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GIS-based landscape design research

Stourhead landscape garden as a case study

Steffen Nijhuis

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For Jan & Mina Nijhuis

For Monique

For Stijn

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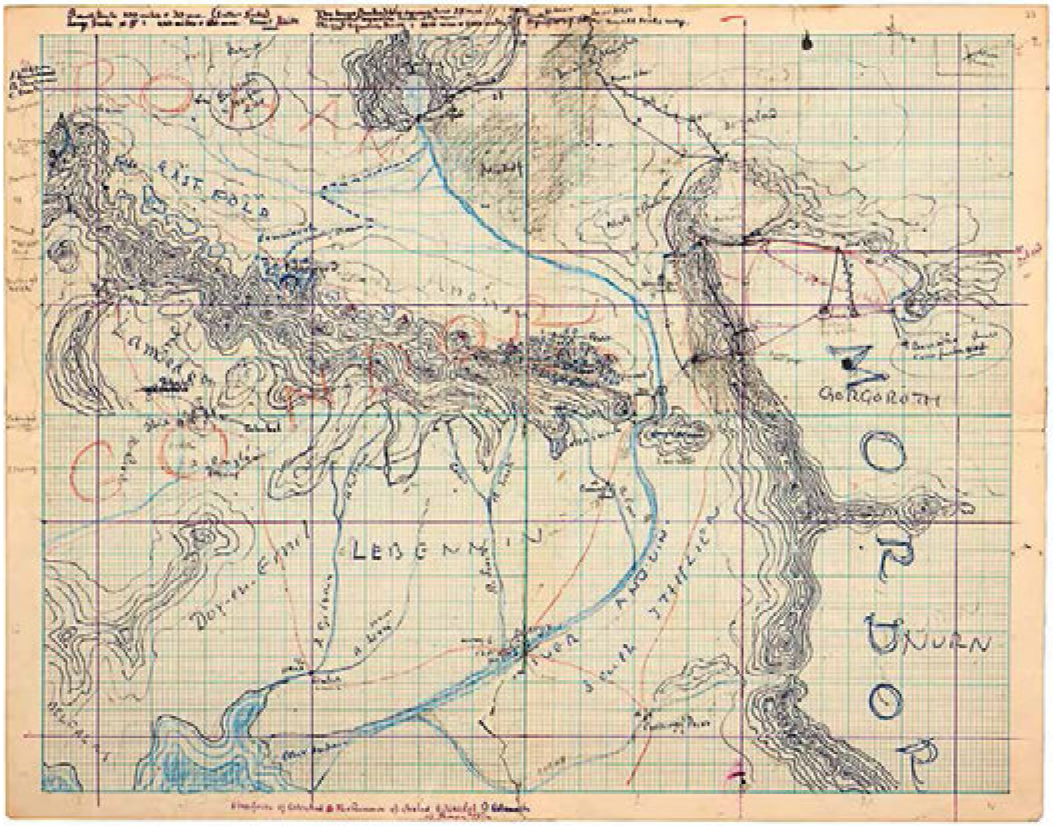

Map of the journey through Middle-Earth by J.R.R. Tolkien, 1937 (image courtesy of The Bodleian Libraries, Oxford University)

"But it does not seem that I can trust anyone,' said Frodo. Sam looked at him unhappily. 'It all depends on what you want,' put in Merry. 'You can trust us to stick with you through thick and thin – to the bitter end. And you can trust us to keep any secret of yours – closer than you keep it yourself. But you cannot trust us to let you face trouble alone, and go off without a word. We are your friends, Frodo."

J. R. R. Tolkien, The Fellowship of the Ring

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Summary

Landscape design research is important for cultivating spatial intelligence in landscape architecture. This study explores GIS (geographic information systems) as a tool for landscape design research – investigating landscape designs to understand them as architectonic compositions (architectonic plan analysis). The concept ‘composition’ refers to a conceivable arrangement, an architectural expression of a mental construct that is legible and open to interpretation. Landscape architectonic compositions and their representations embody a great wealth of design knowledge as objects of our material culture and reflect the possible treatment of the ground, space, image and program as a characteristic coherence. By exploring landscape architectonic compositions with GIS, design researchers can acquire design knowledge that can be used in the creation and refinement of a design.

The research aims to identify and illustrate the potential role of GIS as a tool in landscape design research, so as to provide insight into the possibilities and limitations of using GIS in this capacity. The critical, information-oriented case of Stourhead landscape garden (Wiltshire, UK), an example of a designed landscape that covers the scope and remit of landscape architecture design, forms the heart of the study. The exploration of Stourhead by means of GIS can be understood as a plausibility probe. Here the case study is considered a form of ‘quasi-experiment’, testing the hypothesis and generating a learning process that constitutes a prerequisite for advanced understanding, while using an adjusted version of the framework for landscape design analysis by Steenbergen and Reh (2003). This is a theoretically informed analytical method based on the formal interpretation of the landscape architectonic composition addressing four landscape architectonic categories: the basic, the spatial, the symbolic and the programmatic form. This study includes new aspects to be analysed, such as the visible form and the shape of the walk, and serves as the basis for the landscape architectonic analysis in which GIS is used as the primary analytical tool.

GIS-based design research has the possibility to cultivate spatial intelligence in landscape architecture through three fields of operation:

- GIS-based modelling: description of existing and future landscape architectonic compositions in digital form;
- GIS-based analysis: exploration, analysis and synthesis of landscape architectonic compositions in order to reveal latent architectonic relationships and principles, while utilizing the processing capacities and possibilities of computers for ex-ante and ex-post simulation and evaluation;
- GIS-based visual representation: representation of (virtual) landscape architectonic compositions in space and time, in order to retrieve and communicate information and knowledge of the landscape design.

Though there are limitations, this study exemplifies that GIS is a powerful instrument to acquire knowledge from landscape architectonic compositions. The study points out that the application of GIS in landscape design research can be seen as an extension of the fundamental cycle of observation, visual representation, analysis and interpretation in the process of knowledge acquisition, with alternative visualisations and digital landscape models as important means for this process. Using the calculating power of computers, combined with inventive modelling, analysis and visualisation concepts in an interactive process, opened up possibilities to reveal new information and knowledge about the basic, spatial, symbolic and programmatic form of Stourhead. GIS extended the design researchers’ perception via measurement, simulation and experimentation, and at the same time offered alternative ways of understanding the landscape architectonic composition. This gave rise

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to the possibility of exploring new elements in the framework of landscape design research, such as the visible form and kinaesthetic aspects, analysing the composition from eyelevel perspective. Moreover, the case study showcases that GIS has the potential to measure phenomena that are often subject to intuitive and experimental design, combining general scientific knowledge of, for instance, visual perception and way-finding, with the examination of site-specific design applications. GIS also enabled one to understand the landscape architectonic composition of Stourhead as a product of time, via the analysis of its development through reconstruction and evaluation of several crucial time-slice snapshots.

The study illustrates that GIS can be regarded an external cognitive tool that facilitates and mediates in design knowledge acquisition. GIS facilitates in the sense that it can address the 'same types of design-knowledge' regarding the basic, spatial, symbolic and programmatic form, but in a more precise, systematic, transparent, and quantified manner. GIS mediates in the sense that it influences *what* and *how* aspects of the composition can be understood and therefore enables design researchers to generate 'new types of design-knowledge' by advanced spatial analysis and the possibility of linking or integrating other information layers, fields of science and data sources.

The research contributes to the development and distribution of knowledge of GIS-applications in landscape architecture in two ways: (1) by 'following' the discipline and developing aspects of it, and (2) by setting in motion fundamental developments in the field, providing alternative readings of landscape architecture designs.

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Samenvatting

Landschapsontwerponderzoek is belangrijk voor het vergroten van de ruimtelijke intelligentie in de landschapsarchitectuur. Dit onderzoek verkent GIS (geografische informatiesystemen) als een instrument voor landschapsontwerponderzoek, oftewel landschapsarchitectonische plananalyse, met als doel het begrijpen van het landschapsontwerp als architectonische compositie. De term 'compositie' verwijst naar de ruimtelijke organisatie van een plangebied, als uitdrukking van een architectonisch idee of ontwerpprincipe. Daarmee belichamen landschapsarchitectonische composities en hun representaties een grote rijkdom aan ontwerpkennis, als objecten van onze materiële cultuur en als weerspiegelingen van de mogelijke bewerking van de natuurlijke ondergrond, de ruimte, het beeld en het programma tot een karakteristieke samenhangende vorm. Door het onderzoeken van landschapsarchitectonische composities met GIS kunnen ontwerponderzoekers kennis verkrijgen die gebruikt kan worden bij het verfijnen of maken van ontwerpen.

Het onderzoek richt zich op het identificeren en illustreren van de mogelijke rol van GIS als een instrument in het landschapsontwerponderzoek, om op die manier inzicht te krijgen in de mogelijkheden en beperkingen van het gebruik van GIS in deze hoedanigheid. Het hart van het onderzoek wordt gevormd door de kritische, informatiegeoriënteerde casestudy van *Stourhead landscape garden* (Wiltshire, Engeland). Deze landschapstuin is een voorbeeld van een ontworpen landschap dat de volledige reikwijdte van het landschapsarchitectonische ontwerp omvat. De casestudy kan worden opgevat als een plausibiliteitsproef of 'quasi-experiment,' waarin de hypothese wordt getest en die een leerproces genereert als basis voor kennisverwerving. Om dit systematisch te laten verlopen wordt daarbij *mutatis mutandis* gebruikgemaakt van een methode voor landschapsontwerpanalyse die beschreven is door Steenbergen en Reh (2003). Dit is een theoretisch geïnformeerde, analytische methode, die gebaseerd is op de formele interpretatie van de landschapsarchitectonische compositie op basis van vier architectonische categorieën: grondvorm, ruimtevorm, beeldvorm en programmavorm. In dit onderzoek worden hieraan nieuwe analyseonderdelen toegevoegd, die gericht zijn op het begrijpen van de compositie van binnenuit en die te maken hebben met visuele en kinesthetische aspecten van het ontwerp, zoals de verschijningsvorm en de vorm van de wandeling (zogenoemde *walkscapes*). Deze methode dient als basis voor de landschapsarchitectonische analyse waarin GIS wordt gebruikt als het voornaamste onderzoeksinstrument.

Op GIS gebaseerd landschapsontwerponderzoek heeft de potentie om de ruimtelijke intelligentie in de landschapsarchitectuur te vergroten door middel van drie soorten operaties:

- GIS-modellering: het beschrijven van bestaande en toekomstige landschapsarchitectonische composities in digitale vorm;
- GIS-analyse: het ontdekken, analyseren en synthetiseren van landschapsarchitectonische composities om (latente) architectonische relaties en principes inzichtelijk te maken, waarbij gebruikgemaakt wordt van de verwerkingssnelheid en capaciteit van computers voor ex-ante- en ex-postsimulatie en -evaluatie;
- GIS-visualisatie: het weergeven van (virtuele) landschapsarchitectonische composities in ruimte en tijd, om informatie en kennis van het landschapsontwerp te ontdekken en te communiceren.

Hoewel er beperkingen zijn, illustreert dit onderzoek dat GIS een krachtig instrument is om het begrip van landschapsarchitectonische composities te vergroten. Het onderzoek wijst uit dat de toepassing van GIS in landschapsontwerponderzoek kan worden gezien als een uitbreiding in

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het kennisverwervingsproces van de fundamentele cyclus van observatie, visuele representatie, analyse en interpretatie, met als belangrijkste toegevoegde hulpmiddelen alternatieve visualisaties en digitale landschapsmodellen. Het gebruik van de rekenkracht van computers, in combinatie met de toepassing van inventieve modellering, analyse en visualisatie in een interactief proces, heeft het mogelijk gemaakt om nieuwe informatie en kennis over de grondvorm, ruimtevorm, beeldvorm en programmavorm van Stourhead te verkrijgen. GIS heeft als het ware de waarneming van de ontwerponderzoeker verlengd, via metingen, simulaties en experimenten, en daarmee nieuwe perspectieven geopend op de landschapsarchitectonische compositie. Hierdoor konden belangrijke aspecten geanalyseerd worden die te maken hebben met het begrip van de compositie vanaf ooghoogte, zoals de zichtbare verschijningsvorm, en met de daarmee samenhangende rol van beweging, die handmatig niet of nauwelijks te analyseren zijn. Het onderzoek laat zien dat GIS de potentie heeft om verschijnselen te meten die vaak aan de orde zijn bij intuïtief en experimenteel ontwerpen, en om daarmee algemene wetenschappelijke kennis over bijvoorbeeld visuele perceptie en wayfinding operationeel te maken voor het begrijpen van situatiespecifieke ontwerpen. De toepassing van GIS heeft ook de mogelijkheid geboden om de landschapsarchitectonische compositie van Stourhead als een product van de tijd te begrijpen, via de analyse van de ruimtelijke ontwikkeling van de landschapstuin door middel van een reconstructie en de evaluatie van een aantal cruciale *time-slice snapshots*.

Het onderzoek toont aan dat GIS als een extern cognitief instrument kan worden gezien dat faciliteert en bemiddelt in het proces van kennisverwerving. GIS faciliteert in de zin dat de 'gangbare soorten ontwerpkennis' met betrekking tot de grondvorm, ruimtevorm, beeldvorm en programmavorm toegankelijk kunnen worden gemaakt, maar op een meer precieze, systematische, transparante en gekwantificeerde manier. GIS bemiddelt in de zin dat ermee beïnvloedt kan worden wat en welke aspecten van de compositie kunnen worden onderzocht. GIS opent daarmee nieuwe gezichtspunten en kan 'nieuwe soorten ontwerpkennis' genereren, door geavanceerde ruimtelijke analyse en de mogelijkheid om verschillende informatielagen, wetenschappelijke kennis en databronnen samen te voegen of te integreren.

Het onderzoek draagt op twee manieren bij aan de ontwikkeling en verspreiding van kennis van GIS-toepassingen in de landschapsarchitectuur: (1) door de discipline te 'volgen' en aspecten ervan uit te werken, en (2) door nieuwe fundamentele ontwikkelingen in gang te zetten die alternatieve lezingen van het landschapsontwerp mogelijk maken.

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“Visible things often appear very different from what they really are.”
Johann Heinrich Lambert (1752)

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1 Introduction

§ 1.1 Landscape architecture and GIS

Visual representations such as maps, drawings or models, along with text, and still and moving images are the main basis for thinking and communication in landscape architecture. In recent decades various digital media have been added to the toolbox of landscape architecture. Here information is conveyed by voice, image, text and sound using digital technology. Examples are: computers, the Internet, virtual 3D-landscapes, digital video and photography, computer graphics [Figure 1.1], geographic information systems (GIS), computer simulations, computer-aided design (CAD), building information modelling (BIM), virtual reality and mobile telephony. The possibilities for using digital media in landscape architecture expand every day, since many scholars are involved in their development. As a result digital media become increasingly important in the daily practice of landscape architecture as tools for communication and presentation. Publications such as: Bishop and Lange (2005), Mertens (2010), Buhmann et al. (2010, 2012), Amoroso (2012a; 2012b) and Nijhuis (2013a) showcase the wide range of applications in landscape architecture research and design. However, the potential of digital media in landscape architecture has to date been underutilized, since they are often only used for means of visual communication and presentation. The application of digital media as tools for (creative and visual) thinking especially offers opportunities for development.

Geographic information systems (GIS) in particular offer means with great potential for thinking and communication in landscape architecture. Because GIS is an integrating technology that ties together diverse types of data and information through location, in combination with wide-ranging analytical capacities, GIS is directly related to the very heart of landscape architecture, which is about the understanding of, and designerly intervention in the natural and manmade topography of a certain location. By integrating computer-guided applications – such as image processing, CAD, mapping, data modelling and database management – GIS is a tool for getting a grip on complex geographic situations in the present, past or future. GIS can execute analytical and graphical operations accurately and quickly while handling large amounts of information. By utilising the processing power of computers combined with inventive analysis, modelling and visualisation techniques, researchers can develop new information and knowledge on spatial structures, processes and uses. In this respect GIS can be regarded as an instrument to support spatial observation and reflection in landscape architectonic research and design.

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FIGURE 1.1 Digital painting with image processing software. Artist's impression of the landscape design for the new country estate "De Wilddobbe", Grolloo, the Netherlands (image courtesy of Strootman Landschapsarchitecten, 2010)

§ 1.2 Applications of GIS in landscape architecture

Despite the widespread availability of affordable GIS there is evidence that the potential of GIS is not being fully exploited in landscape architecture and related disciplines.[1] Although there is a consensus on the usefulness of GIS in landscape architecture, it has not yet had a significant impact on the daily practice of landscape architecture. The uptake on using GIS is remarkably slow among landscape architects, and when utilised it is often restricted to the basic tasks of mapmaking and data access.[2] There still appears to be a lot of confusion regarding the use of the tool. Surveys amongst landscape architects show that the complexity and the wide range of possibilities of the software, as well as access to and availability of data are important factors in the neglect of GIS in landscape architecture.[3] Scholars and practitioners in general are also not aware of the full potential of GIS in landscape architecture.[4] Another reason is that GIS is usually introduced not by need or demand, but by the mere

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[1] Hanna & Culpepper, 1998; Eckerberg, 1999; Vonk et al., 2005, 2007; Drummond & French, 2008; Göçmen & Ventura, 2010.

[2] Ibid.

[3] Hanna & Culpepper, 1998; Eckerberg, 1999.

[4] Hanna & Culpepper, 1998; Eckerberg, 1999; Vonk et al., 2005, 2007; Drummond & French, 2008; Göçmen & Ventura, 2010.

possibility of using the novelty program.[5] The effect of the use of GIS is thus largely up to the individual users who have a special interest in the technology, while combining it with skills in landscape architecture. Therefore, aside from training and data issues, a lack of knowledge of the possibilities of GIS in landscape architecture appears to be a significant barrier preventing greater use of GIS.[6]

Knowledge development and dissemination of applications of GIS in landscape architecture are key factors in the awareness of the potential of GIS. A brief literature survey, spanning the period 1990-2013, exemplifies the observation that knowledge development and dissemination are lagging behind in comparison with landscape architecture or GIS as autonomous fields (respectively 16,220 and 61,000 references). When combining landscape architecture and GIS, the query only brought up 187 references; 1.15% of all landscape architecture references in that period. When these results are broken down according to the core activities of landscape architecture[7] – landscape planning, landscape design and landscape management – a more precise distribution of knowledge related to GIS can be found [Table 1.1].

keywords	*n*-publications		keywords	*n*-publications	
landscape architecture	3,840		landscape architecture, GIS	9	0.23%
landscape planning	3,510		landscape planning, GIS	89	2.50%
landscape design	5,300		landscape design, GIS	26	0.49%
landscape management	3,570		landscape management, GIS	63	1.70%
total	*16,220*	100%	*total*	*187*	1.15%
GIS	15,200				
urban planning	10,900		urban planning, GIS	429	
urban design	61,000		urban design, GIS	149	

TABLE 1.1 Literature research based on title keywords, 1990-2013

Numbers based on analysis by Google-Scholar and Scopus using key phrases in the title of indexed publications, accessed: 27th February 2013. For Google-Scholar the operator 'allintitle:' is used.

The relatively best developed field, when it comes to GIS-applications, is landscape planning (land use planning). Here well-developed GIS-applications can be found such as resource-based planning approaches, where location specific data and other data are integrated and processed into new information for urban and rural planning.[8] Landscape character assessment[9] and visual landscape research[10] are other applications that have proven to be useful in landscape planning. However, most of the GIS-applications are related to spatial decision support systems (SDSS) or planning support systems (PSS) in urban and rural environments, often involving public participation.[11] Recently geodesign was introduced as a GIS-based planning method, which tightly couples the creation of planning proposals with impact simulations informed by geographic contexts.[12] Geodesign comprises

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[5] Eckerberg, 1999.

[6] Cf. Eckerberg, 1999; Vonk et al., 2005, 2007; Göçmen & Ventura, 2010.

[7] Stiles, 1994a, 1994b; Thompson, 1999.

[8] For example: Hanna, 1999; Steinitz et al., 2003.

[9] For example: Wascher, 2004; Mücher & Wascher, 2007; Eetvelde & Antrop, 2009; Mücher et al., 2010.

[10] For example: Antrop & Van Eetvelde, 2000; Germino et al., 2001; Bishop, 2003; Roos-Klein Lankhorst et al., 2005; Nijhuis et al., 2011a.

[11] For example: Al-Kodmany, 2000; Brail & Klosterman, 2001; Geertman & Stillwell, 2009; Wissen, 2009; Schroth, 2010.

[12] Flaxman, 2010; Miller, 2012; McElvaney, 2012; Steinitz, 2012. The term 'geodesign' as it is used now is introduced by Jack Dangermond in 2005 in order to (re-)present GIS as a framework for planning and design. However, the term was coined by Kunzmann (1993) for the design of spatial scenarios.

a set of GIS-based methods and techniques for planning built and natural environments in an integrated process, and includes project conceptualization, analysis, design specification, stakeholder participation and collaboration.

In landscape management GIS is used to create a basis for monitoring, targeted management and policymaking. Here virtual 3D-landscapes, in combination with ecological models, realistically describe the spatial distribution and expression of ecosystems[13], visualise disappeared historical landscapes or analyse urban development.[14] Cost-benefit analysis and determination of monetary value of landscapes are also useful applications.[15] Further applications are in the development of maintenance strategies for old forests[16], and finally for visual impact studies.[17]

As the literature research exemplifies, GIS is only sparsely applied in the field of landscape design. Notable exceptions are Hanna and Culpepper (1998), which elaborate the role of GIS in the process of site design (though with a regional scope), Eckerberg (1999) investigates the general role of information technology in landscape design, Van Lammeren et al. (2003) proposes GIS-based 3D-landscape simulations in landscape design and Yong et al. (2003) implement a landscape evaluation system for planting in landscape design. More technically oriented studies focus on the application of GIS-based Computer-Aided Manufacturing (CAM) (e.g. 3D-printers, CNC milling, laser cutting) in landscape design[18], or the development of GIS-based tangible user interfaces[19], where interaction between humans and computers is the central topic. Such intuitive interfaces provide a rapid interaction between interventions and their effects.

The aforementioned examples showcase just a limited range of the potential of GIS in landscape architecture, particularly landscape design. This thesis aims to contribute to the development and distribution of knowledge of possible GIS-applications, by exploring GIS as a tool for landscape design research – investigating landscape designs to understand them as architectonic compositions (architectonic plan analysis). Nijhuis (2011) and Joosten (2012) in particular provide useful leads for development. Alongside that, the work of Gaffney and Stančič (1991) and followers in the field of regional archaeology is inspiring. While the scope of their work is not landscape architecture oriented, they used GIS-based analysis to understand spatial distributions of occupation patterns based on site-conditions addressing relevant scale-levels (i.e. region, site, artefact), and employed visibility- and movement-analysis in relation to natural topography, which are relevant concepts for landscape design research. Tandy (1967), Wheatley and Gillings (1995, 2000) and Llobera (1996, 2003) elaborated concepts for GIS-based visibility analysis in order to convey landscape from an observers point of view. The studies by these authors offers a fruitful basis for cultivating spatial intelligence in landscape design research utilising the potential of GIS.

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[13] For example: Paar, 2003; Rekitte & Paar, 2006.

[14] For example: Sanderson & Brown, 2007; Suurenbroek, 2007; Hudson-Smith, 2008; Sanderson, 2009; De Boer, et al. 2011.

[15] For example: Kong et al., 2007; Sijtsma et al., 2013; Dekkers & Koomen, 2013.

[16] For example: Mladenoff et al., 1994.

[17] For example: Ribe, Armstrong & Gobster, 2002; Rød & Van der Meer, 2009; Van der Hoeven & Nijhuis, 2012.

[18] Girot et al., 2009, 2010; Nijhuis & Stellingwerff, 2011.

[19] Piper et al., 2002; Ishii et al., 2004.

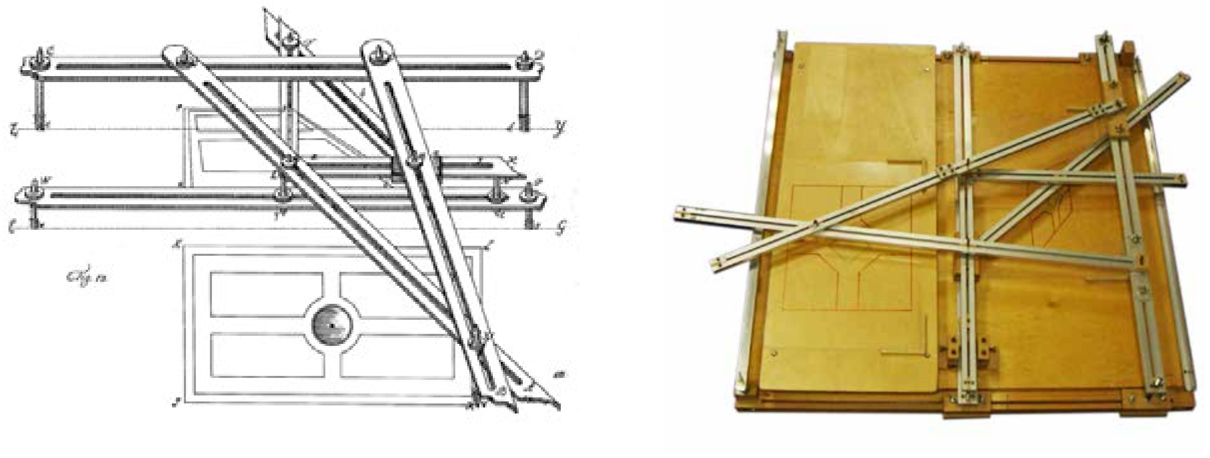

FIGURE 1.2 Johann Heinrich Lambert invented the perspectograph in the 18th century. It could be used to convert a ground plan into a perspective drawing. Left: the original design for the perspectograph from the book *Anlage zur Perspektive* (1752). Right: a modern reconstruction of the instrument (image courtesy of Laboratory of Mathematics, University of Modena and Regio Emilia)

§ 1.3 GIS as tool for landscape design research

Knowledge of spatial design is at the core of landscape architecture. This means that the development of skills for exploring and defining landscape designs as architectonic compositions is a necessity for landscape architects.[20] The concept 'composition' refers to a conceivable arrangement, an architectural expression of a mental construct that is legible and open to interpretation. In that respect the landscape design is regarded as an architectonic system, by which rules of design common to all styles are established.[21] Landscape design research is a vehicle to acquire knowledge of spatial composition via architectonic plan analysis. It is a matter of developing and deploying spatial intelligence[22], the architectural capacity or skill to think and design in space and time. This includes the ability to understand, represent and construct landscape architectonic compositions. These skills can be developed by acquiring knowledge of spatial composition via systematic landscape design research.

Due to the fundamental importance of spatial intelligence, designers have always been eager to employ manual and digital media that can support thinking and communicating about compositions[23] [Figure 1.2 & Figure 1.3]. These tools are extensions of the designers' perception and help to measure *what* can be seen and also determine *how* it can be seen.[24] *What* refers to the selection

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[20] Steenbergen et al., 2002; Dee, 2009; Booth, 2012.

[21] Colquhoun, 1991; Steenbergen et al., 2002.

[22] Gardner, 1983; Gardner, 1999.

[23] Zube, Simcox & Law, 1987; Bishop & Lange, 2005; Nijhuis, 2013a.

[24] Cf. Horrigan, 1995.

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of specific information and *how* to the way that information is acquired. Seeing is used here as a synonym for knowledge acquisition and refers to the digestion of information by the observer. The tools influence and can enrich the employed procedures of investigation and analytical techniques. In fact, the dialectic between research and technology (the tools), and the representation and interpretation of reality has been at the core of science and art for centuries.[25]

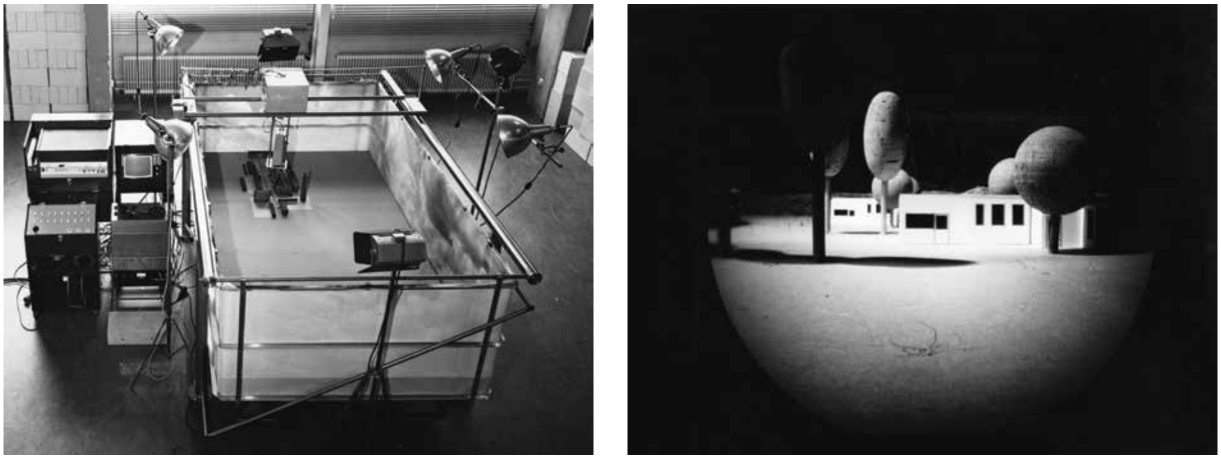

FIGURE 1.3 Since the 1970s, the enthescope has been used to provide insight into the spatial quality of a design. For the design of a town centre, an enthescope is fixed to a camera lens and the camera is placed vertically inside the model in order to take photographs or moving pictures. Left: Enthescope belonging to the Chair of Professor H. van Leeuwen, *'Ecologie van het wonen'* (The ecology of living), Wageningen University. Right: photograph from inside a model (image courtesy of Michiel den Ruijter, 1971)

Although GIS is potentially a powerful tool for landscape design research, in landscape architecture GIS is often regarded as a landscape planning tool or 'map machine' to document, visualise and present geographic realities but not as a tool to increase spatial intelligence for landscape architectonic research and design. However, Jack Dangermond – founder of ESRI[26] and landscape architect – points out: "*The real heart of GIS is the analytical part, where you explore on a scientific level the spatial relationships, patterns and processes of geographic, cultural, biological and physical phenomena*." [27]

Although landscape architectonic phenomena are not mentioned, this definition implies a wide range of possible applications of GIS in landscape design research, as geographic (contextual) relationships and spatial patterns and structures are key concepts for understanding landscape architectonic compositions. GIS, as an integrative platform for exploring spatial patterns and relations between features at all scales, while linking up layers of information through location, is a tool geared for applications in landscape design research, just like it has a wide range of possibilities for capturing, storage, retrieval and display of maps, and other spatial representations. But how can GIS, with its powerful integrating, analytical and graphical capacities, be exploited for means of landscape design research?

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[25] Kemp, 1990.

[26] ESRI is the world's leading off-the-shelf GIS-software developer.

[27] Longley & Batty, 2003, Foreword.

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This study investigates the application of GIS in landscape design research in order to get a grip on the 'DNA' of landscape architectonic compositions.[28] The assumption is that GIS as an extension of the designers' perception can enrich procedures of investigation and analytical techniques in landscape design research while facilitating and mediating which characteristics of the composition are investigated and how these can be explored [Figure 1.4].

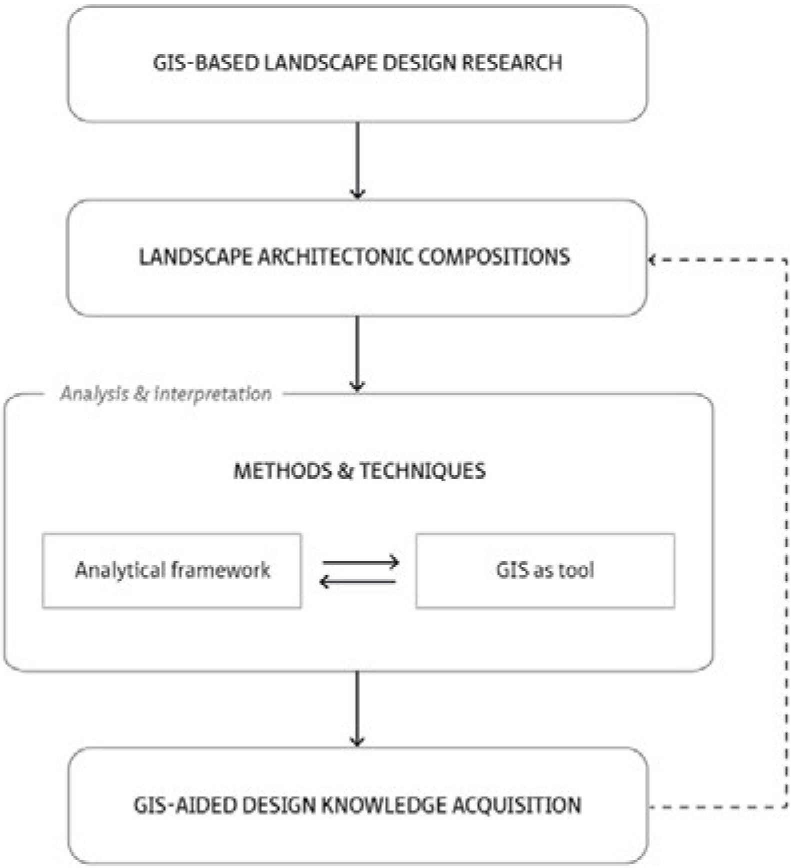

FIGURE 1.4 This study utilises GIS as a tool for landscape design research in order to acquire knowledge from landscape architectonic compositions , which is to be used as input for new landscape designs (graphic: Steffen Nijhuis)

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[28] 'Study' and 'research' are used as synonyms to indicate acquisition of knowledge on an academic subject.

§ 1.4 Research objective and research questions

The central objective of this study is **to identify and illustrate the potential role of GIS as a tool for landscape design research**. This implies the exploration, evaluation and description of relevant GIS-based methods and techniques, so as to provide an idea of the possibilities and limitations of GIS in landscape design research. It involves the critical scrutiny and development of existing methods and techniques for landscape design research with reciprocities for the field of landscape architecture as a whole. In order to meet the objective the following research questions are formulated, which will be elaborated in the following chapters:

1. How can design researchers acquire knowledge from landscape architectonic compositions and in what ways can GIS be instrumental therein?
2. How and to what extent can GIS be practically applied in landscape design research?
3. As a result of the findings, what is the added value of GIS in landscape design research and what future recommendations could be made to develop GIS-based landscape design research?

To explore the potential of GIS in landscape design research the research is primarily based on a case study of an existing landscape architectonic composition: Stourhead landscape garden as an ideal-type of a landscape architectonic design. For the method for investigating the case study, a theoretically informed analytical framework based on the formal interpretation of the landscape design will be employed. GIS is used as the primary tool for data handling, analysis and visual representation. This study considers visual representations to have the same importance as written text in presenting the findings of the research.

§ 1.5 Relevance and scope

This study contributes to academia by extending the knowledge apparatus of landscape architecture via (1) development and implementation of a digital tool for landscape design research, as well as (2) the development of societally relevant applications of GIS-based design research. The instrumental development of the discipline is important because of the potential that geo-information technology offers for knowledge acquisition in landscape design research and for cultivation of spatial intelligence. It is also important because of the increasing interest, in both practice and education, in the role that digital data, information and GIS can play in landscape architecture. Furthermore, with the increasing complexity of spatial design and research, there is a need for new smart design-oriented tools. The development of societally relevant applications of GIS-based landscape design research is of importance due to the increasing demand for knowledge-based planning, design and management of cultural and urban landscapes. Here measurement, simulation and experimentation via transparent and replicable methods serve as the foundation for the formulation of new landscape designs, as well as inform conservation strategies for the development and protection of cultural heritage such as gardens and designed landscapes. In that respect this study will generate knowledge relevant for the development of landscape architecture education and services. On the one hand it will provide material for training and inspiration of students and professionals, and on the other it will contribute to knowledge dissemination and showcase a practical application.

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This study raises the critical questions of *if* and *how* the toolbox of landscape architecture research can be extended by means of GIS. The emphasis of this study is on the application of GIS in landscape design research, not on the implementation in the design process in general. Although the study will provide useful clues for that, it just briefly elaborates its role in design procedures. It will not be putting GIS forward as a 'design machine', but as a tool for knowledge acquisition in landscape design. This study explores the possibilities of GIS as a tool for ex-ante and ex-post research of landscape architectonic compositions in order to gain knowledge as a basis for creation, reflection and evaluation in landscape design.

§ 1.6 Thesis outline

This thesis consists of three parts: (1) Research methodology, (2) GIS-based landscape design research of Stourhead landscape garden, and (3) Synthesis and outlook.

§ 1.6.1 Research framework

Chapter two unfolds the research framework of the study and addresses the theoretical backgrounds, the methods and analytical techniques used, and the research design. It elaborates on the research question: How can design researchers acquire knowledge from landscape architectonic compositions and in what ways can GIS be instrumental therein?

Section 2.2 identifies landscape design research as an important source of design knowledge in landscape architecture. The section elaborates on design as a core activity of landscape architecture and stresses the importance of knowledge acquisition for design. It introduces landscape design research in general and the employed analytical framework for understanding landscape architectonic compositions. *Section 2.3* elaborates on GIS as a tool for landscape design research. This section introduces the basic principles of GIS-based research with modelling, analysis and visual representation as important topics. Furthermore it addresses the role of GIS in knowledge acquisition and communication. *Section 2.4* introduces Stourhead landscape garden as a critical, information-oriented case used to explore the possibilities and limitations of GIS in landscape design research. This section elaborates on Stourhead's origins, and its historical and cultural backgrounds. Furthermore the section presents the results of a literature review summarising existing knowledge of Stourhead. *Section 2.5* presents the research design of this study in order to address the formulated research objective. Furthermore this paragraph introduces the framework for GIS-based landscape design research, which puts into operation methods and techniques for anamnesis of the study area, GIS-aided landscape design analysis and interpretation of the results.

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§ 1.6.2 GIS-based landscape design research of Stourhead landscape garden

Chapters three and **four** are about the application of GIS in landscape design research for modelling, analysis and visual representation of the landscape architectonic composition of Stourhead landscape garden. These chapters form the heart of the study and address the research question: How and to what extent can GIS be practically applied in landscape design research? Both chapters deliver object-related results – providing knowledge of Stourhead's landscape architectonic composition – and tool-related results – providing knowledge on the possibilities and limitations of using GIS in landscape design research.

Chapter three elaborates on the digital modelling of Stourhead landscape garden, which includes data acquisition, storage and retrieval. Here the available digital and analogue contemporary and modern sources on Stourhead are reviewed, described and evaluated. This chapter also includes an elaboration on how these data are used to build digital landscape models as a basis for the GIS-based landscape design analysis.

Chapter four explores Stourhead landscape garden by using an analytical framework for landscape design research and addresses the basic, spatial, symbolic, and programmatic form of the composition. Together these aspects lay out the relation between important characteristics of the architectonic form and its perception, and are operationalized through suitable GIS-based methods and techniques, while testing the possibilities of GIS in the process of knowledge acquisition.

§ 1.6.3 Synthesis and outlook

The final part of the thesis, **chapter five**, sums up the results of the study and addresses the research question: What is the added value of GIS in landscape design research and what future recommendations could be made to develop GIS-based landscape design research? The chapter reflects on the outcome of the study and summarises and generalises the tool-related results. It also discusses the potentials and limitations of GIS in the framework for design analysis and its implications for the discipline of landscape architecture. The chapter ends with recommendations and puts forward the potential areas of further investigation.

2 Research framework

§ 2.1 Setting the scene

Constituent elements of the research framework are the strategy of inquiry, the used methods and analytical techniques, and the research design. The strategy is the system of inquiry, or agenda of thought and action for knowledge formation and provides the theoretical background of the study. The methods are the procedures of investigation and the analytical techniques are the tools of investigation. This study follows a descriptive strategy to identify the role of GIS in landscape design research. To explore the potential of GIS the research is primarily based on a case study: Stourhead landscape garden. As the method to investigate the case study a refined version of the analytical framework for landscape design research of Steenbergen and Reh (2003) is employed. This is a theoretically informed analytical method based on the formal interpretation of the landscape architectonic composition. GIS is used as the primary analytical tool in this framework. From this follows that the research methodology of this study consists of three components: (1) Landscape design research, (2) GIS as a tool for landscape design research and (3) Stourhead as a case study. In order to put these elements into operation the research design guides the investigation.

§ 2.2 Landscape design research

§ 2.2.1 Landscape architecture as an academic discipline

The term landscape architecture – *architecte-paysagiste* – was coined by Jean-Marie Morel (1728-1810) in 1803 and marked the dawn of the 'new discipline'.[29] Landscape architecture as an English term appeared for the first time in a book title 'On the Landscape Architecture of the Great Painters of Italy' by Gilbert Laing Meason (1769-1832) in 1828, which elaborated on Italian architecture in the countryside [Figure 2.1].[30] Subsequently John Claudius Loudon (1783-1843) identified the practice of landscape architecture in the 1840s, but it was William Andrews Nesfield (1794-1881) the first British pioneering practitioner who titled himself landscape architect from 1849 onwards, reflecting Humphry Repton's (1752-1818) appeal to broaden the scope and include scientific, cultural, and social landscapes in urban settings.[31] Via Andrew Jackson Downing (1815-1852) the term came to

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[29] Disponzio, 2002, 2007.

[30] Turner, 1990; Steiner, 2001; Evert et al., 2010.

[31] Antonetti, 2012.

America and was used by Frederic Law Olmstead (1822-1903) and Calvert Vaux (1824-1895) in the design competition for Central Park in New York in 1858. The title became official, when in 1863 'landscape architect' was used by the state-appointed Board of Central Park Commissioners in New York City.[32]

ON
THE LANDSCAPE ARCHITECTURE
of the
Great Painters
of
ITALY.

By G. L. M Esq^{r}.
MDCCCXXVIII.

FIGURE 2.1 The term landscape architecture appeared in English for the first time in 1828 in a book titled 'On the Landscape Architecture of the Great Painters of Italy' by Gilbert Laing Meason (1769-1832)

The definition of landscape architecture according to the International Federation of Landscape Architecture (IFLA) is: "*A profession and academic discipline that employs principles of art and the physical and social sciences to the processes of environmental planning, design and conservation, which serve to ensure the long-lasting improvement, sustainability and harmony of natural and cultural systems or landscape parts thereof, as well as the design of outdoor spaces with consideration of their aesthetic, functional and ecological aspects.*"[33] This definition acknowledges landscape architecture as an academic discipline that is focused on knowledge acquisition principally directed towards a specific practical aim or objective.[34] Here knowledge acquisition is context-driven, problem-focused and interdisciplinary.[35] The research is carried out in the context of application, arising from the very work of problem solving and not governed by the paradigms of traditional disciplines of knowledge: formal,

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[32] Turner, 1990; Steiner, 2001; Evert et al., 2010.

[33] Evert et al., 2010, p. 509.

[34] Cf. OECD, 2002.

[35] Gibbons et al., 1994; Nowotny et al., 2001.

physical, life, social and behavioural sciences.[36] In landscape architecture as a practical research discipline the essential validity question is not 'is it true', but 'does it work according to the aims'.[37] How well the aims are met will differ in each research project. However, general research criteria such as: credibility, applicability, consistency, transparency, significance, efficiency, clarity and originality remain the fundament of research as such.[38] To ensure the quality of the process and output, peer-based evaluation remains a crucial mechanism and constituent element of research in landscape architecture.[39]

Landscape architecture can be broken down in mainly three principle knowledge areas: landscape planning, landscape design and landscape management.[40] Landscape planning is concerned with the long-term development and preservation of natural and cultural landscapes by the development and implementation of strategic goal-oriented concepts and allocation of types of land use. Landscape design is concerned with form and meaning, the development of design principles and the organisation of a physical, functional and aesthetic arrangement of a variety of structural landscape elements to achieve desired social, cultural and ecological outcomes. Landscape management is concerned with the development and application of conservation strategies and enhancement of the long-term beneficial use of landscape resources as well as its heterogeneity, character, and beauty.[41] These knowledge areas overlap and address different scale-levels. They require a multi-layered understanding of landscape.[42]

These knowledge areas focus on extending the body of knowledge in landscape architecture via the application of a wide range of research strategies. Deming and Swaffield (2011) identified nine groups of research strategies in landscape architecture: descriptive strategies (e.g. case studies, direct observation and social surveys), modelling and correlation strategies (e.g. descriptive and synthetic models and simulations), experimental strategies (e.g. preference studies), classification schemes (e.g. typology and taxonomy), interpretative strategies (e.g. discourse analysis and formal analysis), evaluation and diagnosis (e.g. parameters and norms, and landscape assessment), engaged action research (e.g. participatory action research), projective design (e.g. design experiments and design operations), and logical systems (e.g. pattern language).[43]

Landscape architecture is not always recognised as an academic discipline.[44] Over the past few decades landscape architecture has developed an increasingly stronger research focus, but compared with its long and rich history of professional practice, it still needs to develop a research culture.[45] A recent survey amongst landscape architecture academia points out that 'human dimensions of planning and design', 'built environments and infrastructure', 'global landscape issues' and 'green

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[36] Ibid.

[37] Klaasen, 2004.

[38] Groat & Wang, 2002; Klaasen, 2004; Deming & Swaffield, 2011.

[39] Armstrong, 1999; Milburn et al., 2003; KNAW, 2010.

[40] Stiles, 1994a, 1994b; Thompson, 1999.

[41] Vroom, 2006; Evert et al., 2010.

[42] There are many definitions of landscape derived from different cultural and scientific approaches (e.g. Meinig, 1979; Farina, 2006; Muir, 1999; Olwig, 2002; Claval, 2004). In this study landscape is understood as "an area, as perceived by people, which character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000, p. 3; cf. Zonneveld, 1995).

[43] Deming & Swaffield, 2011. This study employs a descriptive and interpretative research strategy, which will be elaborated later in this chapter.

[44] Deming & Swaffield, 2011; Gobster et al., 2010; LaGro, 1999.

[45] Van den Brink & Bruns, 2014.

urban development' are regarded as the most important research domains or overarching themes in which landscape architecture as research discipline engages.[46] Additionally, domains such as: 'biophysical dimensions of planning and design', 'historic dimensions of planning and design', 'theories', 'aquatic environments', and 'tools and technologies' are identified as other important research domains in which research into specific and related topics occur.[47]

§ 2.2.2 Landscape design as object of knowledge

This study considers landscape design as an important object of knowledge in landscape architecture. The basic premise is that design can be considered research or a culture of thinking, as elaborated by Schön (1983), Zeisel (2006) and Cross (2006). Landscape design devises courses of action aimed at changing existing situations into preferred ones.[48] In this respect design as a verb and a noun, is used as a vehicle to make spatial problems visual, to generate solutions and to express cultural values by means of architecture. The design itself provides a context for conversation, observation and construction, not only in spatial terms but also in cognitive terms.[49] Landscape design can be considered a form of practical research when it is aimed at the systematic acquisition of knowledge directed to specific practical objectives. This implies a relationship between research and design where research is seen as an activity to create verifiable knowledge that predicts or explains the physical, behavioural, aesthetic and cultural outcomes of design.[50]

There is a wide range of literature available on the relationship between research and design in landscape architecture.[51] However, Duchhart (2011) shows that consistent and systematic elaborations on design-related research strategies, combining research and design, are scarce in the field of landscape architecture. There are only a few serious attempts, such as: Steinitz (1990) introduced a six-level framework that organises questions related with landscape design problems; Milburn and Brown (2003) described general models for the relation between research and design in landscape architecture; Milburn et al. (2003) provided criteria for research quality; Klaasen (2007) reflects an urban planning/design perspective on research-by-design; and Nassauer and Opdam (2008) present a model where fundamental research is the foundation for design guidelines in landscape architecture. Steenbergen et al. (2002, 2008) and Nijhuis and Bobbink (2012) developed a research approach that systematically combines design research (i.e. analysis of existing designs or precedents) and research-by-design (i.e. study through design) into a coherent research approach for landscape design.

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[46] Meijering et al., 2015.

[47] Ibid.

[48] Cf. Simon, 1969.

[49] The design helps setting the problem by 'naming' the things that will be attended to, and frames the context in which they will be attended (framing of thoughts) (Schön, 1983).

[50] Chenoweth, 1992.

[51] For example: Murphy, 2005; Deming & Swaffield, 2011; Thering & Chanse, 2011.

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Characteristics of landscape design

Landscape design translates abstract planning notions into physical structures and lay-outs addressing several scale-levels. Landscape design is a synthesising activity and is about putting things together rather than taking them apart; integration rather than reduction, it is about relations between things and not the things alone.[52] The nature of landscape design can be characterised by the interplay of four principles of study and practice, understanding landscape as a three-dimensional construction, as history, as a scale-continuum and as a process.[53]

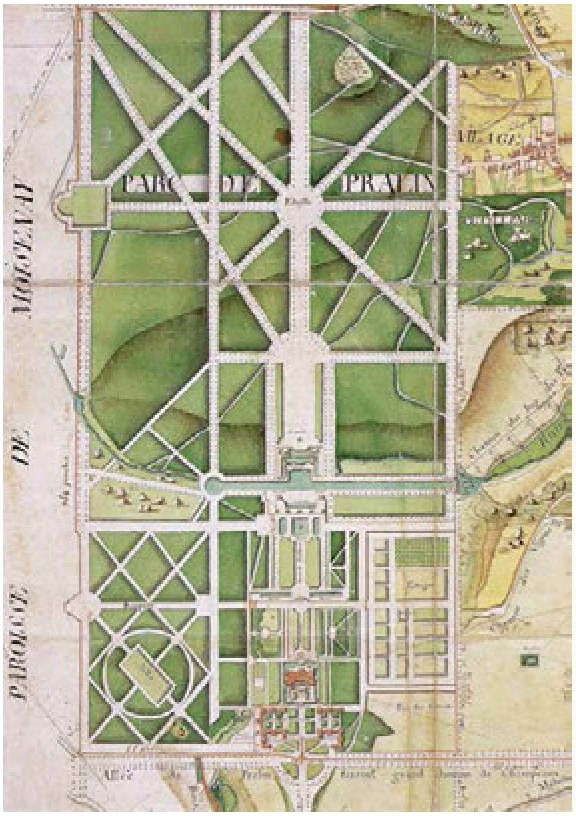

FIGURE 2.2 The magic of optical illusion explored at the gardens and château of Vaux le Vicomte (Maincy, France) by André Le Nôtre, 1653. He made use of methods now known as accelerated and decelerated perspective in the three-dimensional construction of the garden, in which the spatial scale of things is manipulated to the eye of the observer, creating an optical illusion (image courtesy of the Service photographique des Archives et du Patrimoine de Seine-et-Marne)

In *landscape as a three-dimensional construction* the focus is on research and design of the landscape 'from the inside out', as it could be experienced by an observer moving through space. It elaborates on the visual manifestation of open spaces, surfaces, screens and volumes and their relationships in terms of structural organisation (e.g. balance, tension, rhythm, proportion, scale) and ordering principles (e.g. axis, symmetry, hierarchy, datum and transformation).[54] The basic premise is that

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[52] Meyer, 1997; Sijmons, 2012.

[53] This principles are adapted from: Marot, 1995; Prominski, 2004; Nijhuis, 2006, 2013b.

