, lawns and flower beds; and the garden ornaments and buildings which are the physical and aesthetic result of these successive design stages.

    - the water which plays a primary role in the design both as the basic structure around which the design is composed and as the main attraction experienced up close by the visitor in sight, sound and touch.

- the path's course and the structure of avenues which (i) afford movement to experience the composition's three-dimensional effect shaped by the topography, the alteration between open and enclosed spaces and the thus created sightlines and views; and (ii) physically links the landscape's parts.

- the vegetal material, including its cycle of growth, decay and replacement, and its botanical diversity which is one of the major constants in the design

- the build elements — buildings, waterworks, bridges, fencing and other unica — which as garden ornaments represent important attractions and foci in the overall composition.

Nota bene:

❧ The landscape stretches beyond the borders of the complex and includes all landscape elements that characterise the cultural landscape of the Veluwezoom. Rosendael is an inextricable part of this landscape and cannot exist without it.

The thus defined historical framework is the criterion by which every measure of maintenance or design is tested and is never to be affected. Sustaining this framework is of main priority.

More specific, for all involved with changes in and to the park, the abovementioned points can be couched in the following demands that should always be honoured:

❧ geomorphology, topography and the presence of water are the main determinants of Rosendael's design and should always be respected, maintained and were necessary accentuated

❧ oozing wells, artificial channels, ponds and their dams, together with the natural topography, structure the design's general layout and provide the means by which the illusion of a valley with naturally flowing water is created. They therefore should be preserved and maintained at all costs.

❧ much of Rosendael's cultural historical value lies within its pronounced historical layering. All of these successive layers of the park's evolution should therefore be respected and no one period should be given precedence over any other. In order to retain or articulate the cultural significance of the ensemble or its coherence certain layers might need to be restored, reconstructed or adapted.

With the conceptual historical framework defined, its physical representatives are now to be identified in the current landscape.

3.2.3 Step 3: *Rosendael's anamnesis' remaining relicts: the existing low dynamic framework*

In this section I investigate which historical elements survived the ravages of time and as such represent the physical counterparts of the conceptual historical framework defined above and thus constitute the existing low dynamic structure. During this study the attention is focused at the less transient, longer lived of the design considering the following morphological layers and themes within: (i) terrain morphology, (ii) networks: infrastructural network, and (iii) volumes: architecture and garden ornaments. As discussed earlier (section 3.2.2) the indifferences and differences in the landscape's visual composition, represented by the network of sightlines and views, could not be analysed here and are thus not included.

Before embarking on the results, I will elaborate the GIS based methodology used to identify the landscape structures and elements with coherent histories.

Tracing historical relicts in Rosendael's current landscape using GIS

With the time-space composite model ready (section 2.3) it becomes fairly straightforward to select elements with coherent histories. We after all only have to translate all elementary questions such as '*which paths and avenues from 1718 can still be found today's landscape?*' into basic map queries using Structured Query Language (SQL):

("_1718" = 'avenue' AND "_2010" = 'avenue') OR ("_1718" = 'roads_paths' AND "_2010" = 'roads_paths') OR ("_1718" = 'roads_paths' AND "_2010" = 'avenue') OR ("_1718" = 'avenue' AND "_2010" = 'roads_paths')

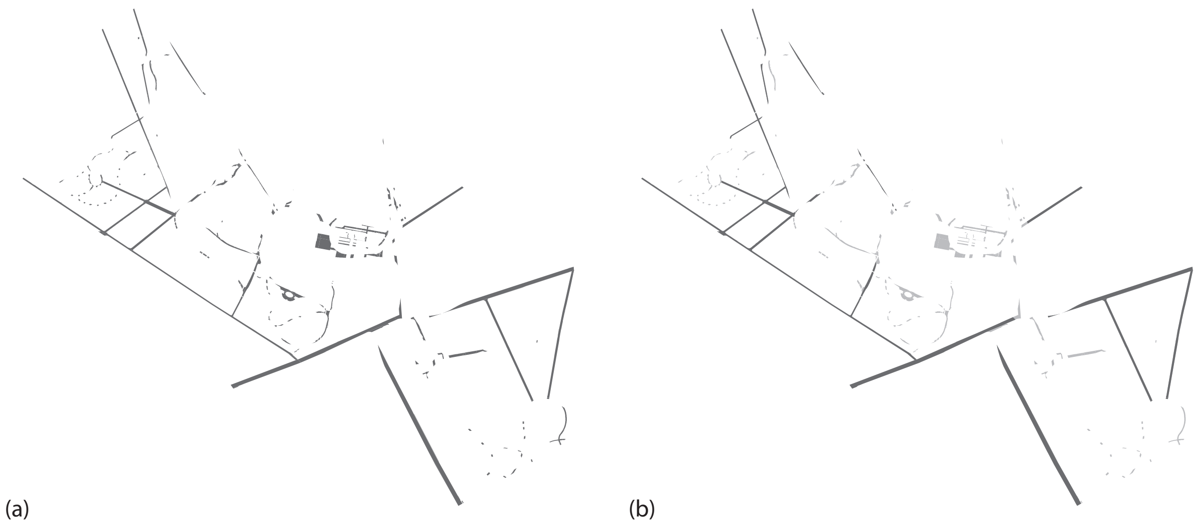

Figure 3.1 (a) Result of the query for remaining paths and avenues from 1718 in the current landscape including coincidental matches without any historical lineage. (b) Corrected result wherein coincidental matches are excluded by qualitative visual interpretation.