[54] For example: Bell, 1993.

the shape of space, plasticity (form of space-determining elements), and appearance (e.g. colour, texture and lighting) of spatial elements in the landscape determine the relation between design and perception. This principle addresses the form and functioning of three-dimensional landscape space, which creates a spatial dynamic. This might be the construction of a pictorial landscape composition, the framing of a landscape or urban panorama, or creating optical illusions [Figure 2.2]. The treatment of space is not only about designing merely, static images but about the design of a kinaesthetic experience. The images are not ends in themselves but part of a series of three-dimensional images that draw together the architectonic or mental image of the composition.[55] Since there is a causal relationship between seeing and moving the role of movement is of great importance.[56]

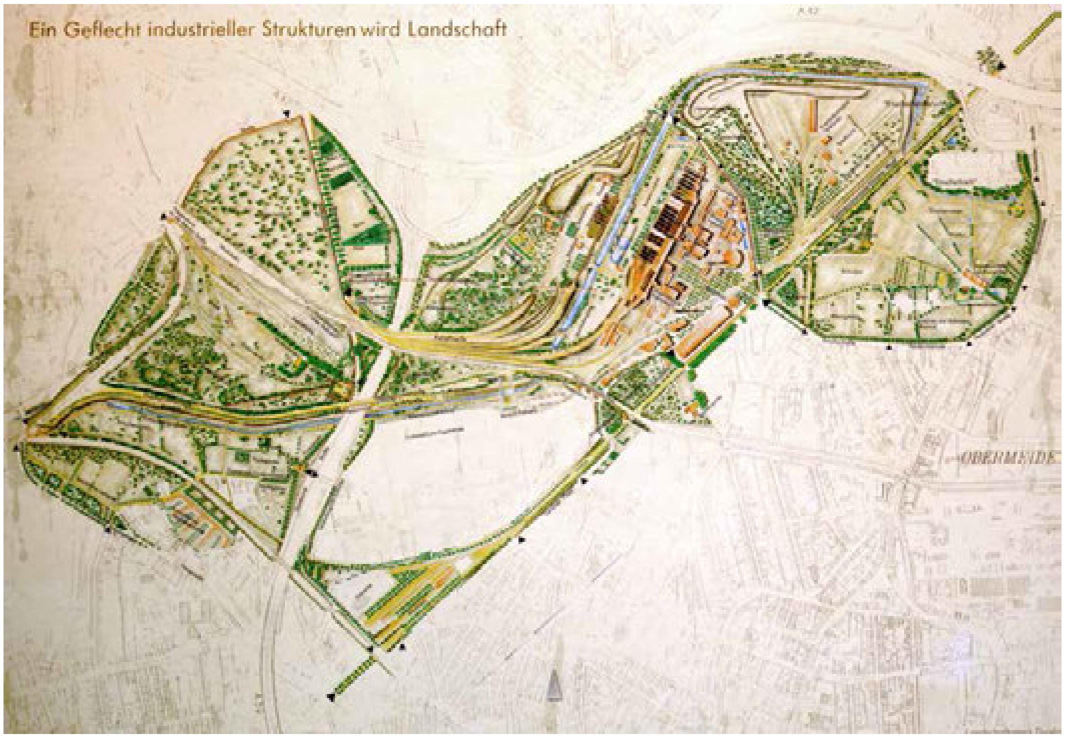

FIGURE 2.3 The 1991 design of Landschaftspark Duisburg-Nord (Germany) by Latz + Partner can be considered a benchmark project for the redevelopment of industrial brownfields into mixed-use use complexes where ecological and socio-cultural objectives blend (image courtesy of Latz + Partner)

In *landscape as history* the landscape is 'read' as a biography, as a palimpsest that evidences all of the activities that contributed to the shaping of that landscape. Here the concept of the *longue durée* is crucial, understanding the landscape as a long-term structure, which is changing rather slowly.[57] The physical traces that time has overlaid can reinforce or contradict each other. Knowledge of these layers is one of the starting points for new transformations of the landscape involved, or for adding a new design layer. This principle involves the evolution of landscape over time and elaborates on

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[55] In this respect routes play a crucial role as structural organisers of the architectonic image (Frankl, 1914/1968; Lynch, 1960; Appleyard, 1970).

[56] For a psychological underpinning: Straus, 1956/1963; Berthoz, 2000. See paragraph 2.2.4 'Clues for development…' for an elaboration.

[57] Braudel, 1966/1992.

operations of 'erasing' and 'writing' history.[58] Operations of erasing history include: complete or partial eradication, etching, excision, entropy and excavation. Operations of writing history include: parcelling, infill, addition, absorption, enveloping, wrapping, overlay, parasitize and morphing. The *genius loci*, the character of the site, is at the heart of this principle.[59] Examples include the re-development of industrial brownfields, and the conservation and transformation of cultural-historical valuable sites [Figure 2.3].

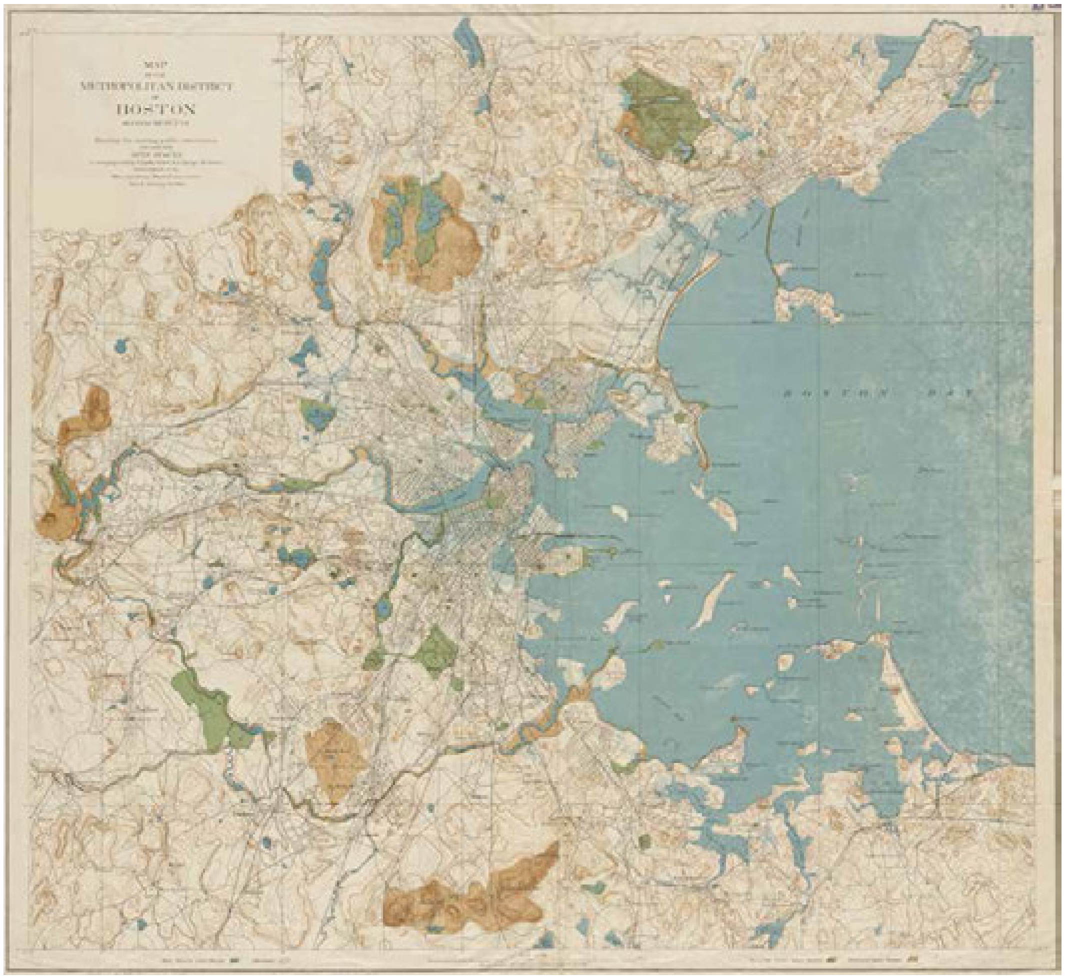

FIGURE 2.4 The Boston Metropolitan Park System as proposed by Sylvester Baxter and Charles Eliot in 1893 offered a new vision for how a green-blue system could function as an armature for the rapidly expanding metropolitan area of Boston (Massachusetts, USA). The plan exemplifies the potential to shape urban and architectural form while employing social and ecological processes to establish a local identity that has tangible relationships to the region (image source: personal archive, Steffen Nijhuis)

In *landscape as a scale-continuum* landscape is considered to be a relational structure connecting scales and spatial, ecological, functional and social entities. Landscape is viewed as a scale-continuum. The design involves establishing relationships via the attachment, connection, and embedment of a specific site or location into the broader context at different scale levels.

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[58] Lukez, 2007.

[59] See paragraph 2.4.3 'Site sensitivity and genius loci' for an elaboration.

A landscape intervention will have impacts on different levels of scale, hitting interests of stakeholders operating on that level. Although scale is a matter of grain and radius, it implies that a particular site is always part of the larger context.[60] Once the extent and grain of the site (object of study) is determined, the rest is regarded as 'context'. The reach of scale is also important, because conclusions on a specific level of scale could be opposite to conclusions drawn on another level of scale (this is called: scale-paradox). This principle addresses working through the scales as an important basic premise, for example for systematic elaboration of planning strategies (e.g. regional planning and design) and design interventions (e.g. project-based realization). This might include, for example, the development of regional park systems as armatures for urban development, or the design of water infrastructures with regional implications [Figure 2.4]. Thus landscape design operates on different scales of intervention, or conceptual zones, which provide a cultural lens to landscape. In sixteenth-century Renaissance Italy these conceptual zones were defined as: the 'first nature', the natural landscape (wilderness, untouched by man), the 'second nature', the cultural landscape (agriculture, urban development's, etc.) and the 'third nature', the designed landscape where the former two where absorbed, used and represented.[61]

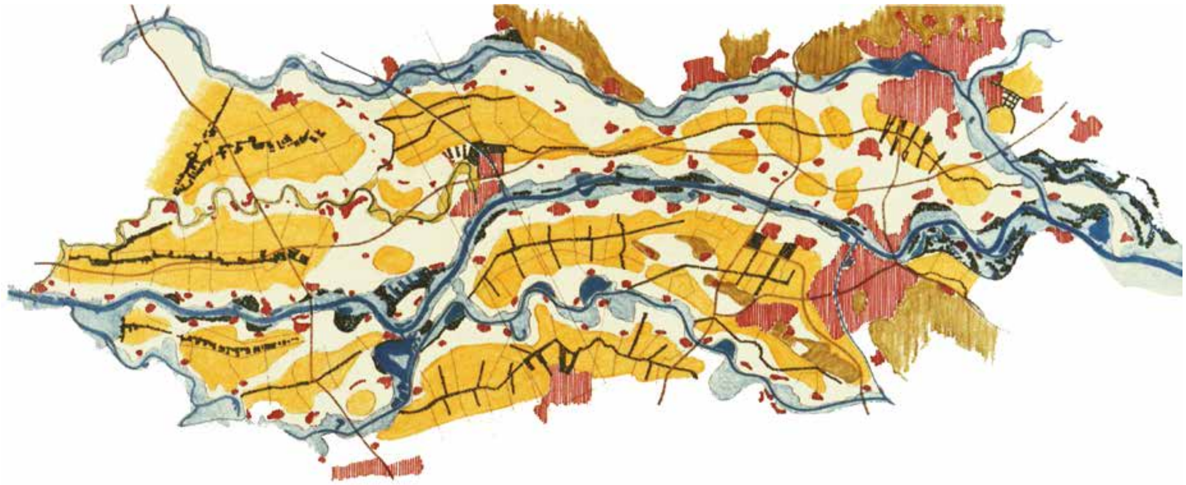

FIGURE 2.5 Plan Ooievaar (Stork) as proposed by De Bruin et al. (1987) offered a ground-breaking vision for the development of a river area in the Netherlands, in which ecological processes are the basis of shaping the landscape and creating conditions for sustainable water management and land-use. This plan provided the foundation for the recent Dutch 'Room for the River' programme, where measures are being taken to give the river space to flood safely, with projects at more than 30 locations (image courtesy of Dirk Sijmons)

In *landscape as a process* the landscape is regarded as a holistic and dynamic system of systems.[62] The landscape is regarded as a layered entity where different processes and systems influence each other and have a different dynamic of change. In that respect landscape is an expression of the interaction between ecological, social and economic processes. The landscape is considered as a process rather than as a result. Natural and social processes constantly change the landscape, making the dynamics

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[60] De Jong, 2006a.

[61] De Jong, 1998, 2006b; cf. Lazzaro, 1990; Hunt, 2000. In analogy Steenbergen and Reh (2011) proposed the *Trias Architectonica*, three crucial realms of landscape design: architectonic landscapes (explicit landscape architectonic spatial forms and types), cultural landscapes (implicit landscape architectonic spatial forms and types of the cultural landscape) and urban landscapes (implicit or explicit landscape architectonic spatial forms and types of urban landscape).

[62] For example: Zonneveld, 1995.

of the transformation a key issue in research and design. The design is like an open strategy, aimed at guiding developments, not a blueprint design. Projects play a role in open-ended strategies, as in staging or setting up future conditions (e.g. manipulating processes of erosion and sedimentation by water or the development of project-based master plans). Operations focus on the interaction between landscape processes and typo-morphological aspects and facilitate social and ecological relationships between natural and human systems. This principle of study and practice elaborates on models for understanding the landscape as system (e.g. layers-approach and systems thinking), and concepts like sustainable urban metabolism and urban ecology. It employs social and ecological processes to create landscapes that serve multiple objectives [Figure 2.5].

The knowledge reflected by these principles of study and practice forms the core of landscape design and expresses the integrative nature of landscape architecture. It embodies a way of thinking typical for landscape architecture and is visible in landscape architecture theories, planning and design processes and products.

Landscape architectonic compositions

The process of design results in a landscape architectonic composition. The landscape architectonic composition consists of natural, cultural, urban and/or architectural elements in relation to spatial, ecologic, social and economic parameters. Regardless of its scale, the composition is the formal framework for the organisation of space and its material substance. The landscape architectonic composition establishes a characteristic relationship between form and content. The form involves the way in which the parts are assembled into a composition.[63] Form is the two- and three-dimensional physical layout and provides for its organisational structure. It is the spatial construction of spaces, paths, edges (i.e. surfaces, screens, objects), foci and thresholds, establishing spatial relationships like sequences, views and vista's.[64] Together with spaces, routes are considered to be paramount structural components of landscape architectonic compositions because they play a crucial role in mediating or facilitating the experience and use. Content is everything that comprises the landscape architectonic object, its physical, biological and cultural substance like landform, vegetation, water and built structures and spaces.[65] The landscape architectonic composition as such determines people's perception, movement, and experience, and provides for scale, proportion, orientation, use and meaning. Landscape architectonic compositions are related to the context and specificity of a location.

Landscape architectonic compositions can be understood by means of landscape design research. This type of research stresses the understanding of the formative elements and the development of design methods and techniques, which can intervene in and direct the development of the landscape.[66] Thus, the basis of landscape design is the understanding and development of landscape architectonic compositions.

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[63] Steenbergen et al., 2008.

[64] Simonds, 1997; Motloch, 2001; Dee, 2009.

[65] Dee, 2009; cf. Bell, 1993.

[66] Ibid.

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§ 2.2.3 Design knowledge in landscape architecture

Design knowledge is important for the cultivation of spatial intelligence in landscape architecture. There are three sources of design knowledge, which together constitute the body of knowledge in landscape architecture.[67] The knowledge is embodied in:

1. design theories: objectives and principles;
2. process of design: design methods and techniques;
3. products of design: compositions and their representations.

Early essays on landscape design, such as Repton (1803), Meyer (1860), André (1879) and Hubbard and Kimball (1935) offer valuable design knowledge by presenting principles of landscape design based on practical experience and experimentation. These essays can be considered as a theoretical condensation of design knowledge. Recent examples include: Simonds (1997), Motloch (2001), Pechère (2002), Loidl & Bernard (2003), Dee (2009) and Booth (2012). Another source to acquire design knowledge is the study of the design process in landscape architecture. Examples include: Steinitz (1990, 1991), Milburn and Brown (2003), and Von Seggern et al. (2008).[68]

However, the products of the landscape design process – landscape architectonic compositions – embody a great wealth of design knowledge as objects of our material culture. They carry knowledge about how to satisfy certain requirements, how to perform tasks, and it is a form of knowledge that is available to everyone.[69] Leupen et al. (1997) put it like this: "*If designing is a creative process that produces something that did not exist previously, analysis begins with the outcome of that process and then attempts to get at the underlying ideas and principles. This analysis [...] is predicated on hypothesis, it is not intended to reconstruct the design process.*"[70] In particular, by studying landscape architectonic compositions knowledge can be acquired of the possible relationships between conceptual thinking and the three-dimensional aspect.[71] In this respect the landscape design, as expressed by its spatial composition, is a container of design knowledge (object specific knowledge and typologies), and serves as a basis for new designs, as advocated by Baljon (1992) and Reh (1995). It provides a basis for knowledge-based design, where knowledge of landscape architectonic compositions is the prerequisite for the formulation of new designs.[72] Therefore, landscape architectonic compositions are an important source of design knowledge. This implies that landscape design research is at the core of landscape architecture.

Through landscape design research it is possible to acquire design insights, design principles, or typological knowledge that can be used in the creation (or refinement) of a new design.[73] The knowledge derived from an existing composition can extend beyond the intention of the designer; the design researcher can reveal insights other than those the designer consciously put in the design. So it is possible to explore and to identify aspects of the design other than the designer's immediate goals.

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[67] Adapted from Cross, 2006; cf. Gänshirt, 2007.

[68] For more general observations see: Foqué, 1975, 2010; Hamel, 1990; Lawson, 2004, 2008; Zeisel, 2006; Cross, 2006.

[69] Cross, 2006.

[70] Leupen et al., 1997, p.18.

[71] Steenbergen & Reh, 2003.

[72] De Jong & Van der Voordt, 2002; Steenbergen et al., 2002; Klaasen, 2004; Nijhuis & Bobbink, 2012.

[73] For typological knowledge as basis for architectonic design see: Argan, 1963; Vidler, 1976; Franck & Schneekloth, 1994.

The design researcher's interpretation can therefore be of equal or other value for the meaning of the design as for the designer's intention.[74]

Data, information and knowledge

In order to understand what design-knowledge actually is, it is important that there is a hierarchical relationship between data, information and knowledge, referred to as the 'knowledge hierarchy'.[75] This hierarchy points out that information is defined in terms of data, knowledge in terms of information, and understanding in terms of knowledge [Figure 2.6]. When applying this hierarchy to landscape design research the process of knowledge acquisition starts with the collection and recording of data – the bare 'facts' related to the design – by direct and indirect observation and measurement of the spatial construction and the geographical context. Data is an abstraction of elements that represents tangible or intangible aspects of the landscape architectonic composition. Important sources of data are: two- and three dimensional measurements and recordings of the site and it's use (e.g. in land surveying). Data is also contained in contemporary documentary sources (e.g. design plans, writings, photographs, paintings, etchings and oral histories), maps of physical, biological and cultural features (e.g. topographic, contour, soil, hydrologic, land use or vegetation maps), and aerial photographs or geo-databases (e.g. Digital Elevation Models). Other sources include modern studies, reviews, interviews, and questionnaires about the spatial composition involved, and can also provide relevant data regarding intentions and reception.

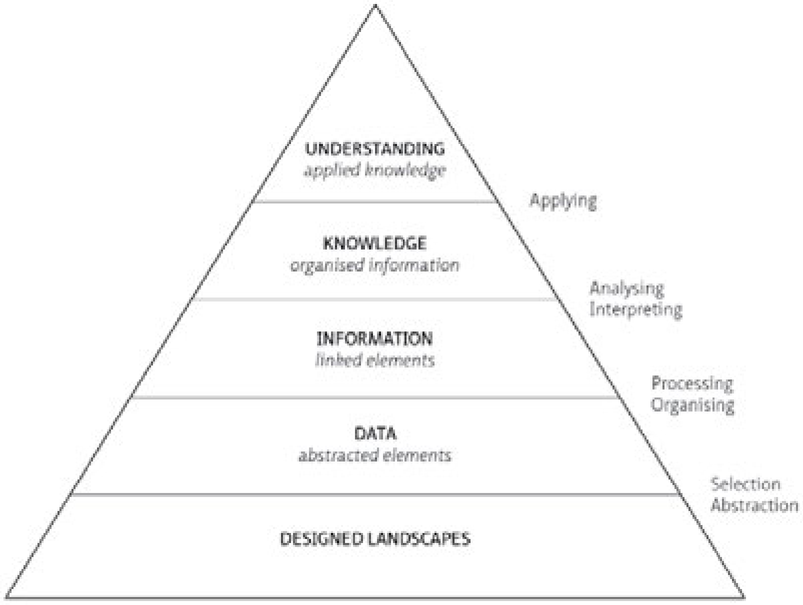

FIGURE 2.6 The knowledge hierarchy points out that information is defined in terms of data, knowledge in terms of information, and understanding in terms of knowledge (graphic: Steffen Nijhuis, adapted from Adler, 1986 and Kitchin, 2014)

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[74] Baljon, 1992; Reh, 1995.

[75] Adler, 1986; Ackoff, 1989; Rowley, 2007.

From the acquired pool of data design, researchers seek to retrieve information on the landscape architectonic composition that answers imposed questions or satisfy the criteria of the research. Information is differentiated from data in that it is 'useful'; information has some meaning, but data holds the potential to become meaningful.[76] Information is inferred from data by 'giving form or shape to' it in the process of answering interrogative questions, like who, what, where, how many, and when?[77] It is about exploring, analysing and synthesising data in order to increase the level of understanding on (aspects of) the composition in terms of spatial relations, structures and patterns. According to DiBiase (1990) "*exploration is about revealing pertinent questions and characterised by a willingness to look for what can be seen, whether or not anticipated. Analysis is confirmation of apparent relationships in the data in perspective of a hypothesis, and synthesis about combination and generalization of findings.*"[78] Designerly information represents connections between two or more physical, biological, cultural or architectonic systems, sets of attributes, or phenomena at a time. It reveals and confirms the existence of relations, hierarchies, conflicts, opportunities and problems.

Knowledge is the interpretation, synthesis and application of information, and answers how-questions. It refers to 'know-how', 'know-who' and 'know-when', each gained through practical experience.[79] Knowledge and information are fundamentally different in three ways: (1) knowledge entails a knower; information exists independently, but knowledge is intimately related to people, (2) knowledge is harder to detach from the individual than information, and (3) knowledge requires much more assimilation; individuals digest it rather than hold it.[80] The information becomes knowledge in relation to an individual interpreting, synthesising and applying information. It is about grasping spatial principles by critical observation and inventive representation. Not the outward appearance of a composition matters in this stage, but it's constructive elements or driving forces. Knowledge has truth value (verifiable, testable) and is applicable (generic, transferable), consistent (reliable) and neutral (rational, systematic, transparent).[81] Understanding is the application of knowledge, increasing effectiveness, and adding value by judgement.[82] It enables the application of knowledge to design alternative futures.[83]

From this it follows that knowledge acquisition in landscape design research depends on the interaction between data, information and the design researcher. The acquisition of knowledge is not possible without processing and 'digestion' of data and information by means of thinking.

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[76] Harvey, 2008, p. 38.

[77] Rowley & Hartley, 2006; Rowley, 2007.

[78] DiBiase, 1990, p. 3.

[79] Ackhoff, 1989; Zeleny, 2005.

[80] Longley et al., 2011.

[81] Groat & Wang, 2002; Klaasen, 2004; Deming & Swaffield, 2012. Other quality measures for knowledge-acquisition in landscape architecture can be found in: Milburn et al., 2003. For design disciplines in general: KNAW, 2010.

[82] Rowley & Hartley, 2006.

[83] Understanding is also referred to as: 'insight', 'to grasp the meaning of' or 'to have thorough or technical acquaintance with or expertness in the practice of' (cf. Hamel, 1990).

Visual representation: Visual thinking and communication

Thinking is not something that goes on entirely, or even mostly, inside individual's heads.[84] Objects of knowledge are created in the process of their emergence. How this is achieved varies, but the knowledge that is thereby generated must itself work, it must function.[85] The developed knowledge and practices in science and technology are therefore called 'working knowledges'.[86] Common ways of knowing and working (working knowledges) range from observation, reading, writing, drawing, to measuring and experimenting, to elaborate simulation and computer models.[87] Instruments such as paper, pencil, measurement instruments and visual representations are important external 'cognitive tools' in this respect.[88] This implies that knowledge acquisition from landscape architectonic compositions can be understood as a cyclical cognitive process in which the design researcher acquires knowledge of the object via interaction with observations, measurements, texts and visual representations.

In the process of knowledge acquisition in landscape architecture visual representations such as maps, plans, elevations and three-dimensional drawings, as well as virtual and physical scale models, are important vehicles for thinking and communication [Figure 2.7]. Maps in particular have fulfilled the role of data handling tools for a long time.[89] They convey spatial information and facilitate knowledge of things, concepts, conditions, processes or events in the human and/or natural world.[90] Maps of a much larger scale are plans. These are detailed maps with a high level of accuracy and provide precise information on buildings, vegetation, water, or paths.[91] Plans present views of a horizontal slice of the landscape design from above and represent the patterns and geometric relationships of a ground plan. Elevations and sections are like plans but present a vertical slice of the landscape design and provide a sense on how it works internally. Three-dimensional drawings are visual representations of solid objects on a two-dimensional surface depicting their relative positions, sizes and relationships viewed from a particular view point. Virtual and physical scale models add the possibility to switch viewpoints dynamically (i.e. through movement) and to construct or observe spatial relationships three-dimensionally.

These visual representations are generally relational, projective and geometrical techniques for depicting landscape architectonic compositions on paper, (computer) screens or as three-dimensional scale models.[92] Sketches, diagrams, photographs, films, collages, computer simulations and Virtual Reality are also useful visual representations in landscape architecture.[93] In order to create and interact with visual representations, different types of tools can be employed, ranging from hand drawing to digital media, such as: GIS, CAD, Computer-Aided Manufacturing (CAM), digital drawing and rendering (i.e. computer graphics), digital photography and film.

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[84] Bertin, 1977/1981; Ware, 2004.

[85] Nowotny, 2008.

[86] Pickstone, 2007.

[87] Ibid.

[88] Bertin, 1977/1981; Ware, 2004.

[89] Harley & Woodward, 1987; Dorling & Fairbairn, 1997. The Bedolina Petroglyph (Valcominca, Northern Italy) is one of the oldest known maps. The map represents a rural settlement carved in rocks, dated c. 1,500 BCE (Anati, 1960; Blumer, 1964).

[90] Harley & Woodward, 1987.

[91] Hardy & Field, 2012.

[92] For an overview of projections and geometrical techniques see: Leupen, et al. 1997, pp. 203-215; Steenbergen et al., 2008, pp. 408-409.

[93] Overviews of the wide range of visual representations in landscape architecture can be found in: Andersson et al., 2005; De Jong, et al., 2008; Mertens, 2010; Amoroso, 2012a, 2012b; Nijhuis, 2013a.

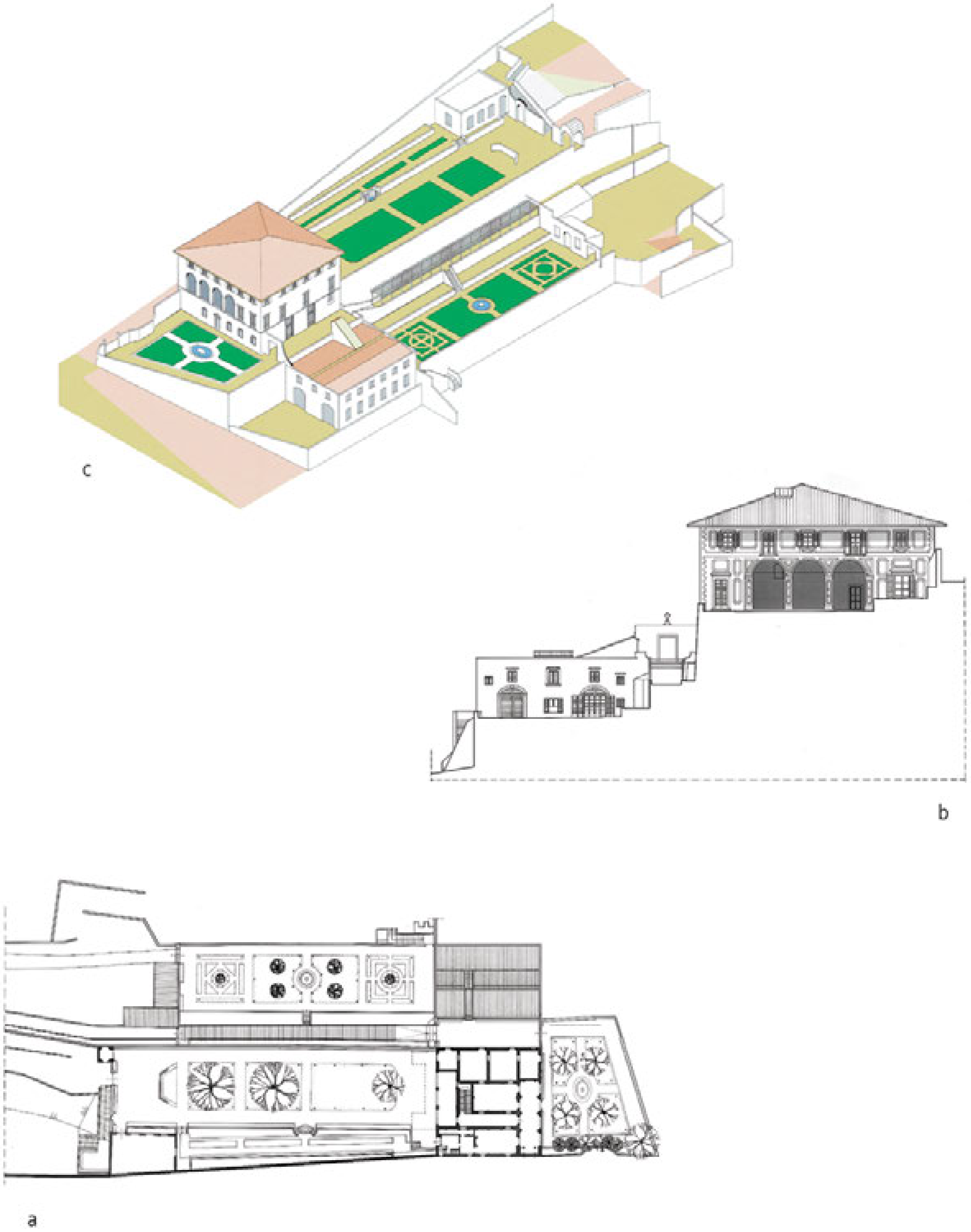

FIGURE 2.7 Plan (a), elevation (b) and three-dimensional drawing (c) of Villa Medici (Fiesole, Italy), a 15th century Italian Renaissance villa (image source: Steenbergen et al. 2008, montage by Steffen Nijhuis)

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There are three activities in landscape architecture in which visual representations become crucial:[94]

1 analysis and evaluation of situations, designs or precedents: simplification, selection, combination and organisation of locational and contextual information in order to gain understanding and acquire design knowledge;
2 design generation: origination, development and testing of new ideas and information entailing experimentation, transformation, addition and evaluation;[95]
3 presentation and public communication: effective and comprehensible communication of ideas and/or situations to a wider audience.

The first two activities are about the 'conversation' of the design researcher with visual representations, and the latter about conversation with a wider audience. Visual representations are used as vehicles for *visual thinking* and *visual communication*. Visual thinking implies the generation of new knowledge through the creation, inspection, and interpretation of visualisations of the previously non-visible elements (seeing the unseen).[96] Visual communication refers to effective distribution of information in visual form in order to transfer knowledge.[97] Thus drawings, maps, films and scale models – and the involved actions: research by drawing[98], mapping[99], filming[100] and 3D-model making[101] – are not only suitable for depicting a (future) reality sharing information, but are also inevitable instruments for creating information by analysis, manipulation and expression of ideas, forms and relationships in processes of knowledge acquisition and distribution [Figure 2.8 & Figure 2.9].

In conclusion, visual representations are fundamental tools for knowledge discovery in landscape design research.[102] They facilitate knowledge acquisition of landscape architectonic compositions by making information visual in a spatial manner. Visual representations can help to reflect upon the emerging insights, appraise the composition in its totality, and observe the relationships between the parts and the whole.[103]

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[94] Appleyard, 1977; Lawson, 2008; Nijhuis, 2013a.

[95] Origination, development, and testing are modes of operation related to different iterative cycles of the design process. The origination-cycle is about the creative evocation of the latent, half-formed internal representations in the mind of the landscape architect, which by externalisation in a self-simulating/stimulating recursive process achieve their initial tentative tangible form. The development-cycle is a nurturing procedure, involving the creative responses of the designer to the 'embryonic' model developed to a greater degree of explicitness, coherence, completeness and specificity. The testing-cycle is the 'moment of truth', when the model is evaluated against the criteria and standards given by the design-brief or the expectations of the audience. Because of this interaction visual representations are far from being incidental outputs but rather outputs central to the thinking process (Schön, 1983; Thiel, 1997; Lawson, 2008; Lawson & Dorst, 2009).

[96] DiBiasi, 1990; cf. Zube et al., 1987.

[97] Ibid.

[98] Corner, 1992; Steenbergen & Aerts, 2002.

[99] Corner, 1999. Suggestive or explorative mapping is a particular type of mapping where different sorts of data are combined in order to offer alternative readings of the landscape. Examples include: Corner & MacLean, 1996; Mathur & Da Cunha, 2001, 2009; Berger, 2006.

[100] Girot & Wolff, 2010; Truniger, 2013.

[101] Nijhuis & Stellingwerff, 2011.

[102] Dee, 2004; Treib, 2008a, 2008b; Steenbergen et al., 2008. In relation to design thinking: Lockard, 1982; Knauer, 1991. In relation to architecture: Robbins, 1994; Porter, 1997; Cook, 2008. For drawing in general: Lambert, 1984; Petherbridge, 2010.

[103] Cf. MacEachren, 1995.

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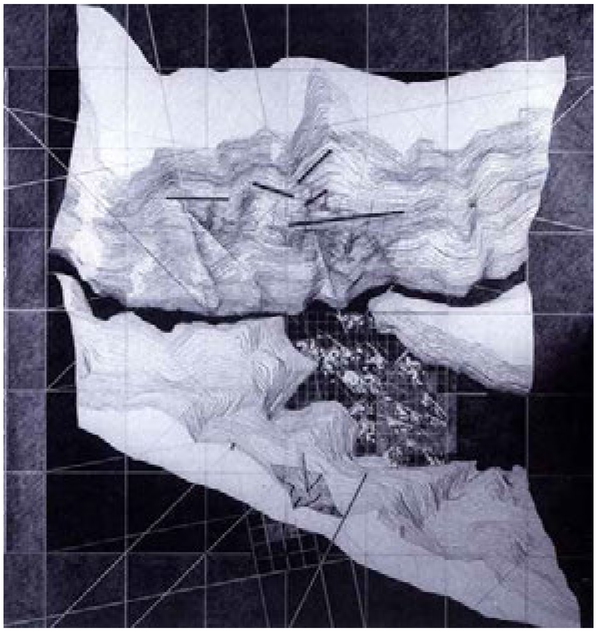

FIGURE 2.8 *Jardin Élémentaires* is a theoretical experiment in which drawing was used to explore natural processes of erosion and sedimentation by water manipulated by dams, creating changing patterns of streams and sedimentary islands in a valley landscape. Theoretical project by Michel Desvigne, 1988 (image courtesy of Michel Desvigne)

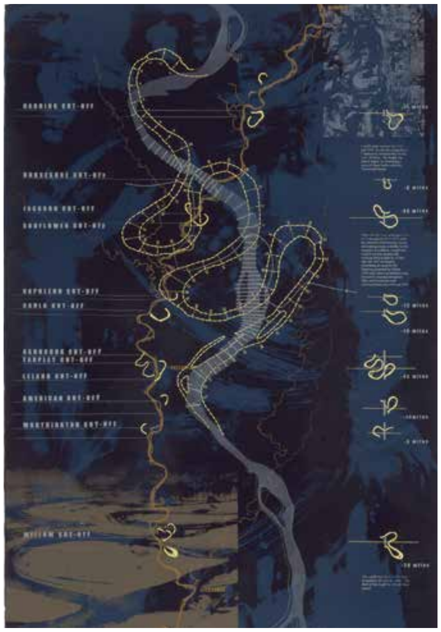

FIGURE 2.9 Cross-reference mapping connects understanding with design thinking. This 'suggestive' cartography offers alternative readings of a landscape and explores certain relationships while integrating thematic maps with statistical information, photographs, diagrams, and sections. 'Engineered Curves' by Anuradna Mathur and Dilip Da Cunha (University of Pennsylvania, 2001) is an application of this mapping technique to a study of the dynamics of the Mississippi River in relation to human interventions (image courtesy of Anuradna Mathur)

§ 2.2.4 A formal approach to landscape design research

Landscape design research is an undertaking through which design researchers strive to increase knowledge of spatial design while using adequate methods of research inquiry. Looking to the field of landscape design research there are several ways to study landscape architectonic compositions.

Ways to study landscape architectonic compositions

Differences in ways to study landscape architectonic compositions are caused by diverging research objectives and approaches. Based on their strategies of inquiry (methods) and research techniques at least nine different discourses can be identified.[104] Most of the landscape design research can be considered *history studies,* which focus on (social) historical aspects or stylistic characteristics of landscape design.[105]

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[104] Partly adapted for landscape architecture from: Moudon, 1992, 1994; Carmona et al., 2010.

[105] For example: Gothein, 1914; Coffin, 1972; Mosser & Teyssot, 1991; De Jong, 1993/2000; Weiss, 1995; Bonnechere & De Bruyn, 1998; Bezemer-Sellers, 2001; Rogers, 2001; Giannetto, 2008; Leslie & Hunt, 2013.

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Visual-aesthetic studies focus on the textual and graphical description of 'good' environments. In these types of studies the emphasis is on the visual qualities of the (urban) landscape design.[106] *Cognitive studies* include significant works on how people visualise, conceptualise and understand the rural or urban landscape.[107] The study of relations between people and their surroundings can be characterised as *environment-behaviour studies*.[108] *Place studies* emphasise knowledge and theories of place, which are based on the importance of people's relations to their environment.[109] Cultural and designed landscapes are an important area of interest of *material culture studies*. Here the focus is on the study of objects and tools of cultures and societies.[110] *Morphology and formal studies* have a common aspect in that the landscape design can be read and analysed via the medium of its physical form. They focus on the tangible results of physical, biological and socio-cultural forces.[111] Spatial configurations of space ('the logic of space') and studies of spatial grammar – the space syntax – of city and park while linking social and geometrical elements of space are subjects of *spatial pattern studies*.[112] *Nature-ecology studies* consider the natural landscape and its processes a necessary and essential components of landscape design research.[113]

The 'Delft approach' in landscape design research

Morphology studies have proven very useful in landscape design research as exemplified by protagonists of this approach such as Shepherd and Jellicoe (1925), Franck (1956), Kask (1971) and Hazlehurst (1980). As argued by these authors, field survey-based plans, sections and perspectives of villa's and gardens, as well as analysis of their geometrical properties and position in the landscape, are important sources for acquisition of knowledge about landscape design. Morphological or formal analysis is an interpretative research method (also called: hermeneutics[114]), in which knowledge is acquired through formal design analysis and interpretation of visual representations of landscape designs. The form is regarded a purely evidential system without prepossession regarding the meaning of its evidence, and presupposes a minimum of assumption.[115] Morphology studies have three characteristics.[116] Firstly, they consider all scales of landscape design, from garden to cultural landscapes. Secondly, they combine volumetric characteristics of landscape structures with patterns of space and movement. Thirdly, they are a morphogenetic approach, since the landscape architectonic composition is a product of time – the time of its conception, development or mutation.[117] Morphology studies can be found in urban design, architecture, art and geography.[118]

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[106] For example: Bijhouwer, 1954; Higuchi, 1975/1988; Bell, 1993; Loidl & Bernard, 2003; Nijhuis, 2011.

[107] For example: Girot & Wolff, 2010; Truniger, 2013; Lanza et al., 2014.

[108] For example: Hall, 1969; Kaplan & Kaplan, 1989; Nasar, 1988, 1998; Gehl, 2001, 2010. This field of study is oft related to environmental psychology approaches, see for an overview: Nijhuis et al., 2011a.

[109] For example: Halprin, 1970, 2011; Norberg-Schulz, 1979/1980; Lassus, 1998; Olin, 2008.

[110] For designed landscapes examples are: Bentmann & Müller, 1970; Mukerji, 1997; Harris, 2003. For cultural landscapes examples are: Bijhouwer, 1943, 1946, 1977; Jackson, 1984; Spirn 1998.

[111] For example: Vroom & Meeus, 1990; Baljon, 1992; Leupen et al., 1997. See also 'The Delft approach in landscape design research'.

[112] For example: Alexander et al., 1977; Hillier, 1996; Thiel, 1997.

[113] For example: Manning, 1913; Bijhouwer, 1933, 1947; McHarg, 1969; Spirn, 1984.

[114] For a full account on hermeneutics in philosophical context see: Ankersmit, 1984.

[115] Sauer, 1925/1963, p. 327.

[116] Adapted from Moudon, 1994.

[117] For the importance of time in the development of urban structures and architecture see: Bobić, 1990; Trachtenberg, 2010.

[118] Fundamental works in urban morphology are: Muratori, 1959; Conzen, 1960. For an overview and backgrounds see: Malfroy & Caniggia, 1986; Moudon, 1992, 1997; Koster, 2001. For the Delft tradition in urban design research see: Meyer, 2005. Protagonists

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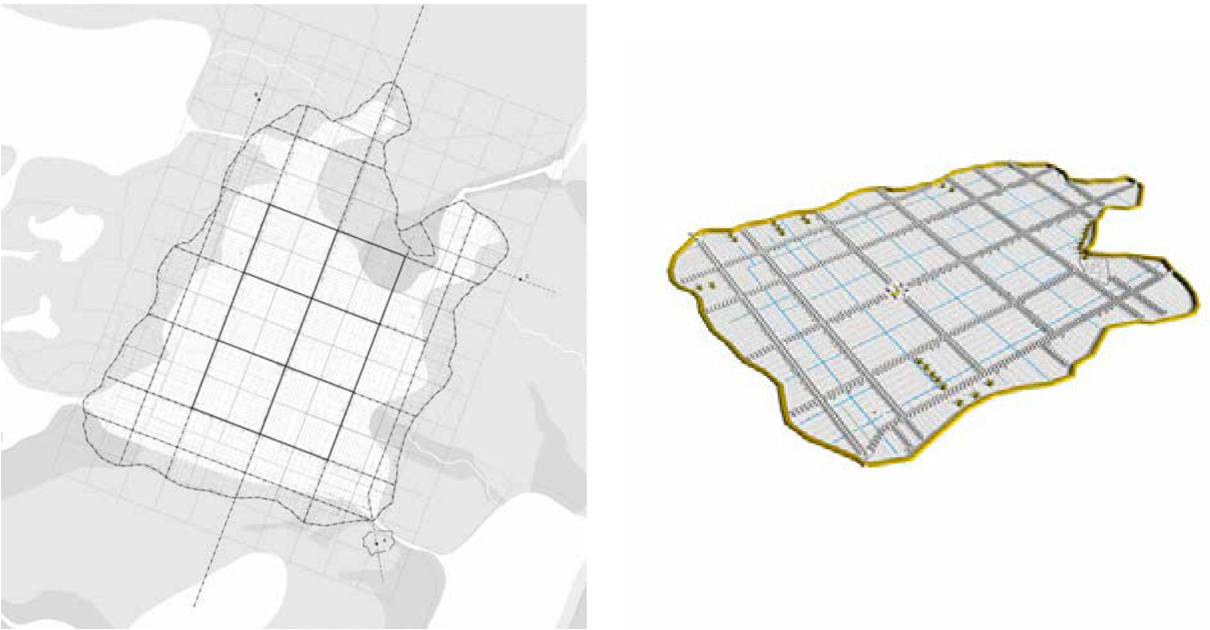

FIGURE 2.10 The Delft approach to landscape design research. Formal analysis of the Beemster, a Dutch lakebed polder created at the beginning of the 17th century, where aesthetic ideals and practical insights into water management and land division blended into a landscape architectonic composition. Left: the geometry and relation to the natural landscape explored. Right: three-dimensional abstraction of the composition (analysis: Steffen Nijhuis, image source: Steenbergen et al., 2009)

In order to acquire knowledge from landscape architectonic compositions a method is needed for systematic landscape design analysis. However, methods for morphological landscape design analysis are only scarcely available. In the Dutch academic context there are examples of landscape design research methods that can be characterised as morphology studies. Meeus (1990) proposes an analysis where the design methods (routing, orientation, coherence, dominance and meaning), principles (historical continuity, space continuity, flexibility, fragmentation and formal autonomy), design concepts (fragmented pragmatic, eclectic and puristic) and styles (functional, classic and romantic) are explored, but refers mainly to parks in urban context.[119] A formal cultural-history approach is the *Cascade*-method by Oldenburger-Ebbers (1998), where historical estate designs are investigated on their *genius loci et temporis* (qualitative characteristics of place and time), *canon auctoris* (characteristic formal principles) and *historia plantarum* (characteristic plant assortment).[120] Wassink (1999) elaborated an analytical method that focuses on the analysis of landform, networks and volumes.[121] This landscape morphological-model focuses on rural landscapes and there is a lack of attention to socio-cultural expression of form.

This study uses and adapts the analytical framework for landscape design as developed by Steenbergen and Reh (2003), referred to as the 'Delft approach' to landscape design research. It is focused on the formal analysis of landscape architectonic compositions as exemplified by Steenbergen

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of morphological approaches in art: Wölfflin, 1888; Focillon, 1948. Carl Sauer (1925/1963) laid down the fundaments for a wide spread morphological approach in geography, called cultural geography ('the Berkeley school of taught'). This approach is best typified by his dictum: *"Culture is the agent, the natural area is the medium, the cultural landscape is the result"* (Sauer, 1925/1963, p. 343). For more backgrounds in morphological research in geography see: Duncan & Duncan, 2009.

[119] Meeus, 1990, pp. 123-164. For an application of this approach see: Baljon, 1992, pp. 291-294.

[120] Oldenburger-Ebbers, 1998, pp. 60-72.

[121] Wassink, 1999, p. 57ff.

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and associates, and is grounded in the notion of precise geometric delineation of designed landscapes.[122] The method consists of the systematic analysis of four landscape architectonic categories: the basic form, the spatial form, the symbolic form and the programmatic form.[123] The basic form is the way in which the topography of the natural landscape or the man-made landscape is reduced, rationalised and activated in the ground plan of the design. The spatial form is about the form and functioning of three-dimensional landscape space. The symbolic form refers to the way in which iconographic and mythological images and architectonic structural forms are connected with one another and with elements from nature. And finally: the programmatic form leads to a functional zoning or layout in relation to logistics and functional patterns of movement. These categories systematically lay out the relationship between the various aspects of the landscape architectonic form and its perception.[124] It is not only about analysis and description of its form, but also its function and the way it has been made. [125]

The four landscape architectonic categories are explored by means of analogue and digital visual representations – particularly drawings, maps and scale models [Figure 2.10].[126] Thus visual thinking, the creation and interaction with the visual representation, is a constituent element of the method in order to explore and analyse the patterns and relationships in landscape architectonic compositions as a result of the landscape architectonic treatment of topography, space, image and program. In order to create and interact with the visual representations different types of tools are used, ranging from hand drawing to digital media.[127]

This analytical framework is based on the work of the German architectural historian Paul Frankl (1878-1962), which in turn was highly influenced by the historians Albert Brinckmann (1881-1958), Aloïs Riegl (1858-1905), and especially August Schmarsow (1853-1936).[128] In 'Die Entwicklungsphasen der neueren Baukunst' (1914), Frankl established a critical system with four categories for the analysis of architectural monuments: (1) spatial composition, (2) treatment of mass and surface, (3) treatment of light, colour, and other optical effects, and (4) relation of the design to social functions.[129] Steenbergen and Reh have adapted these categories and elaborated them for landscape design research.

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[122] For example: Steenbergen, 1990; Van der Kooij & Steenbergen, 1991; Van der Ree et al., 1992; Steenbergen & Reh, 1996, 2003; De Wit & Aben, 1999; Steenbergen et al., 2009; Steenbergen et al., 2008; Steenbergen & Reh, 2011; Smienk & Niemeijer, 2011; Cooray, 2012; De Wit, 2014.

[123] Steenbergen & Reh, 2003, pp. 383-385; Steenbergen et al., 2008.

[124] Ibid.

[125] Ibid.

[126] For an overview see: Steenbergen et al., 2008.

[127] Ibid.

[128] Ackerman, 1968; Watkin, 1980; Porter, 2005.

[129] Frankl, 1914/1968.

Clues for development of the analytical framework

Critique on the analytical framework by Steenbergen and Reh focuses on the lack of attention to sensorial aspects of the composition.[130] More specific, and relevant to formal analysis, is that the role of movement and the fundamental difference between the physical, metric reality (Euclidean space) and its visual appearance (perceived space) is neglected.[131] The morphogenetic aspect, the development of the composition through time, also remains underdeveloped. These critiques can be considered clues for the development of the analytical framework and serve as a basis to redefine and enrich the original landscape architectonic categories for analysis.

With regards to the spatial form, the emphasis of the framework by Steenbergen and Reh is on the corporeal form; the physical metric reality of a three-dimensional composition. However, Frankl (1914/1968) emphasised that the design also consists of a perceptual space, it's visual reality, addressing the sensorial experience that emerges only by movement (movement of the eye and body) and is affected by atmospheric conditions. As opposed to corporeal form, he suggested visible form as an important aspect of a design's three-dimensional composition. This visible form derives from the act of perceiving, which is linked with the sequential unfolding of information as our bodies pass through space.[132] It refers to the visual manifestation of three-dimensional forms and their relationship in space, it is about the appearance, the face of the landscape architectonic composition. The distinction between corporeal and visible form can be underpinned by the work of Straus (1956/1963), a neurologist who in analogy made the distinction between the systemized space of coordinates and perceptual space, as observed by an individual within that space.[133]

How can visible form be understood in order to extract design knowledge? According to Salingaros (2005) "*individuals define their living space by connecting to solid boundaries, visually and acoustically as well as through physical contact. Strictly speaking, outdoor space doesn't need [e.g.] buildings at all; only surrounding surfaces, nodes for sitting and standing, and paths.*"[134] In short, individuals define their environment as a collection of surfaces, screens and objects in space. So a landscape architectonic composition consists of a given spatial relationship between these, though it will change according to the diurnal and seasonal variations in natural light. The visible attributes of the space-establishing elements are position, size, direction, number, shape, colour and texture, which every visible form possess under any condition of illumination.[135] The observer's relationship to these visual descriptors is of a higher geometrical order and they locate their position by using a rough polar or vector orientation in terms of distance and direction.[136] This optical structure is called an *ambient optic array* and was introduced by Gibson (1961). He explained the optic array as a set of nested solid angles corresponding to surface elements in the environment. The architectonic space exchanges

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[130] De Wit, 2014. For the importance of including all senses in architectonic design see: Pallasmaa, 2012.

[131] Nijhuis, 2011.

[132] Frankl, 1914/1968; Psarra, 2009.

[133] Straus made the distinction between the space of geography and the space of landscape from a psychological point of view (Straus, 1956/1963, p. 318 ff.) The space of geography can be described in terms of coordinates. The space of landscape in terms of visible relationships of objects within and making the landscape. Lewin (1934) proposed the term 'hodological space' to describe the factual topological, physical, social, and psychological conditions a person is faced with on its way ('Hodos', a Greek word meaning 'way'). See for conceptual representation of hodological space: Lewin, 1938; Schaal, 1978; Thiel, 1997.

[134] Salingaros, 2005, pp. 41ff.

[135] Thiel, 1961; Gibson, 1986; Bell, 1993.

[136] Gibson, 1986.

information via these fields with our senses; they are visual information fields.[137] The meaning attached to it is referred to as semantic information, and is dependent on the receiver.[138] Thus there is a subjective part containing symbolic, cultural and personal elements that finally determines the experience of landscape architectonic space.[139]

Related to the visual perception of landscape architectonic space is the 'sense of movement' or kinaesthesia.[140] According to Berthoz (2000) and Berthoz and Petit (2008) kinaesthetic experience involves several sensory channels for an active participation with the spatial environment. The brain integrates information from proprioception and the vestibular system into its overall sense of body position, movement, and acceleration, which is important for spatial orientation.[141] Bodily sensation and muscle movement are thus closely related to visual perception. As Gibson (1986) elaborates: *"Locomotion is guided by visual perception. Not only does it depend on perception but perception depends on locomotion inasmuch as a moving point of observation is necessary for any adequate acquaintance with the environment. So we must perceive in order to move, but we must also move in order to perceive."*[142] The visible form is therefore determined by a kinaesthetic experience of the composition where visual perception is inherently connected to one's abilities and possibilities for movement offered by the composition. Landscape architectonic compositions stimulate, or at least permit, certain kinds of movement with different modalities, and manage speed and direction.

The visible form of a landscape architectonic composition derives from the act of visual perception, which is linked with the sequential unfolding of visual information by movement through space. Individuals move through a landscape and its visible form alters or changes constantly, as does its internal relationships.[143] Related to movement through space three modes of vision can be distinguished: stationary, slow-motion and fast-motion vision.[144] Stationary vision refers to standing still or sitting with a (more or less) frontal perception of a fixed scene. Slow-motion vision is related to walking, cycling and horse riding and slow sequential frontal and/or lateral perception of scenes. And fast-motion vision refers to car driving, motorcycling and travelling by train and fast sequential frontal and/or lateral perception of scenes. The characteristics of these modes of vision have wide ranging implications for the visible form. For instance, the speed of movement determines the visual angle and the focus towards the landscape (e.g. with increasing speed the visual angle narrows down). Stationary vision and slow-motion are particularly important modes of vision because they closely relate to the primordial act of walking as an aesthetic and social practice.[145] According to De Jong (2007) the walk– as an action, but also as a route – represents "*an important unifying and structural principle in landscape design [...] and the discovery of landscape from past to present. It must be*

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[137] Gibson, 1986; Salingaros, 2005.

[138] Haken & Portugali, 2003; Sekuler & Blake, 2006.

[139] For example: Kaplan & Kaplan, 1989.

[140] In traditional Asian culture it is common to link visual perception with movement as exemplified by the Chinese character for 'to see' 見 in which the upper part symbolises the eye 目and the lower part symbolises the feet of a person 儿.

[141] Berthoz, 2000; Berthoz & Petit, 2008.

[142] Gibson, 1986, p. 223.

[143] The interpretation of every single image as three-dimensional that one receives from different viewpoints are (usually) not ends in themselves but part of a series of three-dimensional images which draw together the architectonic image (mental image) of the composition (Frankl, 1914/1968; Appleyard, 1970; Lynch, 1960). This kinaesthetic experience of the observer who arrives at a 'single' image as the product of many partial images is summarised by Hoogstad (1990) as: Space = Time (+ memory) x Movement. In other words, visible form is about the construction of time-space relationships among the space establishing elements and their attributes (Hoogstad, 1990).

[144] Nijhuis, 2011.

[145] König, 1996; Solnit, 2001; Careri, 2002; Schmidt, 2007.

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considered the hinge that steered more than anything else the changing options for use, experience, and design and contributed fundamentally to both personal and cultural developments."[146] Routes are thus important structural components of (designed) landscapes because they play a crucial role in the use and reception of these compositions. The shape of the walk – the formal aspects of routing such as the tracing and gradient of the paths – determines the tactile and kinaesthetic experience and is the means to organise the visual logic of a site by directing the individual's gaze at views or focal points (e.g. buildings, objects) and their sequence (serial vision).

From this follows that the analytical framework should include the analysis of the visible form, with the shape of the walk as an important condition.

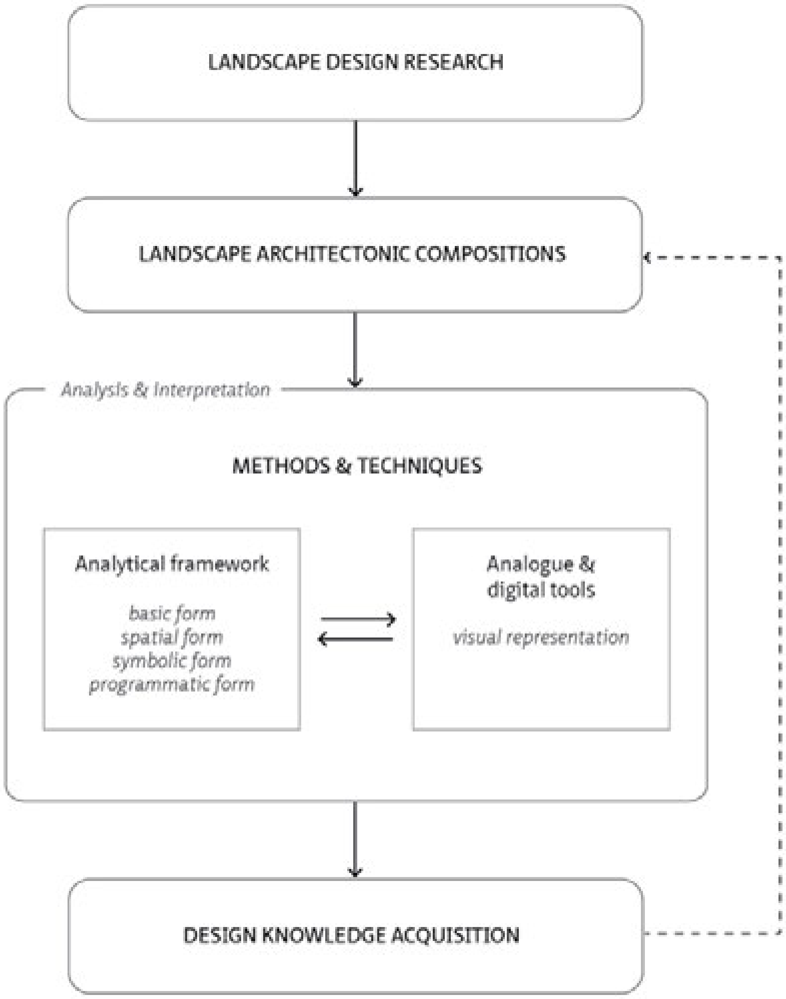

FIGURE 2.11 Framework for landscape design research. This is a theoretically informed analytical method based on a formal interpretation of the basic, spatial, symbolic and programmatic form of the landscape architectonic composition, while employing analogue and digital tools for knowledge acquisition (graphic: Steffen Nijhuis)

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[146] De Jong, 2007, p. 20.

§ 2.2.5 Analytical framework for landscape design research

This study adapts the analytical framework by Steenbergen and Reh (2003) as the methodical fundament for landscape design analysis but takes the critique as a basis to develop it. The original categories for landscape architectonic analysis are redefined based on the above discussed clues. This adjusted version of the framework includes new aspects to be analysed (e.g. visible form and the shape of the walk) and serves as the basis for the landscape architectonic analysis in which GIS is used as the primary analytical tool [Figure 2.11]. By analysing several important time stages one can grasp the development of the composition, understanding it is as a long term structure.

The basic form

The basic form refers to the reduction, rationalisation and activation of the natural or manmade landscape in the design plan. It is about making use and manipulation of geomorphological, hydrological, soil and geographical conditions. In this respect landscape architectonic compositions are always related to the geographic context, specificity or *genius loci* of a location with particular landforms and spatial conditions (e.g. location by the sea, in a hilly area, or on a plain). It is about its place in the natural landscape (*topos*), its place in the matrix of the cultural landscape (*locus*) or its place in the topology of the urban system (*nodus*).[147]

The spatial form

The spatial form refers to the corporeal and visible form of the composition. It includes implicit visual and formal elements, as well as explicit architectonic definitions in terms of points, lines and planes, spaces, views and sight lines. The corporeal form addresses the three-dimensional (space defining) forms made by spatial patterns composed of open spaces, surfaces, screens and volumes in the landscape (Euclidean space). It determines scale, proportion, orientation and provides its organisational structure. The visible form addresses the appearance of the landscape. It is about the perceptual space which can be understood as a kinaesthetic experience that emerges only by bodily movement. Routes are regarded as important operative structures since they determine how individuals move through space and experience the composition.

The symbolic form

The symbolic form refers to the morphological conditions for reception – which is the compositions ‘interface’ between the intentions of the designer and the reception of the users – while provoking and promoting a rich palette of emotions, ideas and stories.[148] Often a landscape design is the result of individuals’ attempt to carve out an ideal place in nature or an inspiration for an ideal human life.[149] Sometimes by deploying the metaphorical or referential function of compositional elements – such as architecture, sculptures, framed views and water – parts of the landscape are intended to mean

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[147] Steenbergen & Reh, 2011, p. 17.

[148] Cf. Hunt, 2004, pp. 191-223.

[149] Cooper, 2006; Giesecke & Jacobs, 2012.

or symbolise something.[150] Therefore, the landscape architectonic composition as a whole can also become an emblematic bearer of meaning, producing a narrative via symbolic representations.[151] Narratives link the sense of time, event, experience, memory and other intangibilities to more tangible aspects of the site.[152] Here narratives of use intersect with narratives of design; the latter may be confirmed or challenged by the former.[153]

Programmatic form

The programmatic form relates to programs aimed at production, recreation and culture. It is about functional zoning and the organisation of the program in relation to functional patterns of movement in terms of logistics and accessibility. The classical concepts of *otium*, recreational and cultural interests, and *negotium*, business activities, play an important role in this design process, as the landscape architectonic composition searches for a balance between economic benefit, cultural reflection and a meaningful encounter with nature.[154] Uncertain or varying programmes require a framework that can grow and can accommodate various programmes.

The presented analytical framework is an interpretative research method, in which understanding and insight is sought through formal design analysis and interpretation of visual representations of the landscape architectonic composition. In this type of study, knowledge is acquired via the interplay between the observed data, theoretical concepts and the design researcher 'making sense' of it.[155] Thus, this approach sits between objectivist and subjectivist positions in academia, as the knowledge gained is based upon the interaction between the researcher and the landscape architectonic composition.[156] Landscape design knowledge is therefore constructed, rather than found or discovered through induction or deduction via data observations, and must always be interpreted in its context.[157] Nevertheless, the findings should be of value and relevance beyond the subjectivity of an individual or group of individuals.[158]

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[150] For example a grotto representing the underworld, or plants as traditional emblems of love.

[151] Cf. Pieper, 2009.

[152] Potteiger & Purinton, 1998.

[153] Hunt, 2004, p. 171.

[154] Steenbergen et al., 2008.

[155] Deming & Swaffield, 2011, p. 152.

[156] Ibid., p. 8.

[157] Ibid., p. 9. This process is also called abduction or abductive reasoning (Peirce, 1955, p. 150-151; Magnani, 2001).

[158] Ibid.

§ 2.3 GIS as tool for landscape design research

§ 2.3.1 Geographic information systems (GIS)

The term geographic information systems, abbreviated as GIS, was first used by Roger Tomlinson (1933-2014)[159] in 1968 for a geo-information technology that developed from the integration of four different computer applications: image processing (raster-based), computer-aided design (CAD) (vector-based), mapping or map-making, and database management.[160] According to Maguire et al. (1991), DeMers (2009), Chang (2010) and Longley et al. (2011), GIS is a platform that can process, display and integrate different data sources including maps, digital elevation models, GPS-data, images and tables. GIS is fundamentally different from CAD or 3D-modelling software, in that it is an integrating technology, which ties together diverse types of data and information through location, with added intelligence through its wide-ranging analytical capacities. This combination enables researchers to explore spatial relationships and patterns at all scales of a landscape. Thereby GIS can also function as a database management tool and is used for modelling-related tasks such as exploratory data analysis and data visualisation.[161] Though there are many definitions of GIS[162], this study employs the following definition: *"GIS is an integrated system of components for performing spatial analysis. Via data about the [landscape], which has been abstracted and simplified into a digital database of spatial and non-spatial features, and in conjunction with specialised software and hardware, and coupled with the expert judgment of the user, one gains insight into the [landscape]"* [163] [Figure 2.12].

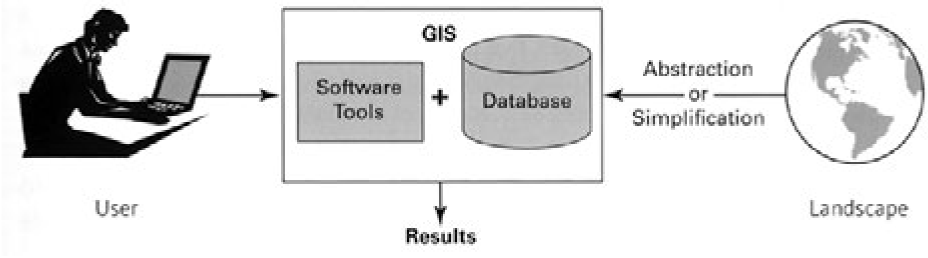

FIGURE 2.12 GIS as integrated system of components for performing spatial analysis (adapted from: Maantay & Ziegler, 2006)

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[159] Chrisman, 2006; Maguire et al., 1991. A common used equivalent of 'geographic information systems' in Europe is 'geospatial information systems' (Bartelme, 2012).

[160] Kraak & Ormeling, 2003.

[161] Chang, 2010.

[162] Overviews of definitions can be found for example in: Maguire, et al., 1991; Bartelme, 2012. Common definitions of GIS are: 'GIS is an umbrella concept for all automated systems that integrate and handle geo-referenced data and information' (Hendriks & Ottens, 1997, p. 9), or 'GIS are computer systems for capturing, storing, querying, analysing, and displaying geo-data' (Bartelme, 2012, p. 147).

[163] Adapted from: Maantay & Ziegler, 2006, p. 8.

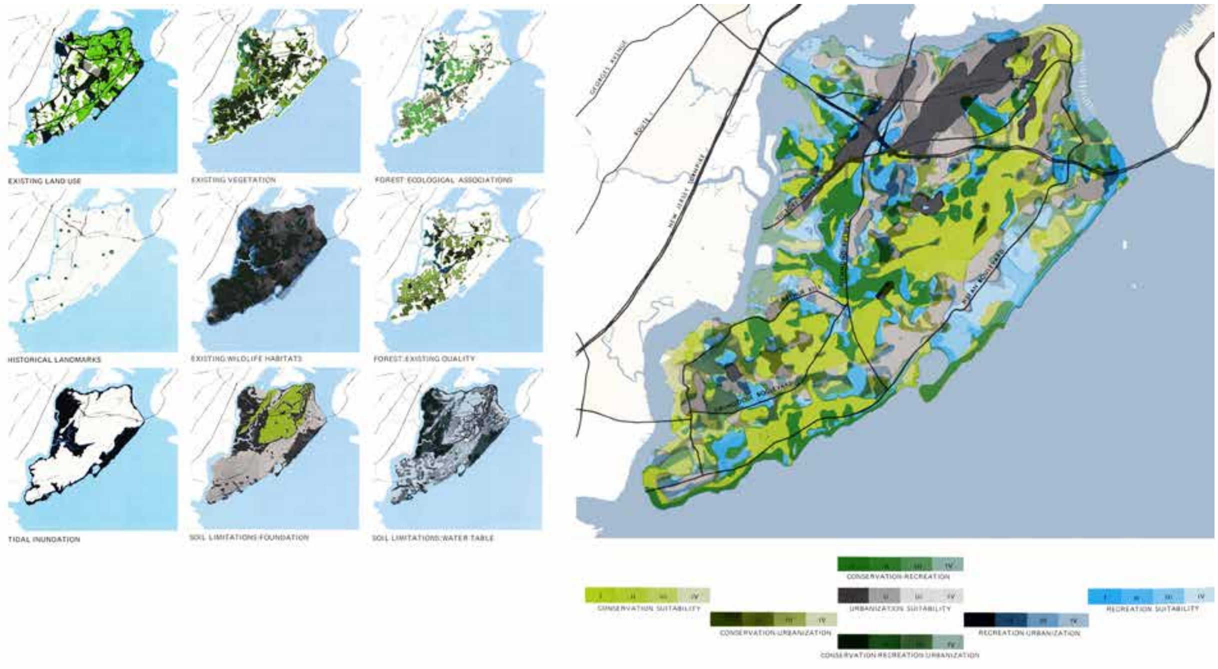

FIGURE 2.13 Sieve map from Staten Island (image source: McHarg, 1969; montage by Steffen Nijhuis)

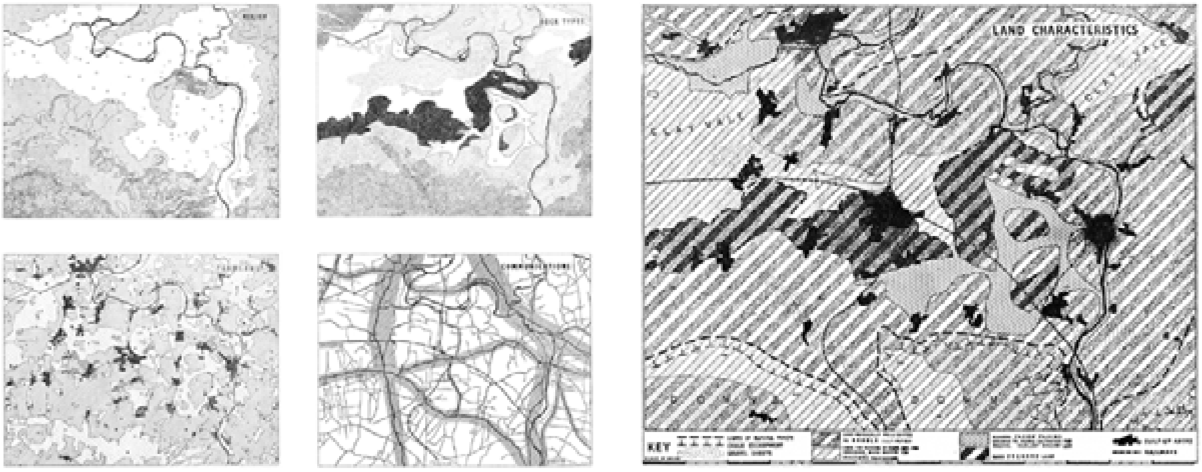

FIGURE 2.14 Example used by Jacqueline Tyrwhitt to explain overlaying as an analytical operation. Thematic map overlays of relief, rock types, communication, farmland, etc., resulting in a synthesis map pointing out the characteristics of the landscape (image source: Tyrwhitt, 1950; montage by Steffen Nijhuis)

This definition stresses that GIS is a platform for spatial analysis, which is also at the heart of landscape design research. It also puts forward that the computer and software cannot make sense of data without the expertise of the user. This implies that results of using GIS not only depend on the GIS-skills of the design researcher, but also depends on the research focus (what is researched) and the research methods used (how it is researched), and both in relation to the discipline involved. In other words, when geographers are using GIS for landscape research there will be different types of results produced to when design researchers use the technology. In that regard, the output expresses a way of understanding. In fact, this dialectic between research and the involved technology (the tools) and the representation and interpretation of reality always has been at the core of science and art.[164] Like the microscope or a telescope enables scientists to explore aspects of the world one cannot see without them, it is useful to consider GIS as a tool for landscape design research, with the potential to see and measure aspects of the landscape architectonic composition that cannot be seen by the naked eye. Here, seeing is equated with knowledge acquisition.

Alongside considering 'GIS as a tool', there a two other positions in academia regarding GIS: 'GIS as tool-making', and 'GIS as science'.[165] The position of 'GIS as a tool' sees GIS as a vehicle to advance a specific purpose. The tool is neutral, and its use driven by its application in a specific context. The 'GIS as tool-making' position is concerned with advancing the tool's capabilities and ease of use. It is focused on the development of the technology. Finally, the 'GIS as science'-position insists on a more intimate and reciprocal connection between the tool and information science. Therefore, Goodchild (1992) introduced the term 'geographic information science (GISc)', addressing the fundamental issues underlying GIS.[166] In this study the focus is on applications of GIS in the specific context of landscape design research, rather than on the development of GIS-technology or the fundamental issues underlying GIS, which has already been pushed forward by an extensive field of research, as exemplified by the literature survey in the introduction. This study investigates GIS as a tool in the analytical framework for landscape design research, exploiting its integrating, analytical and displaying capabilities, henceforth called: GIS-based landscape design research.

Origins and development of GIS as an analytical tool

The origins and development of GIS as an analytical tool are characterised by the collective endeavour of geographers, computer-scientists, cartographers and landscape planners, whose ideas and techniques mutually influenced each other from the early 1960s onwards.[167] While many scholars contributed to the 'GIS vision' in that time, just a few had the opportunity to influence the technology in such a direct matter as the landscape architects Philip Lewis, Ian McHarg (1920-2001), Carl Steinitz and Jack Dangermond, all based at Harvard University from 1967 onwards.[168]

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[164] Kemp, 1990.

[165] Wright et al.,1997.

[166] For the full breadth of GISc and the background to it see: Goodchild, 1992; Kemp, 2008; Wilson & Fotheringham, 2008.

[167] For example see: Tobler, 1959; Horwood et al., 1963; Tomlinson, 1962, 1963, 1967, 1968; Warntz, 1965, 1966; Tomlin, 1983, 1990; Goodchild, 1987. For a comprehensive history of GIS see: Coppock & Rhind, 1991; Chrisman, 2005, 2006.

[168] Chrisman, 2005, 2006.

Lewis and McHarg advocated assembling maps from a variety of sources using transparent map overlays for analysing spatial relationships in the (urban) landscape (e.g. between soil structure and vegetation patterns), to grasp the essence of the landscape.[169] Aside from it being a valuable means of analysis, it was considered a planning tool. Characteristics of a landscape are shown in a composite map, called a sieve map, which renders (parts of) the landscape unsuitable for a particular purpose (i.e. constraints) [Figure 2.13].[170] Whether this overlaying technique was used for analysis or planning, Lewis and McHarg pointed to the integrative role of the landscape architect – looking at the whole and seeing patterns – a role that still defies direct translation to computer technology.[171] The quintessence of this approach is that information is combined through location, allowing seemingly unrelated phenomena to be linked through overlaying maps. Map overlays as such were not new, and their use by landscape architects stretches back to Charles Eliot (1859-1897), who used sun prints (a technique that uses sunlight as a developing or fixative agent) produced in his office window, to systematically document and evaluate information to be used for the Boston Metropolitan Park plan in 1893.[172] Warren Manning (1860-1938) refined this technique for the town plan of Billerica, Massachusetts, in 1912, using electric light boxes.[173] It was Jacqueline Tyrwhitt (1905-1983), mother of planning, who was the first to describe the overlaying technique in an academic setting [174] [Figure 2.14]. However, what is important is that the overlaying technique as a practicable means of analysis came together with the development of computer techniques for this purpose.[175]

Map overlaying became the basis for the integrating and analytical capacities of GIS. Lewis and McHarg provided their input to a project in Delmarva. This was the first urban planning project on which Steinitz (1967) applied computer-generated maps, databases and digital overlaying techniques for means of urban analysis using SYMAP, an early computer-based information system [Figure 2.15 & Figure 2.16]. Ever since, the overlaying technique became a method for evaluating landscape change and future impacts of planning alternatives, via computer models.[176] In that period Tomlinson coined the term 'geographic information systems' for such computer-based information systems.[177] While working with Steinitz at Harvard in 1968, Jack Dangermond recognised the potential GIS had, in particular in its role in landscape planning. Soon afterwards, he started ESRI (now world's leading off-the-shelf GIS software business), developing tools for map-making, spatial analysis and making GIS available to a wide audience.[178]

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[169] Lewis, 1963, 1996; McHarg, 1969. The methods presented in this books are respectively called the 'Resource-pattern-methode' and 'McHarg Suitability-methode' (Ndubisi, 2002).

[170] Tyrwhitt , 1950; Keeble, 1952.

[171] McHarg's book (1969) in particular was very influential for ecological or environmental planning, and has been considered one of the foundations of what became GIS practice (Spirn, 2000; Ndubisi, 2002; Chrisman, 2005).

[172] Eliot's personal account on this technique see: Eliot, 1902/1999, p. 496. For the Boston Metropolitan Park plan: Baxter & Eliot, 1893. The idea of manual map overlay can be traced back even further in history, exemplified by map use in the American Revolution. During the Battle of Yorktown in 1781 the French cartographer Louis-Alexander Berthier employed map overlaying to examine the relation between George Washington's troops and those of Britain's Charles Cornwallis (Wikle, 1991).

[173] Manning, 1913. Cf. Steinitz et al., 1976. Other early applications include: Bijhouwer, 1933, 1947; Keeble, 1952.

[174] Tyrwhitt, 1950, p.157.

[175] Chrisman, 2005, 2006.

[176] Steinitz & Rogers, 1970; Steinitz, 1979; Steinitz et al., 2003. Nowadays this (GIS-based) planning approach is known as a framework for geodesign, wherein the creation of planning proposals with impact simulations informed by geographic contexts are tightly coupled (Flaxman, 2010; Miller, 2012; McElvaney, 2012; Steinitz, 2012).

[177] In the article 'A geographic information system for regional planning' (Tomlinson, 1968) he proposed the term for a computer-based information system for the storage and manipulation of map-based land data, which was developed for the government of Canada in the early 1960's (Tomlinson, 1962, 1963, 1967).

[178] Chrisman, 2006.

FIGURE 2.15 Delmarva was the first urban planning project to apply computer-generated maps, databases, and digital overlaying techniques as means of urban analysis. Carl Steinitz (right) and Peter Rogers (left) working at the Laboratory for Computer Graphics, Graduate School of Design, Harvard University, in 1967 (image courtesy of Carl Steinitz)

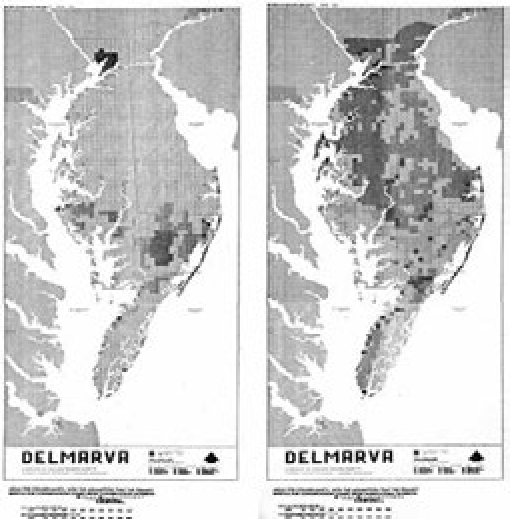

FIGURE 2.16 In the Delmarva project, data was combined using quantitatively weighted indexes to evaluate relative attractiveness for vegetable (left) and grain agriculture (right) (image courtesy of Carl Steinitz)

Map overlaying, integration of information and spatial analysis

GIS differs from other tools such as computer-aided design (CAD), computer mapping, and standard database management systems (DBMS) in that it has integrative and analytical capabilities, in particular layer-based analysis and related topological operations.[179] By combining and integrating information through overlaying techniques, GIS has the ability to synthesize and analyse spatially oriented information from different sources, as long as the information has a known geographic location. Map overlaying procedures contribute to the development of new hypotheses, new theories and new laws about the nature, composition, relevance and causal relationships among spatial phenomena.[180]

Map overlaying makes the integration of relevant spatial features and attributes from different sources possible, to pave the way to new insights via the interpretation of the overlay-analysis by the researcher. However, in a technical sense, combining maps by overlaying alone will not really integrate information from different sources. Additional geographic information analysis operations are required, before or after the map overlaying, to produce new information. Usually, these analytical operations are specific forms of the overlaying process, which truly synthesize different sources of spatial information by set-theory and map algebra.[181] Set-theory uses spatial entities to formally express relations between different layers of information (e.g. landscape element A is contained by B; A is equivalent to B; and A is intersected by B).[182] It allows logical operations to be performed on spatial entities, and answers queries about relationships between spatial extents using operators from Boolean algebra.[183] The utility of

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[179] Cowen, 1988.

[180] Cf. DeMers, 2009, pp. 313-332.

[181] Cowen, 1988; Chrisman, 2002; Harvey, 2008; DeMers, 2009.

[182] Schuurman, 2004.

[183] Boolean algebra is a subarea of algebra in which the values of the variables are the truth values *true* and *false* (1 and 0 respectively). Instead of elementary algebra where the values of the variables are numbers and the main operations are addition and multipli-

set-theory is expanded by map algebra; a set of arithmetical operations that can be performed on raster data, and can add, subtract, divide and multiply values associated with spatial areas.[184] This technical capability of GIS provides possibilities for the integration of disparate sources, and the connection of various fields of knowledge via map overlaying, while synthesising and analysing different layers of information through location. Map overlaying is fundamental for GIS-based research and provides the basis for a wide range of possible analytical operations.

The integrative and analytical nature of GIS, via map overlaying and related topological operations, makes it potentially useful for application in and development of GIS-based landscape design research.

§ 2.3.2 Three potential fields of operation for GIS-based landscape design research

In order to explore GIS as a tool in the analytical framework of landscape design research, it is important to understand that GIS as an information technology consists of four interactive subsystems: (1) an input subsystem for data acquisition and converting maps and other data into digital form, (2) a storage and retrieval subsystem, for processing data prior to their use in specific analyses, (3) an analysis subsystem, generating specific information through advanced spatial analysis, and (4) an output subsystem for producing maps, tables, and other visual representations.[185] These subsystems are potentially operational for landscape design research in a repetitive and cyclical process that includes: processing of data into a digital landscape model (subsystems 1 and 2), followed by exploration of the digital landscape model by advanced spatial analysis (subsystem 3) and finally, the selection and construction of a visual representation such as a map, a virtual 3D-landscape or a table (subsystem 4). Thus, for the application and development of the analytical framework for landscape design research there are three potential fields of operation in which GIS can be instrumental: modelling, analysis and visual representation.

GIS-based modelling

Using models as a basis for experimentation, analysis and visualisation is a common practice in science and technology for means of knowledge acquisition.[186] In the analytical framework for landscape design analysis the model is a simplified representation, description or reproduction of an existing, past or future landscape architectonic composition.[187] GIS-based modelling in landscape design research is the construction of a digital model of a designed landscape, by employing the data acquisition subsystem and the storage and retrieval subsystem of GIS.

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cation, the main operations of Boolean algebra are the conjunction ‘AND’ (denoted ∧), the disjunction ‘OR’, (denoted ∨), and the negation ‘NOT’ (denoted ¬).

[184] Schuurman, 2004.

[185] Adapted from: Gaffney & Stančič, 1991; DeMers, 2013.

[186] Bertels & Nauta, 1969.

[187] Cf. Bertels & Nauta, 1969.

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FIGURE 2.17 3D laser scan of a tree combining terrestrial laser scanning and point cloud technology (image courtesy of Ron van Lammeren, Wageningen)

Data acquisition

The data acquisition subsystem enables data input in GIS. Data from designed landscapes can be acquired by various types of data acquisition methods using ground-based, airborne (aeroplane) and orbiting (satellite) tools.[188] Examples of ground-based data acquisition is land surveying by means of measuring tapes, levels, theodolites, terrestrial laser scanning [Figure 2.17] and electronic distance-measurement – collectively called field instruments.[189] An emerging type of ground-based data acquisition is field informatics.[190] Here, via human sensing, bio-logging and ethnography, behavioural data about humans and animals is collected (for instance about movement, location, or point or line of sight), by means of hand-held GPS, cell phone, eye-mark recorder and other sensors.[191] High resolution images and airborne Lidar (Laser imaging detection and ranging) are examples of airborne data acquisition [Figure 2.18]. Photogrammetry makes it possible to map large areas very accurately by orthogonal aerial photography[192] and airborne laser scanning. The latter, in particular, includes successful applications such as the creation of accurate Digital Elevation Models (DEM) and 3D city models. Close-range photogrammetric techniques can also be used for the extraction of 3D information about objects from images.[193]

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[188] Lemmens, 2011; Cramer et al., 2012.

[189] Land surveying is at the heart of spatial data acquisition, and is about two- and three dimensional measurement and recording of the site and its use. In history landscape designers were usually trained land surveyors or surveyors acted as landscape designers, but since the specialisation of the disciplines it became exclusively the domain of Geodesy, Geomatics or Geo-information technology (Pouls, 1997; Lemmens, 2011).

[190] Ishida et al., 2012; Taylor & Lauriault, 2014.

[191] Ishida et al., 2012. See for example: Van der Spek et al., 2008; Du Pont et al., 2013.

[192] For example, for landscape research in the Netherlands Cornelis von Frijtag Drabbe (1955) used interpretations of aerial photographs to understand landscape features and create maps known as 'red-blue or wet area maps'. On these maps it could be seen which parts of a landscape were wetter or drier at times of bad drainage and flooding.

[193] Fryer et al., 2007.

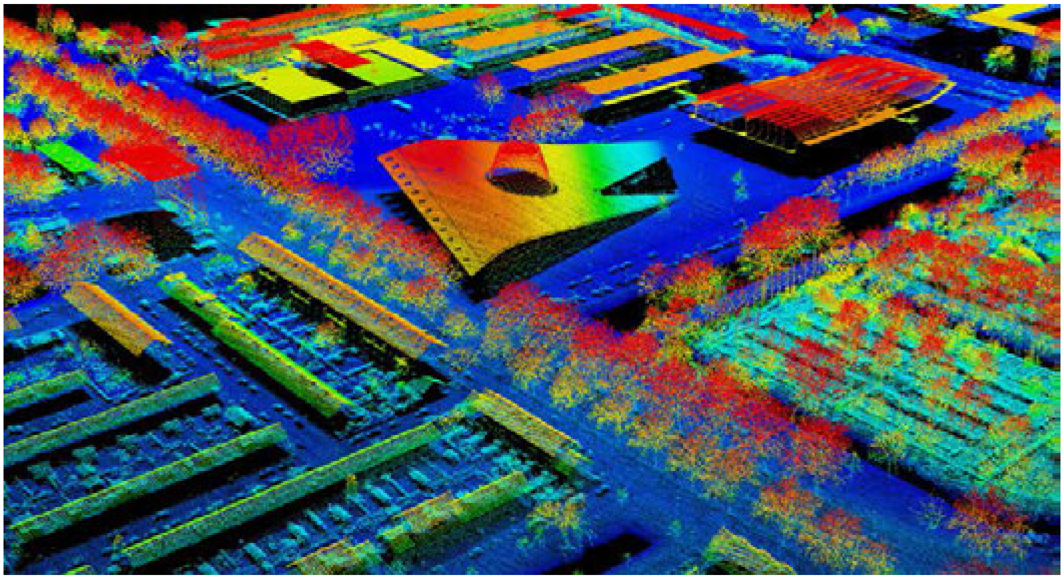

FIGURE 2.18 A 3D city model of a part of the campus of TU Delft based on airborne Lidar-data. The library and the auditorium are clearly recognisable (image courtesy of Michiel Pouderoijen, TU Delft, 2011)

Examples of orbiting data acquisition are earth observation systems from space, such as remote sensing (optical and radar) and Global Navigation Satellite Systems (GNSS). Optical high-resolution satellite imagery by means of photogrammetry is used for creating topographic maps (up to a scale of 1:10,000), generating thematic maps (e.g. land use, vegetation, and soil maps) and cadastral mapping. Radar satellite imagery is used to create large-scale DEM's (e.g. Shuttle Radar Topography Mission, SRTM). GNSS is not only suitable for navigation (car and bike), but also for land surveyors for example, for the collection of data in the field for precise positioning at centimetre level accuracy.[194]

Other important sources of data include digitising, enquiries, crowdsourcing[195], Web2.0-applications[196] and non-commercial and commercial datasets. Digitising through scanning and vectorisation by CAD (computer-aided design) of analogue (historical) maps is very important for landscape design research, as detailed data of designed landscapes is usually sparsely available. When the focus is a past or future composition, the design is digitised through CAD as well, constructing the past or future reality in a digital environment. To handle spatial information in GIS, positioning information is needed. In order to geo-reference the digitised composition a reference coordinate system is required, as well as the selection of control points and a geometric transformation.

As data is the basis for the generation of knowledge, the reliability and validity of acquired data is an important issue. Therefore, it is necessary to consider and acknowledge the imperfections of the data, which is referred to as the presence of positional, temporal and thematic uncertainty.[197]

In GIS-based landscape design research the data acquisition subsystem is focused on deriving and processing of data of the designed landscape while exploiting the wide range of available sources and data-acquisition tools.

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[194] Lemmens, 2011.

[195] Sui et al., 2013.

[196] Crowdsourcing via participation and interaction via Internet (e.g. geo-tagged digital photo's) is an important source of data, made possible by Web2.0 (O'Reilly, 2005; Goodchild, 2007; Jones et al., 2008).

[197] Longley et al., 2011, p. 124.

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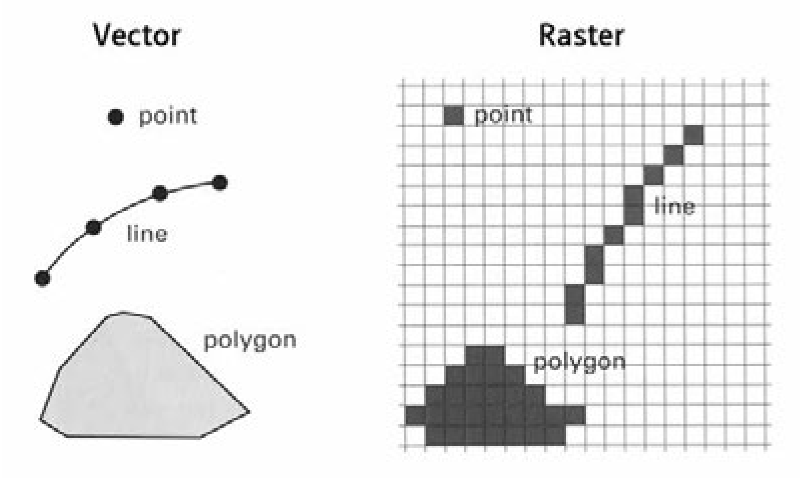

FIGURE 2.19 Data is stored as a digital model, which is a structure of data. Models can be vector-based or raster -based (image source: Maantay & Ziegler, 2006)

Data storage and retrieval

Once the data is acquired, the data storage and retrieval subsystem comes into play via a sophisticated set of computer-based procedures and algorithms for handling data.[198] When stored in GIS the data consist of geometric, attribute and temporal data. Geometric data refers to location, trajectory (sequence of locations), shape and dimensions. Attribute data refers to the non-geometrical aspects (e.g. quantity, velocity, force), and temporal data to the moment in time where both the geometric and attribute data are valid.[199] GIS data always includes a location component ('where'), an attribute component ('what') and a time component ('when').[200] The acquired data usually consists of millions of measuring points, which are processed and handled by GIS in order to become (potential) sources of information.[201]

The data is stored as a digital model, which is a structure of data. Models can be vector-based or raster based [Figure 2.19]. The choice depends on the nature of the model, data sources and the computing algorithm.[202] There is a distinction between *descriptive* and *procedural* models.[203] Descriptive models are usually formal in nature, and describe how something is (objects, features) or functions (process). Procedural models are models that include procedures by which computational simulation can be performed for prediction and planning. These models are defined in a programming language.[204]

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[198] Cowen, 1988.

[199] Kraak & Ormeling, 2003, p. 3.

[200] Lemmens, 2011.

[201] The amount of data to handle is hard to imagine, as exemplified by Google Earth. The familiar image of the globe on the web-interface consists of 10 petabyte of data, corresponding with 10 million gigabytes. To compare: 1 million gigabytes is an equivalent of 500 billion book pages (Brotton, 2013).

[202] Chang, 2010.

[203] Steinitz & Rogers, 1970; Maantay & Ziegler, 2006.

[204] Ibid.

Descriptive models are the cornerstone of GIS-based landscape design research. Here modelling is about creating digital structures of data useful for landscape design analysis. This implies that the constituent objects and features of the existing or conceived landscape architectonic composition are abstracted as a *digital landscape model (DLM)*, according to predetermined criteria, and stored as data in GIS, as a basis for analysis and visualisation.[205] The DLM is merely a representation of things that exist (or are conceived), and represent the landscape architectonic composition in the formal system of the digital world.[206] In this respect, the DLM does not only represent the spatial construction of form, space and material substance of the designed landscape, it is also contextual, territorial and geo-referenced (earth-related). More precisely, it includes the interaction and co-dependency between cultural, natural and design elements in a specific territory.

Technically the DLM consists of a terrain layer – a digital elevation model (DEM) – supplemented with a volume layer of 2D and 3D referenced objects, like buildings, trees and other artefacts. This DLM can be represented via a surface, vector or raster definition in a 2D or 3D geo-referenced setting.[207] There are three possible ways of including time in the DLM: as a time-slice snapshot, via versioning, or as a space-time composite.[208] Time-slice snapshots convey the physical shape and pattern of the site at certain moments in time. Versioning is a base-state with amendments superimposed. The space-time composite combines multiple time-slice snapshots technically in one.

The storage and retrieval subsystem is focused on the creation of descriptive digital data structures – the digital landscape models (DLMs) – of the designed landscape based on the acquired data. GIS-based modelling as a field of operation in landscape design research concentrates on data acquisition, storage and retrieval through digital landscape models, which represent landscape architectonic compositions as a basis for GIS-based analysis.

GIS-based analysis

Analysis is the exploration, evaluation and synthesis of data in order to reveal new or latent patterns and relationships as the basis for knowledge acquisition. The analytical framework for design analysis provides a way to study landscape architectonic compositions via formal analysis and description of the basic, spatial, symbolic and programmatic form. GIS-based analysis in landscape design research is the exploration and evaluation of the digital landscape model of a landscape architectonic composition, to reveal patterns and relationships while employing the analysis subsystem of GIS.

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[205] Li et al., 2005; Van Lammeren, 2011.

[206] Van Lammeren, 2011, cf. Mark, 1999.

[207] Van Lammeren, 2011.

[208] Langran 1992; Gregory & Ell, 2007.

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GIS-based analysis is a process for looking at patterns in spatial data, and at (topological) relations between features. Basic analytical operations in GIS are[209]: combination (overlaying, but can include union, intersect and spatial join), query (spatial or attribute-based query)[210], buffering (proximity), classification/rating (ranking, weighting, reclassification), spatial arrangement/neighbouring (connectivity, adjacency), measurement (length, area, perimeter, distance) and geo-statistics (e.g. 2D and 3D-terrain analysis, and statistical surfaces). These basic analytical operations are usually combined in particular ways, depending on the research objective. Typical principles for GIS-based analysis can be divided according to their perspective on the designed landscape: the vertical and horizontal perspective.[211]

The vertical perspective

The vertical perspective considers the designed landscape from 'above' – the map, or the view from the air – and is about horizontal referenced analysis of spatial patterns and relationships (coherence), structure and process, function and change. Depending on the chosen scale (frame and granule), varying from a few square meters up to several kilometres, topological and chorological dimensions of the landscape can be studied.[212] The topological dimension addresses the vertical relationships between various landscape strata: soil, water, vegetation, climate and human action. The chorological dimension addresses the horizontal relationships among patches or programmatic units. In the framework for landscape design research these dimensions are particularly important for understanding the way in which the landscape architectonic composition adapts to and manipulates geomorphological, hydrological, soil and geographical conditions. It offers a means for understanding the characteristics of the natural landscape and land-use, the spatial and functional organisation of the ground plan, the organisation of programmatic domains and their functional relationships. These and other aspects related to the basic and programmatic form can be explored employing the following principles for GIS-based analysis:[213]

- Location / allocation: the analysis of objects or areas with certain characteristics, and selections and combinations thereof [Figure 2.20];
- Density: the analysis of spatial patterns based on distribution and concentration of objects or areas (and possibly numerical properties);
- Distance / range: the analysis of objects or areas that have a relationship based on distance, meet a distance criterion or a specific range in time;
- Movement / change: the analysis of patterns of change or movement of objects or areas;
- Quantity: the analysis of objects or areas on the basis of properties expressed in numerical values, quantities, proportions, and order.

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[209] Chang, 2010; DeMers, 2009; Maantay & Ziegler, 2006; Harvey, 2008.

[210] Also known as a phenomenon-based search or a containment search within a region.

[211] In analogy with Antrop, 2007.

[212] Zonneveld, 1995, p.1.

[213] Cf. Mitchell, 1999.

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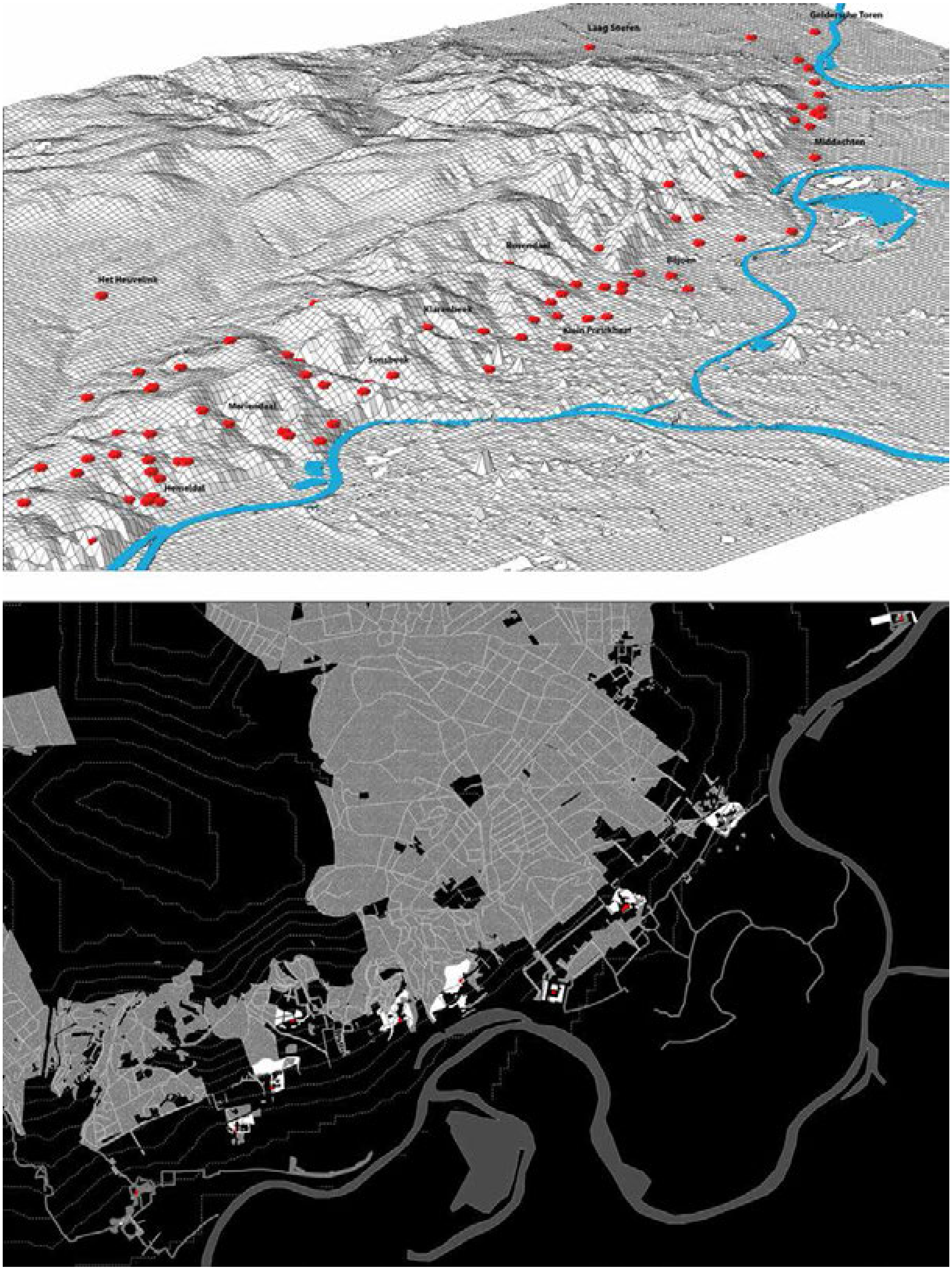

FIGURE 2.20 GIS-based analysis of the distribution and location of the historical estates of Guelders Arcadia (near Arnhem, Netherlands) in the natural landscape dominated by the ice-pushed ridges of the Veluwe-East (top), and analysis of landscape architectural compositions of selected individual estates showing a remarkable sensitivity towards natural conditions (analysis: Steffen Nijhuis)

A special type of analysis from the vertical perspective is cartometric analysis. Cartometric analysis is an automated map analysis employed to measure planimetric accuracy of modern and historical maps, and is useful for critical evaluation of resources. This type of analysis can generate distortion grids, vectors and circles that visually express the local variances in planimetric accuracy across the original maps.[214] However, this can also be considered to be part of the pre-processing of data.

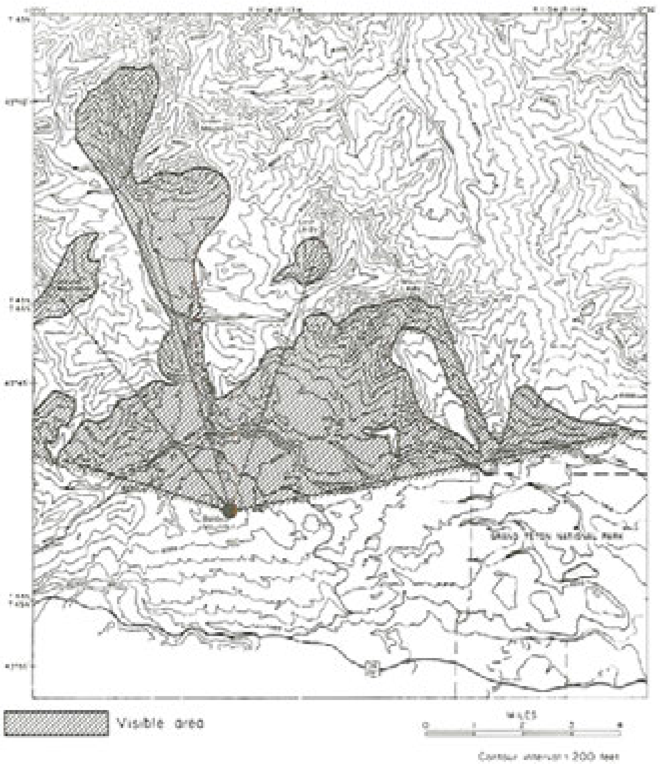

FIGURE 2.21 An early application of viewshed analysis by Kevin Lynch. The terrain visible from a major viewpoint in the Teton National Forest, Wyoming (USA) (image source: Lynch, 1976)

The horizontal perspective

The horizontal perspective considers the designed landscape from 'inside out' – as experienced by an observer standing in or moving through a virtual space. It addresses the physiognomy of space; the face of the composition. It combines horizontal with vertical referenced analysis of the form and function of the two- and three-dimensional composition, exploring visual and formal elements, as well as explicit architectonic definitions in terms of open spaces, surfaces, screens, volumes, views and sight lines. Further functional aspects of the three-dimensional composition can also be explored such as: organisation of visual logic, space-making, composition of views, their sequence and the control of movement.[215] These concepts refer to the visible form of the composition, the visual manifestation (appearance) of three-dimensional forms and their relationship determined by conditions of spatial perception such as: eye-level, vantage point, view angle, view direction, movement and atmospheric circumstances.