Done for all time periods it is then known which historical elements are preserved today and from which time period they date. However, since all matching polygons are incorporated into the selection, including coincidental matches that do not represent any historical lineage, further qualitative interpretation of the results is inevitable (Figure 3.1).
Interpretations were based on both the original and the georeferenced data. During these interpretations also the data's uncertainty and its origins/status were kept in mind. Especially the latter proved to be important for the landscape style plans of Zocher and Wattez, as their maps appeared to barely match the final realisation. Tracing their possible remains using the abovementioned querying methodology consequently returned unsatisfactory results and extensive interpretation was needed to still be able to track them. These interpretations inevitable make the results less certain as those obtained for the earlier maps (i.e. Smit/Elshof and Marot), which largely represent the design's as they were executed. This was expected for the Smit/Elshof map as it was made after the realisation of a design, but was more surprising for the Marot map which probably presents a design proposal as well. The match between this map and what was actually executed probably relates to its status as a factual document conveyed by its presentation as a 2D topographical map (De Jong and Dominicus-van Soest, 1996).
To include more of the landscape context in the results additional smaller scale maps were consulted, i.e. the *Geometrise Caart van de Roosendaalse Plantagie toebehoorende aen den H.W. Gestr. Heer L.A. Baron Torck, Heer van de Heerlijkheijd Roosendaal* (1723) by Elshof; *Kaart van de IJssellinie* (1783) by Herman van Hoof; the *Topografische kaart van de Veluwe en Veluwezoom* (1810) by Maximiliaan Jacob de Man; and the Dutch sequence of (chromo) topographical maps (±1850, ±1910, 1927/31, 1953/58, 1964/66, 1969/72, 1974/77, 1980/85, 1987/90), as well as the research done by Bierens de Haan (1994). Doubtful or too coarse information was not included in the end result.
To understand what remains of the avenues besides their routing also their existing tree-lining is included in the low dynamic structure. Since the tree ages are not known any many of the original tree-lining is rejuvenated they are, unlike their surface area, not assigned to a period.

The existing low dynamic structure

The existing physical historic framework is defined by the results of the previous step (Figure 3.52) and includes all physical elements that lend Rosendael its outstanding cultural-historical meaning. The trees that accompany the avenues are also indicated to better understand what is left of them besides their ground surface.
In the next step this framework is compared to conceptual historical framework to identify deficiencies and finally measures are proposed to remedy these in order to attain a solid and coherent historical framework.

3.2.4 Step 4: Assessment of the existing low dynamic structure

Although Rosendael's historical framework is generally speaking well preserved and in concordance with the conceptual historical framework described above, the following points require further attention, since they violate the basic principles defined above or negatively influence Rosendael's overall cultural-historical value.

- Rosendael's major parts, i.e. the central layout around the castle, the Kraaienberg, and the Koningsberg, appear unrelated and are not experienced as an interdepended whole. The potentiating effect of each part on the other is therewith lost and consequently its unique value as a complete ensemble.

- The structure of eighteenth century avenues, one of the few remains of Van Arnhem's time, is disintegrating and will eventually disappear if no measures are taken. The landscape is therewith to lose one of its oldest and most unique layers.

- The landscape style design around the ponds and the surrounding structure of eighteenth century avenues are physically and visually poorly related and generally lack coherence. The same holds true for the landscape style design around the ponds and Wattez' design for the Sterreberg. As a result the overall unity gets into a thigh corner and these more peripheral parts might end up perished in anonymity.

- Besides being cut off from the rest of the landscape it is inseparably related with, the Koningsberg in general suffers from neglect and decay. Rosendael is therewith to lose a valuable part of its landscape.

The next step addresses these issues and proposes measures to remedy them in order to attain a complete and coherent historical framework.

3.2.5 Step 5: Measures proposed to preserve, reinforce and complete the existing low dynamic structure

In this section measures are proposed to remedy the incompleteness of the existing historical framework in order to attain a comprehensive and solid spatial framework that is able to retain the landscape's cultural significance for the long term and is fit to withstand and guide developments at the short term. First, the completed framework is briefly introduced as a whole, thereafter the individual measures that shape up into the first are discussed separately following the order of the framework flaws identified in the previous step.

The completed framework (Figure 3.53-3.60)
Given the relative completeness of Rosendael's existing historical framework already, only a few measures are taken to further complete and articulate it.
In order to pull together the now separated parts, i.e. the central layout around the castle, the Kraaienberg, and the Koningsberg, the once unifying, but now fragmented, structure

of avenues is restored; paths are slightly re-routed, streamlined and new ones are added to enhance their function as physical link and structural element between the parts; a walk is proposed to meet the same end; and visual relations are (re-)established.
Similar efforts are made at a slightly larger scale to unify the Sterreberg, and the structure of eighteenth century avenues with the landscape style layout around the ponds.
For the Koningsberg a more pro-active approach was required as the remaining historical elements were fragmented and indistinct. In order to bond these together and make the Koningsberg to be experienced as a park-like structure I designed a new path structure that integrates all historical elements in a coherent whole and offers plenty opportunities for varied walks.

Individual measures proposed to complete the historical framework

Below the individual measures that lead up to Rosendael's historical framework are discussed in more detail. The morphological layers at which this measures are aimed are listed between square brackets.

1. Re-instating the spatial and visual relationship between Rosendael's central layout, the Kraaienberg and the Koningsberg

(i) Restoring the spatial relationship [networks: infrastructural network]
In order to improve the spatial relationship between Rosendael's parts and also its wider landscape I propose to restore and articulate the remaining eighteenth century avenues (Figure 3.56 and 3.59) and to reinstate it as Rosendael's main unifying structure. Herewith also the now poorly integrated and articulated historical layer from the eighteenth century becomes valued again. Additional research is, however, required to determine which tree species should be used where. This topic should not be dealt with light-hearted as trees and shrubbery itself are an essential, but often undervalued, or even forgotten, part of the cultural-historical heritage Rosendael represents (Maes, 2011).
In addition, I propose to devise a walk in the tradition of d'Outrein's in the eighteenth century, that physically connects the central layout, the Kraaienberg and the Koningsberg (Figure 3.61). Today, this connection is undefined and unclear to the un-informed visitor. For this walk new paths climbing and descending the Kraaienberg are constructed and the extension of the western avenue at the Koningsberg, aimed at the former 'Logement', is restored and made accessible (Figure 3.58). To scale the steep rises along the Kraaienberg's outlines I suggest to use simple corten-steel stairs slightly raised over the slope (Figure 3.62 and 3.64).
Finally, I advise to use the same material, i.e. dolomite, to furnish all of Rosendael's paths with so that every path can be recognised as being part of Rosendael's united landscape.

(ii) Restoring the visual relationship [networks: network of sightlines and views; volumes: architecture and garden ornaments]

With the recent demolishing of Zocher's 'Logement' at the Kraaienberg and the neglect of the belvedere at the top of the Koningsberg in the 18th century and the growth of vegetation thereafter, two important visual connections between the central layout and these topographical heights disappeared. I propose to re-instate these sights by (i) constructing a new, contemporary building where the 'Logement' used to stood as a new visual focus for several sightlines from the park and the Koningsberg, and (ii) to construct a new, contemporary belvedere at the top of the Koningsberg (Figure 3.63). The latter offers a splendid view along the valley onto Rosendael's central layout and on the wider landscape of the Veluwezoom and the IJsselvalley, thereby connecting the Koningsberg to the rest of Rosendael, and the whole of Rosendael to its wider landscape context.

2. Reinforcing the spatial structure and coherence of Rosendael's central layout [networks: infrastructural network, network of sightlines and views; volumes: planting]

I propose to reinforce the spatial structure and coherence of the central layout along two ways: (i) by a slight adaptation of paths' courses, and (ii) by (re)-establishing visual relations between the lay-outs parts.

(i) Adapting paths

Although not to say with utmost certainty it is very likely that the paths lost some their original fluency and 'Schwung', especially at those places were parts from different era and designers meet. Here the connection seems hampered and the visitor is not tempted to explore the park beyond the restricted walk around the ponds. Leaving a visit to Rosendael more to be a visit to a landscape style garden than to the historically richly layered estate it is. I therefore propose, historically just or not, to slightly redirect and streamline some paths. By doing so a better coherence and more fluent transitions between parts from different periods can be established and the now peripheral parts, i.e. the Sterreberg and the eighteenth century structure of avenues, are withheld from decay in anonymity (Figure 3.55 and 3.58).

(ii) (Re)-Establishing visual relations

Besides physically connecting the different landscape parts I also propose to (re)-establish the visual relationships between the landscape parts, especially between Wattez' Sterreberg and Zocher's design around the ponds. By the selective felling and thinning of the trees and shrubbery between the Sterreberg and the northern pond the parts become a spatial and visual unity (Figure 3.59).

3. Redesigning the Koningsberg [networks: infrastructural network, network of sightlines and views; volumes: planting]

The Koningsberg is a mere shadow of its former self: the tree-lines along the eighteenth century avenues are either lost or seriously impoverished; the belvedere is by long gone; little remains of Wattez' layout but a few paths, some topographical traces (Figure 3.49) and a handful of special trees; and, consequently, the whole is barely experienced as being part of Rosendael.

Keeping in mind that the existing historical structure should be preserved as much as possible, the main task is to forge these elements into a coherent whole that is to be perceived as an integral part of Rosendael. The historical framework is thus to be completed.

Given that little of the authentic fabric is left, historical information is sparsely available, and it is aspired to maintain as much the landscape's historical layering as possible, the completion can only be contemporary. Any reconstruction to one of the known previous states would after all be fundamentally wrong as it violates the conceptual historical framework and falsifies history.

For the completion of the historical framework at the Koningsberg I respected the remaining historical elements and structures, restored them and incorporated them as an integral part of the completed historical framework. Concretely, I restored the eighteenth century structure of avenues and their planting; restored and reinstated the remains of Wattez' path structure; and integrated both in a new path structure that links all these elements in a coherent park-like whole (Figure 3.58). To add some suspense and surprise to the otherwise nearly transparent and rather monotonous planting I added three massive bushes of undergrowth that obscure parts of the paths' course and make the visitor feel lost, whilst still knowing where he/she is (Figure 3.59). Additionally, all superfluous wildshoots should be removed, especially alongside the forest fringe; and remarkable trees in terms of species, shape and age should be set free.

In addition to these measures to complete the historical framework model I suggest (i) to restore the remains of the 'Hoge Vijver' and of the old oozing well just downslope of it to further accentuate the site's historical relationship with the water and to create refugees for the uncommon spring flora and fauna characteristic to these kind of landscapes; and (ii) to cover the slopes of the 'Zwitserse Partij' with moss, similarly as is done in Estate Elswout, to accentuate its steep topography and its appearance as a spring (Figure 3.65).

IV

Discussion and conclusions

In this chapter the main conclusion of this research are presented en discussed. With that there is special attention for the use of GIS and the historical framework methodology beyond the presented case. First, attention is given to the construction of geodatabases for landscape design analysis in general. Secondly, conclusions are given on the use of GIS as an analytical instrument for landscape designs, its limitations are discussed briefly and points of further interest are indicated. Finally, the historical framework methodology is discussed briefly.