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[214] Heere, 2008; Jenny, 2006; Jenny et al., 2007.

[215] Nijhuis, 2011.

In order to convey the composition from an observers point of view, and to enable visual analysis of the landscape, Tandy (1967) introduced the concept of isovists or viewsheds. An isovist or viewshed is an area that is visible from a specific location, also called 'limit-of-vision plottings' or 'visual watersheds'. Early applications can be found in Higuchi (1975/1988), Lynch (1976) and Benedikt (1979, 1981) [Figure 2.21]. Due to advances in computer science visibility-analysis is nowadays a widespread phenomenon with a broad palette of applications.[216] Moreover, advances in GIS offer design researchers interesting ways to engage in the field of visual research, in particular using GIS-based isovists (sight field polygons)[217] and viewsheds[218]. Both concepts address the physiognomy of space with visibility as a key element. The potential of 'being able to see' is mapped out and addresses plausible and/or probable visible space.[219] It exposes spatial patterns composed of open spaces, surfaces, screens and volumes, as they could be experienced by an individual moving through a virtual space, by making use of GIS-based isovists and viewsheds. The technical difference between the two concepts is that the raster-based viewsheds represent parts of space that are visible, taking into account horizontal and vertical viewing angles and elevation, while the vector-based isovists consider visible space in the horizontal plane.[220] The result is a closed polygon that can be characterized with different numerical parameters.[221]

Virtual 3D-landscapes are another way to get a grip on the three-dimensional aspects of the composition. Virtual 3D-landscapes in current GIS programmes are generally limited to the horizontal, two dimensions (2D topology), but utilise three-dimensional visualisation. GIS supports three-dimensional display of terrain models (DEMs), interactive navigation, 3D-symbols/geometries[222], surface analysis (i.e. viewsheds and isovists) and viewpoint and path creation (i.e. fly-through animations).[223] However, the embedding of 3D topology and, consequently, 3D analysis tools to be become true 3D-GIS, is still under development.[224]

To summarise, principles related to the horizontal perspective offers means of analysing the visible form within the framework for landscape design research. The horizontal perspective offers means to describe and evaluate volumetric characteristics, scenography and movement, treatment of the panorama, and development over time. It also addresses symbolic, iconographic and mythological elements, and architectonic structures, and how they are connected with one another, giving insight into the meaning of the composition. These and other aspects related to the spatial and symbolic form can be explored employing the following principles for GIS-based analysis:

- Visibility: the analysis of the visible area or the visual range of objects or areas based on three-dimensional field analysis by means of viewsheds or isovists (sight field polygons) [Figure 2.22];
- Virtual 3D-landscapes: the imaging of objects and areas and their horizontal and vertical spatial structure, operation and coherence in a virtual, three dimensional environment.

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[216] Nijhuis et al., 2011b.

[217] For example: Batty, 2001; Rana, 2002.

[218] For example: Gaffney & Stančič, 1991; Wheatley, 1995; Llobera, 2003.

[219] Fisher, 1995, 1996; Weitkamp, 2010.

[220] 3D-isovists are in development: Fisher-Gewirtzman et al., 2003, 2005; Van Bilsen, 2008; Morello & Ratti, 2009.

[221] Batty, 2001, Turner et al., 2001a.

[222] This includes custom 3D-modelling, importing GIS data, importing 3D-data, 3D-laser scanning.

[223] Kemp, 2008; Raper, 1989, 2000.

[224] See on this matter: Batty, 2000, 2008; Abdul-Rahman et al., 2006.

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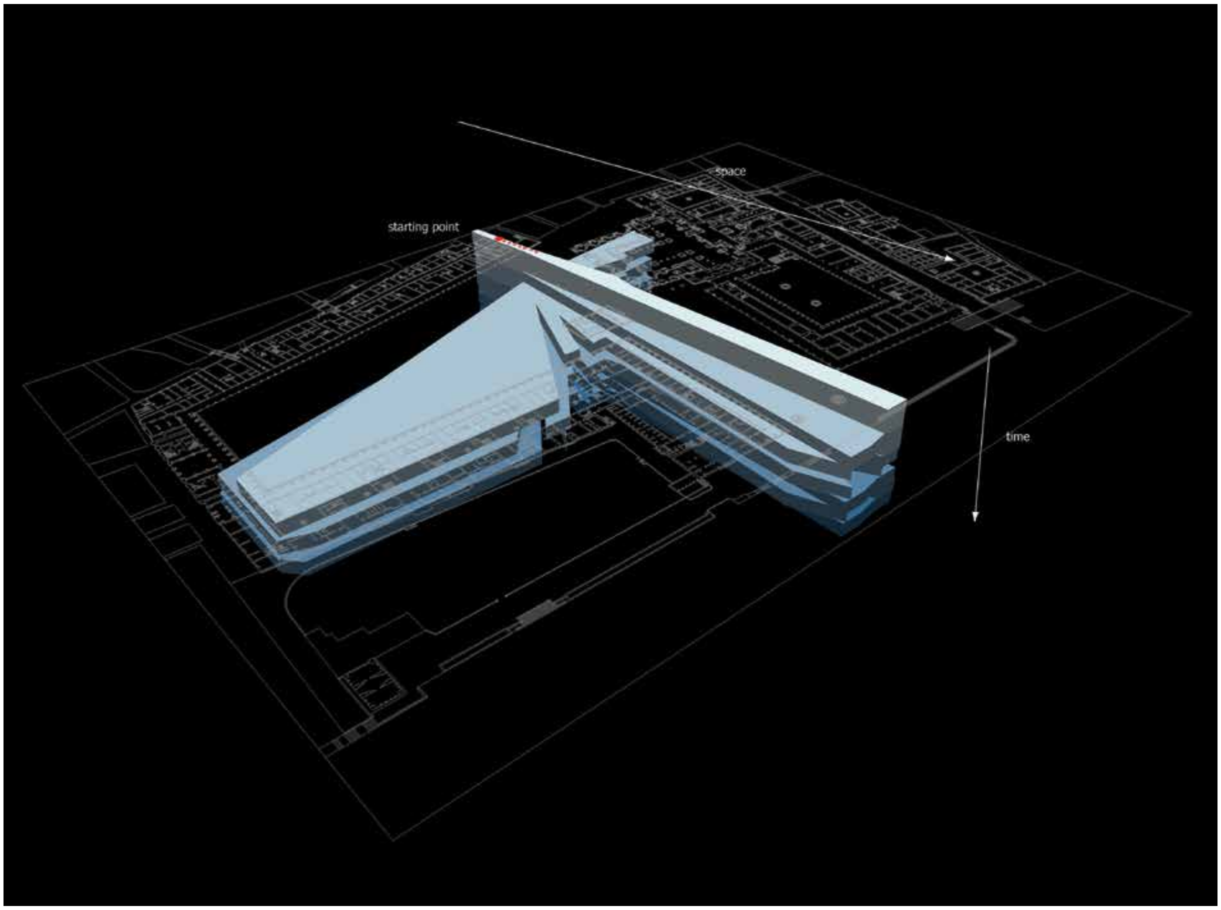

FIGURE 2.22 Minkowski-model from Piazza San Marco approached from the *Torre dell'orologio*. The top layer of the model represents the first isovist at the starting point; the bottom layer represents the last isovist (source: Nijhuis, 2011)

The vertical and horizontal principles of GIS-based analysis are useful in their own right but can often serve as building blocks for more advanced spatial analysis. By adding analytical capability, in terms of procedural modelling – e.g. integration of cellular automata-based models, agent-based models and other expert-systems – GIS can be used for advanced spatial analysis.[225]

The analysis subsystem is focused on generating specific information through advanced spatial analysis. GIS-based analysis, as a field of operation in landscape design research, concentrates on revealing patterns and relationships in designed landscapes, through exploring digital landscape models of landscape architectonic compositions from the vertical and horizontal perspective.

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[225] Overviews can be found in: Longley & Batty, 2003; De Smith et al., 2007.

GIS-based visual representation

Given the fact that the individual's brain is mainly visual oriented, with many areas with groups of neurons responding only or mainly to visual stimuli[226] [Figure 2.23], more information is acquired through vision than through all of the other senses combined.[227] So, visual representations are powerful vehicles for knowledge acquisition.[228] In this respect, visual thinking is employed in the framework for landscape design research to facilitate the dialogue between the real designed landscape and the abstract visual representation. GIS-based visual representation in landscape design research is the visualisation of (aspects of) the digital landscape model, and analysis results, while employing the output subsystem of GIS.[229]

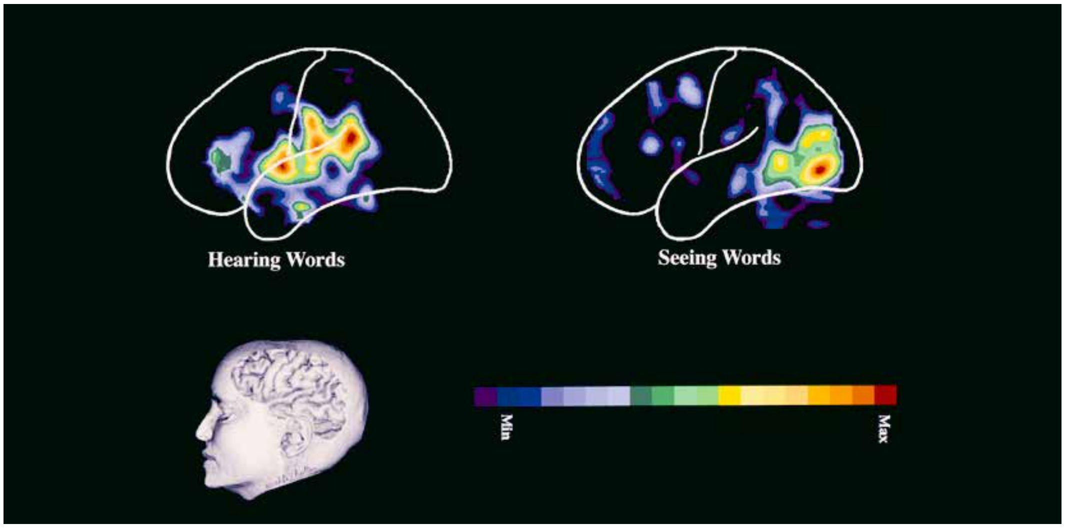

FIGURE 2.23 Brain activity maps (derived from Positron Emission Tomography scans) show the change in local blood flow in the brain, associated with local change in neuronal activity that occurs during different states of information processing. Note the concentrated area of brain activity when hearing words versus the multiple areas of brain activity when seeing words (image courtesy of M. Raichle, Department of Neurology, Washington School of Medicine)

GIS-based visual representation can be understood as the process of representing data and information synoptically, for the purpose of recognising, communicating and interpreting patterns and structure.[230] It encompasses the computational, cognitive and mechanical aspects of generating, organising and comprehending visual representations.[231] In particular, GIS-based visual representation is the use of any visual representation designed to facilitate the spatial understanding of things, concepts, conditions, processes or events.[232]

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[226] Bressan, 2009.

[227] Ware, 2004; Kosslyn, 2006.

[228] For more backgrounds on visual representation as cognitive tools see: Bertin, 1977/1981; DiBiase, 1990. For computational visualisation see: Ware, 2004, 2008. For graphics see: Tufte, 1997, 2001; Wilkinson, 2005; Kosslyn, 2006. For maps see: Robinson, 1952; Bertin, 1967/2011; MacEachren, 1994, 1995. For drawings see: Purcell & Gero, 1998; Goldschmidt, 1991.

[229] Throughout this study the term 'GIS-based visual representation' is used instead of 'GIS-based visualisation', since the latter one usually refers to computer graphics and excludes other visual output such as 3D-prints (Cf. Bishop & Lange, 2005).

[230] Buttenfield & Mackaness, 1991.

[231] Ibid.

[232] Dodge et al., 2008, p. 2; cf. Harley & Woodward, 1987.

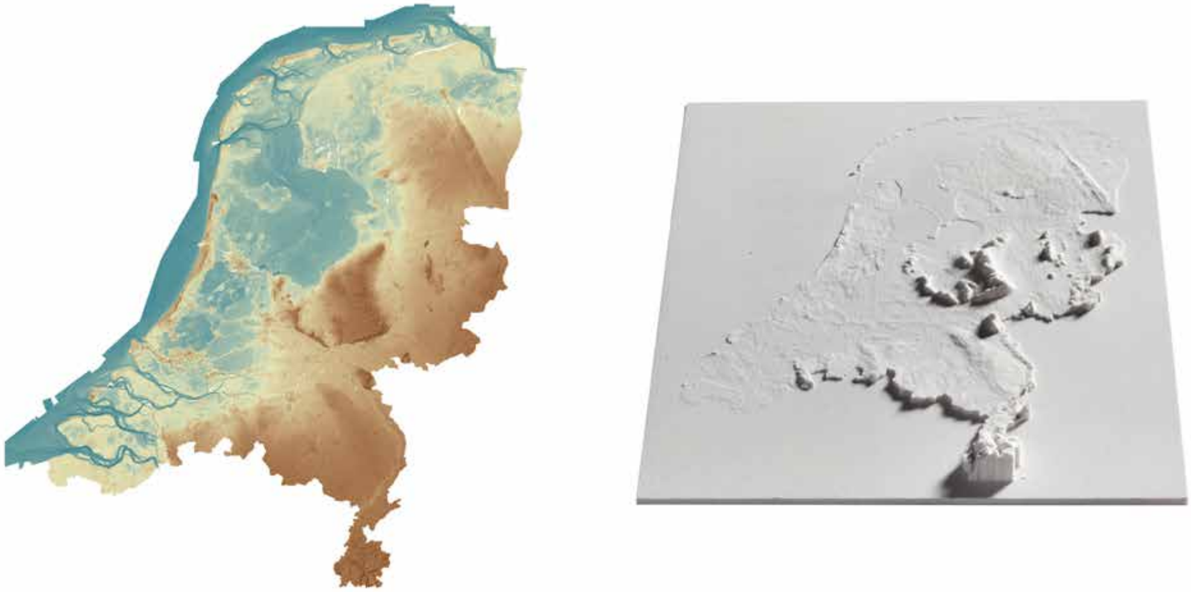

FIGURE 2.24 GIS-based computation of data on altitudes in the Netherlands. The precise data can be visualised in various ways: As a map (left), where the colours represent the altitude in relation to sea level. A shadow cast in the background makes altitude differences clearly visible. Areas below sea level are blue and those above sea level are brown; or, as a 3D-print, in which the altitude data from GIS are translated by a 3D-printer into a model – with a scale of 1 to 500,000, and the height exaggerated one hundredfold (model & images: Steffen Nijhuis, 2011)

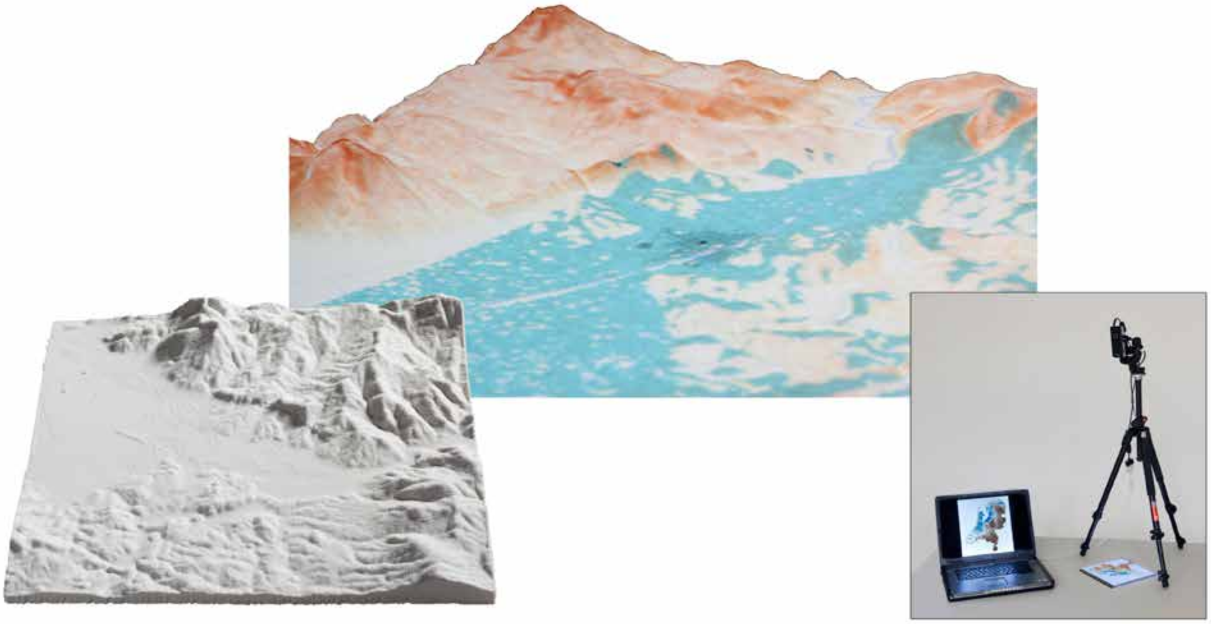

FIGURE 2.25 Left: 3D-printing of the landscape around Florence (Tuscany, Italy). Top: 3D-printing augmented with projections of a viewshed analysis from Villa Medici, Fiesole. Right: experimentation setting (model & images: Steffen Nijhuis, 2011)

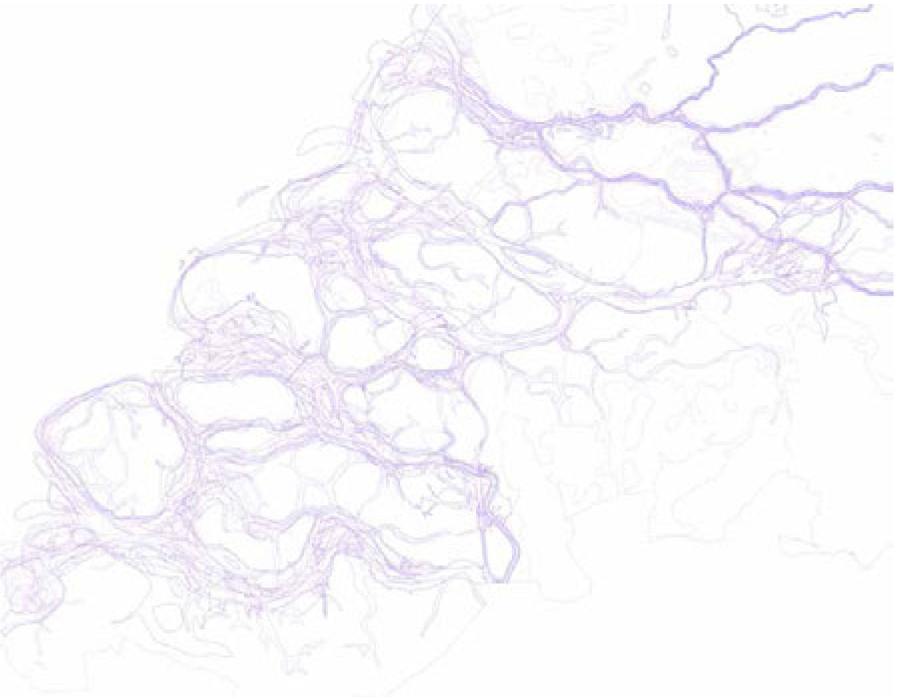

FIGURE 2.26 Mapping of change in space and time via overlaying. Different time-slice snapshots from different eras of the land-water contour are combined into a composite space-time map in order to show the dynamics and development of the southwest Dutch Delta (map: Steffen Nijhuis)

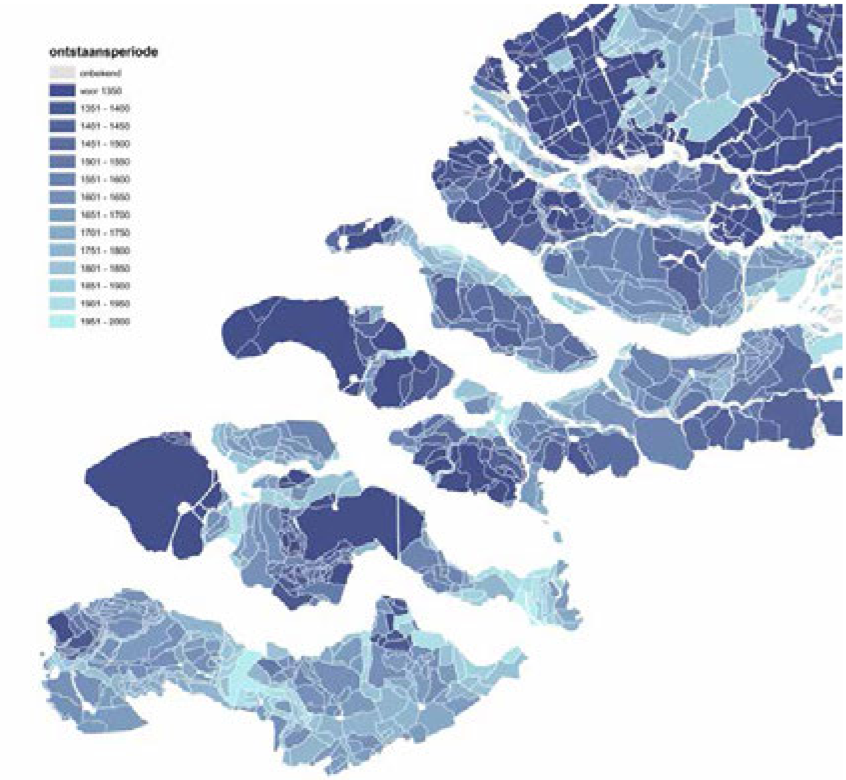

FIGURE 2.27 The development of the landscape expressed in attributes. The development of the polder system in the southwest Dutch Delta; the gradient from dark to light blue expresses the period of origin of the polders from 1250 CE through 2000 (image source: Nijhuis & Pouderoijen, 2014)

Common outputs of GIS are maps, virtual 3D-landscapes, charts or tables in digital or analogue form. However, 3D-printing and other forms of rapid prototyping also make it possible nowadays to envision information in alternative ways, such as physical 3D-models and augmentation of them with (dynamic) projections of analysis results [Figure 2.24 & Figure 2.25].[233]

MacEachren et al. (1999), Ervin (2001), Slocum et al. (2001) and Bishop and Lange (2005) identified several major variables in GIS-based visual representation: applications for knowledge discovery versus presentation of known knowledge; abstract versus realistic representations; dimensionality; and dynamic versus static representations.[234]

Applications for knowledge discovery versus presentation of known knowledge

Visual representations are traditionally modes to visualise information. There are four different objectives of visual representation: exploration, confirmation, synthesis and presentation.[235] Exploration and confirmation are about knowledge discovery (visual thinking), and synthesis and presentation about presentation of known knowledge (visual communication). In exploration visualisation is used to manipulate and examine unknown and often raw data. Here the visual representations remain in the private realm of the design researcher and are not considered for communication with others. In confirmation visualisation is used to confirm initial suspicions.[236] Separately or in combination with each other the visual representations show the outcome of (computational) analysis or draw attention to anomalies by combining or transforming original observations. In synthesis the visual representation is used to show a coherent, but abstract statement concerning patterns and relationships being uncovered. Here the design researcher makes informed decisions about what to emphasize, what to suppress and which relationships to show.[237] In presentation the data, digital landscape models or results of analysis are displayed in a way that a wider audience can understand the visual representation.[238]

Common graphic techniques for processing basic material applied for knowledge discovery are dissection, comparison, and addition.[239] *Dissection* is about discovering spatial patterns by selection and reduction, and often serves as the basis for spatial association analysis, which explores the relation between different patterns. For instance, spatial association analysis via graphic overlaying explores relationships by applying thematic overlays to a geographic location in order to explore such things as the correlations between environmental conditions and patterns of the designed landscape. *Comparison* is about finding similarities and dissimilarities in space, time, and theme between designed landscapes, as well as within a singular composition. As spatial dynamics and changes over time are hard to express in a static visualisation, different time-slice snapshots need to be presented in order to delineate the development. These time-slice snapshots can be compared in several ways: via graphic overlays [Figure 2.26], thematic visualisation of a single attribute [Figure 2.27] or in a thematic visualisation of more attributes in a series [Figure 2.28].

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[233] For an elaboration see: Nijhuis & Stellingwerf, 2011.

[234] See also: Appleyard, 1977; Zube et al., 1987; Sheppard, 2001; Ervin & Hasbrouck, 2001.

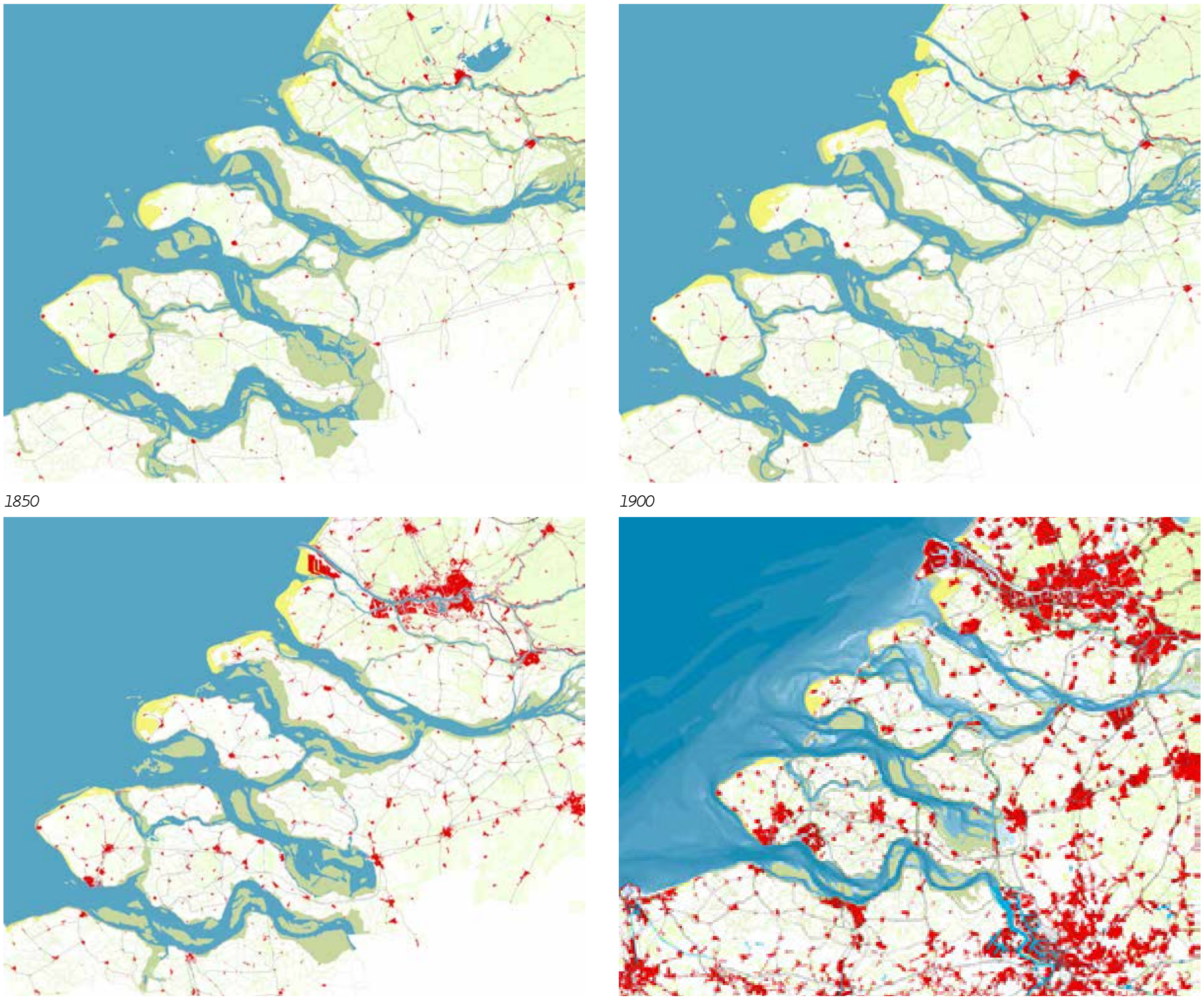
[235] DiBiase, 1990; MacEachren, 1994; Kraak & Ormeling, 2003.

[236] MacEachren, 1994.

[237] Ibid.

[238] DiBiase, 1990; MacEachren, 1994.

[239] Cf. Nijhuis & Pouderoijen, 2014; Leupen et al., 1997.



1850

1900

1950

2000

FIGURE 2.28 Mapping spatial and temporal changes via a map series. The development of the southwest Dutch Delta in four time-slice snapshots: 1850, 1900, 1950 and 2000 (image source: Nijhuis & Pouderoijen, 2014)

In *addition* new information is added to the visual representation. Here, location-specific information is superimposed or merged with other layers of information. This offers alternative readings of a landscape and explores certain relationships while integrating thematic maps with statistical information, photographs, diagrams, sections or adding information about the underlying geometrical system. A specific type of addition is cartographic data analysis. Cartographic data analysis can be used to reveal information through employment of perceptual properties such as differentiation, order, distance and proportions.[240] The possibilities depend on the type of measurement used to acquire the data. There are four types of measurement: nominal, ordinal, interval, and ratio.[241] Nominal data is qualitative data that is defined by difference characteristics, such as land-use categories, and is easiest revealed employing differentiation. Ordinal data can be ranked in terms of relative quality, such as road classifications (e.g. highways, major roads and secondary road), and relate best to perceptual properties of order. Interval data is quantitative data, classified on a linear calibrated scale,

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[240] Kraak, 2014, p.64ff.

[241] Stevens, 1946.

but not relative to a true zero point in time or space. Examples include time of day, calendar years and walking time, and are best expressed in terms of distance. Ratio data is classified relative to a fixed zero point on a linear scale, such as distance, height, age and volume, and is related to proportion perceptual properties.[242]

Presentation of known knowledge is about employing visual variables for effective visual communication of the findings. Bertin (1967/2011) identified size, value, texture, colour, orientation, and shape as important visual variables for visual representation of points, lines, areas and volumes, which are the constituent elements of any visual representation.[243] Cartographic and visualisation disciplines offer useful design principles for effective application of these variables in GIS-based visual representation.[244] There is also a large body of knowledge available regarding effective use and applications of (interactive) landscape visualisation in collaborative planning.[245]

Abstract versus realistic presentations

All GIS-based visual representations are abstractions of reality but vary in level of realism and level of detail.[246] Scale, resolution and degree of reduction (generalization) are important properties. Scale is the ratio of size or distance in a map, 3D-model or plan to the corresponding measurements of the represented object or territory in reality. The concept of scale is complicated by the Earth's curvature, which forces scale to vary across the map and depends on the projection that is chosen consciously or unconsciously.[247] Scale is characterized by grain and extent.[248] Grain refers to the finest level of spatial resolution within a given data set and extent to the size of the object or area under investigation. In this respect, scale refers to the degree of spatial reduction in the length that is used to represent a larger unit of measure. In cartography, large scale means fine resolution (high precision) and small scale means coarse resolution (low precision).[249]

Between physical reality and abstract meaning there is a continuum of visual representations, which range from verisimilar, to schematic-iconic, to symbolic representations.250 Verisimilar are close-to-realism visual representations, they mimic what an individual could see from a horizontal or vertical perspective, with a high degree of similarity-to-reality [Figure 2.29]. Schematic-iconic representations use simplified objects (in accordance with the intended purpose of the model). The object or landscape is still recognisable but its characteristics reduced to their very essence. Form and substance are abstracted, leaving out particulars to expose the morphological or physical structure [Figure 2.30]. Symbolic representations refer to representation through pictograms, signs and other symbols defined by convention or a legend, and have a level of abstraction. In landscape design research schematic-iconic representations are useful as they allow analytical and interpretative applications to discover and delineate patterns and relationships.

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[242] Kraak, 2014, p.64ff; Wade & Sommer, 2006.

[243] For three-dimensional topographic maps see: Häberling, 2003. For interactive maps see: Buziek, 2003.

[244] For GIS-based visual representation see: Kraak & Ormeling, 2003; Dykes et al., 2005; Dodge et al., 2008. For GIS and cartography see: Robinson et al., 1995; Kimerling et al., 2009. For colour schemes in GIS-visualisation see: Brewer, 1994. For visualisation of topographical data and landscapes see: Imhof, 1965; Ervin & Hasbrouck, 2001; Bishop & Lange, 2005; Mach & Petschek, 2007.

[245] Van Lammeren & Hoogerwerf, 2003; Schroth, 2010.

[246] Bodum, 2005.

[247] Snyder & Voxland, 1989.

[248] Turner et al., 2001b, p. 29.

[249] Ibid. Common scales in landscape design research range from 1:50,000 (small scale) to 1:500 (large scale).

[250] MacEachren, 1994; Bodum, 2005.

FIGURE 2.29 Verisimilar representation of a GIS-based virtual 3D-landscape (image courtesy of Philip Paar, Wieland Röhricht, Olaf Schroth and Ulrike Wissen, Lenné3D & ETH Zürich, 2004)

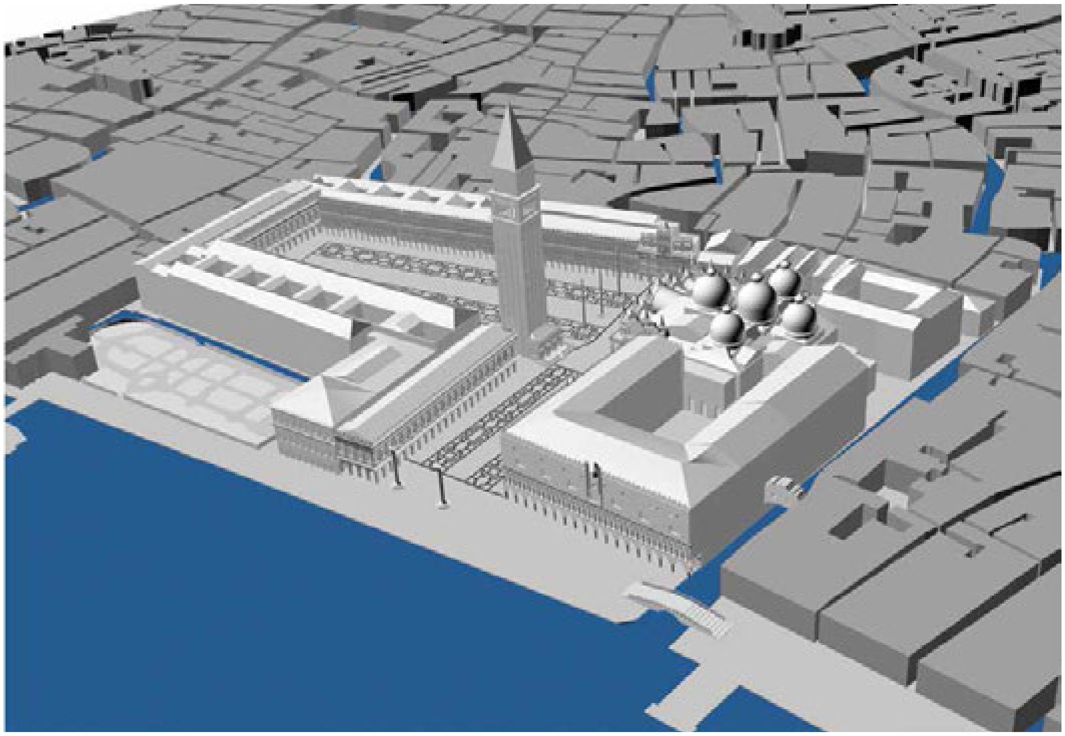

FIGURE 2.30 Schematic-iconic representation of a GIS-based virtual 3D-landscape (model: Steffen Nijhuis & Joris Wiers)

This is achieved by focusing on selected features while purposefully omitting details. They sit in between realistic representations and symbolic representations.

Dimensionality

Another important aspect of GIS-based visual representation is dimensionality. When features of a designed landscape are represented in plane – e.g. maps or sections – it is seen two-dimensionally. When features are represented as three-dimensional but the locations are not 'accessible', the representation is two-and-a-half-dimensional, as on a flat screen or on paper. A three-dimensional representation refers to three-dimensional geometric entities in a virtual or analogue setting. Aside from the fact that a three-dimensional representation is usually easier to understand because of its parallel to a real-time situation (and the direct cues for visual depth-perception), the assumption is that expanding the dimensions of an indispensable variable will make visual representation of higher dimensional information more successful.[251] The dimensions of a three-dimensional visual representation do not have to match the real-time situation. The dimensions can be used to increase the readability of a visual representation and also to add extra layers of information for purposes of knowledge discovery. There is a distinction in GIS-based visualisations based on the extent to which the dimensions match the dimension of the reality.[252] The first group of models are spatially iconic: the dimensions match the reality (in scale). There is concordance with the actual situation in reality now or in the future. When one of the three dimensions, usually the vertical, is used for something other than the geographic dimension of height, the visualisation may be described as spatially semi-iconic. The third group is spatially symbolic and refers to the fact that the axes of the display environment are quite unrelated to real world dimensions (e.g. statistical landscapes). The chosen mode depends on the purpose of the visual representation.[253]

Static versus dynamic representations

Landscapes change over time by modifications (e.g. by human interventions) or follow certain rhythms of change over various time scales (e.g. diurnal, seasonal, and geological changes).[254] The movement *through* landscape, the movement *of* landscape and the interaction *with* the landscapes are also important dynamic aspects.[255] How to capture these spatiotemporal dynamics is an important issue in GIS-based visual representation.[256] Common models for expressing change in time and space are the space-time composite, multiple time-slice snapshots (in a series) or dynamic representations.[257] The space-time composite shows change in a single two- or three dimensional representation (e.g. flow line maps, cartograms and space-time cubes). Multiple time-slice snapshots show change via a series of two-or three-dimensional representations depicting the site or object in a sequence with a certain time interval or at crucial states of development.

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[251] Tufte, 1990; MacEachren, 1995; Wilkinson, 2005.

[252] Bishop & Lange, 2005; Thiel, 1997.

[253] See for example Sheppard (2001), who identifies five principles that are important for decision making and public communication: accuracy, representativeness, interest, visual clarity, and legitimacy.

[254] Zonneveld, 1995.

[255] Ervin, 2001.

[256] Langran ,1992; Ervin, 2001; Slocum et al., 2001.

[257] Cf. Langran, 1992; Kraak, 2014.

Dynamic representations as opposed to static ones, refer to two- or three-dimensional representations that change continuously, either with or without user control (e.g. animated maps, fly-overs and walk-throughs), but depend on digital technology and cannot be used in analogue form.[258]

The output subsystem of GIS is focused on the creation of visual representations of a digital landscape model or of analysis results. GIS-based visual representation as a field of operation in landscape design research concentrates on revealing and communicating knowledge from landscape architectonic compositions through a wide variety of visual means offered by the technology.

For the application and development of the analytical framework for landscape design research GIS offers three potential fields of operation. The first field is GIS-based modelling, which consists of data acquisition, processing, and description of existing and future landscape architectonic compositions in digital form. The second field is GIS-aided architectonic analysis, which is about the exploration, analysis and synthesis of landscape architectonic compositions in order to reveal new or latent architectonic relationships, while utilising the processing capacities and possibilities of computers for ex-ante and ex-post simulation and evaluation. The third field is computer generated visual representation, which is about representation of (virtual) landscape architectonic compositions in space and time in order to retrieve and communicate information and knowledge of landscape design.

§ 2.3.3 GIS in the process of knowledge acquisition

The role of GIS in landscape design research can be understood by exploring the dialogue between the design researcher and GIS in the process of ex-post or ex-ante analysis of landscape architectonic compositions. Ex-post analysis is about gaining knowledge of existing landscape designs in order to learn from them. Ex-ante analysis is about gaining insight into conceived landscape designs in order to refine the design. Both types of analysis can be part of a design process, but here the emphasis is on knowledge acquisition from landscape designs in general.

In literature on the use of GIS for knowledge acquisition the emphasis is usually on technical issues and advances, but only a few scholars address interactive analysis processes where individuals add information to the information flow.[259] Van der Schans (1990, 1995) proposed the LM/VM-framework for evaluating the interaction process between man, computer and landscape.[260] This framework will be used in adapted form to help to understand the role of GIS in knowledge acquisition. In this framework landscape is equated with designed landscape or landscape architectonic composition. The interaction process can be regarded as a dialogue between the designed landscape, mental models, digital models and visual representations, with possible interactions in different trajectories between these components [Figure 2.31]. It is a framework for describing the process of data and information handling and not an analysis of the information content or structure.

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[258] Slocum et al., 2001.

[259] Notable exceptions are: Van der Schans, 1990, 1995; Turk, 1993; Nyerges, 1993; Ormeling & Van der Schans, 1997.

[260] This framework or paradigm is mainly based on the work of Bertin (1967/2011, 1977/1981) that regards visual representations as a means for data processing, interpretation and knowledge discovery. It also makes a distinction between content and expression, and regards the individual to be an integral part of the information process and thus does not only rely on the visual representation itself.

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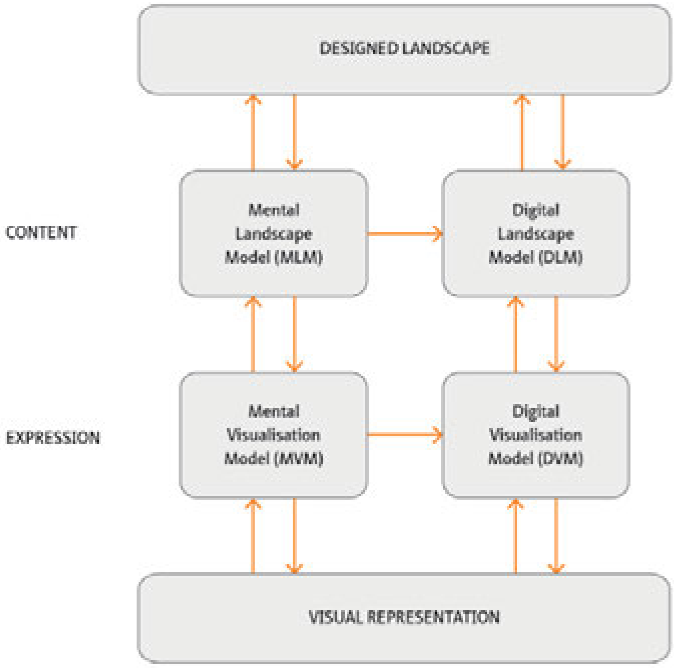

FIGURE 2.31 Knowledge acquisition as an interactive process between the designed landscape, mental models, digital models and visual representations (graphic: Steffen Nijhuis, adapted from Van der Schans, 1995)

Visual representation and knowledge acquisition

Analysis is differentiated from purely making visual representations because it generates more information that can be gleaned from visual representations alone.[261] Knowledge acquisition by means of analysis is a synergetic means of extracting information from data using visual representations, and it provides a valuable means for the brain to discern patterns.[262] To understand the role visual representation plays in knowledge acquisition it is useful to make a distinction between content and expression.[263] More precisely, there are two types of mental models that are important for the interaction with visual representations: the *mental landscape model* (MLM) and *mental visualisation model* (MVM) [Figure 2.32].[264] The MLM is the mental content (*gedachteninhoud)* the abstract landscape architectonic composition regardless of its visual representation. The MVM determines the mode of expression (*uitdrukkingsvorm*).[265] The link between the landscape architectonic composition and the visual representation is established via mental content and the mode of expression. In other words: In analysing the landscape architectonic composition the design researcher constructs a MLM, externalising/symbolising the mental content via a MVM and displaying it as a visual representation[266] (Figure 2.32: trajectory from designed landscape, to MLM, to MVM, to visual representation).

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[261] Schuurman, 2004.

[262] Ibid.

[263] Cf. Bertin, 1967/2011.

[264] Van der Schans, 1997; Ormeling & Van der Schans, 1997; cf. Hamel, 1990.

[265] Ormeling & Van der Schans, 1997.

[266] In case of (aerial) photography the relation is more direct, here there are no MLM and MVM present since the existing designed landscape is directly captured by a photo.

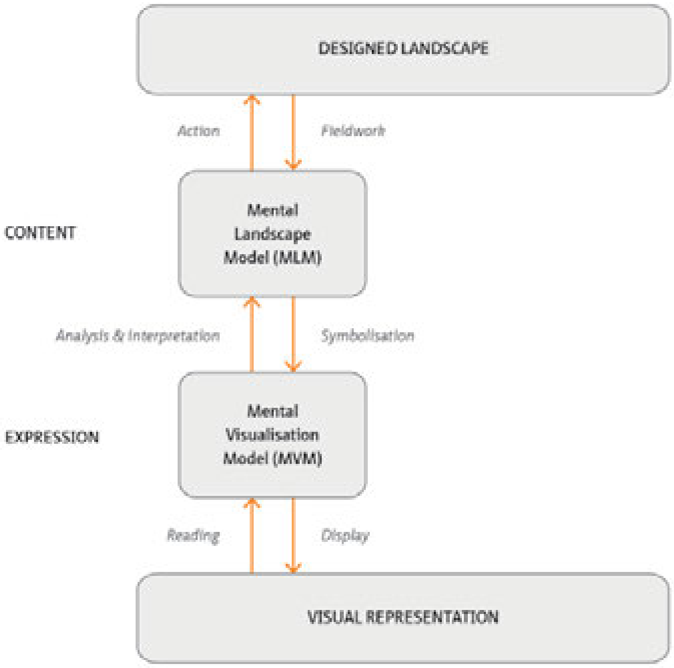

FIGURE 2.32 The translation of the landscape architectonic composition via mental content (MLM) and mode of expression (MVM) into a visual representation and vice versa (graphic: Steffen Nijhuis, adapted from Van der Schans, 1995)

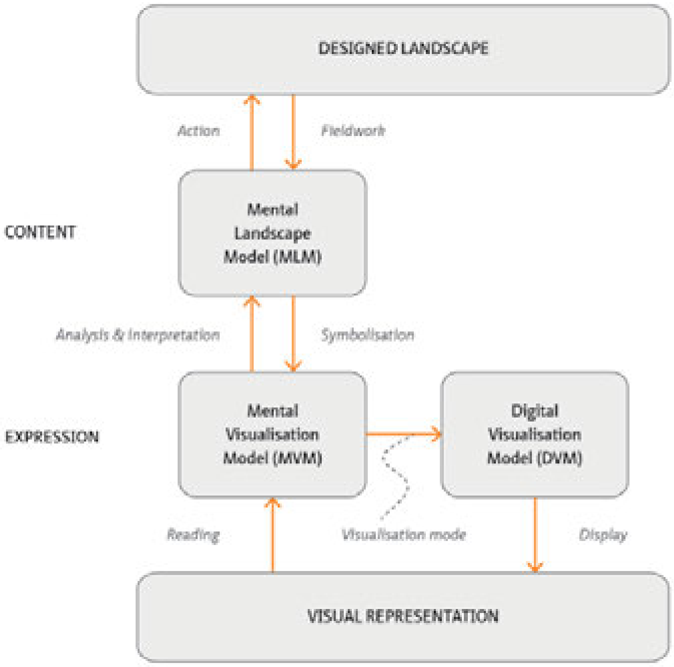

FIGURE 2.33 The translation of the designed landscape via mental content (MLM) and mode of expression (MVM) into a visual representation and vice versa, augmented by the application of a digital visualisation model (DVM) (graphic: Steffen Nijhuis, adapted from Van der Schans, 1995)

The resulting visual representation is compared with the existing designed landscape, which refines or changes the mental content (i.e. knowledge acquisition) in a cyclical process. The other way around, the visual representation can be the starting point for building up mental content (MLM), via interpretation and analysis of the MVM (Figure 2.32: trajectory from visual representation, to MVM, to MLM, to landscape architectonic composition). In both trajectories the visual representation facilitates the understanding of the landscape architectonic composition.

In the analysis of a designed landscape data from observation (i.e. via fieldwork or other means) is transformed via visual representation into information and via interpretation to knowledge, the 'knowledge formation-cycle'. The visual representation becomes an external image of the internal construct of the mind in a cyclical process where both are influenced by each other. Here the visual representation is confined to the two dimensional surface of paper and the three dimensional models it allowed to construct.[267] In this process of creating visual representations of landscape architectonic compositions (without digital means) content and expression are connected mentally and cannot be separated in reality. The creation of the drawing, map or 3D-model is intrinsically part of the thinking process in terms of eye-brain-hand coordination and helps to frame thoughts. At the same time, it enhances the design researcher's capacity to capture, store, manipulate, manage and reflect (i.e. 'seeing that', 'seeing as' and 'seeing in').[268] *Evocation* and *serendipity* are important 'functions' of the visual representation.[269] Evocation is about appearance, expressiveness and the potential to inspire. Serendipity is the potential to light on clues and ideas while not intentionally looking for them.

Digital visualisation model (DVM)

GIS enables design researchers to describe and transform the MVM electronically into a digital visualisation model (DVM).[270] Directly related to the MVM, GIS has the capability to function as a powerful DVM, with the integration of image processing, CAD and mapmaking offering various, interactive and dynamic display possibilities based upon geographic location. In employing GIS for virtual 3D-landscapes, computer graphics, and computer-aided design (CAD), the MVM is translated by means of the DVM into a visual representation [Figure 2.33]. The DVM is reliant on the functionality and possibilities of the software and the skills of the operator. Via the DVM, graphic variables like size, value/hue, grain/texture, colour, orientation and shape of symbols like points, lines and areas are determined and manipulated. In this respect GIS is used as a tool to visualise the MVM via digital means (Figure 2.33: trajectory from landscape architectonic composition, to MLM, to MVM, to DVM, to visual representation).

Here GIS-functions, such as CAD, image processing and 3D-modelling, provide more flexibility in terms of graphic applications and display functions in producing visual representations than do their hand-crafted counterparts. They are particularly beneficial for editing and updating, and enhance the user's speed, productivity and precision in creating all sorts of imagery.[271]

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[267] Nowotny, 2008.

[268] Purcell & Gero, 1998; Goldschmidt, 1991; Schön & Wiggins, 1992.

[269] Stellingwerff, 2005.

[270] Ormeling & Van der Schans, 1997.

[271] For the benefits of the application of CAD, computer graphics and 3D-modeling in landscape architecture and architecture see: Kalay, 2004; Gänshirt, 2007; Cantrell & Michaels, 2010; Cantrell & Yates, 2012. See also: MacDougall, 1983; Mutunayagam & Bahrami, 1987; Cowen, 1988.

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Editing, altering, copying, scaling, rotating, mirroring, tilting, moving or deleting features from a digital drawing is possible in a fraction of the time required to accomplish these things manually.[272] Efficiency is enhanced via automation, portability, replication and transformation.[273]

Next to this rather basic view, the implementation of a DVM also offers the possibility of representing the landscape architectonic composition in three and four dimensions, as virtual landscapes. The DVM can help designers to see what cannot be seen by the naked eye, realistically simulating future and past situations or superimposing information for means of analysis (Figure 2.33: trajectory from visual representation, to MVM, to MLM, to landscape architectonic composition). Two dimensional drawings are then replaced by or translated into dynamic three-dimensional virtual landscapes, with the possibility of virtually walking through them, showing past, present or future situations. The visualisation can be more or less realistic, depending on the intention and the time available.