Setting up a historical geodatabase for landscape design analysis

The development of the historical geodatabase for landscape design analysis as presented here is at the frontiers of both GIS and landscape architectural knowledge and fills the gap between those historical GIS studies that focus at smaller scales (e.g. China Historical GIS, 2002; HisGIS Fryslan, 2007; Heere, 2008) and those that merely consider the urban context (e.g. Tucci et al., 2010; Laycock et al., 2011; Tucci and Giordano, 2011). As such it provides some preliminary, generic guidelines for those intended to work with historical landscape design data in GIS.

Assess the maps content before using it

For each of the maps that one want to include in a historical geodatabase a critical qualitative appraisal of its status should be made as it not only might have a significant influence on its uncertainty, i.e. spatially, temporally and thematic, but also on its further use and interpretation. In this regard the classification and description of plan statuses and types by Seiler (1985) are still valid and very insightful especially accompanied by the informational work of De Jong and Dominicus-van Soest (1996) on the representation of (Dutch) gardens in the arts.

Make a careful selection of control points

When looking for control points (CPs) during georeferencing it is advised to look first for the least ambiguous points, i.e. those that have both a clear and a likely consistent delineation over time (e.g. buildings and map gridlines) and thereafter, if deemed necessary, to replenish them by more ambiguous points with less consistent delineations (e.g. road crossings), since the chosen CPs have a potentially big and propagating influence on the results, especially when few CPs can be identified.

If a highly accurate historical map is available it might be used as an intermediate to reference older maps by. Although such decision inevitably introduces additional uncertainty, the informational value obtained by being able to reference older maps generally negates the often small increase in uncertainty.

Record your decisions and their consequences

All decisions made during further georeferencing should be made explicit and if possible their consequences for the end result as well (e.g. geometric transformation chosen, it's RMSE and all further information concerning the maps spatial, temporal, and thematic uncertainty). It is strongly recommended to record these findings together with the results of the qualitative appraisal in a metadata file attached to each historical dataset used. In addition it is wise to include the original, raw data as separate files to the database so that future users can trace back decisions on the selection of CPs; the way the file was digitised; and the thematic classes discerned.

Do not be afraid of the data requirements
Although the current data standards set by the Infrastructure for Spatial Information in the European Community (INSPIRE) (EU, 2007) indicate that a very large dataset is required for the analysis of environmental applications, I would like to argue that, at least for the analysis of historical landscape designs, a much more limited dataset, containing historical maps, highly detailed aerial pictures and height data, suffices for most applications.

Although inevitably restricted, these guidelines, supplement by the work in chapter 2, provide a first generic and reproducible framework for the initial analysis of the data itself and their structuring upon which future research can further improve. By incorporating the data's contextual information these can easily be integrated in larger multi-scale Spatial Data Infrastructures (SDI) which in its own turn might create a platform for new, cross-disciplinary research. Additionally, the database itself presents a new way to preserve, display and share landscape architecture's cartographic heritage and additional GIS analysis of these materials might provide new insights into the maps their selves, but more importantly, also on the design methodologies and principles adopted by our predecessors. There are, however, also several considerations that have to be kept in mind when constructing a historical GIS.

Information availability and the limitations of map studies
The step wise methodology proposed and used for this thesis implies that there are sufficient and detailed topographical data available to describe the evolution of a garden, park or landscape accurately over a prolonged period of time. Unfortunately, Rosendael occupies an unique position and few other parks or estates can complement themselves with such a well-documented cartographic history. For landscapes with little of such information the time and costs for the construction of a geo-database will generally not be worthwhile, although the generally better available information at coarser scales (>1:10,000) might still fit one's purpose.
In addition, it should always be remembered that a landscape's evolution is not only recorded by maps, but rather also by illustrations, photographs and text. A mere study of maps is thus far too restricted to describe a landscape's life history. I therefore regard it of importance to research methods and techniques to translate the information contained in these non-spatial data spatially. Evidently, illustrations et cetera can be geo-tagged, but I rather refer here to their translation to a planar map. Herewith, more information can be included in the analysis; facilitating interpretation and allowing extensive cross-checking as a means to validate the information contained. Additionally, these efforts help us to better understand the techniques used to record and represent the landscape. Both generate knowledge upon which choices for restoration, reconstruction or contemporary completion can better be substantiated and communicated to the general public.

Spatial uncertainty and its implicit consideration
The inherent uncertainty of historic data compel us to careful interpretations. Especially at the detailed scale considered here and the spatial delicacy of the many of the landscape elements under study (i.e. path structures, channels) the data's spatial accuracy might have a

profound influence on the analytical results, especially on the space-time composite's query results. In this study the issue of uncertainty is dealt with inexplicitly as part of the interpretational process. In the future, however, this process might be made more explicit by using probabilistic maps to indicate the probability of a historic map element to be present at a certain location.

The time and costs involved when constructing a historical geodatabase
The time needed to construct a geodatabase similar to the one presented here is substantial. Even although the data acquisition for this case only took a few hours as much of the data were already digitally available, the combined effort of georeferencing and digitising took nearly 3 months of full time work — a time during which there is little obvious short-time award and scientific credit generally lacks (Gregory and Healy, 2007). Before embarking on this time-consuming and costly task one has to carefully consider these costs and whether the end product justifies them. More positively, however, a properly constructed geodatabase provides a research source structure in ways that no other approach can manage and offers a resource beyond the initial research questions it was designed for, for many scholars in the years to come (Gregory and Ell, 2007).