However, when it comes to analytical operations the DVM as such has severe limitations. Virtual 3D-landscapes, computer graphics and CAD have no intelligence or volition of their own, but make the execution of some specific tasks more efficient, more precise, or more effortless.[274] They can replace traditional paper and pencil with electronic means, but do not fundamentally change the task of drawing and thinking in the process of landscape design research.[275] The DVM is used to translate the MVM into a digital form, but the actual landscape architectural analysis remains thinking and (digital) drawing by the design researcher (Figure 2.33: trajectory from landscape architectonic composition to MLM, to MVM, to DVM, to visual representation, to MVM and MLM). When GIS is used to create virtual 3D-landscapes, computer graphics and CAD the processing power of computers is employed to generate, store and manipulate visual representations, but not necessarily for (computed) analytical operations. The analytical operations remain graphical, solely depending on the interaction between MLM and MVM.

Digital landscape model (DLM)

In addition to the DVM, GIS also employs a digital landscape model (DLM). In the DLM the constituent objects and features of the landscape design are abstracted as a digital structure, according to predetermined criteria, and stored as data in GIS. It can also simulate some aspects of the composition where data is incomplete, unmeasured, or difficult to obtain.[276] The DLM is a digital representation and/or description of the landscape architectonic composition regardless of its visual representation. In fact the DLM provides an electronic counter-image of the brain (MLM). In contrast to the MLM, the DLM is a digital representation of the object of study and can independently serve as the basis for both analysis and visual representation.

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[272] Mutunayagam & Bahrami, 1987; Cantrell & Michaels, 2010.

[273] Ibid.

[274] Kalay, 2004.

[275] For a lively discussion about manual vs digital drawing see e.g.: Treib, 2008b; Belardi, 2014.

[276] Maantay & Ziegler, 2006.

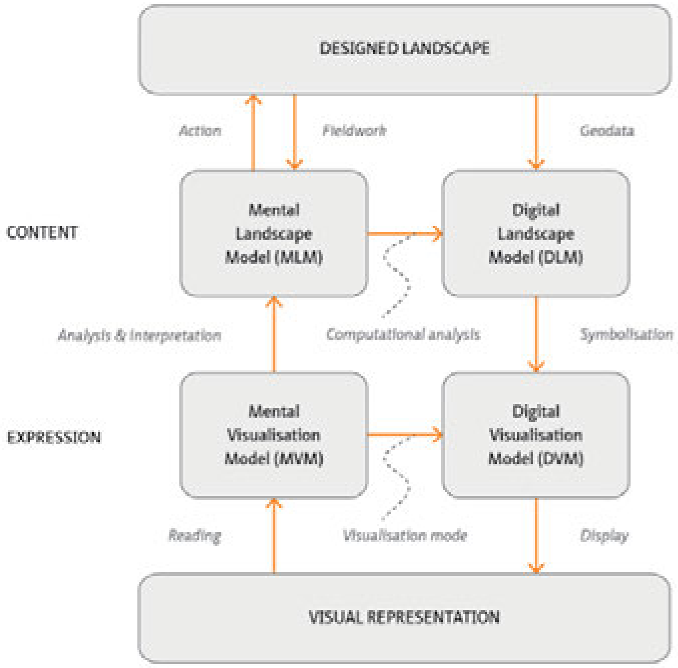

FIGURE 2.34 The translation of the designed landscape via mental content (MLM) and mode of expression (MVM) into a visual representation and vice versa, augmented by the application of a digital landscape model (DLM) and digital visualisation model (DVM) (graphic: Steffen Nijhuis, adapted from Van der Schans, 1995)

Here GIS differs fundamentally from other digital technology, such as CAD and 3D-modelling, but also from standard database management systems (DBMS), in that it employs a DLM and has integrative and analytical capabilities [Figure 2.34].[277]

DLMs form the basis for computational analysis. In that respect DLMs are useful since they can help design researchers learn something new about the represented landscape architectonic composition. While exploiting the analytical capabilities of GIS through computer simulations, measurements and experiments the analysis goes beyond the limitations imposed by the operator.[278] Based on the DLM GIS can calculate, carry out, store and reproduce logical operations performed on large amounts of data and information, with unimaginable speed and precision.[279] The analysis results can be displayed via the DVM in a wide variety of possible visual representations, including tables or graphs showing quantitative information.

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[277] Cf. Cowen, 1988; Ormeling & Van der Schans, 1997.

[278] People have a limited capacity to retain and process information in their Short Term Memory (STM). Miller (1956) came to the conclusion that people can process a maximum of 2.5 bits (5-7 variables) of information, while computers are able to process 32 bits, or even 64 bits of information. Recent research has adjusted his findings to four variables (e.g. Ericsson et al., 1980; Cowan, 2000).

[279] Gänshirt, 2007.

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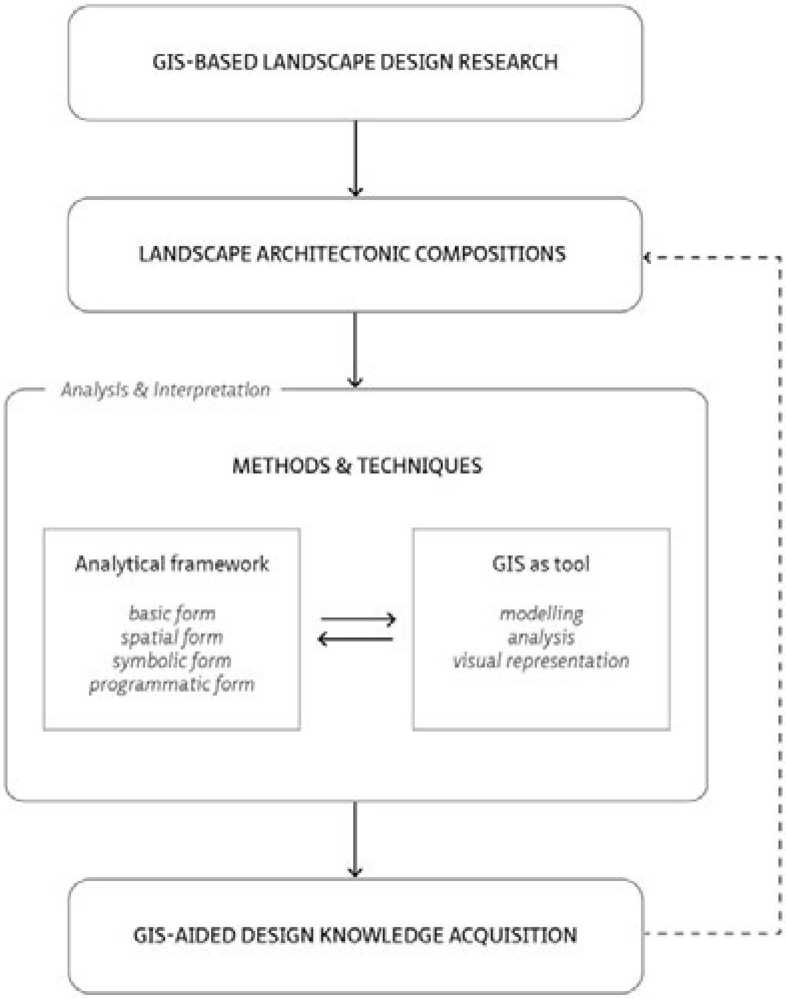

FIGURE 2.35 Framework for GIS-based landscape design research (graphic: Steffen Nijhuis)

§ 2.3.4 GIS-based landscape design research

This study explores GIS as the primary tool in the analytical framework for design research in order to derive knowledge from landscape architectonic compositions via formal analysis of the basic, spatial, symbolic and programmatic form. In this GIS-based landscape design research three fields of operation are investigated [Figure 2.35]:

- GIS-based modelling: creating digital designed landscapes and/or structures of data for landscape design analysis;
- GIS-based analysis: exploration, analysis and synthesis of data in order to reveal patterns and relationships in designed landscapes;
- GIS-based visual representation: visualisation of designed landscapes in two, three or four dimensions.

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This study considers GIS as a vehicle to facilitate and mediate in knowledge acquisition through landscape design analysis in a systematic, interactive and visual way. Though other digital media might be of use in the process of knowledge acquisition, GIS as a geographic information technology is distinguished from other digital media by its ability to generate, integrate and analyse spatial (locational) information, while exploiting the possibilities of computer-aided design, cartography and database management. GIS-based design research combines modelling, analysis and visual representation of landscape architectonic compositions with geo-information technology.

§ 2.4 Stourhead landscape garden as a case study

§ 2.4.1 GIS-based landscape design research of Stourhead as an exploratory exercise

To explore the potential of GIS in landscape design research, the research is primarily based on a case study.[280] Case-study research is, according to Gerring (2004), "*an intensive study of a single case with an aim to generalise across a larger class of cases.*"[281] This research strategy is widely acknowledged as suitable for complex, multifaceted investigations and is particularly useful when it comes to studying complex phenomena including landscape compositions and the use of GIS in landscape design research.[282] In this type of research there is no clear boundary between the focus of the research and its context, as in a laboratory setting. Here, it is not possible to isolate key factors that can be controlled and manipulated in order to derive measurements that can, for example, be analysed statistically. This is a justifiable rationale for conducting an exploratory case study, the goal being to answer the research questions and develop propositions for further inquiry.[283]

The selected study area is Stourhead landscape garden (Wiltshire, UK), which is considered to be a critical, information-oriented case[284] [Figure 2.36, Figure 2.37 & Figure 2.38]. It is an ideal-type of a landscape architectonic design that permits logical deductions like: 'if this is (not) valid for this case, then it applies to all (no) cases'. Stourhead is of strategic importance to the research objective for four reasons.

Firstly, Stourhead is a critical example because it is one of the best preserved and widely acknowledged English landscape gardens. Since the landscape garden still exists, it is possible to verify results of the research experiments empirically via direct observation (e.g. site visits and field research). In general, the English landscape garden marks an important phase in the development of landscape architectonic design as it has developed over five centuries.[285]

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[280] Overviews of suitable research strategies in landscape architecture are provided by: De Jong & Van der Voordt, 2002; Groat & Wang, 2002; Deming & Swaffield, 2011

[281] Gerring, 2004, p. 341.

[282] Cf. De Jong & Van der Voordt, 2002; Groat & Wang, 2002; Gerring, 2004, 2007; Flyvbjerg, 2006, 2011; Yin, 2009; Deming & Swaffield, 2011.

[283] Yin, 2009, p. 9.

[284] Terminology adapted from Flyvbjerg, 2011.

[285] Steenbergen, 1995; Steenbergen & Reh, 2003.

FIGURE 2.36 Stourhead landscape garden, view towards the Pantheon (photo: Steffen Nijhuis, 2011)

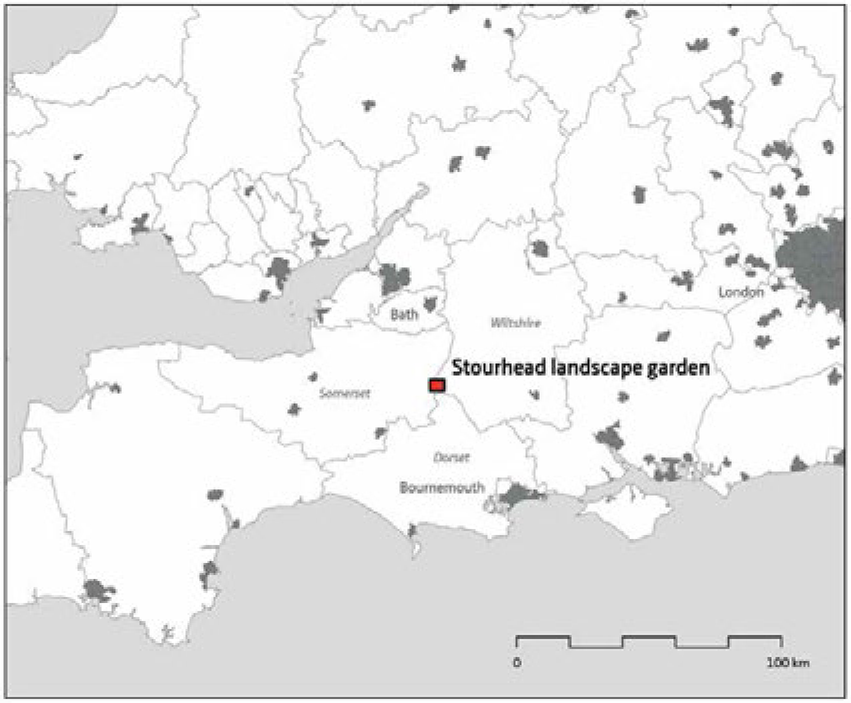

FIGURE 2.37 Location of Stourhead landscape garden within the United Kingdom (Wilshire, UK) (map: Steffen Nijhuis)

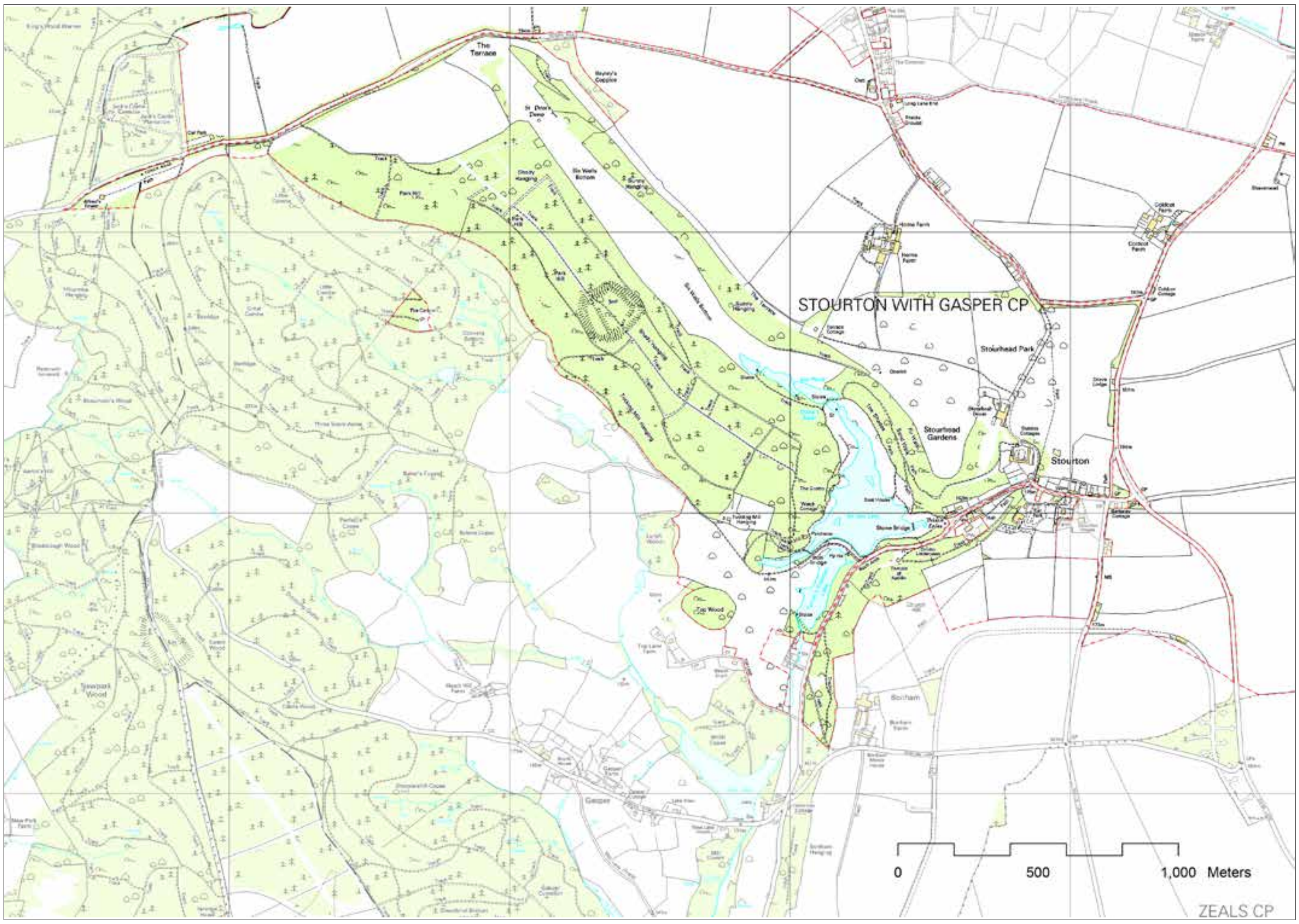

FIGURE 2.38 Stourhead landscape garden with the Great Lake as centrepiece. Ordnance Survey Map of Stourton, 1:10,000 (image not to scale) augmented with National Trust Ownership (the map is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey licence number AL100018591)

Here, the landscape architectonic vocabulary culminates in a formal typology that became the design model of public city parks and suburban residential environments from the nineteenth century onwards.[286] Although the design model later transformed and sharpened to find the right balance between the drama of the scenic image and the generic public character, the English landscape garden usually embodies a rich palette of available design instruments. The landscape garden represents an accumulation of design knowledge that had developed over centuries.

Secondly, Stourhead is an information-oriented case showcasing the application of a wide range of landscape design instruments. As a result of its dramatic geological setting, the landscape architectonic composition embodies a designerly treatment of the topography of the natural landscape, while also activating natural particularities of the site (e.g. making use of a valley to create a circuit walk or natural heights for panoramic views). The landscape design under investigation is also rich in implicit visual and formal elements, as well as in explicit architectonic definitions in terms of points, lines and planes, spaces. Views and sightlines were carefully planned combining formal, transitional and progressive elements with an evocative metaphorical structure.

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[286] Steenbergen & Reh, 2003, 2011.

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The composition incorporates the concepts of visual perception with the organisation of visual logic, space-making, composition of views and the control of movement.

Thirdly, because of its historical and landscape architectural significance there is an extensive body of knowledge available on Stourhead landscape garden, such as general descriptions, landscape architectonic explorations and interpretative-historical research. There are also contemporary sources available, including survey plans, maps, etchings, written descriptions and letters about Stourhead. This makes it possible to construct accurate models, compare and verify analysis results, and establish a chain of evidence using multiple sources.

Fourthly, given the availability of a formal landscape architectonic analysis of Stourhead landscape garden employing drawings as analytical tools, it is possible to compare outcomes and to reflect upon the added value of GIS in landscape design research.

§ 2.4.2 Short history of Stourhead landscape garden

Stourhead landscape garden is located in the Vale of Warminster at the western edge of the Salisbury Plain (Wessex chalk lands), on the border of three counties: Wiltshire, Somerset and Dorset. The topography is varied and directly related to the geology. This is the oldest inhabited landscape in England, as exemplified by a vast number of archaeological sites, such as settlements and fortifications from the prehistoric and Roman periods, which can be found in the environs of Stourhead. Significant features in the ridges surrounding the site are two Iron Age hill forts: Whitesheet Hill and Park Hill Camp. Kingsettle Hill is the supposed mustering place of Alfred the Great's Anglo-Saxon army before the famous Battle of Edington where he defeated the Danes in 878 CE, an important moment in the emergence of England as a distinct political and cultural entity.

Stourhead landscape garden is part of an estate that was established in 1448 when Sir John Stourton was granted a license by Henry VI to enclose 404 hectares (1,000 acres) of woodland, pasture and meadows in the surroundings of the family manor in Stourton[287] [Figure 2.39 & Figure 2.40]. In 1714, Sir Thomas Meres bought the estate after it had fallen into debt. It passed in 1717 to the banker Henry Hoare (1677-1724), member of a burgeoning financial elite.[288] In 1718, he pulled down the old manor and built a new house nearby in the Palladian style and named it Stourhead.[289] After his death, Henry Hoare II 'the Magnificent' (1705-1785) set about designing the Stourhead landscape garden, assisted by Henry Flitcroft (1697-1769) and other architects, resulting in one of the finest English landscape gardens in Europe.[290] Though the estate includes a Pleasure Garden around the house and agricultural land with pastures and woodland, the Valley Garden with the village Stourton is the nucleus of the landscape architectonic composition. The Valley Garden was created around a lake in the period from about 1743-1770, at a place called 'Paradise', three hundred metres southwest of the house where the grounds fall steeply and two valleys converge. This lake was made by building a dam across the southwest corner of the valley to contain the headwaters of the Stour. Around the

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[287] Mowbray, 1899.

[288] For a history on the Hoare banking dynasty see: Hutchings, 2005.

[289] Mowbray, 1899; Woodbridge, 1982/2002.

[290] It is likely that Charles Hamilton's (1704-1786) garden at Painshill and his discussions with Henry Hoare played a noteworthy part in the creation of Stourhead (Thacker, 2002).

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lake, he built an Arcadian landscape with framed views containing classical temples. In addition to the classical architectural features, Gothic and oriental features were integrated to become part of an interconnected system of visual relationships. As each feature was constructed, it also became a goal in its own right; a stage in a pictorial circuit walk. Following the pictorial circuit, initially beginning at the house and ending at Stourton's inn, provides individuals with a sequence of views with sightlines directed across the lake terminating in the architectural features placed in the valley landscape and beyond.

FIGURE 2.39 Eighteenth century reconstruction of the demolished Manor of Stourton by Richard Colt Hoare (image source: Mowbray, 1899)

FIGURE 2.40 The location of the Manor of Stourton indicated on a fragment of the ordnance survey map,1900 (the map is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey licence number AL100018591)

In 1785, Richard Colt Hoare (1758-1838) inherited the estate. He broadened the palette of plant material as an increasing number of exotic species became naturalised in England. He removed features and changed the path structure considerably.[291] Structurally, Stourhead has changed very little since then. In 1946, about 1,014 hectares of the estate including the house and the garden were bequeathed to The National Trust.[292] The National Trust owns now 1,049 hectares of the estate. The western part of the estate is still owned and managed by the Hoare family and includes 496 hectares of woodland.[293]

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[291] Woodbridge, 1982/2002.

[292] The National Trust (NT), an abbreviation of: National Trust for Places of Historic Interest or Natural Beauty, is a conservation organisation in England, Wales and Northern Ireland and one of the largest landowners in the UK.

[293] For more historical background: Mowbray, 1899; Woodbridge, 1976, 1970, 1982/2002; Hutchings, 2005.

§ 2.4.3 Concepts in English landscape garden design

Though there is a great number of publications available on the backgrounds and development of the English landscape garden in general, it is vital to know some basic concepts, as it is otherwise impossible to understand Stourhead as a landscape architectonic composition.[294] The English landscape garden, also referred to as the picturesque garden[295], is the result of a garden revolution that took place in the period of 1720-1750 in England and between 1760-1790 in the rest of Europe.[296] It was an era of changes in political thinking, morals, aesthetics, and religion that were represented and discussed through the model of gardens.[297] In this period, the more formal, symmetrical gardens transformed into natural, irregular gardens. Nature was not imitated, but its potentialities and capabilities were developed and realized in accordance with the formal rules set by the contemporary aesthetic ideals of beauty and the picturesque.[298] Arcadian landscapes were laid out either amid fertile agrarian land, or in more natural settings with spectacular geological phenomena.[299] It was regarded as a paradisiacal place where there was harmony between humans and nature, a combination of the idyllic (pastoral rustic) and the 'real' wilderness.[300] Influential practitioners in England included: Charles Bridgeman (1690-1738), William Kent (1685-1748), Lancelot 'Capability' Brown (1715-1783) and Humprey Repton (1752-1818).[301] In continental Europe, these included Friedrich Ludwig von Sckell (1750-1823), Peter Joseph Lenné (1789-1866) and Édouard André (1840-1911).[302] In North America, Andrew Jackson Downing (1815-1852) and Frederick Law Olmstead (1822-1903) were important protagonists of English landscape garden design.[303] Important examples of landscape gardens include: Stowe (Buckinghamshire, UK), The Leasowes (Shropshire, UK), Painshill (Surrey, UK), Wörlitz (Dessau, Germany), Bois de Bologne (Paris, France) and Central Park (New York, USA).

According to Pevsner (1956) the English landscape garden is characterised as asymmetrical, informal, varied and made of features such as the serpentine lake, the winding drive and winding path, trees grouped in clumps, and smooth lawn reaching to the house.[304] Contemporary writers such as Joseph Addison (1672-1719), Alexander Pope (1688-1744), Horace Walpole (1717-1797), Thomas Whately (1726-1772) and Christian Cay Lorenz Hirschfeld (1742-1792) put forward the combination of nature and reason, inspiration from classical antiquity, association with painting, and involvement of the surrounding landscape as important landscape design principles.[305]

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[294] See for example: Hussey, 1967; Lang, 1974; Jarret, 1978; Clark, 1980; Von Buttlar, 1982, 1989; Watkin, 1982; Hammerschmidt & Wilke, 1990; Hunt, 1992a; Tabarasi, 2007; Siegmund, 2011. For the Dutch situation: Tromp, 2012.

[295] Pevsner, 1974; Hunt, 2002.

[296] Tabarasi, 2007.

[297] Tabarasi, 2007; Von Buttlar, 1982; Siegmund, 2011.

[298] Clark, 1980.

[299] Clifford, 1962. The term Arcadia refers to a rural agrarian setting on the Greek Peloponnese island as a symbol for a mythical place of pastoral simplicity (Vroom, 2006, p. 45).

[300] Schama, 1995, pp. 517-578.

[301] See on Bridgeman: Willis, 2002. On Kent: Hunt, 1987; Mowl, 2006. On Brown: Turner, 1999. On Repton: Daniels, 1999; Rogger, 2007.

[302] See on Lenné: Günther, 1985.

[303] See on Olmstead: Beveridge & Rocheleau, 1995.

[304] Pevsner, 1956, p. 164.

[305] See for example Pope, 1956; Whately, 1772/1982; Walpole, 1782/1995; Hirschfeld, 1779-1785/2001. The German, Hirschfeld is an important source because his work provides a comprehensive overview of English landscape gardening principles, derived from English and French contemporary writings.

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FIGURE 2.41 The beauty of attractive three-dimensional curving lines as expressed by the movement pattern of the dance by William Hogarth in his seminal work 'The Analysis of Beauty' (1753). See details nr. 26, 49, 59, 71, 122. Plate II, The Analysis of Beauty. The Whole Works of the celebrated William Hogarth, re-engraved by Thomas Cook (1812) (image courtesy of London Namur archive ©Photo SCALA, Florence)

The garden revolution induced a landscape architecture that absorbed and consumed space through movement by a spectator, by setting sites into moving perspectives, expanding outward to incorporate larger portions of space.[306] It was an era where garden views were among new forms of spatio-visual pleasure and combined imagination with physicality.[307]

The related aesthetic ideals were described by William Hogarth (1697-1764) and Edmund Burke (1729-1797).[308] Both stress the importance of variety and gracefulness as fundaments of beauty. In his influential 'Analysis of beauty' (1753/1997), Hogarth goes a step further and describes the

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[306] Bruno, 2002, p. 172.

[307] Ibid.

[308] Hogarth, 1753/1997; Burke, 1757/1958.

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physical form of beauty that should be expressed in landscape design, sculpture, and painting. The 'Line of Beauty'; a S-shaped curved or serpentine line, and the 'Line of Grace', its three-dimensional variant, were according to him the best formal expressions to excite the attention of the viewer and evoke liveliness and movement through smoothly transitioned variety [Figure 2.41]. This formal expression and the related principles is, according to Gothein (1914), at the heart of English landscape garden design.[309] Other important concepts for landscape garden design include: site sensitivity and *genius loci*, scenic composition as an art of gardening, and routes as silent guides of the stroller.

Site sensitivity and genius loci

Site sensitivity was a 'latent' design concept for English landscape gardens. Pope (1956) stated: *"instanced in architecture and gardening, […] all must be adapted to the genius of the place, and […] beauties not forced into it, but resulting from it.*'' Here, the 'genius of the place' or *genius loci*, is referred to as an atmospheric quality of the site, which was to be consulted in the planning and design of houses, gardens, and other architectural features. *Genius loci* was used in Roman times as a metaphoric description of a site.[310] Pope used the term to devise certain aesthetics of association, in which a sensitivity to the character of the site is expressed in the landscape architectonic composition. In this respect, *genius loci* can be defined as the character of the site, not only geographical but also the historical, social, and especially the aesthetic character.[311] Reh (1995) describes the term as a hybrid concept that encompassed the Greek notion of *topos* – the mythical landscape without geometric elements, which was labyrinthine, infinite and without scale – and the Roman notion of *locus* – the artificial, architectonic landscape determined by human intervention and geometry.[312] According to this view, the English landscape garden is a place where the mythic landscape mingled with both the natural landscape and the artificial landscape in the architecture of the landscape garden.[313]

For centuries, architects and landscape designers have exploited terrain conditions to construct and express urban and cultural landscapes. For example, Hippocrates' writings (ca. 5th century B.C./1994) related issues of health with the location of cities, and the Roman architect Vitruvius (ca. 1st century B.C./1999) specified the layout of streets, and the arrangement and orientation of houses related to natural features. In the fifteenth century, the Italian architects Alberti (1485/1988) and Palladio (1570/1997) wrote influential treatises advocating the characteristics of the natural environment as a prerequisite for the planning and design of cities, villas, and gardens, particularly regarding location and orientation.[314] These traditions are an important basis for the eighteenth century sensitivity to the qualities of the site, which includes not only the physical makeup but also how it is perceived. It became an important driving force for architects and landscape designers transforming entire estates into landscape gardens while combining functional and aesthetic ideals.

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[309] Cf. Myers, 2004.

[310] For a full account on *genius loci* is referred to: Pieper, 1984; Kozljanič, 2004. See for its significance in architecture and urban design: Norberg-Schulz, 1979/1980; Valena, 1994/2014.

[311] Pevsner, 1956, p. 168.

[312] Reh, 1995, pp. 45-46; cf. Steenbergen & Reh, 2003, p. 238.

[313] Ibid.

[314] See for example Pieper, 1997; Bertsch, 2012; Blum, 2015.

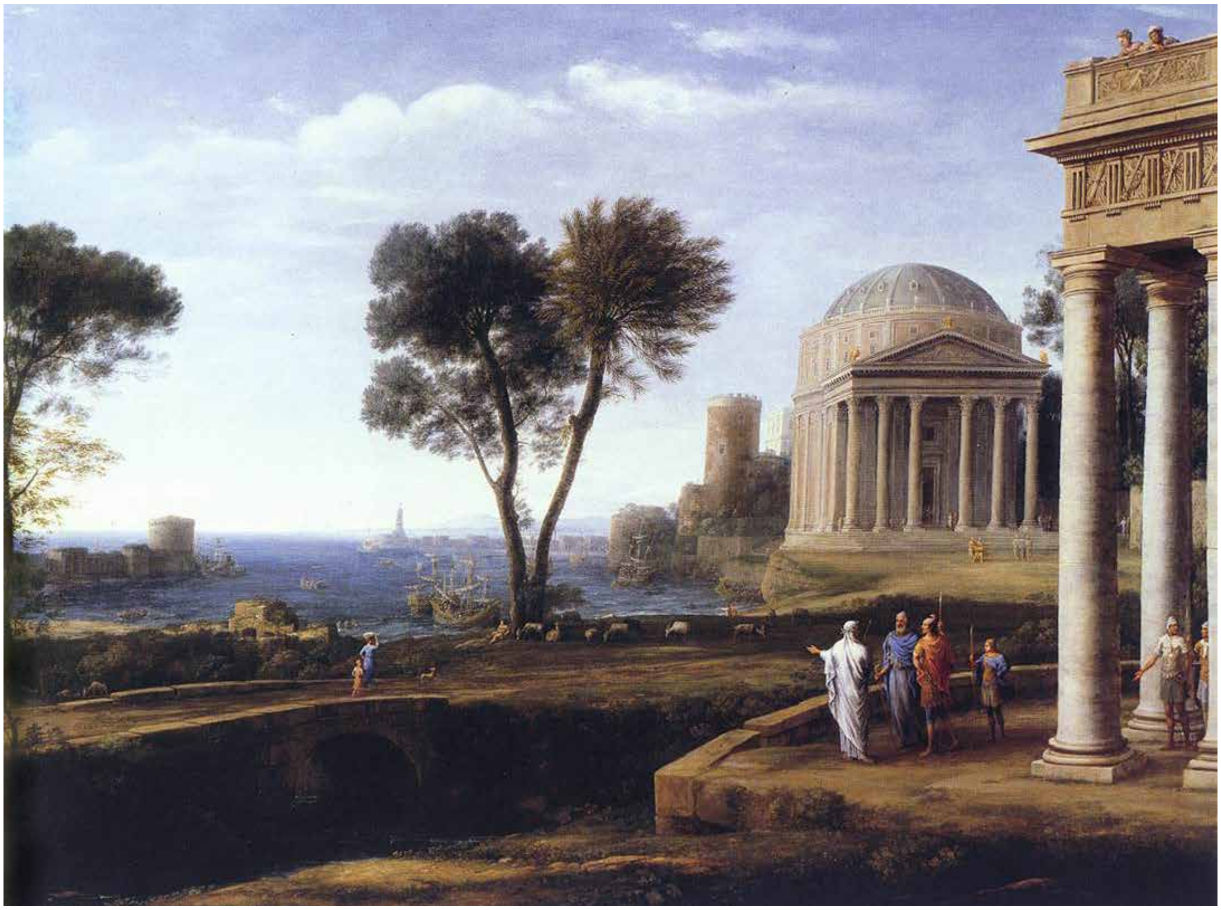

FIGURE 2.42 The designs of garden scenes were inspired by paintings like these. Landscape with Aeneas at Delos by Claude Lorrain, 1672 (image courtesy of The National Gallery, London)

Scenic composition as an art of gardening

The English landscape garden evolved in an era when topographical view painting and cartography were developing into landscape design and panoramic vision.[315] 'Painted' landscape composition was seen as a model for landscape design.[316] Scenic composition was an art of gardening, inspired by the paintings of Claude Lorrain, Nicolas Poussin, and Salvator Rosa [Figure 2.42]. Formal lessons from landscape painting – the disposition of various terrain, the handling of light and shade, perspective – could teach landscape designers techniques for organising real three-dimensional space by translating techniques from illusionary painted surfaces.[317] The landscape and nature were to be experienced in the form and shape of a view and, as in a picture, were to be viewed as an unfolding narration full of associations.[318] Urns and seats, temples and grottos, artificial ruins, the serpentine river, lakes and cascades, were used not only for their pictorial value, but as emotional stimuli designed to evoke a

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[315] Bruno, 2002. Cf. Daniels, 1993. For the relation between topographical view painting and cartography see: Büttner, 2000; Gehring & Weibel, 2014.

[316] Grandell, 1993.

[317] Hunt, 1992a, p. 107.

[318] Bruno, 2002.

whole range of feelings from sublimity and melancholy to gaiety.[319] Landscape gardens were also filled with references to paradise, myths and sagas and were places of memory to commemorate particular individuals or (historical) events. The garden was like a 'museum' that gave local form to souvenirs from the Grand Tour[320], or an expression of passion or political perspective.[321] The garden pictures offered opportunities to design scenes, which were to be completed by visitors as both actors and spectators.[322] In that way, the landscape garden functioned as a theatre.[323] At the end of the eighteenth and beginning of the nineteenth centuries, the garden-viewing activity was augmented by the use of a Claude glass, a concave mirror made of tinted glass, which was used to observe, colour, frame and modify the viewed scene. [324]

Composed of a series of pictures, the landscape garden was constructed scenographically. The pictures were designed to be experienced in motion.[325] Scenes dissolve into each other in a cinematographic experience. The sequential experience of 'moving pictures' also became the basis for film and cinema, as beautifully illustrated by the eighteenth-century rolled-up panoramic landscapes on translucent paper by the French painter and landscape designer Carmontelle.[326]

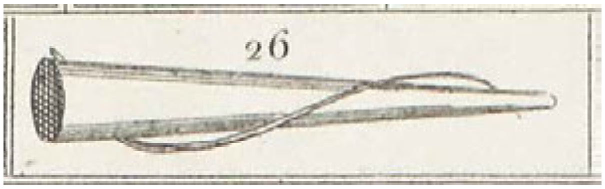

FIGURE 2.43 The three-dimensionality of the route links up with Hogarth's concept of the 'Line of Grace', represented by a fine wire, twisted around the elegant and varied figure of the cone. Detail of Plate I, The Analysis of Beauty. The Whole Works of the celebrated William Hogarth, re-engraved by Thomas Cook (1812) (image courtesy of London Namur archive ©Photo SCALA, Florence)

Routes as silent guides of the stroller

Together with views, routes are important for the landscape garden because they play a crucial role in mediating or facilitating its use and reception.[327] English landscape gardens stimulate, or at least permit, certain kinds of movement with different modalities, and manage speed and direction. The routes do not only provide passage but also direct movement through the composition. Movement

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[319] Clark, 1980.

[320] The Grand Tour was the traditional trip though Italy undertaken by young men from the English upper-class in search of art and the roots of Western civilization, focussed on the cultural legacy of classical antiquity and the Renaissance, and served as an educational rite of passage (Chaney, 2000).

[321] Hunt & Willis, 1988; Hunt, 1992a.

[322] Hunt & Willis, 1988.

[323] Hunt, 1989.

[324] Ibid. See for an elaboration on the Claude glass: Crary, 1990; Maillet, 2004.

[325] Through the centuries the principles of view-making in relation to movement has been a constant factor, while the context of landscape architectonic composition itself has varied (Grandell, 1993; cf. Solnit, 2001).

[326] De Brancion, 2008.

[327] Verschragen, 2000; Hunt, 2003, cf. Seiler, 1985a.

thus takes place partly in response to or in accordance with the designer's intentions.[328] Routes are the 'silent guides of the stroller'[329] and facilitate the primordial act of walking as an aesthetic and social practice.[330] The simple act of walking also stimulates the complex, iterative process of landscape design.[331] It supports and integrates engagement (intensively perceiving space), flow (encouraging intuition), and reflection (supporting organisation).[332]

FIGURE 2.44 The process of tracing routes with a tracing stick (image source: Von Sckell, 1825/1982)

Designing routes was an activity undertaken on site, directly determining the course line in the terrain, and not on a drawing board.[333] According to Hogarth (1753/1997), the eye is captivated by both the line of the route and the movement expressed by it. In the English landscape garden, the irregular winding paths adapt to the rise and fall of the ground, and respond to planting, water, and architectural features. The three-dimensionality of the route links up with Hogarth's concept of the 'Line of Grace', represented by a fine wire, properly twisted around the elegant and varied figure of the cone [Figure 2.43]. According to him, the serpentine line is at its best when it is activated by motion in a forward direction

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[328] Conan, 2003; Hunt, 2004.

[329] Using the words of Meyer (1860, p. 184): "*der stumme Führer der Spatziergänger*".

[330] Careri, 2002; König, 1996; Solnit, 2001; De Jong, 2007.

[331] Schultz, 2014, p. 134ff.

[332] Ibid.

[333] This process is elaborately described by Goethe in '*Die Wahlverwandschaften*' (1809) where garden design mainly consists of planning and constructing paths. See Niedermeier, 1992; Verschragen, 2000, pp. 151-159.

and in upward and downward directions, and can be regarded as one of the highest forms of beauty. Von Sckell (1825/1982) explains that the course of the route was determined by intuitively walking a line in accordance with the potential of the local environment, while tracing it in real time with a tracing stick [Figure 2.44].[334] In this process "*[]…both the contour and the character of the ground, as well as the individual scenes, dictate when paths linger in low areas or rise along with the land, when they follow a straight line or a curved.*"[335] And: "*The paths should not only allow for variation and diverseness but also for the most advantageous disclosure of the best views and vista's, sometimes suddenly, sometimes gradually, while on the other hand concealing any unpleasant sights.*" [336] Usually, the paths were designed after the landscape garden's parts and scenes were shaped and planted.[337]

§ 2.4.4 Readings of Stourhead landscape garden

A review of modern documentary sources on Stourhead landscape garden reveals different readings of the site that can be stratified into at least four groups: Stourhead as 'Gesamtkunstwerk', Stourhead as allegorical structure, Stourhead as phenomenological experience, and Stourhead as landscape architectonic composition. These categories are not exclusive and overlap, nor are they to be considered an exhaustive classification. They merely provide a way of organising the vast amount of complementary ideas used to understand Stourhead landscape garden.

Stourhead as '*Gesamtkunstwerk*'

According to Hussey (1967), Sühnel (1977), Von Buttlar (1989), Hammerschmidt & Wilke (1990), and Walter (2006) Stourhead is a total work of art, or '*Gesamtkunstwerk*'.[338] To these scholars, Stourhead is a vehicle to communicate aesthetic relationships in a way that is pleasing to look at, artistic, and tasteful, often in analogy to a gallery of three-dimensional seventeenth century landscape paintings with iconographic elements. In fact, it is a four-dimensional expression of art in which the process of reception is guided through a sequential unfolding of complex experiences via movement and directed by viewpoints and routes. According to this view, Stourhead evolved through combining human intention and aesthetic effects, which can only be studied in the cultural context and period of creation. The landscape garden is essentially interpreted on the basis of the language of art, such as sensory properties (qualities that are experienced through the senses: shape, line, texture, value, colour, space, and scale), formal properties (how the sensory properties are organized to achieve a sense of unity, balance, variety, movement, and harmony), technical properties (appearances of shapes, contrast, colours, etc., that are due to the use of materials such as planting, landform, etc.), and expressive properties (expression of ideas, ideals and feelings).[339]

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[334] Von Sckell, 1825/1982, p. 68. For a description of the tracing stick: ibid., p. 76.

[335] Hirschfeld, 1779-1785/2001, p. 251ff.

[336] Ibid.

[337] Von Sckell, 1825/1982; Hirschfeld, 1779-1785/2001.

[338] Hussey, 1967, pp. 158-164; Sühnel, 1977; Von Buttlar, 1989, pp. 44-50; Hammerschmidt & Wilke, 1990, pp. 71-79; Walter 2006, pp. 25-35.

[339] Properties adapted from: Silverman, 2002.

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Stourhead as allegorical structure

In interpretive-historical research, scholars elaborate on Stourhead as allegorical structure. According to Mallins (1966), Hussey (1967), and Woodbridge (1965, 1970, 1982/2002), Henry Hoare II used the text of Virgil's Aeneid as an important iconographic theme for the design of Stourhead. In their view, the pictorial circuit can be interpreted as a series of stations evoking Aeneas's journey from Troy to his founding of Rome, an odyssey that for Henry Hoare II might have symbolised his establishment of a family seat at Stourhead.[340] Turner (1979a) and Kelsall (1983) argue that, juxtaposed on these Virgilean scenes, medieval Gothic buildings and monuments like Alfred's Tower refer to England's past. This tower at Kingsettle Hill marks the legendary mustering place of the Anglo-Saxon army led by King Alfred the Great just before he defeated the Danes in 878 CE. King Alfred is considered to be a founding father of the British Empire. In this view, the iconographic programme evokes the dialogue between Aeneas, representing the founding of the Roman Empire (culminating in the Pantheon), and King Alfred, representing the founding of the British Empire (culminating in King Alfred's Tower).[341] Paulson (1975) and Schulz (1981) read this double iconographic structure as a Christian's pilgrimage through life. Charlesworth (1989, 2003) posits the mythical choice of Hercules as allegorical structure for inculcating morality. Garden features like the path structure and buildings like the Temple of Apollo (also: Temple of Virtue) refer to the moment when Hercules has to choose between idleness and laziness on the one hand, and virtue and industriousness on the other, on his virtuous path through life.[342] Recently, Magleby (2009) has pointed to the lack of attention to the dismantled exotic pavilions such as the Turkish Tent and Chinese pagoda in these studies, and proposes a more inclusive reading that includes the British discourse about the Ottoman Empire.

Stourhead as phenomenological experience

Scholars like Sirén (1950), Olin (2000) and Walter (2006) offer a phenomenological reading of the site.[343] These studies mainly focus on the feel, flavour, and ambience of the site, but also the richness of mental constructs and associations, and seek to reveal the unique sense and value of Stourhead as a place.

Stourhead as landscape architectonic composition

Reh (1995) elaborates on Stourhead landscape garden as a landscape architectonic composition and offers a mainly formal reading of the layout.[344] His work is an important source for this study. According to Reh, three levels of scale can be distinguished in which active composition elements are employed. First, there is that of the house and its immediate surroundings. Second, there is that of the estate or middle plan. Third, there is the panoramic scale of the landscape outside of the estate. There is no immediate architectonic relationship among (or even *possible* among) these elements; visual coherence is brought about by the morphology of the landscape or by movement (e.g. river valley, avenue, drive). In this way, the composition scheme differentiates itself into a number of separate composition schemes that, in their mutual dialectic, bring the panoramic scale of the natural landscape into relation with the scale of the house.

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[340] Mallins, 1966; Hussey, 1967; Woodbridge, 1965, 1970, 1982/2002.

[341] Turner, 1979a; Kelsall, 1983.

[342] Charlesworth, 1989, 2003.

[343] Sirén, 1950, pp. 47-52; Olin, 2000, pp. 257-276; Walter, 2006, pp. 25-35.

[344] Reh,1995, pp. 248-277. Adapted in English: Steenbergen & Reh, 2003, pp. 321-331.

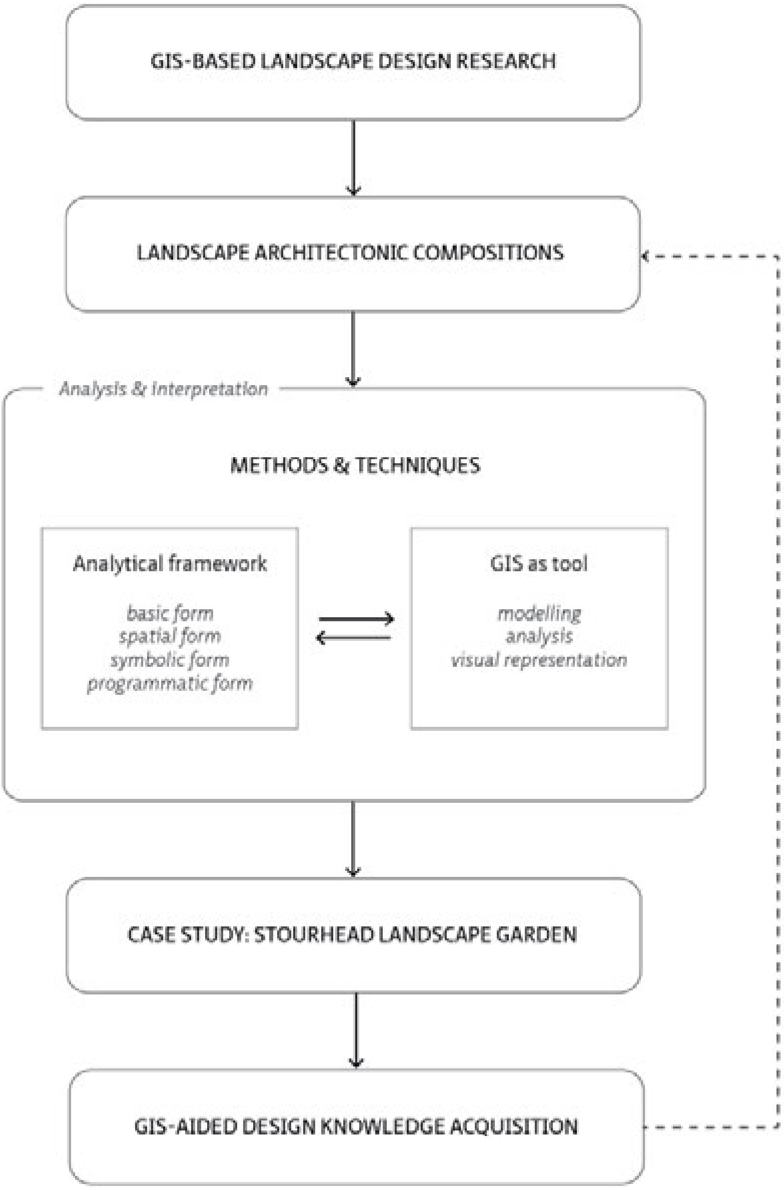

FIGURE 2.45 Application of the framework for GIS-based landscape design research on Stourhead landscape garden as exploratory exercise (graphic: Steffen Nijhuis)

§ 2.4.5 Stourhead as a critical, information-oriented case

This study considers Stourhead landscape garden to be a critical, information-oriented case because of its strategic importance in the field of landscape design. Stourhead is employed as a case study to test and evaluate the possibilities GIS offers in landscape design research. The study as such can be understood as a plausibility probe, pilot study, or exploratory exercise.[345] Here the case study is considered a form of 'quasi-experiment', testing the hypothesis and generating a learning process that constitutes a prerequisite for advanced understanding, adapting the framework for landscape design analysis of Steenbergen & Reh (2003). Outcomes of the case study can – to a certain extent – be summarised and generalised in order to contribute to the development of knowledge.[346] Here the case study is the basis for testing the possibilities for modelling, analysis, and representation in GIS-based landscape design research.

§ 2.5 Research design

In order to construct validity, reliability and verifiability the case study research makes use of a research design to guide the investigation, while relying on multiple sources of evidence.[347] As discussed in the previous sections the research framework consists of three components [Figure 2.45]:

1. The analytical framework for landscape design research addressing the basic, spatial, symbolic and programmatic form of the landscape architectonic composition;
2. GIS as tool for landscape design research, addressing modelling, analysis and visual representation as fields of operation;
3. Stourhead as a critical information-oriented case to test and evaluate GIS-based design research.

In order to put this research framework in operation the following research steps are followed: Construction of the digital landscape model of Stourhead landscape garden (step 1), GIS-based analysis of the digital landscape model (DLM) (step 2), and review and evaluation of the results (step 3).

§ 2.5.1 Construction of the digital landscape model (DLM) (step 1)

The study starts with the construction of a GIS-based digital landscape model of Stourhead landscape garden based on a multitude of sources. For the construction of the digital landscape model (DLM) an inventory and review of contemporary and modern data and information available are an important activity.[348] Because the research is spatial oriented, those sources that provide an

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[345] Gerring, 2007, p. 19ff.

[346] Yin, 2009; Gerring, 2007; Flyvbjerg, 2011.

[347] Yin, 2009, p.131.

[348] Cf. Schmidt, 1985; Nehring, 1985; Goultry, 1993; Watkins & Wright, 2007.

impression of spatial patterns and visual appearance of the site at a certain moment in time are of particular importance.[349] The material is evaluated for its relevance and reliability (source criticism) using methods such as triangulation, using different data sources that are mutually reinforcing each other, and cartometric analysis, reviewing the accuracy and reliability of (historic) maps.

Contemporary documentary and published sources from archive searches such as: contemporary estate maps, historic ordnance survey maps and estate maps, etchings, prints, and drawings are considered key sources. Photographs, estate and personal papers, as well as guide books and visitors' descriptions too can be useful. For this study the available historic plans and maps of Stourhead were acquired from the Wiltshire Record Office, British Ordnance Survey and the Royal Academy of Fine Arts, Stockholm. Important sketches and maps by Bamfylde (in the period 1753-1777), Piper (1779), Grimm (1790) and Nicholson (in the period 1811-1813) offer visual representations of Stourhead landscape garden contemporary to the respective period.[350] Regarding contemporary writings on Stourhead the work of Woodbridge (1965, 1970, 1982) is the main source.

Modern surveys and maps of physical, biological and cultural features (e.g. topographic, contour, soil, hydrologic, land use or vegetation maps), photographs, aerial photographs, geo-databases (e.g. Digital Elevation Models), were also reviewed and collected. Important suppliers of digital data were: The National Trust, the British Ordnance Survey and online-sources (e.g. Google Maps).

These sources are the basis for the construction and reconstruction of different time-slice snapshots of Stourhead in digital form. The resulting DLMs represent different stages of the compositions development, taking into consideration actual and estimated heights of vegetation, buildings, et cetera. In order to reconstruct vegetation-heights in past situations, to create accurate DLMs, plant-physiological models and contemporary etchings were used.

In this stage of the research the modelling and visual representation capacities of GIS are exploited for the (1) collection, evaluation and interpretation of contemporary and modern data, (2) digitising geo-rectification and vectorisation of data and (3) integration and processing of the topographic data into a digital landscape model (DLM).

§ 2.5.2 GIS-based landscape design analysis (step 2)

The GIS-based design research encompasses the analysis of the basic, spatial, symbolic and programmatic form of the composition and its development while employing different principles for GIS-based analysis. The constructed digital landscape model (DLM) of Stourhead landscape garden is the basis for these explorations.

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[349] Seiler, 1985b; Halpern, 1992. On the role of maps in the attribution of historical evidence see: Harley, 1968; Koeman, 1968; Blakemore & Harley, 1980; Van Mingroot, 1989; Ligtendag, 1991; Donkersloot-de Vrij, 1995.

[350] Overviews of their work can be found in: Karling et al., 1981; White, 1995; Woodbridge, 1970, 1982/2002; Harris & Olausson, 2004.

GIS-based analysis of the basic form

The GIS-based analysis of the basic form addresses Stourhead landscape garden's adaptation to the terrain conditions. It explores how natural features such as ridges, plains, valleys, and availability of water were considered in the design, and how man-made features and patterns were integrated. Overlaying and integrating cartographic models on soil, geology, hydrology and land-use provides a basis for the analysis of formal and geometrical configurations from the vertical perspective, addressing topological and chorological relationships. Basic principles for GIS-analysis employed here focus mainly on location/allocation, distance, change, and quantities. Geo-statistical operations such as morphometric, solar radiation, and hydrological analysis and interpolation, as well as attribute-based querying, play an important role. The GIS-based analysis of the basic form concentrates on:

- Stourhead in context: analysis of the major features and processes of the natural landscape like geological formations (incl. soil), landform, climate and water;
- Layout and development of Stourhead House and garden: formation of the Great Lake; the analysis of the allocation and orientation of the house; the layout of the garden around the house (Pleasure Garden and Valley Garden); and the allocation of architectural features and the tracing of routes across the estate.

GIS-based analysis of the spatial form

The GIS-based analysis of spatial form addresses the spatial and visual characteristics of Stourhead landscape garden. It elaborates on the definition and arrangement of space and space-defining elements, as well the views, sightlines and panoramic views. On one hand the investigation focuses on the corporeal form, analysing the three-dimensional forms made by the spatial patterns of open spaces, surfaces, screens and volumes (Euclidean space). On the other hand this investigation looks at the visible form, the appearance of the landscape (visible space) as would be seen by an observer moving through the space, taking into account (atmospheric) conditions of visibility. Here the horizontal perspective is important, considering the composition from inside out. Basic principles for GIS-analysis employed here see virtual 3D-landscapes and visibility analysis with single, cumulative and sequential viewsheds, as well as hemispherical visibility-analysis as the main important operations. GIS-based analysis of the spatial form focuses on the:

- Characteristics of the three-dimensional composition: analysis of the corporeal form and its development through time;
- Visual manifestation of the three-dimensional composition: analysis of the visible form; space visibility and views; the scenography of specific routes; and the visual integration of the different parts of the estate and its environs.

GIS-based analysis of the symbolic form

Physical and natural structures are the point of departure in trying to get a grip on the meaning of the symbolic elements of Stourhead landscape garden; the GIS-based analysis of the symbolic form. The investigation focuses on exposing the morphological conditions for reception – which is the composition's 'interface' between the intentions of the designer and the reception of the users and

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provokes and promotes a rich palette of emotions, ideas and stories.[351] In particular the sequence of images with iconographic elements, organised by the composition and the imposed routes, connecting tactile experience and visual appearance, are of interest. Different intensities of light influenced by patterns of sun and shadow are also important in the experience of the composition. Contemporary and modern sources are employed to understand the composition's appraisal via map-distortion-analysis and crowdsourcing. Here the basic analytical GIS-principles from the vertical and horizontal perspective are combined and focus on location/allocation, distance, change, duration, quantities, and visibility. GIS-based analysis of the symbolic form concentrates on:

- The potential relationship between space and meaning: analysis of the organisation and distribution of elements that dictate views (focal points) and the relationships between routes, views and iconographic elements, in terms of sequence and timing; and: analysis of the experience and reception.

GIS-based analysis of the programmatic form

This GIS-based analysis of the programmatic form elaborates on the functional zoning and organisation of the program aimed at functions (e.g. production, recreation and culture) and activities (e.g. living, recreation, and agriculture). It also addresses the functional patterns of movement in terms of logistics and accessibility. Basic cartographic models on land-use and network-accessibility models are employed in order to analyse functional patterns, cohesion and interaction from the vertical perspective. Basic principles for GIS-analysis employed here focus on location/allocation, distance, movement, densities and quantities. The following aspects in particular will be addressed:

- Organisation of the programmatic domains: analysis of land use in relation to *otium* and *negotium*;
- Functional relationships of space: analysis of the patterns of activity and their relationships.

In this stage of the research the analytical and visual representation capacities of GIS are exploited for the (1) exploration of the DLM in order to reveal patterns and relationships employing analytical principles from the horizontal and vertical perspective, and (2) measurement, simulation and experimentation of aspects of the designed landscape.

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[351] Hunt, 2004, pp. 191-223

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§ 2.5.3 Review and evaluation of the results (step 3)

This part of the investigation discusses, summarises and generalises the results of the case study. The case study is used as a quasi-experiment to identify and illustrate the potential role of GIS as a tool for landscape design research in a process of discovery. Pattern matching logic is employed for strengthening the internal validity of the research.[352] Such a logic compares the findings of the study with existing research and other applications in order to draw conclusions based on a chain of evidence within the context of the research. The results can be summarised and generalised in order to contribute to knowledge development. Two types of results can be expected:

1. Object-related results: providing knowledge of Stourhead's landscape architectonic composition;
2. Tool-related results: providing knowledge on the possibilities and limitations of using GIS in landscape design research.

Ultimately, conclusions can be drawn regarding GIS as a tool in landscape design research and answers the questions if and how GIS can contribute to the development of design-knowledge in landscape architecture, extending the toolbox available to the discipline.

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[352] Yin, 2009, p. 136.

3 Digital Stourhead landscape garden

§ 3.1 Modelling the estate

The digital landscape model (DLM) is the basis for the GIS-based analysis of Stourhead landscape garden. The DLM consists of a ground layer, which is a digital elevation model (DEM) supplemented by a terrain layer of 2D and 3D referenced objects, such as buildings, trees and other artefacts.[353] This DLM can (partially) be represented via a surface, vector or raster definition in a 2D or 3D geo-referenced setting. Since there is no complete DEM or DLM of Stourhead landscape garden available, these models had to be constructed based on available analogue and digital data. Additionally, when modelling the estate, the incorporation of time is an important aspect as the spatial composition of Stourhead landscape garden as it is now has evolved over a long period of time and is characterised by several important stages in its development. In order to incorporate time, a sequence of time-slice snapshots was used.[354] This resulted in several GIS-based DLMs valid at different points in time, each with a separate surface, vector and raster definition. GIS-functionality and relational database management systems (RDMBS) allow for technical combination of these snapshot models into one space-time composite model (STC), which increases efficiency in data handling and management.[355] This is especially true regarding its flexibility in retroactive data editing, the possibility for querying, and visual representation based on temporal premises. However, for the sake of clarity it is henceforth referred to as several DLMs representing different time-slice snapshots.

§ 3.1.1 Sources of topographic data

When creating the DLMs of Stourhead landscape garden, topographic data was essential to conveying the physical shape and pattern of the site; representing the estate as it lies within one's own direct experience.[356] Maps, plans, and vertical aerial photographs in particular, as well as oblique and eye-level photographs, paintings, etchings and drawings, are all useful sources of topographic data when creating such a model, since they provide an impression of spatial patterns and the visual appearance of the site at certain points in time.[357] Other documentary sources, such as estate and personal papers, guide books and visitors' descriptions, and planting lists can also be used.[358]

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[353] Li et al., 2005. The 'terrain layer' is sometimes also called 'volume layer' (see: Van Lammeren, 2011), but here the first term is preferred because it includes volumetric as well as non-volumetric objects.

[354] Langran, 1992.

[355] Langran, 1992; Gregory & Ell, 2007.

[356] Sauer, 1925/1963; cf. Harvey, 1980.

[357] For plans: Seiler, 1985b. For maps: Koeman, 1968; 1978; Van Mingroot, 1989; Donkersloot-de Vrij, 1995. For paintings, engravings and drawings: Halpern, 1992; Harris, 2003; Harris & Hays, 2008; Richardson, 2013.

[358] Schmidt, 1985; Hunt, 1992b; Williamson, 1992; Grillner, 2006.

Topographic and thematic maps are, furthermore, considered primary sources of topographic data, as they are detailed and generally the most reliable visual representations of cultural and natural features on the ground at a particular time.[359]

A topographic map identifies diverse cultural and natural ground features that can be grouped into the following categories: relief (hills, valleys, slopes, depressions), water (lakes, rivers, streams, swamps), vegetation (wooded and cleared areas, hedges, grassland, orchards), cultural features (roads, paths, buildings, boundaries, arable land), and toponymy (names of places, buildings, water, roads).[360] Donkersloot-de Vrij (1995) provides an useful typology of topographic maps for landscape research, with private estate or property maps (pre-cadastral maps), cadastral maps and ordnance survey maps as important categories for this research. Maps of a much larger scale are plans (i.e. design plans).[361] These are detailed maps with a high level of accuracy and provide precise information on buildings, architectural features, vegetation, water, paths, etc. Seiler (1985b) provides an useful typology of plans in garden architecture research, with design plans, planting schemes, thematic study maps, and technical details as important complementary categories.[362] Thematic maps focus on a specific theme or subject area. Particularly useful are those thematic maps that isolate topographic features such as relief (i.e. contour lines), hydrography, and land use, or show soil types, hydrology and geological features. The data contained by topographic and thematic maps is referred to here as cartographic data, as opposed to other sources of topographic data.

§ 3.1.2 From topographic data to digital landscape model

Creating the DLMs depends on topographic data acquired from different sources, particularly cartographic data. In order to create these DLMs a number of processing steps were taken that will be discussed in this chapter: (1) collection, evaluation and interpretation of topographic data; (2) digitising, geo-rectification and vectorisation of relevant analogue topographic data; and (3) integration and processing of the topographic data into digital landscape models (DLMs).

The stage of data acquisition is characterised by collection, evaluation and interpretation of available historical and current maps and vertical aerial photographs in digital and analogue form, as well as oblique and eye-level photographs, paintings and prints providing topographical data and information (step 1). In the Stourhead case study, most current topographic data were available in geo-referenced digital form (geo-data) as raster and vector formats. For the historical situation most of the material was only available in analogue form. Therefore, historical maps and plans were digitised, geo-referenced and geo-rectified, and topographic data extracted via vectorisation by means of GIS (step 2). Digitising refers to the process of converting analogue images into digital images or raster data via (vertical) photography or scanning. Geo-referencing is the term for the process via which coordinates are converted into geographic coordinates on a projection system. In order to assess the accuracy of the historical cartographic data of Stourhead the maps were geo-rectified and a GIS-based cartometric analysis was performed. Geo-rectification is the process in which historical maps and plans are stretched and rotated

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[359] Koeman, 1968; Donkersloot-de Vrij, 1995.

[360] Adapted from Bos et al. (1991) and Canadian Centre for Topographic Information (2007).

[361] Hardy & Field, 2012.

[362] Seiler, 1985b, p. 123 ff.

(transformed) in such a way that they align as well as possible with current maps, using control points. Based on these geo-rectified maps, selected topographic features are vectorised, meaning that the raster data (digitised maps) are converted into vector data. Vector data represent (topographic) features as discrete points, lines, and polygons. Finally, the topographic data are integrated and processed into DLMs of important time frames in the development of Stourhead landscape garden (step 3).

§ 3.2 Historical topographic data

The corpus of available historic maps of Stourhead is an important source of topographic and thematic data. These maps are powerful tools in the attribution of historical evidence and provide an impression of the spatial structures and patterns of the estate at discrete points in time.[363] As with every source of cartographic information, the accuracy and reliability of the geometric and semantic information must be assessed, particularly when it comes to reconstructing historical situations.[364] With regards to historical cartographic data, questions of scale, precision, accuracy, methods and reasons for creation are such that their utilisation in the GIS context has lagged behind other data sources.[365] There are also specific technical issues surrounding incorporating historical cartographic data into the GIS environment that are unique to this category of data.[366] However, there is a growing body of knowledge that addresses GIS-related issues and the use of historical cartographic data.[367]

§ 3.2.1 Dealing with uncertainty of historical cartographic data

When working with historical maps it is important to acknowledge and consider imperfections in the historical cartographic data, i.e. the presence of uncertainty.[368] There are two general approaches to dealing with uncertainty in this type of data: the 'accuracy approach' as exemplified by Blakemore and Harley (1980), and the 'evidential approach' outlined by Koeman (1968, 1984). This study incorporates and employs elements from both approaches.

In the accuracy approach, three different aspects are assessed: chronometric accuracy, geometric accuracy, and topographical accuracy.[369] Chronometric accuracy consists of dating the map as a physical artefact – via physical tests, watermark analysis, palaeography and cartographic style[370]

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[363] Harley, 1968; Koeman, 1968; Blakemore & Harley, 1980; Margry et al., 1987; Donkersloot-de Vrij, 1995. Regarding historic plans: Seiler, 1985b.

[364] Jenny & Hurni, 2011, cf. Plewe, 2002.

[365] Madry, 2006, p. 35.

[366] Ibid.

[367] Ballettii, 2006; Madry, 2006; Heere, 2008; Jenny & Hurni, 2011. This specific type of research is part of the field 'Historical GIS' and addresses theory, methods and techniques for researching geographies of the past. See also reference works such as: Gregory, 2002; Knowles, 2002; Wheatley & Gillings, 2002; Gregory & Ell, 2007.

[368] Williamson, 1992. In GIS-context: Longley et al., 2011, p. 124.

[369] Blakemore & Harley, 1980.

[370] Harley, 1968.

– and the dating of the information contained in the map. Geometric accuracy consists of two components: geodetic and planimetric accuracy.[371] Geodetic accuracy describes the accuracy of the positioning of the map within a global coordinate system. Planimetric accuracy is the extent to which distances and bearings between identifiable objects coincide with their true values. This can be determined by comparing the positions, distances, areas, and angles of features on the map with their values in reality, thus enabling an assessment of geometric features for their utility for a study of this kind.[372] Topographical accuracy denotes the quantity and quality of information known about landscape objects. Every map or plan contains only a selection of geographic features that are chosen and translated into symbols by the cartographer in line with the purpose of the map. However, the question remains whether the map depicts all features of a certain class, and how accurately the mapmaker has thematically classified the features.[373]

The evidential approach is about comparing the value of historical maps and plans with contemporary written documentation in the attribution of historical evidence.[374] The confusion about and the mistrust in the value of maps and plans as pieces of historical evidence are remedied by dividing them into categories of decreasing value.[375] Ranging from 'the map as one and only mode of expression of a historical phenomenon' (highest value as historical evidence) to 'the map is neither the most reliable nor the most adequate mode of representation of a historical phenomenon of fact, but confirms or supplements written documentation' (lowest value). The main argument is that maps are often the most reliable sources of historical topographic data, since they visually represent geometric distributions of spatial phenomena and landownership, and therefore constitute important historical evidence. Here the accuracy approach is utilised in terms of planimetric accuracy, since the main goal is to derive both spatial patterns and the geometry (location, proportion, measurement, size and form) of the landscape's architectonic composition from the historic maps and plans as accurately as possible. In terms of chronometric accuracy, there is no doubt about the time of production, as the maps and plans are dated. The evidential approach is useful for assessing topographic accuracy given that maps and plans are the most adequate sources of spatial data in this context.

§ 3.2.2 Sources of historical cartographic data

Historical maps and plans of Stourhead were obtained from the Wiltshire Record Office, British Ordnance Survey and Royal Academy of Fine Arts, Stockholm. The available topographic and thematic maps visually represent the estate at different moments in time and can be categorised as: private estate maps, ordnance survey maps and thematic study maps.[376] Other types of maps were not available, including historical design plans and planting schemes for Stourhead.

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[371] Laxton, 1976; Blakemore & Harley, 1980.

[372] Jenny et al., 2007; Jenny & Hurni, 2011.

[373] Laxton, 1976; Balletti, 2006; Jenny & Hurni, 2011.

[374] Koeman, 1968.

[375] Ibid., pp. 75-76.

[376] See appendix 1 for a detailed overview.

Within the category of ordnance survey maps, only the first available versions were selected at the scales 1:2,500 and 10,560. Large-scale maps (1:63,500) were not included due to Stourhead landscape garden being only roughly indicated, making them not particularly useful.[377]

Private estate maps from 1722 and 1785

The private estate maps from 1722 and 1785 are property maps. Why such estate maps were produced is a matter of much debate.[378] A common reason given is that they were made for inventorying, management, or improvement of the estate. These types of maps were developed as administrative and legal tools as land became a commodity with the emergence of capitalism and professional land surveyors.[379] These land surveyors could service the need for landowners and tenants to know their own property and gain perspectives on maximising production.[380] Perhaps they are pre-cadastral maps for means of enclosure, since parcellation (with names and reference numbers) and commons are precisely indicated.[381] The parcels depicted on the plans are linked via reference numbers to an accompanying register. Another possibility is that the maps were made for juridical-inheritance reasons; they were made around the points in time that Henry Hoare I (1724) and Henry Hoare II (1785) passed away.[382] The exact reason why these maps were made remains unclear and is subject to further investigation.

The 1722 map is the first available map of Stourhead and shows the estate in a premature state of development around the time that Henry Hoare II inherited it in 1724 [Figure 3.1]. Visible are a house with a simple cubical form and a garden with an oval forecourt and walled garden, which had been constructed from 1718 onwards. Also visible is the valley with medieval fishponds fed by the springs in the valley, before the Great Lake was established.[383] The boggy conditions in the north of Six Wells Bottom, as shown on the map, indicate that there was a significant amount of water welling from the ground. The map shows the estate as it was before Henry Hoare II began an ambitious tree planting programme and the creation of Stourhead landscape garden with architectural features between 1744 and 1770 (some early interventions date from the 1730s).[384] Furthermore the map provides data on roads and paths, buildings, and land use (e.g. arable land, pasture, commons). In terms of planimetric accuracy, the map appears not to be very reliable.

The 1785 map was made around the time that Richard Colt Hoare inherited the estate [Figure 3.2]. He finally determined a large amount the landscape garden, as it is now known.

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[377] The first ordnance survey maps of this area are large scale maps (1:63,360). These are available for Stourhead region from 1811-1817 ('old series') and 1897-1899 ('revised new series'). See Oliver (2005, p. 168) for a detailed overview of available ordnance survey maps of this area.

[378] Harvey, 1996; Delano-Smith & Kain, 1999, p. 113ff.

[379] Delano-Smith & Kain, 1999, p. 116.

[380] Ibid., p. 118ff.

[381] Maps and plans in that period were often made for enclosure due to the eighteenth century public enclosure-act. Enclosure is the process whereby land that was exploited collectively, or over which there existed common rights, was divided into parcels owned in severalty, with each proprietor exchanging his share of common rights over the wider area for exclusive rights of parts of it (Kain & Baigent, 1992, p. 237).

[382] It is clear that the maps are not made for taxation, because the land tax (called: levy) in England was collected every year between 1692-1798 without a surveyed or mapped base or even a comprehensive register, but based on income related to the property (Kain & Baigent, 1992, p. 257).

[383] More on the medieval fish ponds at Stourhead in: Mayes, 1995.

[384] Dates from Woodbridge, 1970, 1982/2002. See for a sketch of the situation around the house in 1768, with the Fir Walk, the Obelisk and the Statue of Apollo, in the visitor's journal of Sir John Parnell, published in: Woodbrige, 1982.

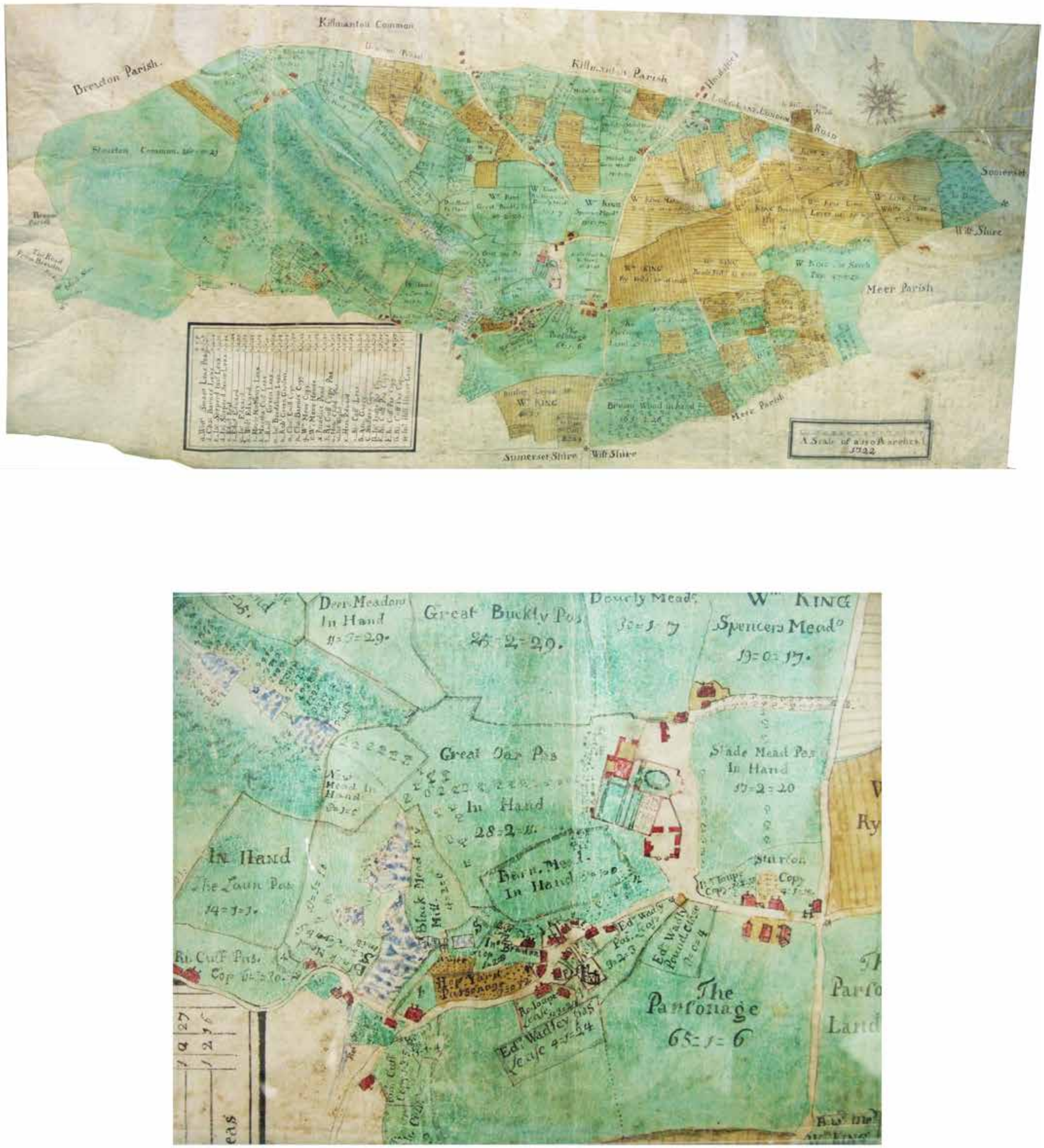

FIGURE 3.1 The estate map of 1722 shows the estate just before Henry Hoare I died. Stourhead House is visible with a railed forecourt with an oval lawn and walled gardens to the south. To the west, the Great Oar Pasture. In the valley one can find the medieval fishponds, which are the basis for the formation of the Great Lake. Detail below (map source: Wiltshire Record Office 383.316)

However, the map showcases the result of Henry Hoare II's extensive activities toward creating his own paradise. Important features like the Great Lake are visible, made possible by a dam reconstruction of the southern fishpond completed in 1757. The Pleasure Garden around the house was also extended, and the walled garden turned into a lawn lined by trees. Also clearly indicated are the architectural features he built, such as the Temple of Flora (or Temple of Ceres), Obelisk, Grotto, Pantheon (or Temple of Hercules), Palladian Bridge, Bristol High Cross, Temple of Apollo, St. Peter's Pump, and Alfred's Tower.[385] Other architectural features that were later removed are also visible, such as the Wooden Bridge, Turkish Tent, Statue of Apollo, and Temple on the Terrace (or Venetian Seat). The path structure as a pre-requisite for experiencing the garden is also clearly indicated. The woodlands are the result of the forestation programme begun in the 1720s, with the Fir Walk on the hillside southwest of the house as a special feature. Richard Colt Hoare continued the forestation programme, mainly planting on enclosed common land.

The 1785 map was made by the surveyor John Charlton in a time when maps were attested by their surveyors on oath as accurate.[386] Homer (1766) describes the precise method of surveying using chains and graduated instruments (e.g. theodolite, circumferentor, or semicircle), which Charlton probably used. Therefore we can expect this map to be accurate and useful for deriving topographic data.

Thematic study map of 1779

The map of Stourhead in 1779[387] by the Swedish court surveyor, civil engineer and landscape designer Frederik Magnus Piper (1746-1824) is the result of an elaborate field study to gain insight into landscape design [Figure 3.3].[388] It is an unique documentary source on the architectonic composition, given that the study of landscape gardens in the period 1730-1790 almost completely relied upon engraved or water-coloured views.[389] His effort was characterised by a differentiated approach to field studies; he revolutionised using plans and views as working instruments to obtain knowledge.[390]
The main aim of his field study was to obtain a (relatively) precise aid, with as exact topographical details as possible (e.g. showing relief through shading), but geared towards the combination of the picturesque, artificial grottos together with an advanced display of water engineering.[391] The map and accompanying sketches and views are very valuable because they provide detailed information on the landscape architectonic composition as well as on architectural features in the landscape garden, with a legend identifying each building.[392]

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[385] Woodbridge, 1970, 1982/2002.

[386] Kain & Baigent, 1992, pp. 236-264.

[387] There are at least three versions of this map dated 1779 and housed at the Royal Academy of Fine Arts, Stockholm of which this is the most complete one.

[388] Harris & Olausson, 2004; Andersson, 2008. Sirén (1950) was the first to draw attention to the maps and views of Piper as an important resource for studying landscape gardens. Piper made studies of Painshill, Stowe and the Kew Gardens, he stayed sufficiently long at these places to make careful measurements and sketches of layouts or parts of the grounds (Sirén, 1950, p. 170). He also visited and studied Italian gardens like Villa Lante and Aldobrandini. See Jellicoe (1977) on this matter.

[389] Harris, 2004, p. 113ff.

[390] Olausson, 2004, p. 159ff.

[391] Ibid., p. 167.

[392] See for his views of Stourhead: Sirén, 1950; Karling et al., 1981; Woodbridge, 1970, 1982/2002; Harris & Olausson, 2004.

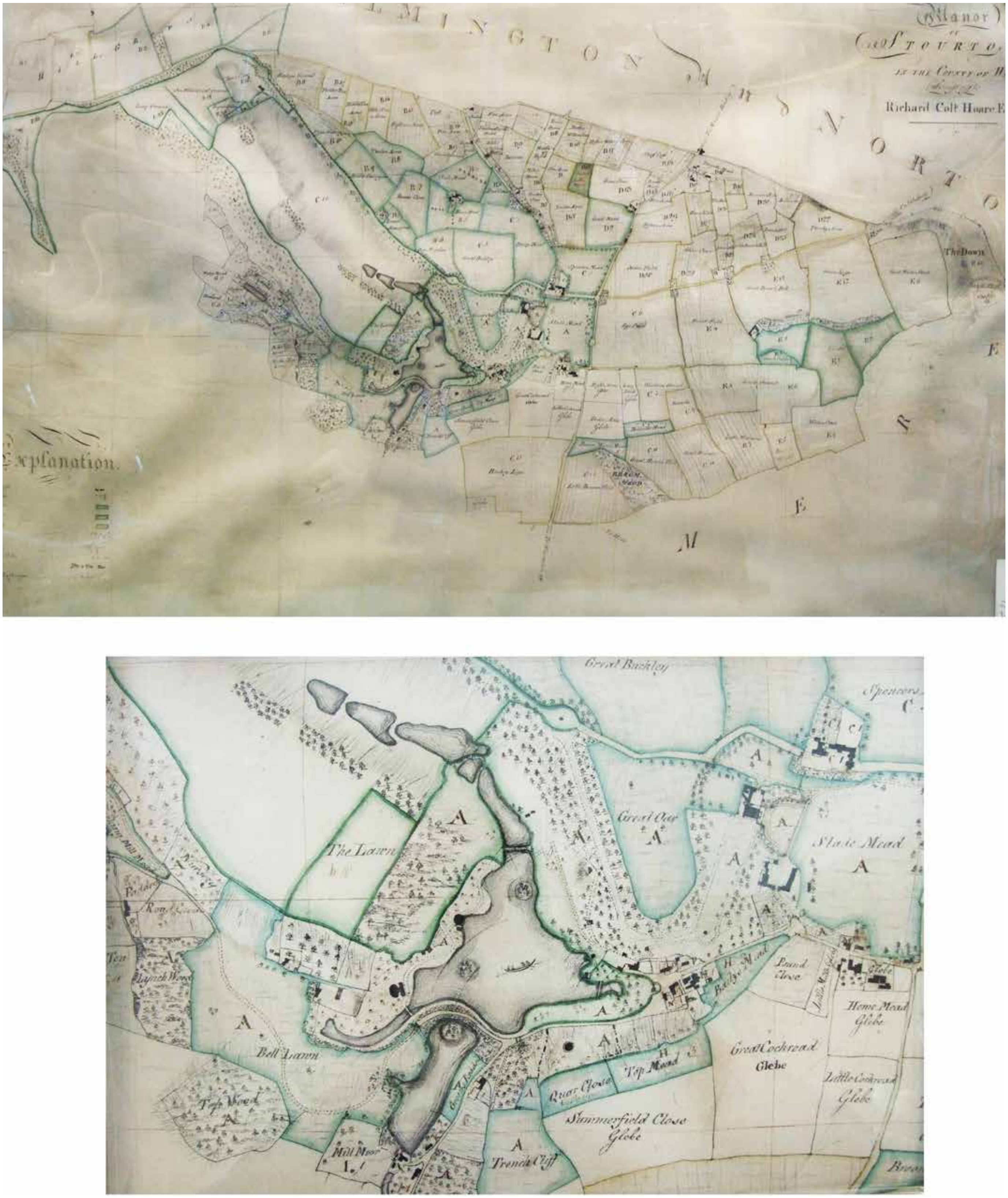

FIGURE 3.2 The estate map of 1785 by the surveyor John Charlton was made around the time that Richard Colt Hoare inherited the estate. The map showcases the results of Henry Hoare II's extensive activities creating Stourhead landscape garden. Detail below (map source: Wiltshire Record Office 135/4)

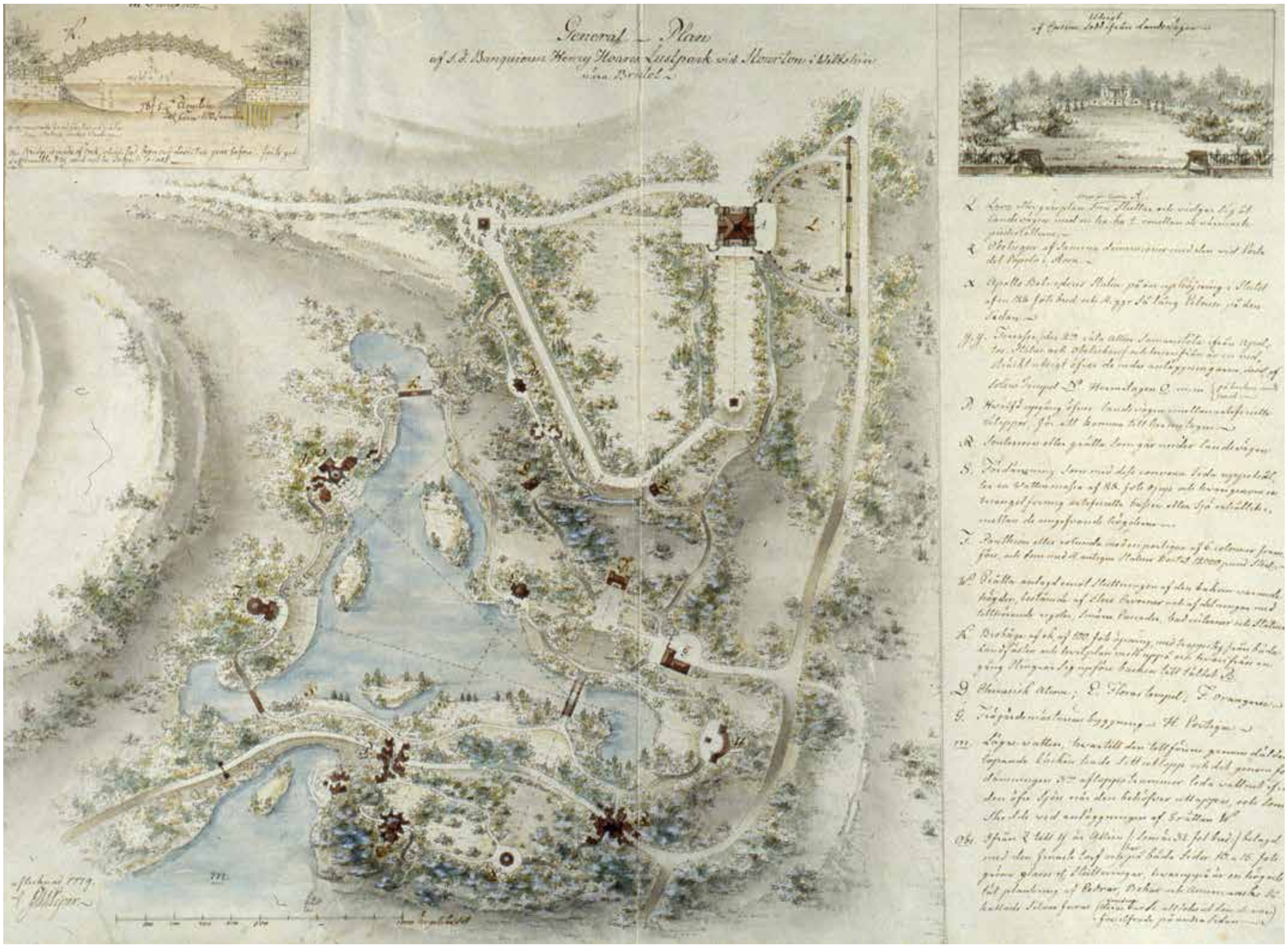

FIGURE 3.3 Study map of Stourhead in 1779 by Frederik Magnus Piper. The plan conveys important aspects of the landscape garden though the eye of a landscape designer, providing topographic data on architectural features and compositional aspects such as important sight lines at eye-level, as well as the disposition and form of vegetation and water (image courtesy of Royal Academy of Fine Arts, Stockholm)

The map shows the architectural features as seen on the 1785 map, but additionally indicates the Chinese Alcove, Orangery, Rockwork Bridge and the Hermitage or Druid's Cell.[393] The annotated key also provides us with some interesting technical details, for instance on the depth of the lake.[394] The map further analyses the landscape garden, presenting important views and visual relationships as experienced at eye-level, delineated as dotted lines. Attention is also paid to the form and distribution of water and vegetation as compositional features. The colours capture the atmosphere of the park with light and shade effects, distinguishing habitus of trees and the movement of the water.[395]

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[393] The Chinese Alcove is not the Umbrella Seat visible in a view by Piper (see for instance Karling et al., 1981, p. 83). The view does not correspond with the location of the Chinese Alcove. The Alcove is drawn as a rectangular structure and presumable it was alike the Alcove depicted in his 'Description of the Idea and General-Plan for an English Park' (1811/12), page 10 (see: Harris & Olausson, 2004). Also Turner (1979b) points to the rectangular nature of the Alcove but mentions that there is no drawing available.

[394] The key on the map states: "Dam which on its concave side retains a mass of water 28 feet of depth and by means of which a triangular artificial lake has been formed between the surrounding hills". This is the only known reference to the depth of the lake and corresponds with the 5.1 meters from the Sonar-GPS-survey by McKewan (2006).

[395] Note the delineation of deciduous trees and conifers and the rippling water were it streams into the lake at the Grotto or water fall in Paddock's Lake.

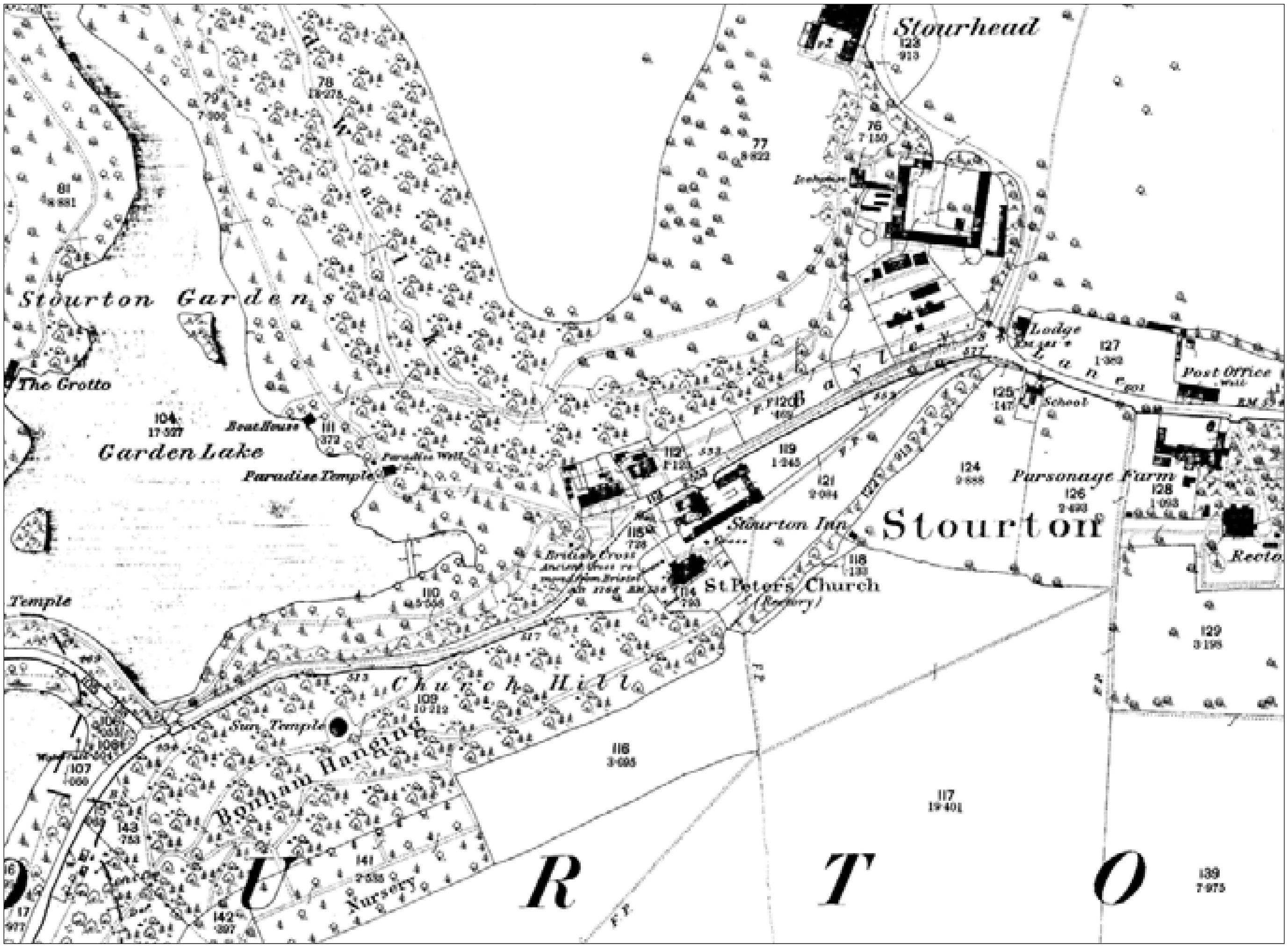

FIGURE 3.4 The ordnance survey map of 1887 is the earliest, most detailed ordnance survey map indicating Stourhead landscape garden at a scale of 2,500. Since the focus was on Stourton, the landscape garden is not completely surveyed (the map is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey licence number AL100018591)

The plan offers thematic information on architectonic aspects and intentions. Hence its didactical purpose and despite the skills Piper had as a land surveyor, the map appears to have proportional distortions in positional accuracy and is focused on particular areas of interest. However, the map conveys the landscape garden as perceived by a landscape designer and is an important record of a crucial stage in the landscape design's development.

Historical ordnance survey maps of 1887 and 1900

The ordnance survey maps of Stourton of 1887 [Figure 3.4] and 1900 [Figure 3.5] showcase a mature version of the estate as it was further developed by Richard Colt Hoare, who passed away in 1838. These maps are the earliest accurate maps available after his death. The maps show that Colt Hoare did little building around the valley, but had a great impact on the appearance of the garden by pulling down cottages in the village that had obscured the view of the church and the gardens. He also removed architectural features such as the Turkish Tent, Wooden Bridge, Statue of Apollo,

FIGURE 3.5 The ordnance survey map of 1900 at a scale of 1:10,560, partly based on the more detailed 1887 map, showing Stourhead landscape garden in its bigger context. The map represents a mature stage of the landscape garden as developed by Richard Colt Hoare (the map is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey licence number AL100018591)

Temple on the Terrace, Chinese Alcove and Hermitage.[396] He also created the feature known as the Gothic Cottage, which was already visible as a building on the 1785 map. Colt Hoare also changed the path structure considerably and created a public entrance. As a plantsman he planted shrubbery (laurel) on a vast scale, along the paths and as under-planting in the woodlands. He also introduced *Rhododendron ponticum* and planted ornamental trees around the lake.[397]

The maps were prepared by the Ordnance Survey, the British national mapping agency.[398] From 1840 onwards, the Ordnance Survey prepared maps of the whole country at a scale of six inches to the mile (1:10,560).[399]

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[396] Woodbridge, 1970, 1982/2002.

[397] Ibid.

[398] The Ordnance Survey is officially founded in 1791, but its origins can be dated earlier in 1747 (Harley, 1975; Oliver, 2005).

[399] Harley, 1975; Delano-Smith & Kain, 1999; Oliver, 2005.

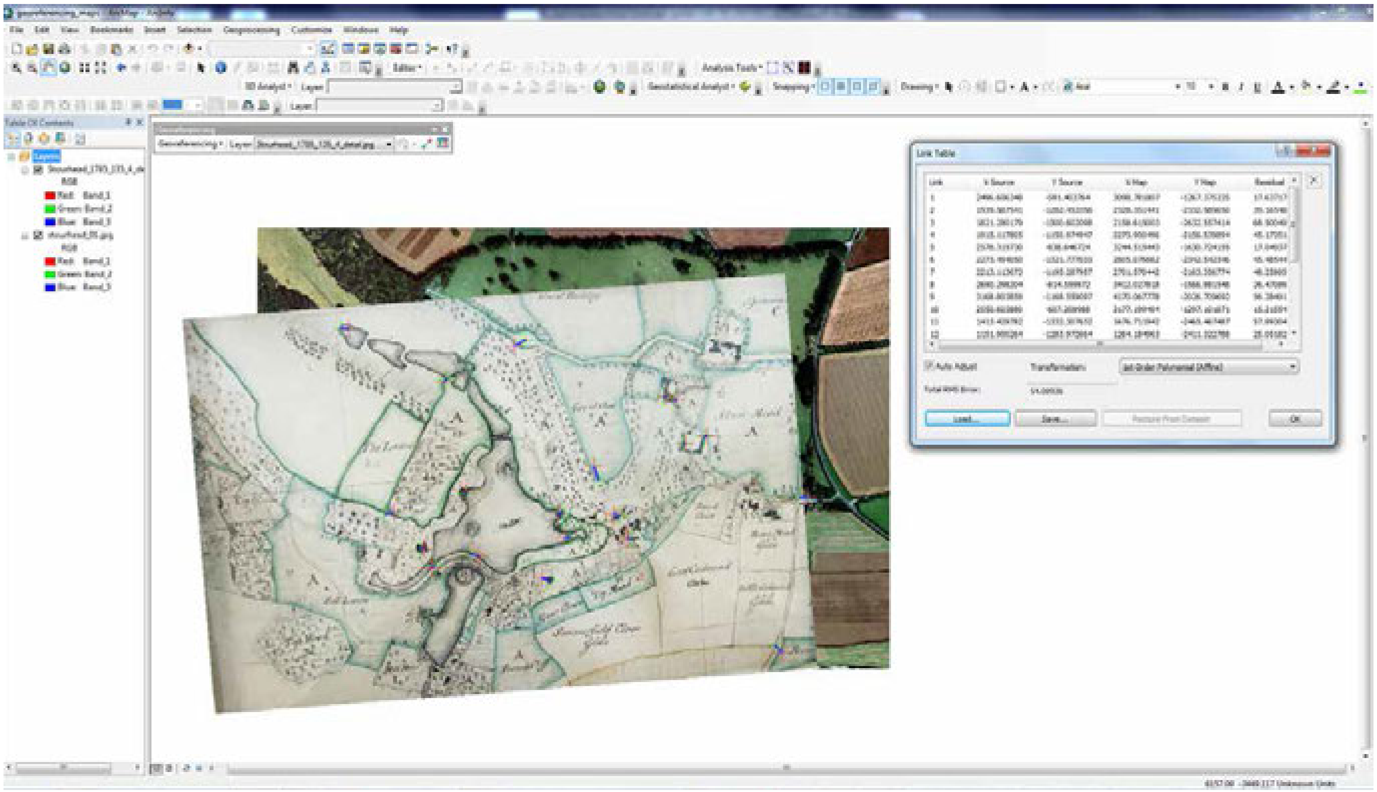

FIGURE 3.6 Geo-rectification of the 1785 map using control points and transformation by means of the geo-referencing function. Shown is an affine transformation (first order polynomial), which shifts scale and rotates the map, though local variances in positional accuracy are not included. For that reason, the adjusttransformation is more suitable (image Steffen Nijhuis, the aerial photograph in the background is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey license number AL100018591)

From 1854, to meet requirements for greater detail, cultivated and inhabited areas were mapped at 1:2,500 ('the county series'), including land-parcel numbers in rural areas and accompanying information. This was first done parish by parish, with blank spaces beyond parish boundaries, and later was expanded to all areas.[400] The 1887 map, at the scale 1:2,500, served as the basis for the 1900 map at the scale 1:10,560 ('the six inches county series'), particularly the cultivated areas.[401] The maps delineate the landscape with great detail and accuracy, and practically all significant artificial features that could be found on the ground are depicted.[402] These maps are regarded as a standard topographical authority and are thus very useful for deriving cartographic data.

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[400] Ibid.

[401] See Oliver (2005, pp. 21, 30) for detailed backgrounds on the ordnance survey maps from 'the county series' at the scales 1:2,500 and 1:10,560.

[402] Harley &Phillips, 1964, cited in Oliver, 2005, p. 24.

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§ 3.2.3 Geo-rectification

Geo-rectification of historical maps is an important step in the process of data acquisition; using the general principle of comparing historic maps and plans with a modern geo-referenced map or vertical aerial photograph [Figure 3.6]. In this case, highly detailed and up-to-date geo-referenced vertical aerial photography of the estate was used as the reference.[403] Such sources offer a true record of the features and conditions present at the time of photography and without generalisation.[404] The historic maps and plans were stretched and rotated (transformed) in such a way that they align as well as possible with the aerial photograph, using control points.[405] Control points are locations (known x, y coordinates) that can be accurately identified on the historical maps as well as in 'real-world coordinates' derived from the aerial photograph (e.g. buildings or other terrain features that still exist). These sets of control points are used to sync the two maps for further analysis and extraction of historical data.[406] The control points are used to build a polynomial transformation (e.g. global affine transformations or warping rubber sheet interpolations) that shifts the historic cartographic data from its existing location to the spatially correct location. The more control points are used, the higher the accuracy and statistical reliability is achieved.[407] Since details on the maps are important, local variances in positional accuracy are a key issue in digital (re-)construction. Therefore, the so-called adjust-transformation was chosen to ensure global and local accuracy of the maps.[408] Once the map is geo-rectified, data can be extracted from the map for cartometric analysis.

§ 3.2.4 Cartometric analysis

The planimetric accuracy of the geo-rectified maps was analysed using the Geo-referencing tool and expressed in metres root mean square error (RMSE), showing the residual error [Table 3.1].[409] RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.[410] Accuracy standards for large-scale maps are set on a minimum range from 0.5 to 2.5 metres RMSE.[411] In order to visually express the local variances in planimetric accuracy across the original maps, MapAnalyst was used to generate a distortion grid, vectors and circles.[412]

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[403] GB 12.5cm AerialPhoto, 2005 (JPG), TIFF (British Ordnance Survey).

[404] Ordnance Survey and British Geological Survey, 2013.

[405] Balletti, 2006; Jenny et al., 2007; Jenny & Hurni, 2011.

[406] Jenny & Hurni, 2011.

[407] Balletti, 2006. According to Federal Geographic Data Committee (1998) a minimum amount of 20 control points is needed to achieve a confidence level of 95%, distributed to reflect the geographic area of interest and the distribution of error in the dataset.

[408] The Adjust-transformation is built on an algorithm that combines a polynomial transformation and triangulated irregular network (TIN) interpolation techniques (ESRI 2012).

[409] Although the RMSE is a good assessment of the transformation's accuracy, a low RMSE does not necessary mean that it is an accurate registration. For example, the transformation may still contain significant errors due to a poorly entered control point.

[410] Federal Geographic Data Committee, 1998, p. 4.

[411] Ibid., p. 23. See appendix 2.

[412] Jenny, 2006; Jenny et al., 2007; Heere (2008, pp. 72-78) provides an overview of possible cartometric analytical methods. MapAnalyst is technically not a real GIS, but a stand-alone Java application. However, implementation in GIS is possible through adjustments in the open-source code of the application.

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The cartometric analysis highlights that the geo-rectified 1722 map has a very low planimetric accuracy (RMSE 5.2 metres) with large local variances, particularly in the valley, as visible in the original map [Figure 3.7]. However, despite its low planimetric accuracy, the map is by necessity the most reliable and preferred to written sources, since geographical interpretation becomes necessary in order to analyse spatial distributions.[413] The 1722 map is the only map available representing the estate in that time period. By using additional sources, features such as the fishponds can be precisely located.

Map	RMSE	*n*-ref points	transformation	map scale
1722	5.21	20	adjust	ca. 1:8,500*
1785	0.95	20	adjust	ca. 1:8,500*
1779	11.4	20	adjust	ca. 1:3,500*
1887	0.88	20	adjust	1:2,500
1900	1.31	20	adjust	1:10,560

TABLE 3.1 Overview results cartometric analysis of the geo-rectified maps and plans

* *the scales are rounded-off and are computed approximations*

The geo-rectified 1785 map has a remarkable planimetric accuracy, with a RMSE of 0.95 metres, and shows evenly distributed local variances in the original [Figure 3.8]. This geo-rectified map meets the modern standards of planimetric accuracy. Given its positional accuracy, the map is very useful for extracting cartographic data by means of vectorisation for buildings, garden, trees, woodland, waterbodies and roads and paths.