Historical landscape analysis using GIS

Although work has been done on many of the individual aspects of the GIS based design analysis (e.g. Nijhuis, 2011), the research presented here adds to this growing body of knowledge by methodologically considering both a landscape design's development and its reverberation in the current landscape. The obtained results are solid and confirm the use of GIS as a suitable, transparent and promising toolbox for the analysis of the designed landscape. Especially with the increased availability of ever more detailed data (Van Lammeren, 2011) all involved with the (historic) landscape will be confronted with GIS eventually. Those that adapt its use early will embrace a technique that is able to read, interpret and manipulate the information contained in the sources rigorously in yet unseen detail. Especially with the onset of 3D data new fields of research and design are about to emerge.
It, however, has to be noted that GIS is particularly good at analysing 2D and 2.5D data; its 3D analytical capability, key to every spatial designer, is still underdeveloped. As a consequence the analysis of a landscapes visual appearance is rather rudimentary. The top down taken height data do neither consider that at eye-level the much thinner trunk is a tree's prime feature, nor the possibility to look underneath a tree's crown. The results (chapter 2) should thus be interpret with caution as they likely overlook some of the landscape's visual subtleties and underestimate the field of sight. Nevertheless, the GIS results give a better substantiated and more detailed illustration of the landscape's visual structure then one would achieve from a plane map.
Besides the data constraint, the tools used to analyse the visual structure themselves are rather restricted especially in terms of (i) parameterisation and their (ii) ability to consider movement.
(i) Unlike its counterpart developed for the analysis of urban landscapes, the isovist, the viewshed is poorly parameterised. Lines of sight, longest line of sight, horizontal viewing angles et cetera are not automatically calculated and general GIS tools proved to be unsuitable for calculating these in retrospect, due to its raster origin and fragmented nature. The

results, however, are of main interest as they are able to quantitatively unravel a sites spatial composition. Especially with the progress made in 3D viewshed construction, renewed attention to the viewshed and its properties might be of considerable interest.
(ii) Any landscape architectural space is experienced in movement by the sequential unfolding of the space as one moves along a path. An analysis of this experience in both space and time is thus of paramount importance for the understanding of a landscape's composition. Unfortunately, the current viewshed operations are poorly equipped to do so as they are unable to use a path as directional guide during their calculations. With this deficit made up and the viewshed parameterisation adapted to human physiology the viewshed will become an important tool to analyse any architectural space — be it historic, contemporary or future — from the perspective of a moving observer.

From analysis to design intervention: the historical framework concept

The historical framework concept was presented here as a methodological framework to analyse, evaluate and eventually intervene in the historic landscape. The concept worked well for the Rosendael case and was able to integrate historic design analysis, cultural-historic valuation and physical intervention. Being one of the first full applications of the concept some premises could not be tested yet.
First, the concept and its application in GIS is said to form a new interdisciplinary platform that facilitates communication and discussion between all disciplines involved. Given the limited time this premises could not be tested yet. A new case should be set up to do so.
Secondly, the physical historical framework, presented as the spatial skeleton that lends the landscape its cultural significance, is not independently validated. In this regard it would be interesting to see how an expert on Rosendael, such as Bierens de Haan, would define and draw the framework.

V

Glossary

Cultural significance: according the Burra Charter (ICOMOS, 1999): 'aesthetic, historic, scientific, social or spiritual value for past, present or future generations. Is embodies in the place itself, its fabric, setting, use, associations, meanings, records, related places and related objects'

Feature class: 'collection of geographic features with same geometry type (e.g. point, line, or polygon), the same attributes and the same spatial reference' (ESRI, 2011c).

Geo-database: one or more structured sets of persistent data about the spatial locations and shapes of geographic features and their attributes, recorded as points, lines, areas, pixels, grid cells or TINs, managed and stored as a unit and generally associated with software to update and query the data (Knowles, 2002).

Geographical Information System (GIS): a computer system that helps to archive, save, manipulate, manage, query, analyse, update and display all forms of geographically referenced data in order to extract information that is needed to answer a certain research question (e.g. Hendriks and Ottens, 1997; Knowles, 2002)

Georeference: to assign coordinates from a known reference system to the page coordinates of an image or a planar map (Knowles, 2002).

Heads-up digitising: a manual method of vectorising raster data using a mouse to trace over features displayed on a computer screen (ESRI, 2011c).

Hillshading: hypothetical illumination of a surface according to a specified azimuth and altitude for the sun. The casted shadows create a three-dimensional effect that provides a sense of visual relief (ESRI, 2011c).

Historical GIS: the use of GIScience methods, tools, and techniques to help understand the history and the historical geography of a place (Gregory and Ell, 2007; Hillier and Knowles, 2008)

Isovist: isovists are viewshed polygons that capture spatial properties by describing the visible area from a single observation point, thereby considering only the horizontal plane.

Inverse Distance Weighted (IDW): method of interpolation that estimates cell values by averaging the sample point's values in the neighbourhood of each processing cell. The closer the point to the centre of the cell being estimated, the more influence, or weight, it has in the averaging process (ESRI, 2011c).

Meta-data: structured data which describe the characteristics of a resource.

Oozing well (Dutch: spreng): artificially dug water well that provides an artificially brook (Dutch: sprengenbeek) with water for the propulsion of water mills or to feed moats and ponds (Renes, 2011).

Planimetric accuracy: describes the extent to which distances and bearings between identifiable objects coincidence with their true values (Laxton, 1976).

Relational database management system (RDBMS): 'type of database in which data are organised across one or more tables. Tables are associated with each other through common fields called keys' (ESRI, 2011c).

Structured Query Language (SQL): 'syntax for retreiving and manipulating data from relational databases. SQL has become an industry standard query language in most relational database management systems (RDBMS)(ESRI, 2011c).

Viewshed (procedure): calculates which locations (i.e. grid cells) can be connected by means of an uninterrupted straight line or LoS, to a viewpoint location within any specified distance (Llobera, 2003). The procedure thus calculates which locations or objects are not obstructed by topography when using a DTM model, or by the topography with all objects on it, when using a DLM model. Since viewshed are calculated in three-dimensional space their shape is usually irregular fragmented, often they are comprised rather of discrete patches than of a single continuous bounded area (Llobera, 2003).

VI

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VII

Appendix

APPENDIX I: Federal Geographic Data Committee (FGDC) National Standard for spatial data accuracy

Planimetric accuracy limiting RMSE [m]	*Map scale*
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1:1 000
0.50	1:2 000
1.00	1:4 000
1.25	1:5 000
2.50	1:10 000
5.00	1:20 000

APPENDIX II: Landscape-morphological model

The generic landscape-morphological model was devised in 1999 by Wassink as a systematised instrument to analyse the morphology of stream valleys in the Dutch sandy soils. The model uses the following three morphological layers to describe the landscape's form:

- terrain morphology: comprised by the terrain's topography, including its water surfaces, and considered the primal layer over which the network and volumes layers are draped.
- networks: represents all linear elements in the landscape, both natural and artificial, real and conceptual (e.g. stream network, infrastructural network, network of parcel boundaries, network of sightlines and views)
- volumes: all landscape elements with a certain height and mass, living (e.g. planting) and non-living (e.g. architecture).

The inventory is presented in this order as the relations between the layers usually display a similar hierarchy: the terrain's morphology generally structuralises the networks and volumes and the networks in their turn often organise the volumes (Wassink, 1999). The interplay of all layers together shapes the space as it is experienced by the visitor.

APPENDIX III: Digital Elevation Model preparation for visual design analysis

This appendix elaborates on the technical preparation of the Digital Elevation Model (DEM) necessary for its use during the visual design analysis. Two different DEMs were prepared: the filtered AHN2 and the raw AHN2 (both at 0.5m resolution). The latter represents the height values as they were obtained during the LiDAR measurements and as such includes height information on vegetation, buildings and other objects. The first represents the ground level height values: information on vegetation et cetera is filtered. In literature these models are called the Digital Landscape Model (DLM) and the Digital Terrain Model

(DTM), respectively.
The technical preparation of these datasets is aimed at (i) replacing NoData values by reliable height values (DTM and DLM), and (ii) at removing and replacing spurious data values by reliable height values (DLM). NoData values are to be replaced since they are not considered during geo-processing and show up as data holes which might blur further results. Spurious data add further uncertainty and, if not removed, might lead to unexpected results. Both the NoData values and the spurious data values are most common in water surfaces as these do not reflect the LiDAR pulses or give spurious values due to sun glint.
Below I will discuss the procedures followed to remove and replace both starting with the preparation of the DTM, followed by the preparation of the DLM. Finally, I will discuss the ultimate DLM used for the visual analysis.

Preparing the Digital Terrain Model
I used two different procedures to fill the NoData values: one to fill the NoData values contained in the water surfaces, the other to replace the remaining NoData values.
Filling the water surfaces. To fill the water surfaces with their actual values, or at least a representative value, these were inserted manually. First, all water surfaces were selected from the digital 2010 map and their height values were added. I determined their heights by using the lowest height value obtained during a manual quick scan of the water's edge height values. Subsequently, a rasterised version of this file, *rHeights_water*, was used in a conditional statement to replace all NoData values in the original file, *AHN_f*, by the values expressed in the *rHeights_water* file:

“*AHN_f_waterfilled*” = Con(IsNull(“*AHN_f*”), “*rHeights_water*”, ”*AHN_f*”)

After this procedure all NoData values that represented water are replaced by the water surface's height values.
Filling the remaining NoData values. To fill the remaining NoData values with reliable height values I re-interpolated the AHN2 points using the Inversed Distance Weighing algorithm, *AHN_f_IDW*, and used these values in a conditional statement to replace all remaining NoData values in the *AHN_f_waterfilled* file.

“*AHN_f_tot_filled*” = Con(IsNull(“*AHN_f_waterfilled*”), “*AHN_f_IDW*”, ”*AHN_f_waterfilled*”)

Which finally resulted in a fully filled ground level DEM.

Preparing the Digital Landscape Model
For the preparation of the DLM I used a similar procedure as described above with the main exception that all spurious data had to be removed first.
Removing spurious data. To remove the spurious data I first manually selected them by drawing polygons that enveloped them. These were then assigned a value of
-9999 and the area's remaining extent a value of 1. After rasterising, I multiplied this file with the original, *AHN_r*, which results in a raster with negative values for all spurious cells whilst retaining the original values for all other cells, *AHN_r_SpuriousCut*. Using the following expression these negative values were then converted to NoData:

"AHN_r_SpuriousND" = SetNull(*"AHN_r_SpuriousCut"* < 0, *"AHN_r_SpuriousCut"*)

This resulted in a cleansed file, which, however, still contained the NoData values to be filled.
Filling the NoData values. To remove small NoData holes (Ø<3m), common in the heights representing vegetation, without losing to much surface roughness, a simple focal mean function was used:

"AHN_r_sND_fMean" = Con(IsNull(*"AHN_r_SpuriousND"*), FocalStatistics(*"AHN_r_SpuriousND"*, NbrCircle(3,"CELL"), "MEAN"), *"AHN_r_SpuriousND"*)

The larger remaining NoData holes I assumed equal to the ground level values as expressed in the DTM (*AHN_f_tot_filled*):

"AHN_r_tot_filled" = Con(IsNull(*"AHN_r_sND_fMean"*), *"AHN_f_tot_filled", "AHN_r_sND_fMean"*)

Which resulted in a fully cleansed and filled raw DEM.