The geo-rectified 1779 map has a low planimetric accuracy of about 11.4 metres RMSE due to proportional distortions [Figure 3.9]. These distortions have been the subjects of further investigation and will be discussed later. Although the plan is not accurate in terms of geometric position it provides useful relative positional and thematic information. It is a crucial source for interpreting the landscape design at that particular stage of development.

The 1887 map and 1900 map have high levels of planimetric and topographic accuracy [Figure 3.10] as a consequence of the preceding methodological and technical advancements in land surveying. These maps were based on the Principal Triangulation of Great Britain (completed in 1858)[414], which was later developed as the basis for modern geodesy in England.

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[413] Cf. Koeman, 1968.

[414] Seymour, 1980.

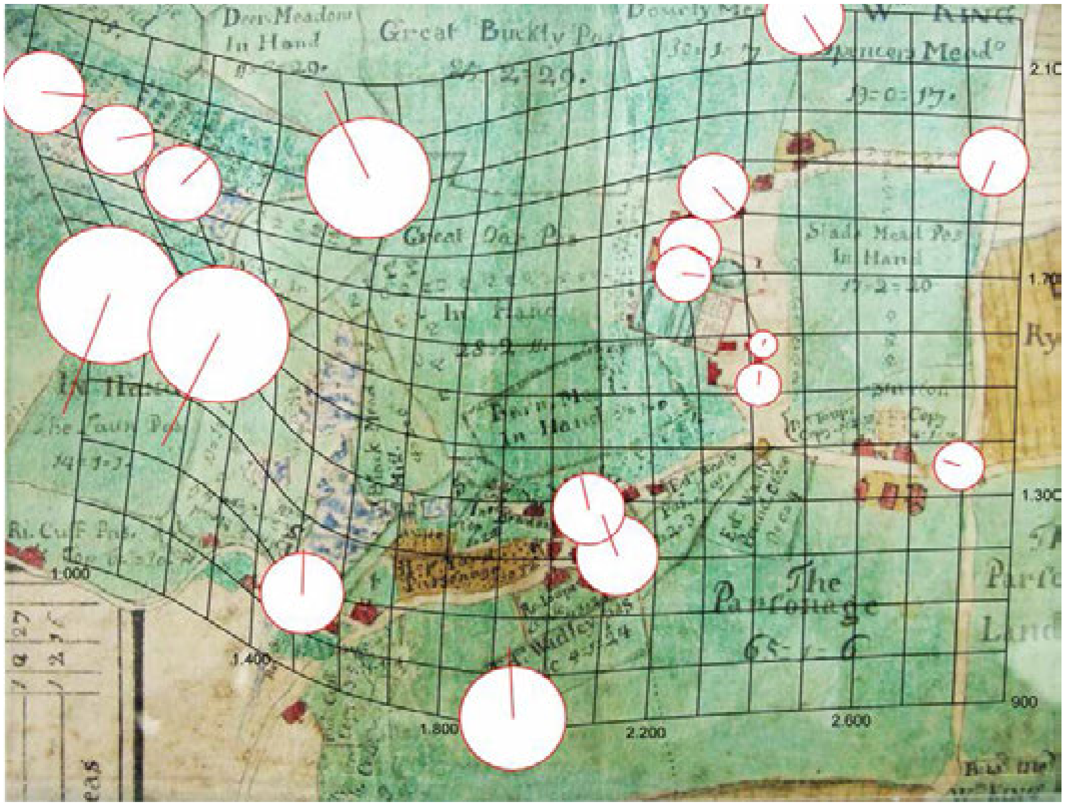

FIGURE 3.7 Cartometric analysis of the 1722 map represented as distortion grid with a cell size of 100 metres. The map has a very low planimetric accuracy (RMSE 5.2 metres), with large local variances, particularly in the valley. The vectors show the direction of distortion and the circles indicate the amount of distortion (analysis: Steffen Nijhuis; map source: Wiltshire Record Office 383.316)

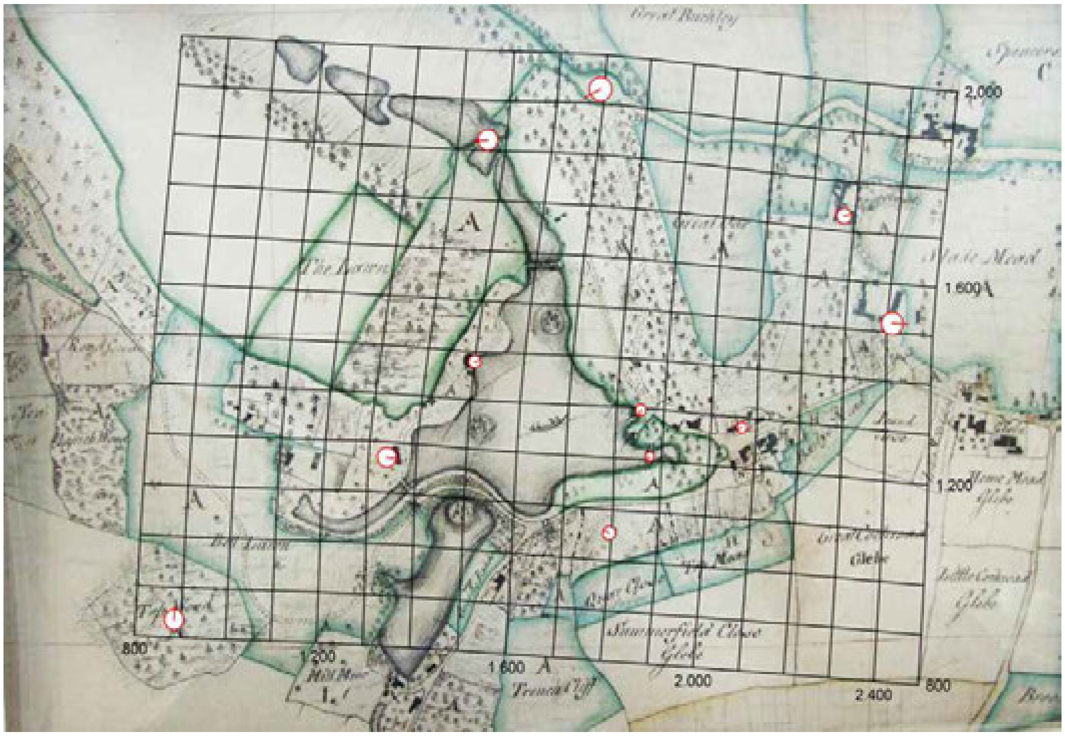

FIGURE 3.8 Cartometric analysis of the 1785 map represented as distortion grid with a cell size of 100 metres. The map has a remarkable planimetric accuracy, with an RMSE of 0.95 metres, and shows evenly distributed local variances. The vectors show the direction of distortion and the circles indicate the amount of distortion (analysis: Steffen Nijhuis; map source: Wiltshire Record Office 135/4)

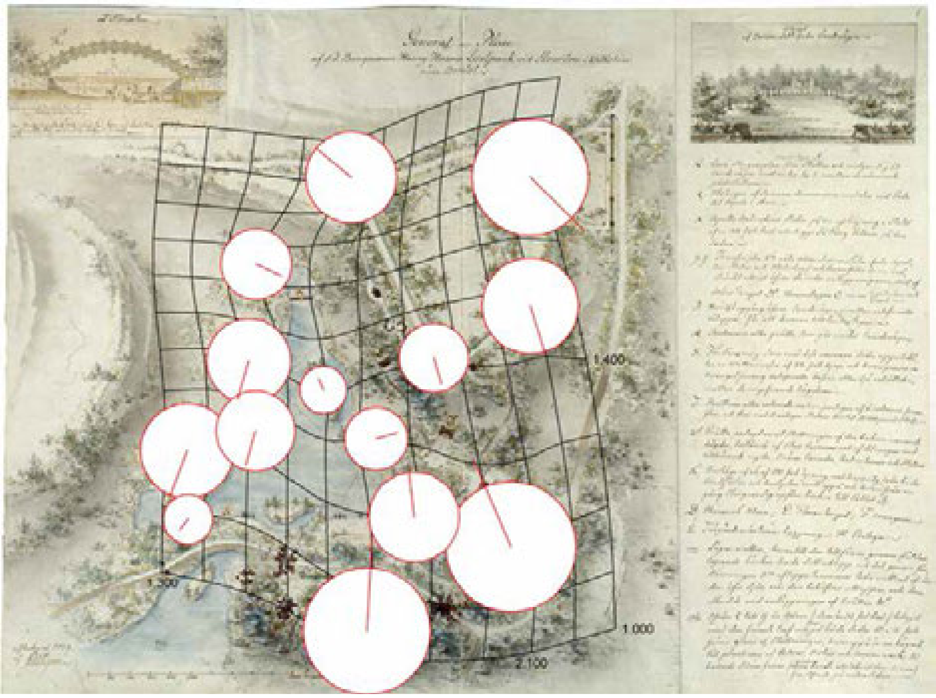

FIGURE 3.9 Cartometric analysis of the 1779 map represented as distortion grid with a cell size of 100 metres. The map has a low planimetric accuracy of about 11.4 metres RMSE due to proportional distortions. The vectors show the direction of distortion and the circles indicate the amount of distortion. However, the map is very valuable as it provides detailed information on the architectural features and aspects of the landscape architectonic composition. Although the map is not accurate, it offers a contemporary view by a landscape designer of Stourhead landscape garden (analysis: Steffen Nijhuis; map source: Royal Academy of Fine Arts, Stockholm)

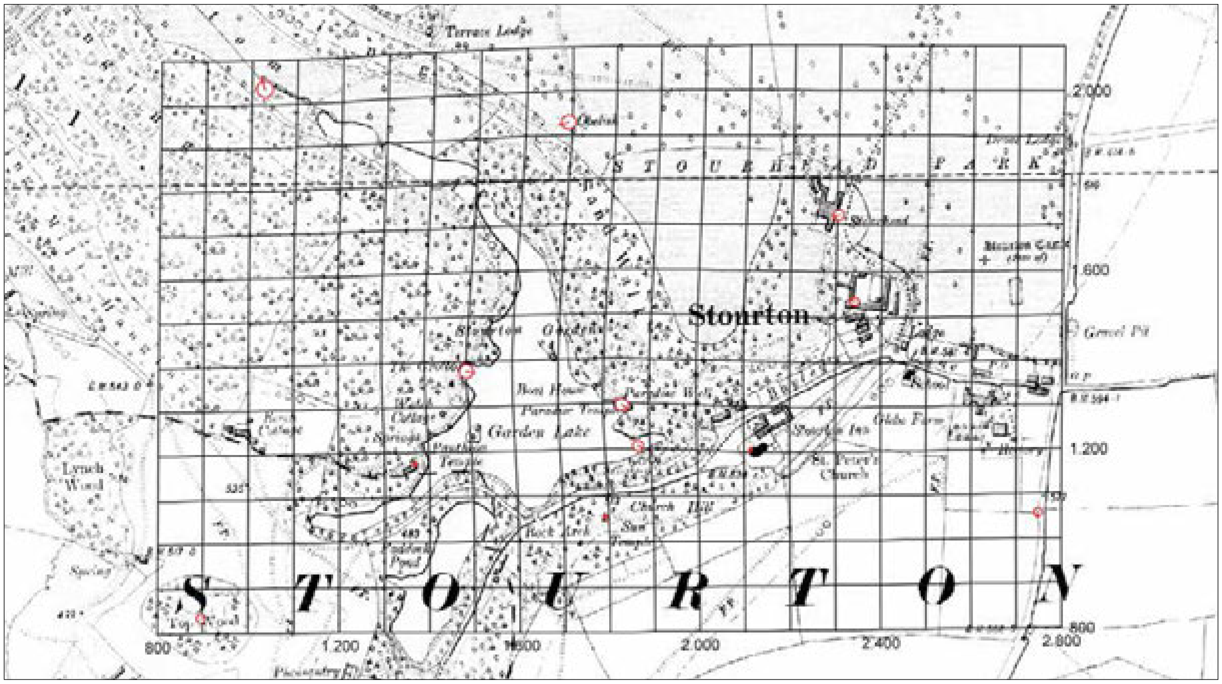

FIGURE 3.10 Cartometric analysis of the 1900 map represented as distortion grid with a cell size of 100 metres. The ordnance survey map of 1900, partly based on the more detailed 1889map, has a high level of planimetric and topographic accuracy. The vectors show the direction of distortion and the circles indicate the amount of distortion (analysis: S. Nijhuis; the map is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey license number AL100018591)

§ 3.2.5 Complementary sources of historical topographic data

There is a great wealth of eighteenth century landscape views of Stourhead landscape garden available as documentary sources. These include the engravings, drawings and paintings of C. W. Bampfylde (1770)[415], F. M. Piper (1779)[416], S. H. Grimm (1790)[417], F. Nicholson (1813)[418], and also depictions on the Green Frog Service (1773-1774)[419] by Josiah Wedgwood. These depictions were made for various reasons and despite uncertainties inherent to such historic landscape views, they can be highly informative as evidence beyond formal and material configurations as long as they are examined within their cultural context using multi-source analysis.[420] The consistency of details between the depictions suggests that scenographic accuracy was a priority for each artist.[421] As complements to the historical maps and plans, they can offer important topographical information on the landscape design, including on the disposition of architectural features and trees, as well as on their spatial appearance and expression [Figure 3.11]. They also give an idea of the perspective of important views, the relief effect of the vegetation (visual depth), and the colour scale in terms of contrast (e.g. light/dark, textures). The depictions also provide information about the species of trees used, as tree and shrub-species can be recognized by their habitus. These can be verified using historical plant lists available for the estate.[422]

FIGURE 3.11 The spatial densification of the Valley Garden exemplified by comparing the views of Bampfylde (1770) (left) and Nicholson (1813) (right). Visible is the effect of forestation efforts on the ridges at the South bank of the Great Lake (images from: Woodbridge, 1982/2002)

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[415] Housed at Stourhead Library, British Museum and Victoria and Albert Museum. For overviews: Woodbridge, 1970, 1982/2002; White, 1995.

[416] Housed at the Royal Academy of Fine Arts, Stockholm. For overviews: Sirén, 1950, Karling et al., 1981; Woodbridge, 1970, 1982/2002; Harris & Olausson, 2004.

[417] Housed at the British Museum. For overviews: Woodbridge, 1970, 1982/2002.

[418] Woodbridge, 1970, 1982/2002.

[419] Housed at the Hermitage, St. Petersburg. For an overview see: Raeburn et al., 1995. This service was commissioned by Catherine the Great and it is besides its intrinsic value of great historical significance because of the 1,244 views of buildings and landscapes in various parts of England.

[420] Halpern, 1992; Williamson, 1992; Harris, 2003; Harris & Hays, 2008, Richardson, 2013.

[421] See for an example Magleby, 2009, pp. 40-41.

[422] Woodbridge, 1976; 1982/2002, pp. 61-70.

The available historic landscape views (and maps) not only provide documentary sources necessary for assessing formal aspects, they are also historical sources crucial for understanding the broader cultural context, and also serve to 'produce culture', as Harris and Hays (2008) put it. Seen as a vital part of visual culture, these images are constitutive of 'a history of images' and therefore represent a valuable scholarly source.[423] They communicate assumptions and expectations about the garden, with people as actors in a picturesque backdrop reflecting images considered as desirable by contemporaries.[424] These figures are useful for pointing to specific elements, calling attention to elements difficult to represent in views (e.g. fishpond indicated by figures engaged in the activity of fishing), or in determining scale [Figure 3.12].[425]

FIGURE 3.12 This view of the Great Lake, depicted on a cream bowl of the Green Frog Service by Josiah Wedgwood in 1773-1774, contains information on the use and appearance of this part of the Valley Garden. In the foreground a fisherman (left), indicating that the lake was still in use for breeding fish in the 1770s (image source: Raeburn et al., 1995)

Other documentary sources such as Hoare II's surviving personal documents[426] or the guidebooks written by Colt Hoare in 1800 and 1818 provide rich sources of data about Stourhead's creation and use. Visitors' descriptions, such as those by Sir John Parnell in 1768[427], and travel books like those by Daniel Defoe (1778) record different stages of Stourhead's development.[428] Furthermore, Magleby (2009) discusses two anonymous poets who provide insightful topographic information on the estate as it was in 1749 and 1779.[429]

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[423] Bryson et al., 1994, cf. Richardson, 2013.

[424] Harris, 2003, p. 19 and 62ff.

[425] Harris, 2003, 66ff; Harris & Hays, 2008, p. 29.

[426] Most of Henry Hoare II's documents are housed at the Wiltshire Records Office, file no. 383.4.

[427] Edited and introduced by Woodbridge (1982).

[428] A selection of eighteenth and nineteenth century texts that describe Stourhead can be found in Charlesworth (1993), chapters 70, 101 and 107.

[429] Magleby, 2009, p. 147ff.

Besides the documentary sources, one can also find material sources: copies of architectural features in landscape gardens throughout Europe. Their initiators and designers often visited Stourhead landscape gardens, amongst others (e.g. Stowe, Painshill), for didactical reasons, while copying ideas for implementation in their own gardens. For example, we can find copies of the Wooden Bridge (called: Chinese Bridge) and the Temple on the Terrace (called: English Seat), which survived in Wörlitz landscape garden (Anhalt-Dessau, Germany), where the architect F. W. von Erdmannsdorff constructed the features immediately after his visit to Stourhead in 1763-1764.[430]

§ 3.3 Modern topographic data

In order to get an overview of the current situation, the most up-to-date and detailed topographic data were collected. Most topographic data of natural and artificial features is available as digital maps (cartographic data) in raster and vector formats. Useful analogue maps and plans, as a whole and for selected features, had to be digitised and vectorised. Additional topographic information was acquired through field research and study of relevant documentary sources.

§ 3.3.1 Sources of modern cartographic data

Modern maps and plans of Stourhead were obtained from the British Ordnance Survey (OS), the National Trust (NT)[431] and the British Geological Survey (BGS). The positional accuracy of this cartographic data ranges from 0.4 to 1.1 metres RMSE, for the map scales 1:2,500 and 1:10,000.[432] This meets modern accuracy standards for large-scale maps, which are set on a minimum range from 0.5 to 2.5 metres RMSE.[433] Important additional topographic data came from McKewan (2006), for elevation of the lakes, and Reh (1995) for the landscape architectonic composition in the early stages of Stourhead's development. The available topographic and thematic maps can be categorised as: modern ordnance survey maps, vertical aerial photographs, NT property maps, site elevation, geological and soil maps, and landscape design study-maps.[434]

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[430] Bechtoldt & Weiss, 1996; Kulturstiftung Dessau-Wörlitz, 2005.

[431] The National Trust is also a licensed supplier of OS-data and creates also data about their properties themselves.

[432] Ordnance Survey, 2004, 2013a.

[433] Federal Geographic Data Committee, 1998. See appendix 2.

[434] See appendix 1 for a detailed overview.

FIGURE 3.13 This section of the ordnance survey map of Stourton 1:2,500 (2009) is the most recent and accurate map available that includes Stourhead landscape garden. It is a geo-referenced map in vector format. As the ordnance survey maps show a particular cartographer's interpretation of the ground surface, focusing on roads and buildings, not all topographic features relevant to this study are indicated (the map is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey license number AL100018591)

Modern ordnance survey maps of 2009 and 2011

The most recent maps available of Stourhead are the ordnance survey maps of Stourton at the scales 1:2,500 (2009), 1:10,000 (2009) and 1:25,000 (2011), prepared by the British Ordnance Survey [Figure 3.13]. The maps are available in geo-referenced raster and vector formats. The maps are generalised according to the scale and the cartographer's field of interest, as exemplified by the legends. At the scale 1:2,500 roads, buildings, fences, hydrography, woodlands and contour lines are shown in detail. The shapes of individual buildings are accurately represented as well as being named or numbered.[435] However, specific features, like individual trees are not accurately indicated. This map is an important basis for modelling Stourhead landscape park in its current state.

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[435] Ordnance Survey, 2013b.

FIGURE 3.14 This vertical aerial photograph makes it possible, unlike the ordnance survey maps, to see what was actually on the ground at the time of photography (2005). The 12.5 cm resolution data were acquired as twenty-seven tiles of raw data and converted and mosaicked into a new raster by means of GIS (data reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey license number AL100018591)

For Stourhead in its wider context, the scales 1:10,000 and 1:25,000 are useful. Roads, road names, and major buildings are clearly marked together with rivers, streams, and other topographic features. However, in built-up areas the scales leave insufficient space to show all buildings in detail, so these and other features are identified in a more diagrammatic, generalised way.[436]

Because the ordnance survey maps show a particular cartographer's interpretation of the ground surface, usually focusing on roads and buildings, not all topographic features relevant to this study are indicated. Therefore additional sources are required.

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[436] Ibid.

Vertical aerial photographs 1997 and 2005

For this study, the most recent aerial photographs were obtained as geo-referenced raster imagery with a resolution of 12.5 cm (2005) and 25 cm (1997). The 12.5 cm resolution data was acquired as twenty-seven tiles of raw data and converted and mosaicked into a new raster by means of GIS, which increases the efficiency [Figure 3.14]. Unlike the ordnance survey maps, vertical aerial photography makes it possible to see what is actually on the ground at the time of photography.[437] Maps are, to varying degrees, abstractions of reality and hence subject to collective subjectivity (e.g. map conventions). Vertical aerial photographs are empirical recordings of the topography. While providing an overview of the actual situation they are a means to exploring landscape features not found on a map or not visible from the ground at eye-level.[438] The vertical aerial photographs therefore offer complementary cartographic data to the ordnance survey maps and are used as the main reference for Stourhead in its current state.[439] They enable users to pick out visible features, which range from individual trees, to tree belts, brooks, ponds, land uses and even archaeological features that are not on the ordnance survey maps. For example, the 12.5 cm resolution photograph shows the archaeological remainders of the Manor of Stourton, in front of Stourhead House (east side), which was demolished in 1718 by Henry Hoare I. This can be regarded as physical evidence of what is described by Mowbray (1899) as a 'large castle, having two quadrangles' probably built for Sir John Stourton about 1448 in the reign of Henry IV, when he was granted a license to enclose a thousand acres of pasture, meadow and woodland.[440]

National Trust property maps of 2011

Property boundaries are an inherent constraint for spatial development.[441] Property boundaries are thus of great importance to understanding the development of the site. The grounds became the property of the Hoare family when Henry Hoare bought them from the son of Sir Thomas Meres in 1717.[442] In 1946-47, Sir Henry Hugh Hoare (1865-1747) gave Stourhead, about 1,014.5 ha in size, to the National Trust (NT). The size of the estate has been extended through further acquisitions in 1982 and 1985 up to about 1,049 ha in size.[443] The NT keeps detailed records on boundaries of land ownership, disposals, and acquisitions as geo-referenced vector data as in the NT property maps of 2011.

Elevation data

Elevation is an important topographic feature and shows the landform – the physical shape of the landscape. Landforms like valleys and hills are spatial variations in elevation with slope (gradient) and aspect (orientation) as important characteristics, and determine drainage patterns, suitability for the growth of vegetation and the construction of other features such as paths and buildings.[444]

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[437] Ordnance Survey & British Geological Survey, 2013.

[438] Von Freitag Drabbe, 1955, 1972; cf. Bradford, 1957.

[439] For an elaboration on the complementarity of maps and vertical aerial photographs see: e.g., Von Freitag Drabbe, 1955; Imhoff, 1969, p. 58.

[440] Mowbray, 1899, p. 4ff. For an archaeological survey see: Mayes, 1995. See figures 2.39 & 2.40.

[441] Lagro, 2008, p. 103.

[442] Hutchings, 2005. For a detailed account on the development of land possession by the Family of Stourton see: Mowbray, 1899.

[443] The National Trust Ownership database, 2011.

[444] Lagro, 2008, p. 104ff.

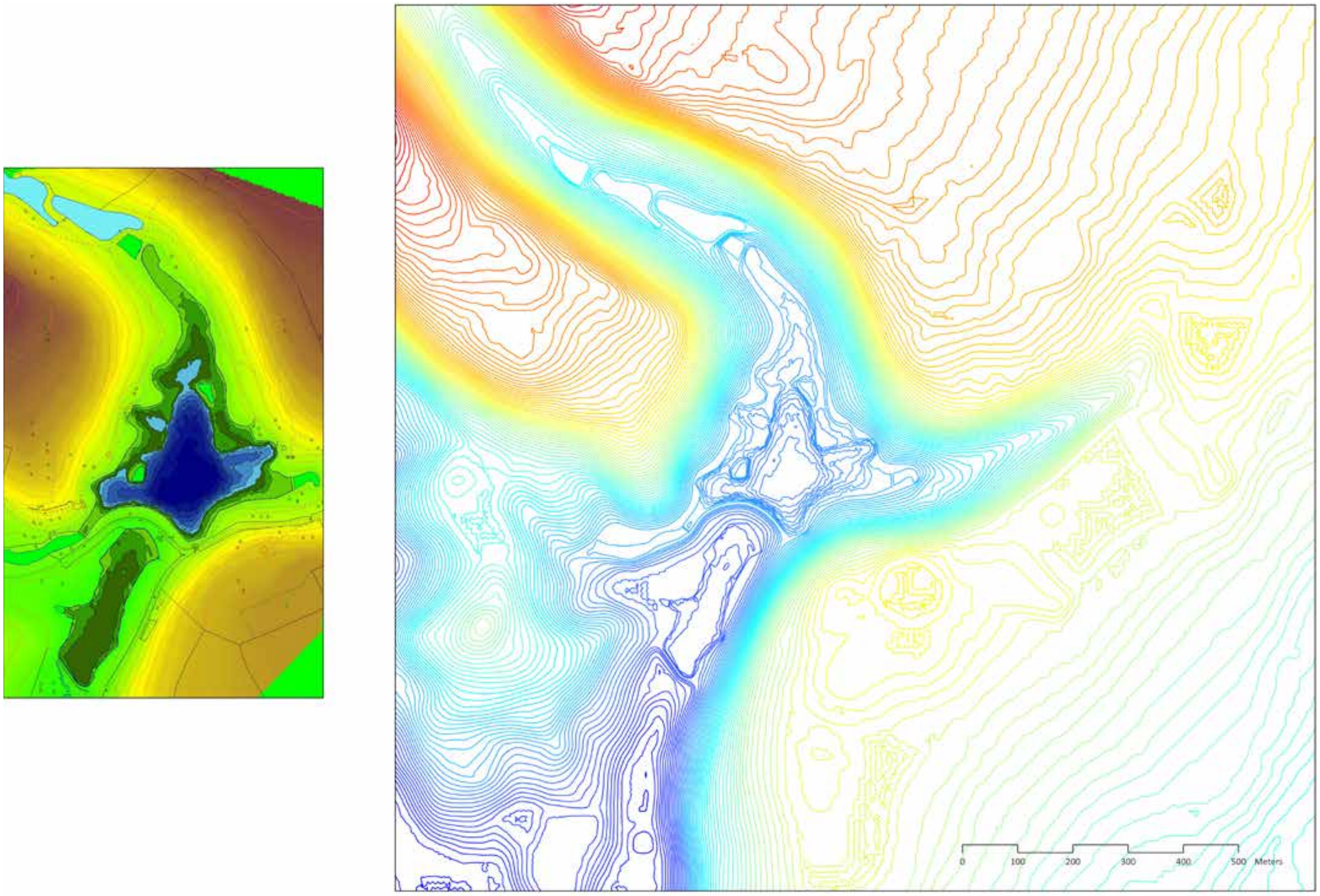

FIGURE 3.15 Bathymetric data of the lakes at Stourhead landscape garden. Left: the Sonar-GPS-GIS-contour map of the relief in the water bodies (source: McKewan, 2006). Right: the geo-referenced and vectorised version merged with a contour map derived from point vector data of terrain heights (map: Steffen Nijhuis & Michiel Pouderoijen)

For Stourhead, a 10 metre grid of heighted points is obtained as point vector data with a vertical error ranging from 0.1 to 2.5 metres.[445] This is the most accurate data available and is derived from an extensive 1:10,000 scale contour mapping programme completed by the British Ordnance Survey in 1987 that used photogrammetric technique. To increase the accuracy, additional spot heights were surveyed and recorded at a scale of 1:1,250 using ground survey methods (mainly spirit levelling).[446] This topographic data was the basis for creating the digital elevation models (DEMs) of Stourhead. To assess elevation in Stourhead's wider context, SRTM-digital elevation data (2010) with a vertical accuracy up to 16 metres is available.[447]

Data on bathymetry, the elevation of the floors of the water bodies below the water surface, were derived from an analogue Sonar-GPS-GIS-contour map prepared by McKewan (2006) with a contour-interval of about 0.40 metres, based on 1,899 survey points in the Great Lake and 286 survey points in Turner's Paddock lake. This map was digitised and geo-referenced in order to vectorise the bathymetric contour lines by means of GIS [Figure 3.15].[448]

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[445] Ordnance Survey, 2012.

[446] Ibid.

[447] Consortium for Spatial Information, 2013.

[448] Many thanks to Michiel Pouderoijen who helped me with this laborious work.

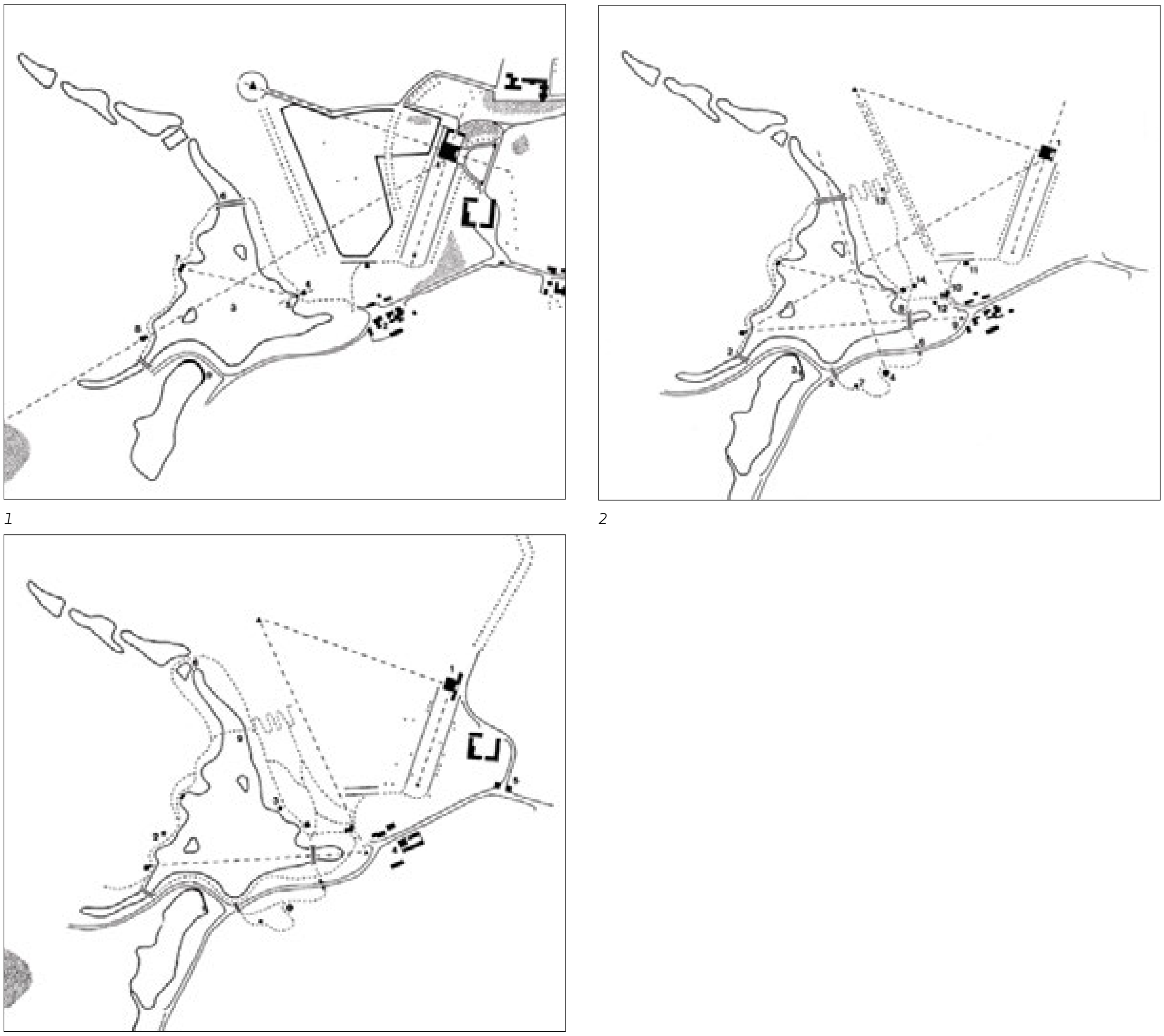

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FIGURE 3.16 Hand-drawn reconstructed maps of the development of Stourhead landscape garden in the periods 1733-1750 (1), 1743-1760 (2) and 1760-1785 (3) (images from: Reh, 1995). These are selective tracings of the historical maps as well as interpretations of literary sources, complemented with an analysis of the landscape architectonic composition. The maps have been digitised, geo-rectified and partly vectorised by means of GIS

Geological and soil maps

A geologic map shows the age and distribution of (igneous, metamorphic and sedimentary) rock and soil.[449] Rock has a persistent influence on the landform due to the different weathering or breakdown rates of the parent material and influences groundwater supply, land use and the construction of buildings, paths and ponds.[450] Soil originates from the process of rock weathering and is the end product of the confluence of the climate, relief (slope), organisms, parent materials

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[449] Gilluly et al., 1975; British Geological Survey, 2013.

[450] Lagro, 2008, p. 109.

(original minerals), and time.[451] Soil is a basic condition for vegetation and agricultural land use, since differences in soil texture, fertility and permeability determine plant growth and development.[452] Cartographic data on the distribution of rock and soil were available in analogue and geo-referenced digital form from the British Geological Survey (1996) at a scale of 1:50,000. Additional data were derived from the European Soil Database (2004) and Jones et al. (2005).

Landscape design study-maps

In general, cartographic studies of the landscape architectonic composition are sparsely available. However, for Stourhead landscape gardens, Reh (1995) provides a detailed reconstruction of the landscape design in the early stages of its development, complemented by an analysis of its landscape architectonic composition.[453] In particular, the hand drawn maps of the estate in the periods 1733-1750, 1743-1760 and 1760-1785 offer useful cartographic data via selective tracings of the previously discussed maps as well as interpretations of literary sources. These maps were digitised, geo-rectified and partly vectorised by means of GIS [Figure 3.16]. However, some topographic features, such as the sunken fence (called: ha-ha) surrounding the Great Oar pasture, are highly speculative, since no documentary source has been found that confirms its existence surrounding the whole pasture. Although the maps may not be accurate in every aspect, they offer the only available formal reading of the landscape architectonic composition.

§ 3.3.2 Additional sources of modern topographic data

Additional topographic information about heights of buildings, terrain and vegetation, plant species, etc. was acquired through personal measurements, observations and inventories in the field.[454] A study of relevant documentary sources included: inventory and conservation reports[455], vegetation classification and mapping projects[456], forest management descriptions[457] and photographic sources.[458]

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[451] Gilluly et al., 1975.

[452] Jones et al., 2005; Lagro, 2008, p. 113.

[453] Reh, 1995, pp. 248-277. See also for reproduction of these maps and an English version of the accompanying text: Steenbergen & Reh, 2003, pp. 321-331.

[454] During multiple visits in July 2009 and July 2011. For collecting locational data a hand held GPS device is used (Garmin Colorado 300).

[455] National Trust, 1973/2000, 1981.

[456] Rodwell, 1998; Hall et al., 2004.

[457] Hoare, 2013.

[458] National Trust Images (2011-2013), Flickr (2011-2013), SmugMug (2011-2013).

§ 3.4 Constructing the digital landscape models (DLMs)

The DLMs of Stourhead landscape garden are the basis for GIS-based analysis and visual representation. In general, a DLM contains the following groups of topographic data: (1) landforms, such as elevation, slope and aspect, (2) natural resources and environments, such as soil, hydrology, vegetation and geology, (3) terrain features, such as hydrographic features (e.g., rivers, lakes), transportation networks (e.g., roads, paths), settlements, buildings, boundaries, etc., and (4) socio-economic data, such as the population distribution, per capita income and agriculture.[459] However, the DLMs of Stourhead were constructed by means of selecting and integrating specific topographic features that constitute the fabric or material substance of the landscape architectonic composition. In particular, these include those topographic features that determine spaces, paths, edges, foci and thresholds in the landscape design, such as landform, water, vegetation, built and constructed elements.[460] These are, according to Whately (1772/1982), the materials that make up the composition of the scene in landscape gardens. These topographic features and their subcategories were derived from the available corpus of modern and historic topographic data as vector data: points, lines and polygons [Table 3.2]. For the construction of the historic DLMs, cartographic data was vectorised from the geo-rectified maps.

Landform	hills, ridges, valleys, slopes, depressions
Hydrography	lakes, streams, fishponds
Vegetation	woodland, trees (groups and individual), orchards, hedges, shrubbery, grassland (pasture and meadow)*, arable land, ornamental planting (e.g. parterre and flowerbed)
Built and constructed elements	paths, roads, houses, barns, gates, bridges, parcellation, architectural features (e.g. temple, tower, obelisk, statue and ha-ha)

TABLE 3.2 Overview of the constituent topographic features of Stourhead's DLMs

* *Pastures are grassland for grazing, meadows are grasslands which are mown for hay crop (Goulty, 1991)*

The DLMs consist of a ground layer supplemented by a terrain layer with 2D and 3D referenced objects. The ground layer is the height of the solid surface of the earth above sea level (elevation) and represents the landform via a digital elevation model (DEM). The terrain layer consists of the other features that make up the topography of Stourhead, such as: hydrography, vegetation, and built and constructed elements.

§ 3.4.1 Periodisation based on available topographic data

Since time is an important aspect in modelling the estate, the sequence of time-slice snapshots had to be determined in order to assemble the topographic data in such a way as to provide useful information and a workable basis. The periodisation is primarily based on the available topographic data, since these convey the physical shape and pattern of the site at certain points in time. The topographic data represents the 'cartographic time', which is the time of the actual recording or

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[459] Adapted from Li et al., 2005, p. 8; Cf. Van Lammeren, 2011.

[460] Simonds, 1997; Motloch, 2001; Dee, 2001.

measurement of the topography. This is usually earlier than the map was made, and thus not the same as the time of map-making.[461] The topographic data were assembled based on their incidence, chronology and nature and resulted in four significant time-slice snapshots (t_0, t_1, t_2, t_3) marking important periods in the development of Stourhead landscape garden. The resulting periodisation provides a feasible and 'empirical' basis for the construction of the DEMS and DLMs.

Stourhead 1722 (t_0)

This time-slice snapshot is regarded as the start of the period in which the landscape garden evolved and represents the estate as it was before Henry Hoare II began to construct the landscape garden (< 1724). The topographic data is mainly derived from the geo-rectified 1722 map, since this is the only available cartographic resource from this initial stage of the estate's development. It was not possible to derive information on the planting, since this is only sparsely indicated on the map.

Stourhead 1785 (t_1)

This time-slice snapshot represents the stage during which the landscape garden was created according to the plans of Hoare II, in the period 1724-1785. In 1785, Colt Hoare inherited the estate and started to alter the landscape architectonic composition. The topographic data is mainly derived from the geo-rectified 1785 map, and supplemented with data from the 1779 map, which provides additional data on the presence, nature, and relative position of architectural features. Data on the Pleasure Garden surrounding the house was derived from the geo-rectified drawings of Reh (1995). Planting is indicated on the 1785 map and species were derived from contemporary plant lists and recognition of habitus in contemporary views. Additional information derived from other contemporary documentary sources (e.g. Bampfylde, Piper, Grimm, Green Frog Service).

Stourhead 1887 (t_2)

This time-slice snapshot represents a mature version of the landscape garden as it had been transformed by Colt Hoare up to his death in 1838. He removed architectural features, changed the path structure considerably, and changed the planting of the Valley Garden by introducing shrubbery on a vast scale as well as ornamental trees around the lake, under-planting, and exotic trees in the period 1785-1838. The landscape garden was preserved in that state by the subsequent owners in the period 1838-1887. Topographic data derived from the 1887 map and supplemented with data (wider context) from the 1900 map. Planting is indicated and species are derived from contemporary plant lists and recognition of habitus in contemporary views. Additional information was derived from other contemporary documentary sources (e.g. Nicholson).

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[461] In case of the 1722, 1779 and 1785-maps it is likely that the maps are made directly after the survey since they are commissioned, or made on the spot in case of the 1779-map, by means of pen and water colouring. In case of the 1887, 1900, and modern maps it is likely that there is a time leap of weeks or months between recording and map-making since they were part of a national mapping programme and were made with techniques like engraving which takes longer to process data, or with modern maps, digital processing by means of several people involved.

Stourhead 2010 (t_3)

This time-slice snapshot represents the present situation as a remainder of the landscape garden left by Colt Hoare in 1838. However, small changes have occurred, including the growth of trees and alterations in the path structure in the period 1887-2010. Topographic data mainly were derived from modern ordnance survey maps (2009, 2011), vertical aerial photographs (1997, 2005) and elevation data (1987). Additional topographic information was acquired through field research (2009, 2011) and study of relevant modern documentary sources.

In line with this periodisation, the topographic data was integrated and processed into DEMs and DLMs, named for the respective years (e.g. DEM 2010, DLM 1785). Although the DEMs served primarily as the basis for the construction of the DLMs, the DEMs themselves are also an useful basis for (morphometric) analysis and visual representation of elevation and land surface.

§ 3.4.2 The digital elevation models (DEMs)

The DEM was derived from an interpolation of a 10 metre grid of heighted points with a vertical error ranging from 0.1 to 2.5 metres.[462] Therefore the ‘topo to raster-function’ was used, an interpolation method specifically designed to create correct DEMs.[463] The spacing of the original data used to construct a DEM effectively limits the resolution of the DEM.[464] Decreasing the grid size beyond the resolution of the original survey data does not increase the accuracy of the DEM. The original elevation data of the land surface is a crucial, but often neglected, characteristic of a DEM.[465] Since the DEM is the basis for the DLM, a course resolution in grid-size is not useful because grid-size influences the analysis results. In other words, in a DEM with a grid size of 10 metres, smaller entities will not be included in the analysis. Therefore, scholars suggest that the size of the primary landscape features of interest should provide a natural guide to determining an appropriate grid size.[466] For the surface definition of the DEM, a grid size of 1 metre was chosen, to balance the original resolution of the elevation data with the size of other relevant topographic features (e.g. width of hedges or walls). The result is a DEM with a continuous floating point grid with a cell size of 1 by 1 metres (x, y) [Figure 3.17].

In order to include bathymetry, the geo-referenced and vectorised contour lines from the analogue Sonar-GPS-GIS-contour map prepared by McKewan (2006) were interpolated, and later superimposed and merged into the DEM. In this form, the DEM represents the land form of Stourhead 2010 (t_3), but since there were no significant human interventions (e.g. large scale excavations, large dam construction works) or geological changes in the geomorphology of that area in the past century, the elevation of Stourhead 1785 (t_1) and Stourhead 1887 (t_2) can be equated with Stourhead 2010 (t_3), henceforth called DEM 1785-2010. The DEM can be represented via a surface, vector or combinatory definition in a 2D or 3D setting [Figure 3.18 & Figure 3.19].

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[462] OS Landform Profile DTM-point vector data (1:1,250-1:10,000); the obtained data set consist of 276,709 heightened points.

[463] This function interpolates a hydrological correct raster surface from point, line, and polygon data (ESRI, 2010).

[464] Zhang & Montgomery, 1994.

[465] Ibid.

[466] Ibid.

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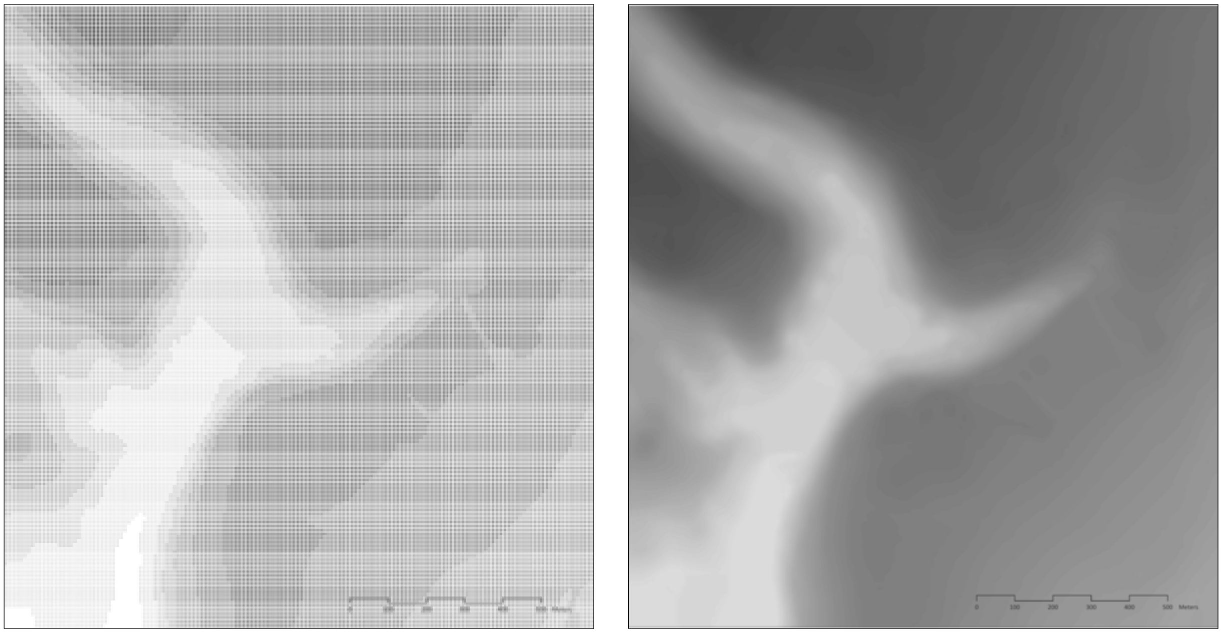

FIGURE 3.17 Section of the 10 metre grid with 29,233 heighted points in vector format (left) is interpolated into a DEM (right) by means of GIS. This DEM is represented here as a 2D-surface in grey tones and does not include bathymetry (maps: Steffen Nijhuis)

Representing DEMs

In order to utilise recognition of landform, visual representations play a crucial role. Contouring, vertical profiling, hypsometric tinting, hill-shading, and perspective views are useful techniques for representing DEMs.[467] All of these techniques depend on the accuracy of survey data, purpose of the map, and scale for their accuracy. Contouring is the most precise way to provide height information and results in an isarithmic map using a system of contour lines (or isolines), lines connecting points of equal elevation.[468] The contour interval represents the vertical distance between contour lines and the arrangement and pattern reflect the landform (e.g. contour lines are closely spaced in steep terrain). The usefulness of contours depends on their contour interval. As interval decreases, more surface detail is visible. For the map scale 1:10,000, in correspondence with the resolution with the available survey data, Imhoff (1965, p. 137) suggests a contour interval of 2-5 metres.

A vertical profile shows changes in elevation along a line.[469] These lines can be straight in order to create longitudinal sections of the DEM or follow a path for plotting the vertical profile.

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[467] Imhoff (1965) provides the most comprehensive account on visual representation of elevation and landform. Cf. Robinson et al., 1995, p. 527ff; Collier et al., 2003; Chang, 2010, p. 268ff. For technical descriptions: Li et al., 2005, p. 247.

[468] Imhoff, 1965, p. 133ff; Robinson et al., 1995, p. 538ff.

[469] Imhoff, 1965, p. 133ff; Chang, 2010, p. 272.