Preparing the ultimate Digital Landscape Model
With both the DTM and the DLM been prepared, I finally constructed the DLM which was used during the actual analysis. In this DLM all pixels representing the paths and roads were assigned their ground level height values. Given the 2.5D character of the data, I inevitably assumed that none of the paths are covered by overhead vegetation. The following procedure is used to integrate the paths and roads in the DLM (*AHN_r_tot_filled*).
First, all paths and roads were selected from the digital 2010 map and their height values was set to -9999. Secondly, after rasterising, *rPaths_2010*, I multiplied the resulting data with the DLM, *AHN_r_PathsCut*. The resulting negative values for all pixels representing paths or roads were then converted to NoData using:

"AHN_r_paths2010ND" = SetNull(*"AHN_r_PathsCut"* < 0, *"AHN_r_PathsCut"*)

The resulting NoData holes, which represent the park's paths, were finally filled using the ground level surface's values.

"AHN_visual_analysis"= Con(IsNull(*"AHN_r_paths2010ND"*), *"AHN_f_tot_filled"*, *"AHN_r_paths2010ND"*).

This final raster thus represents all height values as surveyed in field with the otherwise untraceable paths incorporated at their ground level height.

APPENDIX IV: Inventorying sightlines using GIS

This appendix elaborates on the methodology used to inventory Rosendael's main sightlines, defined here as the visual connection between a view point and a prominent element or focal point at the horizon or in front of it (Vroom, 2005). Two types of sightlines were inventoried: (i) lines of sight between focal points, and (ii) lines of sight between a certain viewpoint and one or more focal points. The methods used to inventory both are discussed below.

(i) Lines of sight between focal points

The methodology to inventory the sightlines between focal points consists of three steps. First, the assumed focal points are determined. Secondly, the visibility for each of these points is calculated. Thirdly, the sightlines between the focal points are drawn on screen.

Determining the focal points. Within Rosendael's landscape the castle's donjon, the orangery, the shell gallery, the pavilion, the 'Bedriegertjes', the stream gods, the gardener's house, and the Kraaienberg are assumed to be the design's most important focal points. This selection was made based on earlier field visits and on an understanding of the design principles commonly used to design landscape style parks (e.g. Hunt and Willis, 1975; Rogers, 2001).

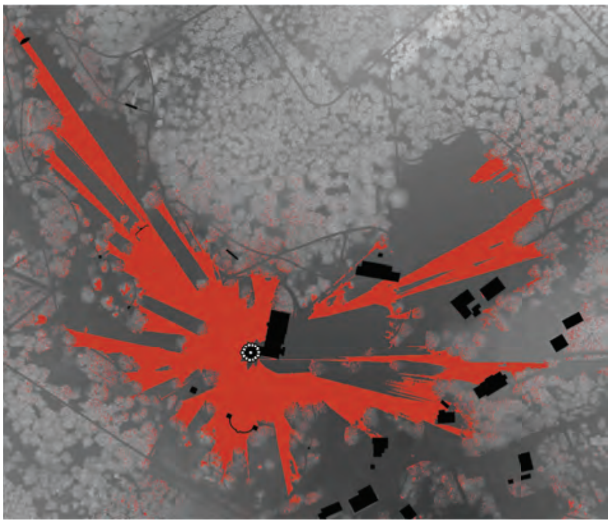

Figure 6.1 Total observer point viewshed generated for the donjon. The white points show the observer points used for this calculation.

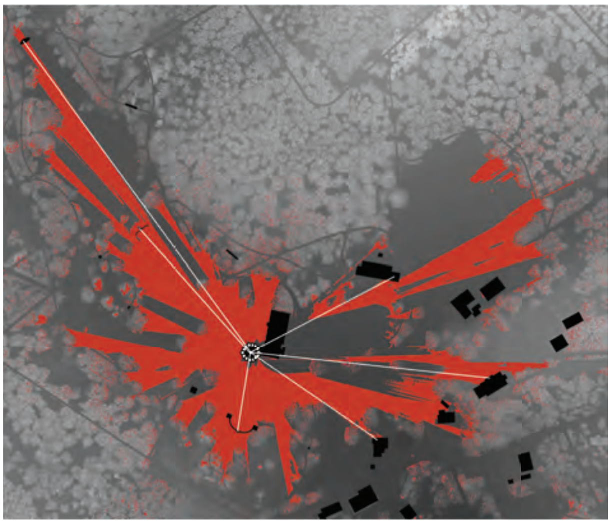

Figure 6.2 Manually drawn sightlines denoting the intervisibility between the donjon and other focal points

Calculating the focal points' visibility. For each of the focal points their visibility was calculated using the Observers Points tool of the Spatial Analyst in ArcGIS 10 (ESRI, 2011b). This tool calculates for each raster cell in the Digital Landscape Model (DLM) whether it is able to see the focal point or not. Because this tool can only be performed for line or point input and the focal points all constitute polygons a sequence of points was used to represent their full extent. Depending on their representation in the DLM these points were placed directly on the focal point's position or slightly in front of it with an height offset of 2 meters (Figure 6.1).

Drawing the sightlines. Unlike its vector based counterpart, the isovist, the viewshed does not facilitate the automatic construction of sightlines, which leaves us to draw them manually on screen. By overlaying the results the interconnecting lines between the focal points were drawn as the middle line of the total visible area of both features (Figure 6.2).

(ii) Other important lines of sight

Besides the mutual visibility of several focal points I also researched the presence of other sightlines that can likely be considered to structure Rosendael's visual landscape. I therefore first determined which focal points can be seen from each location on a path, thereafter I deduced those sightlines that likely structure the visual landscape.

Visibility of the focal points from the paths. To determine which focal points can be seen from which locations on a path the viewshed of each focal point was recalculated using the procedure described above with the exception that a height offset of 1.7 meter — the assumed average human eye level — was incorporated for each raster cell. Using the Spatial Analyst's Reclassify tool in combination with the Raster Calculator (ESRI, 2011b) it was then calculated which locations on a path are able to see which focal points (Figure 6.3 and 6.4) .

Figure 6.3 Example of the focal points' visibility from the park's path structure. Each shade of grey indicates another combination of visible focal points. Check the corresponding file at the dvd for all details. [Observer points analysis and Raster calculator]

Selecting compositional sightlines. With the help of this information I visually selected the views that could be considered compositional based on the presence of a clear background, middle ground and foreground — a compositional technique commonly used to shape views in landscape style parks (e.g. Hunt and Willis, 1975; Rogers, 2001) — and on whether

Figure 6.4 Count of focal points that can be seen from all locations on a path. Note how the combination of a higher concentration of focal points and the relative openness of the landscape in the area surrounding the house lead to visual 'hotspots'. [Observer points analysis and Raster calculator]

the path's course purposefully directs the view, a common technique to unfold the visual landscape to the visitor (e.g. Loidl and Bernard, 2003). For the calculation of each view I used the Spatial Analyst's Viewshed function (ESRI, 2011b) with a spectator offset of 1.7 meter and a horizontal viewing range of 0° till 30° corresponding to the eye's range of vision with highest acuity (Panero and Zelnik, 1979; Snowden et al., 2006)(Figure 6.5).

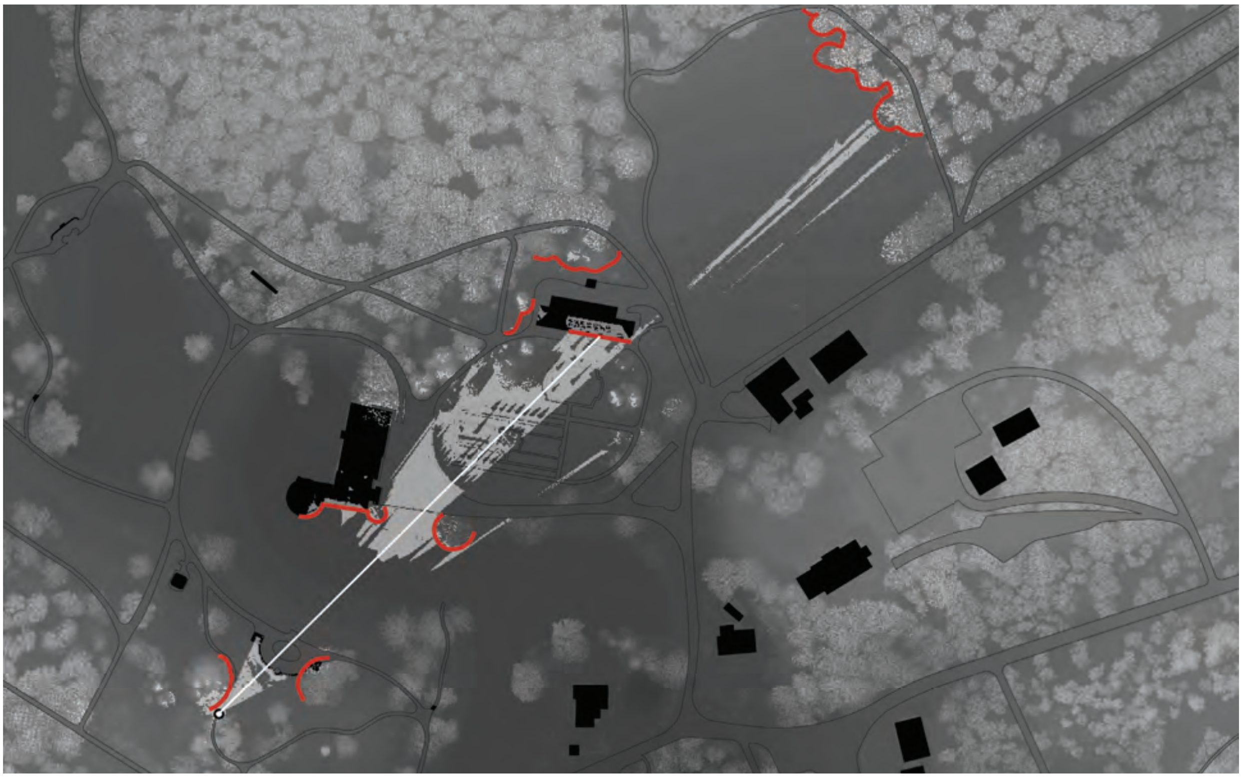

Figure 6.5 Example of a compositional sightline (white line) which view (grey surface) is directed by the path and is shaped by a clear background, middle ground and foreground (orange).