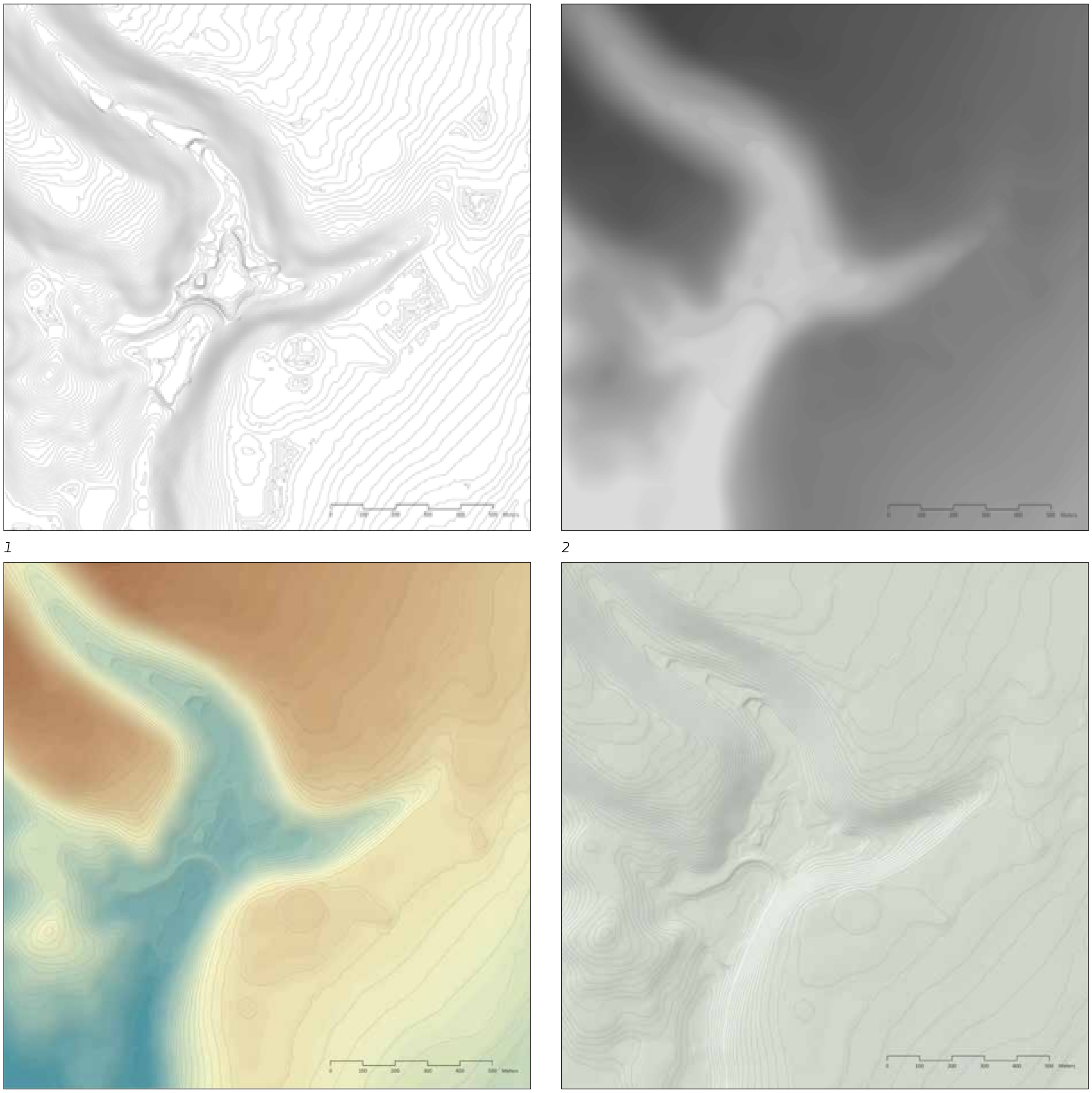

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FIGURE 3.18 Different 2D-representations of the DEM 1785-2010: (1) isarithmic map using a system of contour lines derived from the DEM (polyline vector definition), (2) surface with continuous colour scheme from high to low in a grey gradient, (3) surface with hypsometric tinting in diverging colour scheme and supplemented with contours, and (4) surface in grey with shading supplemented with contours. The recognition of landform has been improved by shading and contour lines (maps: Steffen Nijhuis)

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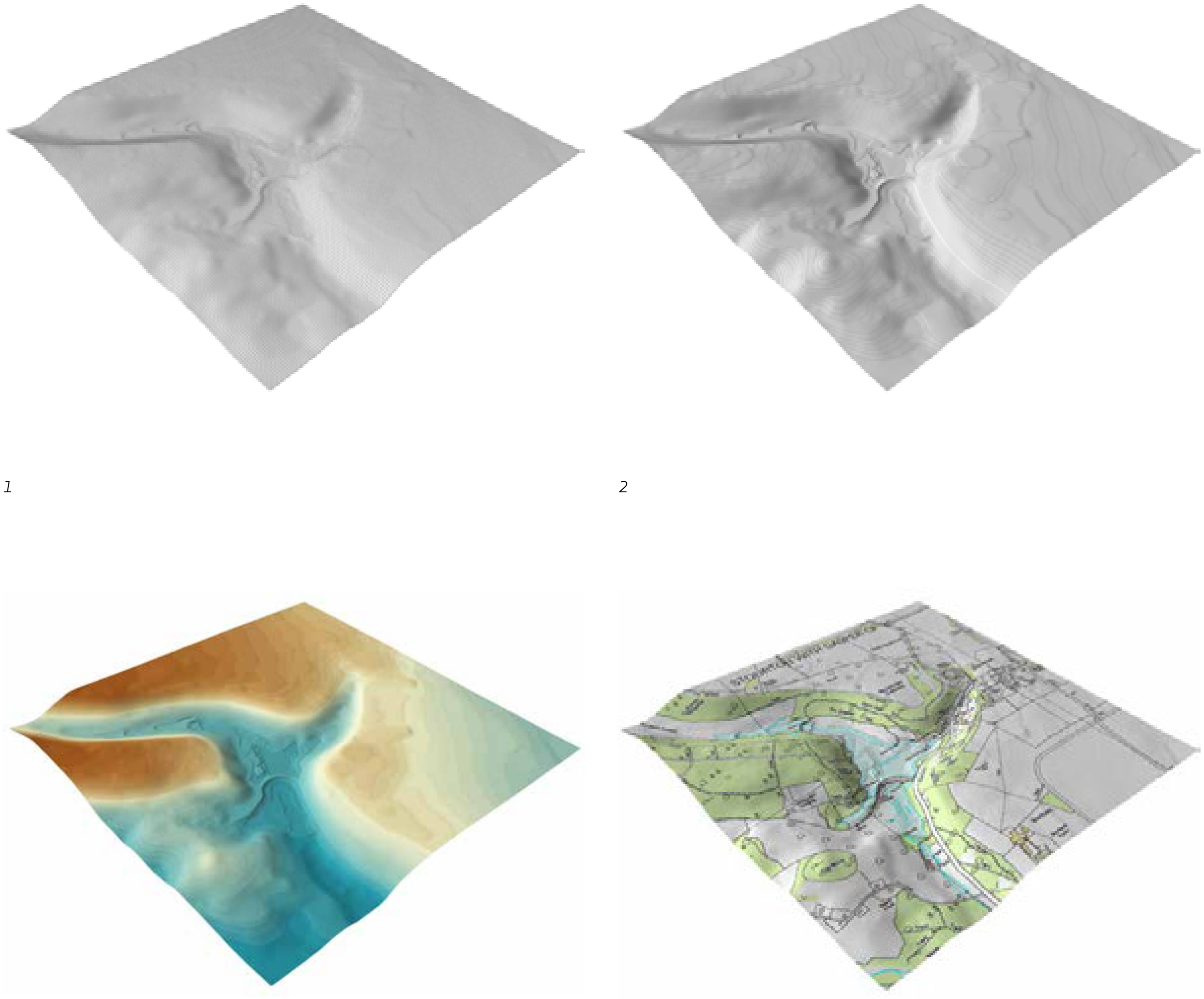

FIGURE 3.19 Different 3D representations of the DEM 1785-2010 (Stourhead from south-west: vertically exaggerated, z=1.5x):(1) fishnet surface with shading (2) surface with shading supplemented with contours, (3) surface with altitude tinting and shading, and (4) surface with a draped texture (maps: Steffen Nijhuis)

The information value of the DEM can be increased by 'escaping the flatlands' of the two-dimensional display (e.g., screen, paper) and effectively utilising and portraying optical depth via hypsometric tinting, hill-shading and perspective view. Hypsometric tinting (altitude or layer tinting) applies colour symbols to zones between the contour lines.[470] There is a range of different colour schemes available, but sequential and diverging colour schemes are the most effective.[471] Sequential or continuous colour schemes are logically arranged from high to low in a preferable one-colour gradient, with light colours representing low values and dark colours high values.[472] In the diverging colour scheme, two colours differentiate increase and decrease above and below a midpoint (e.g. mean, median or zero point).[473] In order to increase depth perception, the application of short wavelength colours (blue, cyan, green) is recommend for lower elevations, since they appear further from the eye, and long wavelength colours (yellow, orange, red) for higher elevations, since they appear closer to the eye.[474]

Hill-shading (relief shading, shaded relief or 'plastic shading') was derived from principles of light and shadow in art and psychological principles of depth perception and is the most realistic landform portrayal method.[475] Hill-shading essentially delineates brightness differences resulting from incoming light being reflected to an observer and utilises the recognition of landforms by different tinting caused by elevation, slope and aspect. Shades from northwest illumination (315° clockwise orientation) have the best results in depth perception.[476] Although this direction is at odds with reality in the northern hemisphere, other orientations cause an optical inversion of depth, called the pseudoscopic effect, with hills appearing as valleys and vice versa.[477]

Perspective views are 3D views of the landform, and are represented as if viewed from an angle from an aeroplane.[478] Viewing azimuth, angle, distance and z-scale are the most important parameters. Fishnet-plots, layered contouring, texture draping and solid rendering are useful techniques to add depth cues to perspective views.[479] Perspectives with fishnet-plot emphasise texture gradient. Contour layering and solid rendering emphasise linear perspective, with shading and shadow as additional cues.[480] There are no empirical comparisons among the different perspective techniques.[481]

Throughout this study, most of the representations discussed are utilised for means of analysis and representation of landform. The choice of representation depends on the aspect to be analysed, and various methods are often combined. However, since hill-shading, with and without contours (with an interval of 5 metres) in a 2D or 3D setting, is one of the most effective means of utilising recognition of landform via the production of easily perceived depth in the DEMs, this will be the preferred mode of presentation.[482] Both hill-shades and contour lines are derived from the DEMs themselves via GIS-based calculation.

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[470] Imhoff, 1965, p. 229ff.

[471] Imhoff , 1965, p. 334ff; Brewer, 1994, p. 123ff.

[472] Brewer, 1994, pp. 137-138.

[473] Ibid., p. 138.

[474] Eyton, 1990.

[475] Imhoff , 1965, p. 190ff; MacEachren, 1995, p. 141; Robinson et al., 1995, p. 544.

[476] Imhoff, 1965, p. 196ff; MacEachren, 1995, pp. 142-143; Chang, 2010, p. 273.

[477] Ibid.

[478] Imhoff, 1965, p. 230ff; Chang, 2010, p. 274ff.

[479] MacEachren, 1995, p. 139ff.

[480] Ibid.

[481] See for the use of fishnet-plots: Rowles, 1978.

[482] Eyton, 1990; Collier et al., 2003.

DEM 1722 and DEM < 1722

The bathymetric contour lines played an important role in reconstructing the landform of Stourhead 1722 (t_0), since they partially reveal the shorelines of the medieval fishponds. In combination with the vectorised basin shorelines, derived from the geo-rectified 1722 map, the precise location of the medieval fishponds could be determined and consequently used to calibrate the form of the vectorised shorelines. The combination of the location and form of the fishponds and the bathymetric data made it possible to locate the former dams and the related heights in the DEM used earlier to construct the DEM 1785-2010. This resulted in DEM 1722, which showcases the probable form of the valley in 1722 with the medieval dams [Figure 3.20].

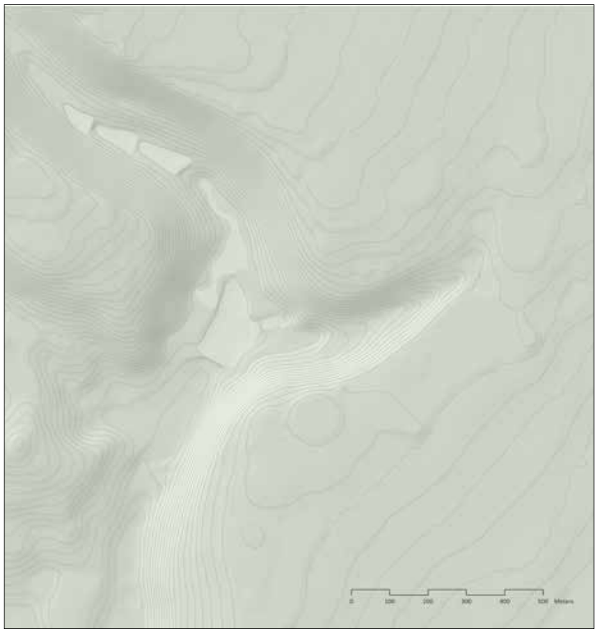

FIGURE 3.20 2D-representation of the DEM 1722 with the medieval dams defining the fishponds (map: Steffen Nijhuis)

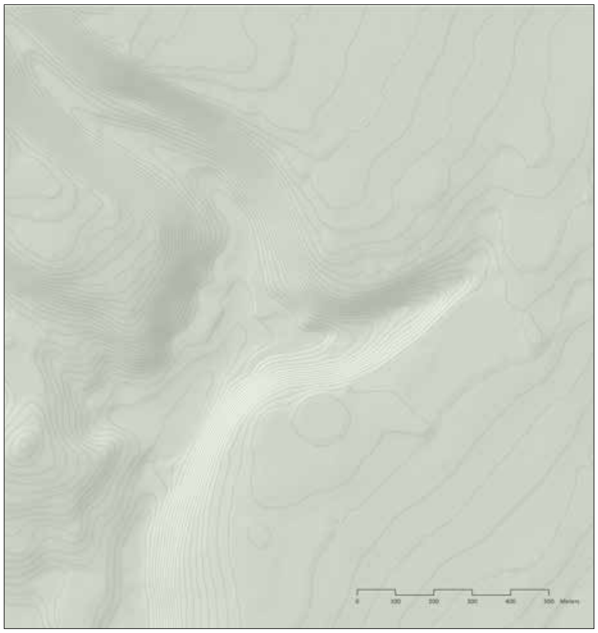

FIGURE 3.21 2D-representation of the DEM <1722 representing the form of the valley before the dams were constructed (map: Steffen Nijhuis)

Based on the DEM 1722, the landform before 1722 could be interpolated based on an evenly distributed gradient derived from known terrain heights. The resulting DEM <1722 showcases the probable natural form of the valley before it was dammed and the water bodies were established [Figure 3.21].

§ 3.4.3 From DEMs to DLMs

In order to construct the DLMs the DEMs are supplemented with topographic features such as water, vegetation, and built and constructed elements (and their subcategories) that make up the landscape architectonic composition [Table 3.2]. Planimetric and volumetric data is crucial to create virtual landscapes representing the physical shape and pattern of the site as it lies within one's own direct experience.

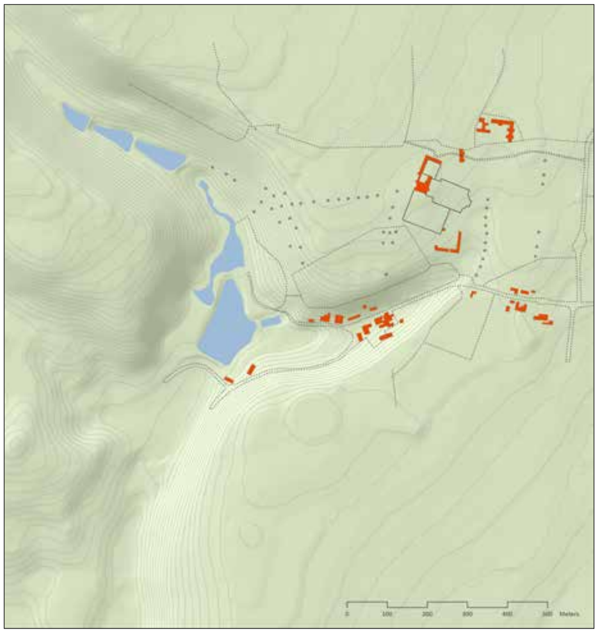

FIGURE 3.22 2D-representation of Stourhead 1722 (t_0) with associative colouring and landform with shading (map: Steffen Nijhuis)

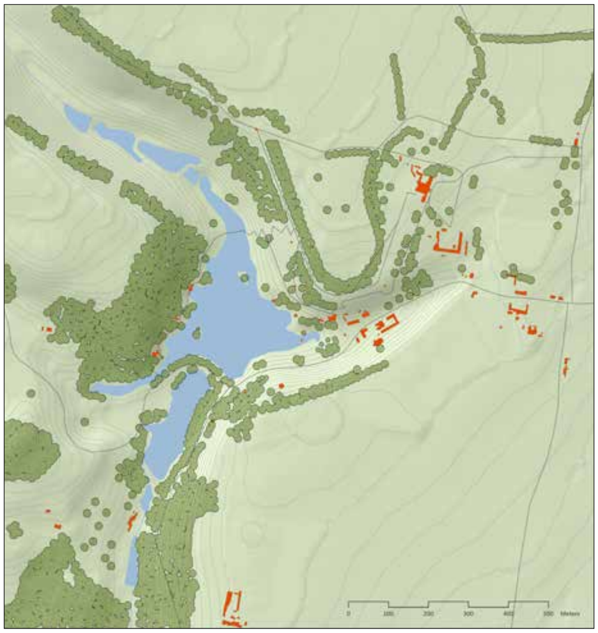

FIGURE 3.23 2D-representation of Stourhead 1785 (t_1) with associative colouring and landform with shading (map: Steffen Nijhuis)

The DEM 1722 was the basis for the DLM of Stourhead 1722 (t_0). In order to create DLM 1722, only water and buildings could be added as there is no cartographic information available on woodland. The DLM 1722 will therefore only be used as a reference for Stourhead's initial state [Figure 3.22].

The DEM 1785-2010 was the basis for the DLMs of Stourhead 1785 (t_1), Stourhead 1887 (t_2) and Stourhead 2010 (t_3). When creating DLM 1785, DLM 1887 and DLM 2010 it was possible to add all relevant topographic features in 2D and 3D definitions with a resolution corresponding with a map scale of about 1:2,500. These three DLMs will play a central role in the exploration of Stourhead's landscape architectonic composition and its development [Figure 3.23, Figure 3.24 & Figure 3.25]. For the DLM 2010, it was possible to add the current heights of the buildings, trees, vegetation and architectural artefacts based on measurements and estimates of the current situation. The important buildings and architectural artefacts of Stourhead were accurately and digitally modelled in three dimensions (3D-geometry) in CAD and 3D-modeling software[483] [Figure 3.26]. These models were later imported and geo-referenced in GIS. Some generic 3D-trees were also generated, reflecting the habitus of common tree species in the woodlands of Stourhead on the ridges (e.g. Park Hill, Convent Bottom, Great Combe). The 3D-trees were evenly distributed within the contours of woodland.

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[483] 3D-studio max. This laborious work was mainly done by Joris Wiers.

FIGURE 3.24 2D-representation of Stourhead 1887 (t_2) with associative colouring and landform with shading (map: Steffen Nijhuis)

FIGURE 3.25 2D-representation of Stourhead 2010 (t_3) with associative colouring and landform with shading (map: Steffen Nijhuis)

Estimating height of trees and woodland in historical situations

For the DLM 1785 and DLM 1887 the heights of trees and woodland had to be estimated. Based on plant physiological characteristics (e.g. kinetics of growth) it is possible to calculate (ideal) growth curves, expressed in units of time and units of size.[484] These growth curves are logarithmic and ideally express an exponential phase, a linear phase and a decreasing growth rate related to the life cycle of the individual species and accounting for location factors (e.g. soil, water supply).[485] Since the growth curve depends on the species, data about heights in relation to time was collected in order to create species-specific growth curves. Useful sources are Colvin (1972) and Ruyten (2006) who measured growth of different species over a longer period of time [Figure 3.27]. This data was logarithmically plotted via a statistical regression or trend line-analysis.[486]

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[484] Bidwell, 1979, p. 379ff.

[485] Bidwell, 1979; Ruyten, 2006.

[486] Second order polynomial regression / trend line-analysis.

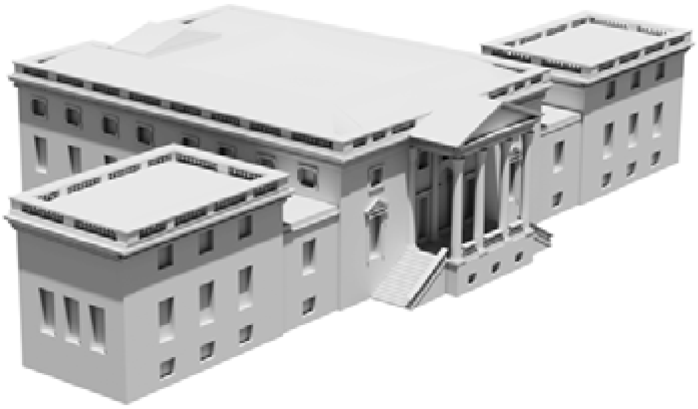

FIGURE 3.26 Schematic-iconic 3D-model of Stourhead House (model: Steffen Nijhuis & Joris Wiers)

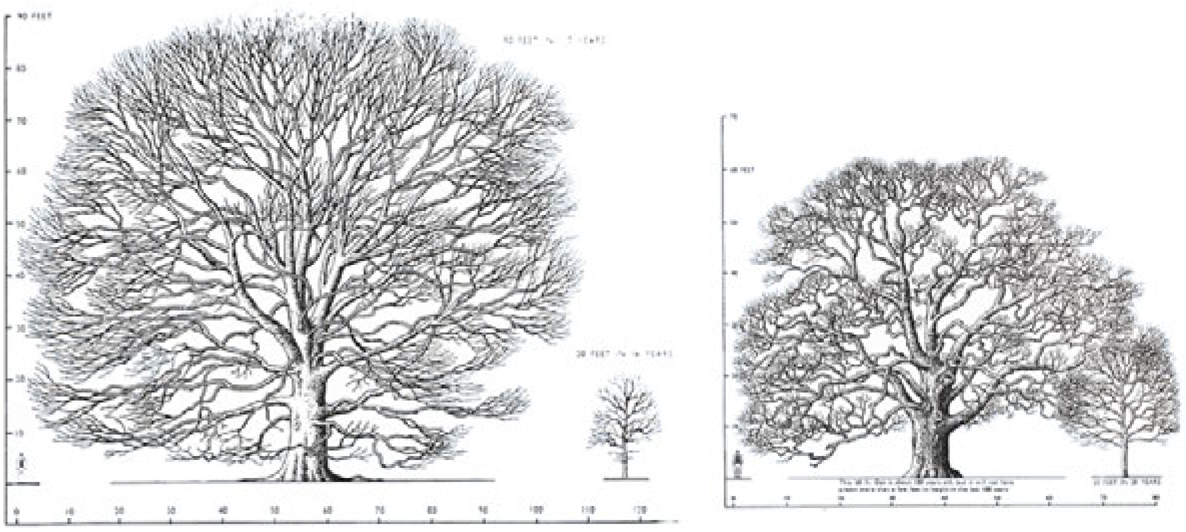

FIGURE 3.27 Comparison of the habitus and growth of beech (left) and oak (right) (image source: Colvin, 1972)

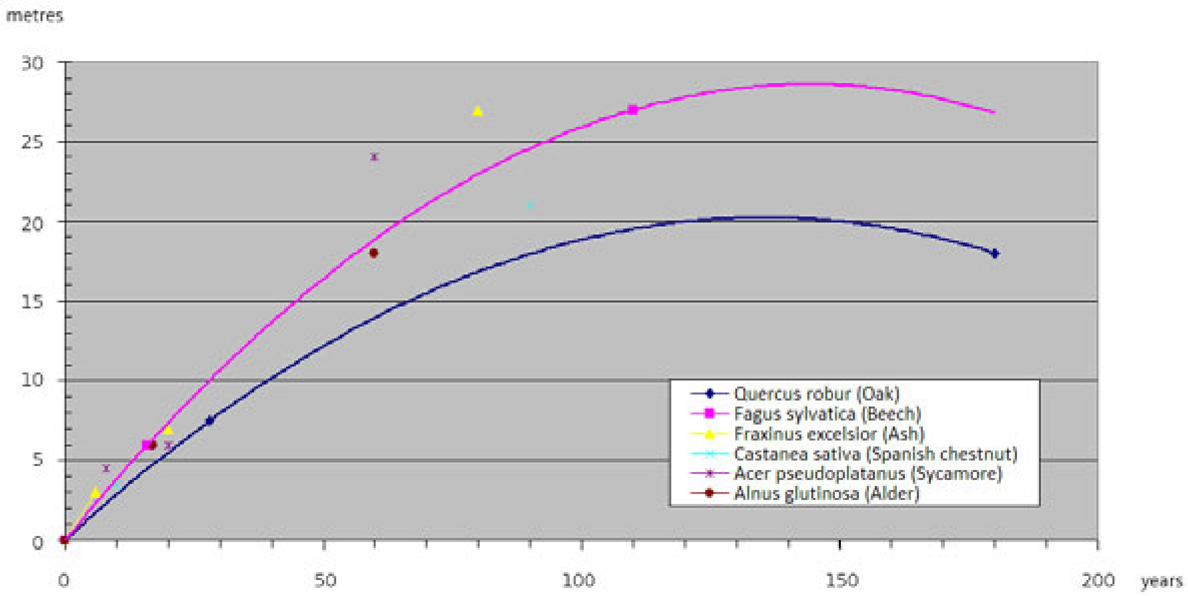

FIGURE 3.28 Distribution of measured growth in height over time for different tree species augmented with a logarithmic plot of the growth curves of beech and oak (analysis by Steffen Nijhuis. Data derived from: Colvin, 1972; Ruyten, 2006)

In order to estimate the heights of the trees and woodland in 1785 and 1887, based on growth curves, it was important to know the common species and their composition. Based on information provided by the forest managers[487] and personal inventories[488] it was possible to specify the woodlands as a type of dry-land woodland.[489] It is characterised by broadleaves such as oak (*Quercus robur*) and ash (*Fraxinus excelsior*), with beech (*Fagus sylvatica*), sweet chestnut (*Castanea sativa*) and sycamore (*Acer pseudoplatanus*). Alder (*Alnus glutinosa*) , ash (*Fraxinus excelsior*), and willow species (e.g. *Salix cinerea*) are coppiced in the wetter areas. However, some stands are dominated by conifers planted for purposes of timber harvesting. Conifer species include: douglas fir (*Pseudotsuga menziesii*), spruce (*Picea abies*), larch (*Larix europaea*), Western red cedar (*Thuja plicata*) and Western hemlock (*Tsuga heterophylla*). For the planting and individual trees in the Valley Garden, the surveys of the National Trust (1973/2000, 1981) were of great use, as were the historical inventories by Woodbridge (1976, 1982/2002).[490]

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[487] Hoare, 2013.

[488] During multiple field visits in July 2009 and July 2011.

[489] It is likely to be an intermediate *Fraxinus excelsior-Acer campestre-Mercurialis* (W8) and *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland (W10). See for descriptions: Rodwell, 1998; Hall et al., 2004.

[490] The National Trust recently initiated an inventory project for recording individual ornamental trees and shrubs with GPS complemented with descriptions in a digital database. However, at the time of this study the database was not ready for use yet.

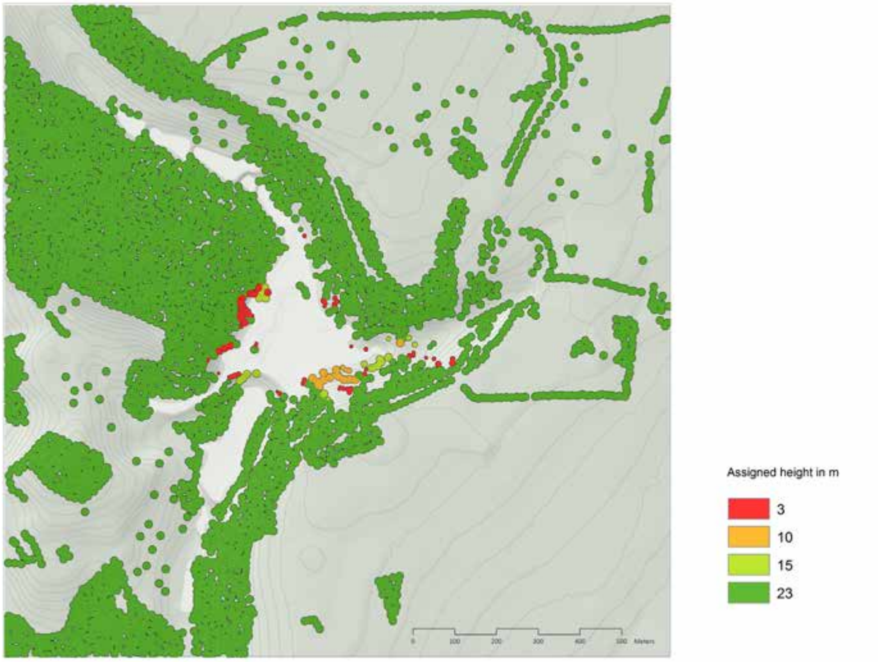

FIGURE 3.29 Assigned heights of shrubbery, trees and woodland in the DLM 2010 (map: Steffen Nijhuis)

The result is shown in figure 3.28, which was the basis for determining the heights of trees and woodland in 1785 and 1887 [Figure 3.28]. The tree species with a long life span were specifically chosen (e.g. oak and beach) to give a representative estimation. The resulting heights for the historical situation were calibrated by interpreting contemporary views of the estate represented by the etchings, drawings and paintings of Bampfylde (1770), Piper (1779), Grimm (1790), Nicholson (1813), as discussed previously. The (calibrated) average height of the trees and woodland is 12 metres for DLM 1785 and 17 metres for DLM 1887. The height of shrubbery is 2-5 metres for DLM 1785 and 2-10 metres for DLM 1887. An average height of 23 metres is assigned for trees and woodland in DLM 2010. This corresponds with the observed average heights of this type of woodland. Some individual trees around the lake have a lower average height varying from 10-15 metres. The average height of shrubbery is estimated at 3 metres [Figure 3.29]. The average heights were added to the 2D raster and vector definitions of trees and woodland of the DLMs, to provide realistic topographic models including vegetation heights. The DLMs do not include the seasonal changes of the planting mass, and the transparency of the woodlands and shrubbery was not taken into account either.[491]

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[491] Buitenhuis et al., 1979; Piessens, 1985.

§ 3.5 Conclusion

As discussed earlier, topographic data are essential for conveying the physical shape and pattern of the landscape garden as it is actually experienced by people and are therefore an important basis for the analysis of its landscape architectonic composition. The available topographic data are regarded as the empirical basis for the reconstruction of the historical situation, as well as a feasible representation of the current situation. This chapter demonstrates the great wealth of topographic data for Stourhead landscape garden available in analogue and digital form. Cartographic sources are particularly regarded as main sources of topographic data, especially on landform, hydrography, vegetation, built and constructed elements. The available maps offer time-sliced snapshots of the estate representing it at important moments in time and providing information on the development of the landscape architectonic composition. In order to ensure planimetric, chronometric, and topographical accuracy, the topographic data was evaluated by means of cartometric and cross-source analysis. Based on this analysis, useful topographic data was selected, and when needed geo-rectified and vectorised and augmented with information about heights etc.

Based on the incidence, chronology, and nature of the cartographic data four significant time-slice snapshots could be determined, which will serve as the basis for the landscape architectonic analysis: Stourhead 1722 (t_0), Stourhead 1785 (t_1), Stourhead 1887 (t_2) and Stourhead 2010 (t_3). These time-slice snapshots roughly correspond with the year of inheritance and death of the subsequent owners Henry Hoare II (inheritance 1724 - death 1785) and Colt Hoare (inheritance 1785 - death 1838). Since both created the landscape garden as we now know it, these time-slice snapshots mark important stages in the development of the landscape architectonic composition. It is possible to articulate the periodisation based on documentary sources highlighting singular events (e.g. the building of particular features) or different stratification of sequences of events. However, since the periodisation is based on the availability and accuracy of cartographic data, articulation of the periodisation is only possible for parts of the estate, but not for its entirety. The available topographical data were processed and included, particularly for the initial stages of the development of the Pleasure Garden around the house (from 1733 onwards). For Stourhead 1722 (t_0), it was not possible to reconstruct the patterns of vegetation for the whole estate, since there was no topographic data available.

The four time-slice snapshots are an accurate and credible basis for the construction of DEMs and DLMs of Stourhead landscape garden that contain relevant topographic features for landscape architectonic analysis. The DEMs and DLMs are unique because they contain commonly available topographic data (e.g. roads, woodland) supplemented with specific tailor -made data (e.g. individual trees, height of the medieval dams, footpaths) as a basis for GIS-based analysis of the landscape architectonic composition.

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4 Exploring Stourhead landscape garden

§ 4.1 GIS-based analysis of the designed landscape

The GIS-based analysis encompasses the application of GIS in the framework for landscape design analysis, while exploiting different principles of GIS-based analysis and visual representation of Stourhead landscape garden [Figure 4.1]. The four time-slice snapshots, represented by the DEMs <1722, 1722, 1785-2010 and the DLMs Stourhead 1722 (t_0), Stourhead 1785 (t_1), Stourhead 1887 (t_2) and Stourhead 2010 (t_3), form the basis of the analysis. These DLMs represent important time-stages in the development of the landscape architectonic composition and enable one to understand it as a long-term structure. The analysis starts with exploring the basic form, addressing Stourhead in its natural context as an important pre-condition for the design. The layout and the development of Stourhead House and garden will then be looked at, as the basis of the composition. The analysis of the spatial form focuses on the three-dimensional construction and the visual manifestation of the designed landscape. The potential relationship between space and meaning is investigated, by exposing the morphological conditions for reception – its symbolic form. This can be regarded as the interface between the intentions of the designer and the reception of the users, provoking emotions, ideas and stories. The analysis of the programmatic form focuses on functional patterns and use of the grounds. Comparing the results of the various analytical operations the object-related findings on Stourhead landscape garden can then be summed up.

§ 4.2 Stourhead in context: The natural landscape

The natural landscape is the pre-condition for different forms of land-use and landscape design interventions. In this respect the features and processes of the natural landscape are fundamental resources, as they supply the materials from which the cultural landscape is formed.[492] Major features and processes of the natural landscape like geological formations (incl. soil), landform, climate and water will be looked at as important conditions for the development of the landscape architectonic composition.

§ 4.2.1 Geological setting

The analysis points out that Stourhead landscape garden is situated in an escarpment landscape on a greensand ledge below the chalk lands [Figure 4.2]. This geological landscape was primarily shaped during the ice-ages, which lasted until 10,000 BC.[493]

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[492] Sauer, 1925/1963, p. 333ff.

[493] Allen & Gardiner, 2006, p. 13ff.

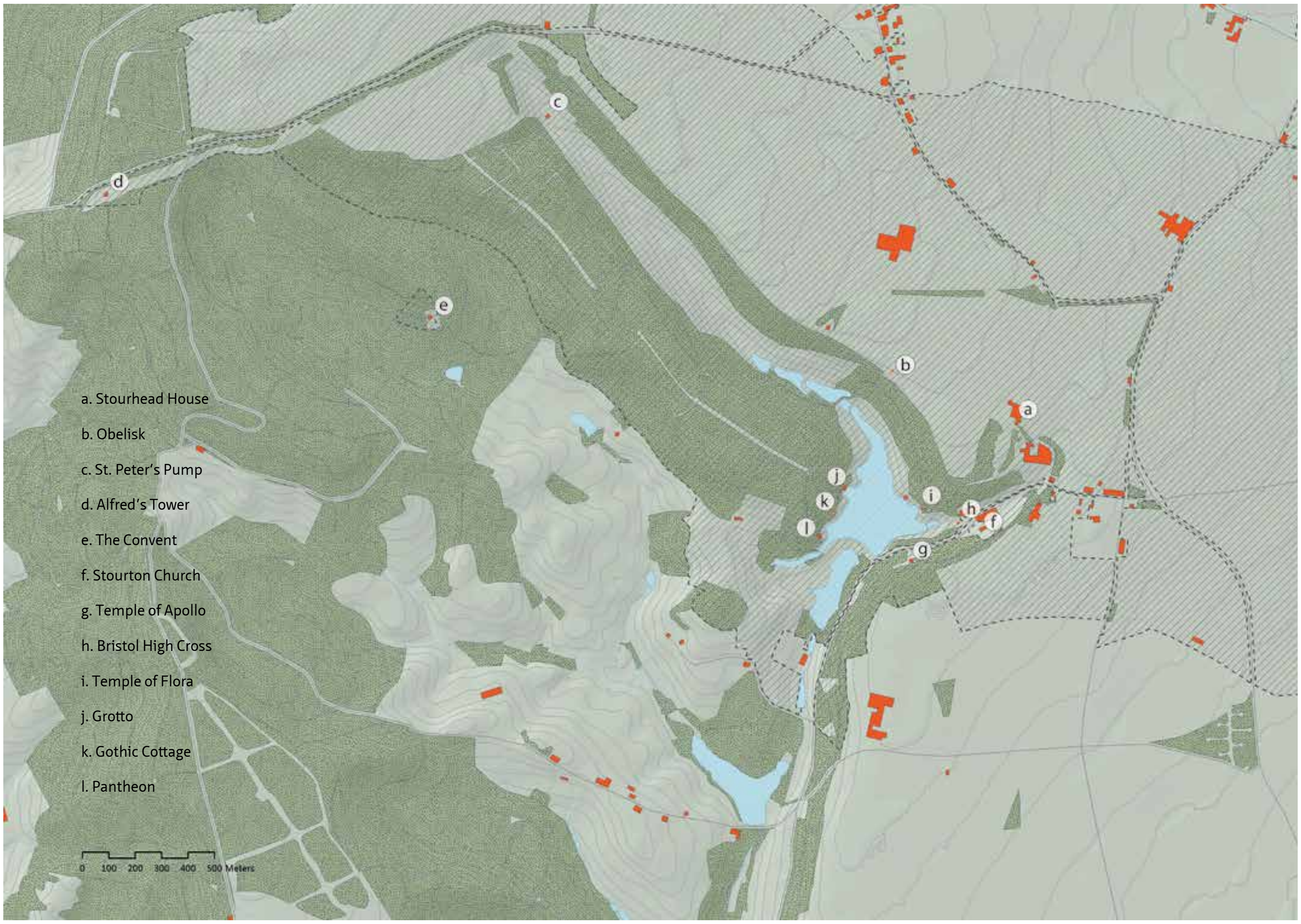

FIGURE 4.1 Stourhead landscape garden with the locations of important architectural features, situation 2010.
→ Composite GIS-map with overlay of woodlands, buildings, roads and water on shaded relief (map: Steffen Nijhuis, based upon OS VectorMap District 1:25,000 with the permission of British Ordnance Survey, and National Trust Ownership)

During the glaciations the advance and retreat of ice sheets repeatedly locked up and released millions of litres of water. The erosion of (melt)water has removed the weakened chalk and exposed the underlying up-folding older greensand rock. Greensand is a shallow marine sediment dating from the Cretaceous era (millions of years ago), which was a relatively warm period, with high sea levels creating numerous shallow inland seas. In this shallow water glauconitic sand accumulated and developed into sandstone. Later, the ice sheets sculpted and moulded the hard rock, over which they flowed, into the smoothed form it has nowadays.[494] During the last ice age the ice did not reach this region. The formative processes of erosion and sedimentation by meltwater, icy winds and temperature differences (freezing and thawing) articulated the geological landscape, softening the harder rock with gentle slopes and varying profiles, and were also important for soil formation.[495]

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[494] Ibid.

[495] Ibid.

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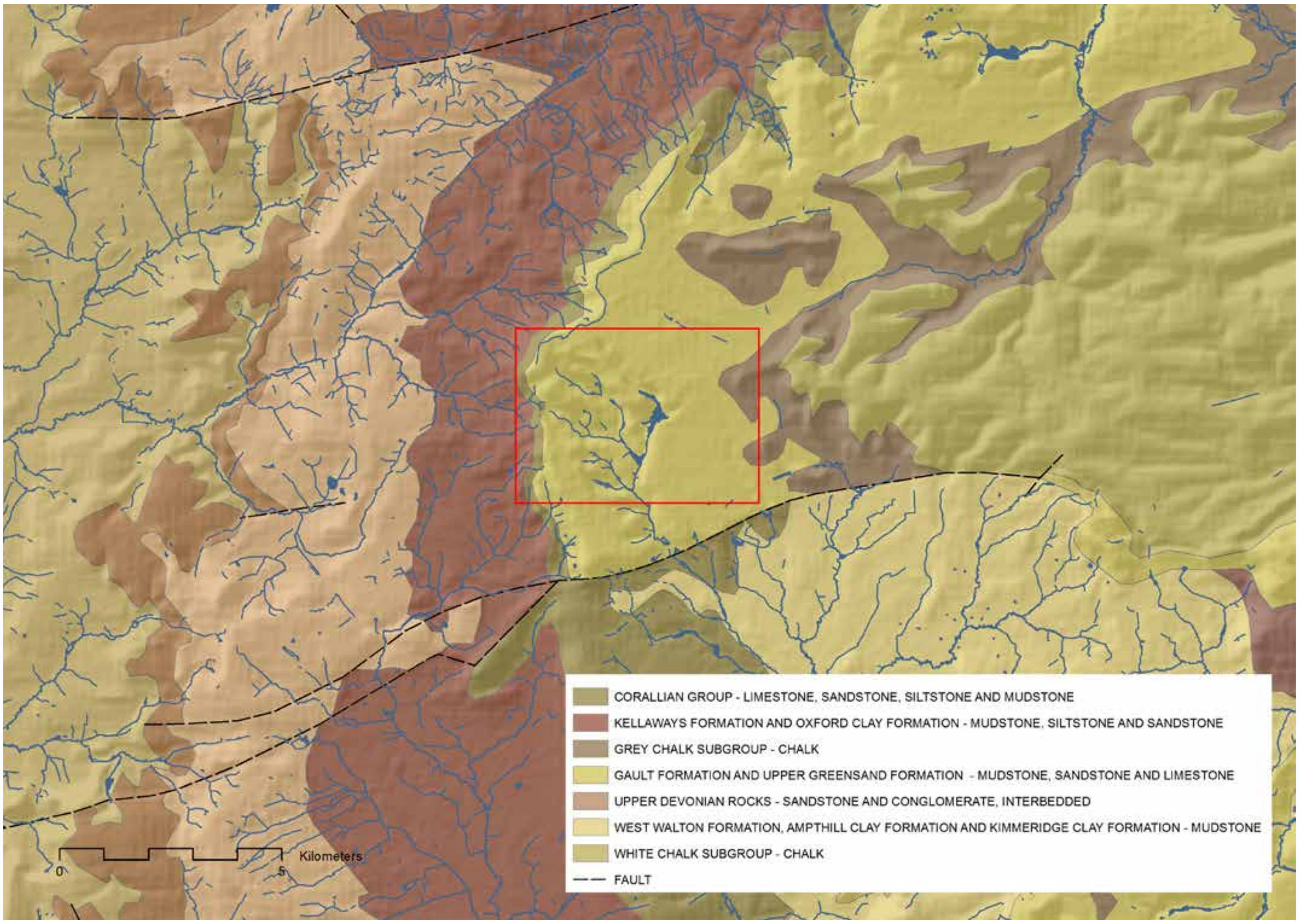

FIGURE 4.2 Stourhead in its geological context. The landscape garden is situated in an escarpment landscape on a greensand ledge below the chalk lands, in geological terms part of the Upper Greensand formation with silty sand and sandstone, as well as part of the Gault formation with heavy clay.
→ Composite GIS-map with overlay of geology and water on shaded relief (map: Steffen Nijhuis, based upon DiGMapGB-625, 1:625,000, with the permission of the British Geological Survey; and OS VectorMap District hydrography 1:25,000 with the permission of British Ordnance Survey)

The undulating greensand ledge can be characterised by two soil formations: the Upper Greensand formation, which consists of silty sand and sandstone, and the lower lying and poorly draining Gault formation which consists of heavy non-calcareous clay (mudstone).[496] In the eastern part of Stourhead landscape garden the Upper Greensand formation can be found, which consists of well-drained sandstone [Figure 4.3]: the Boyne Hollow Chert (sand and chert), and Shaftesbury Sandstone (alternating beds of sand and sandstone). The western part, the Stour valley, consists of the poorly draining Cann Sand (fine-grained yellowish, glauconitic sand) and mudstone: the underlying Gault Clay (fine-grained, greenish, glauconitic sandy clay). The latter keeps water in and provides for boggy conditions.

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[496] Bristow et al., 1999; Geddes, 2000.

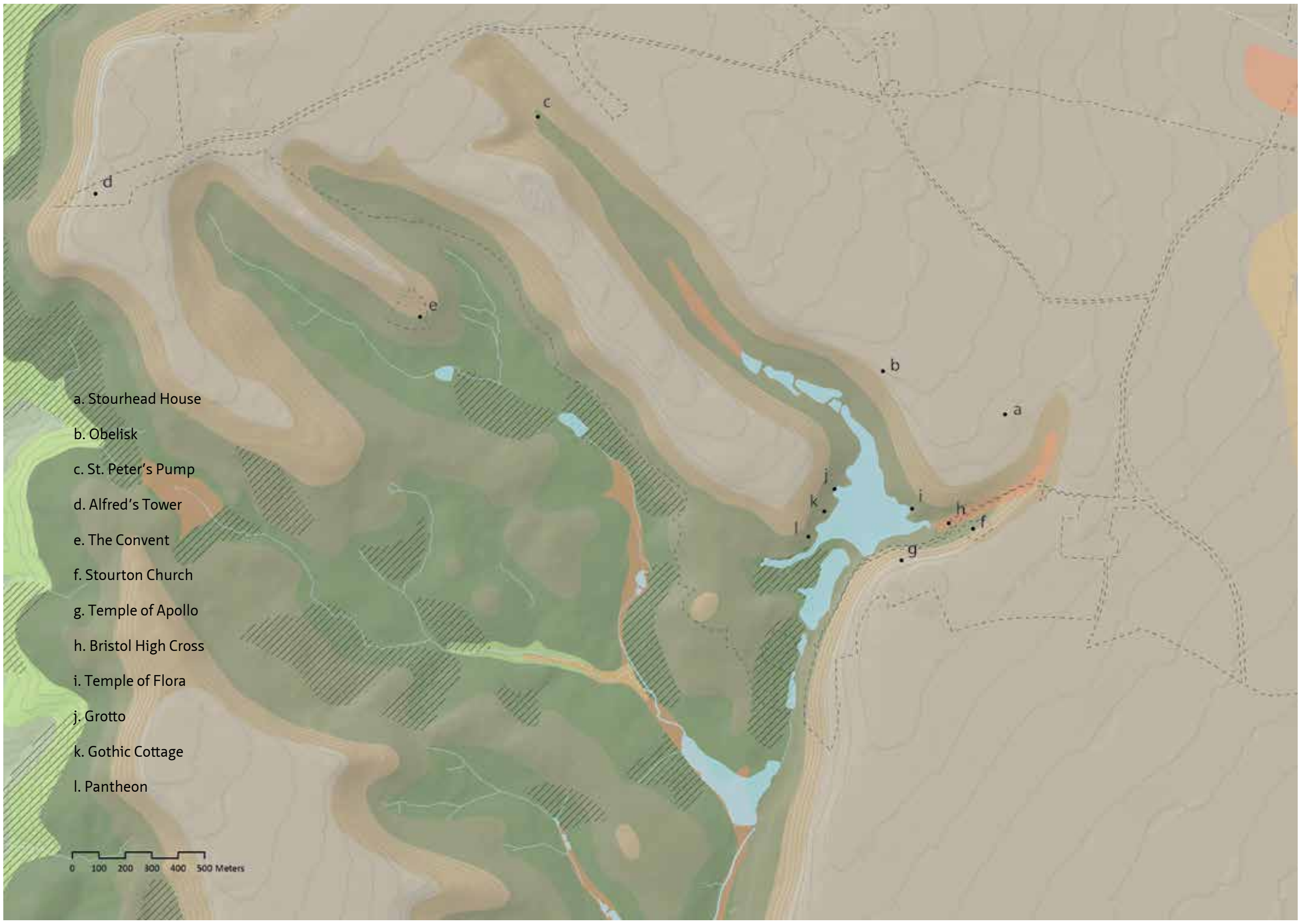

FIGURE 4.3 Distribution of soil. In the eastern part well drained sandstones such as the Boyne Hollow Chert and Schaftesbury Sandstone. In the western part, the Stour valley, the poorly draining Cann Sand and the mudstone of the Gault Clay.
→ Composite GIS-map with overlay of soil on shaded relief augmented with contour lines and locations of the main architectural features and water bodies (map: Steffen Nijhuis, based on BGS 1:50,000 soil database, with the permission of the British Geological Survey)

§ 4.2.2 Geomorphology

Due to its geological setting the grounds offer a great variety in geomorphology, in the form of a plateau (or terrace), valleys[497], hills, and gentle and steep slopes. The variations in landform are analysed via morphometric analysis of the DEM, with elevation, slope (gradient) and aspect (orientation) as important indicators for the basic form.[498] These are important determinants for drainage patterns, suitability for the growth of vegetation and the design of features such as paths and buildings.

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[497] Valleys are also called 'bottoms' or 'combes'.

[498] Kimerling et al., 2009, pp. 347-364.

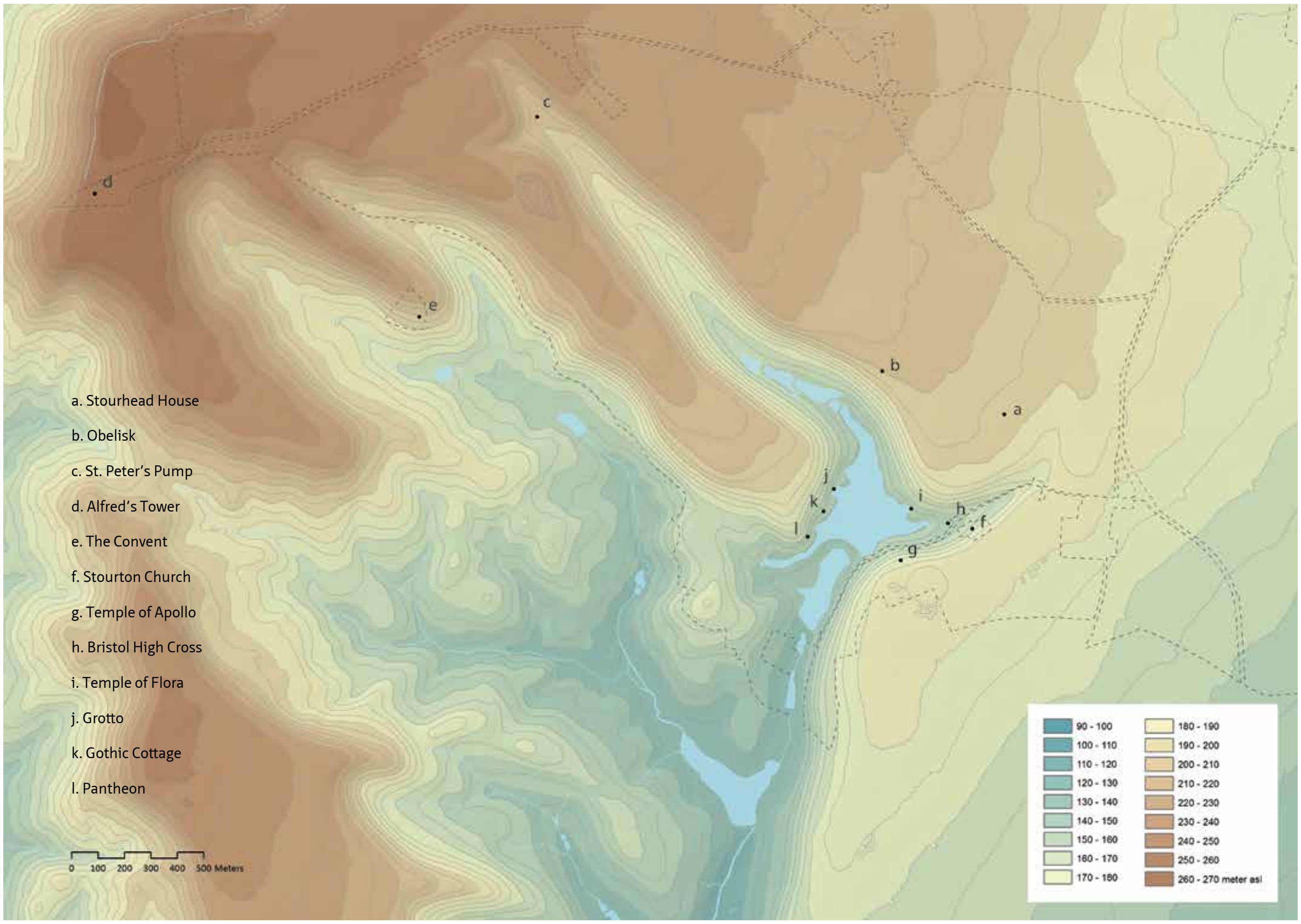

FIGURE 4.4 Elevation. The height of the land surface varies from 262 metres above sea level in the west (Kingsettle Hill) to 99 metres in the south (Stour Valley). → Composite GIS-map with overlay of elevation on shaded relief augmented with contour lines and locations of the main architectural features and water bodies (map: Steffen Nijhuis, based on DEM 2010)

The elevation map [Figure 4.4] represents the height of the land surface above average sea level, and varies from 262 metres in the west (Kingsettle Hill) to 99 metres in the south (Stour Valley). The elevation map indicates that the grounds of Stourhead roughly consists of two geomorphological complexes: the plateau and valley. The higher part corresponds with the sandstone and is a plateau with several prominent hills and ridges, such as the Greensand Hills of Stourhead, and chalk downs – sitting atop the Greensands (e.g. Zeals Knoll, Beech Knoll). To the south, in the centre of the map, the grounds fall steeply to a dip where several valleys converge, henceforth called the valley, with the Cann Sand and mudstone.

The analysis of the variation in slopes is expressed in percentages [Figure 4.5]. The percentage slope is a measurement of the rate of change of elevation over a given horizontal distance, in which the rise is divided by the run and then multiplied by one hundred (a 45-degree slope and a 100-percent slope are the same).[499] The dominant slope percentages on the plateau vary from 0% to 10%.

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[499] Wade & Sommer, 2006, p.159.

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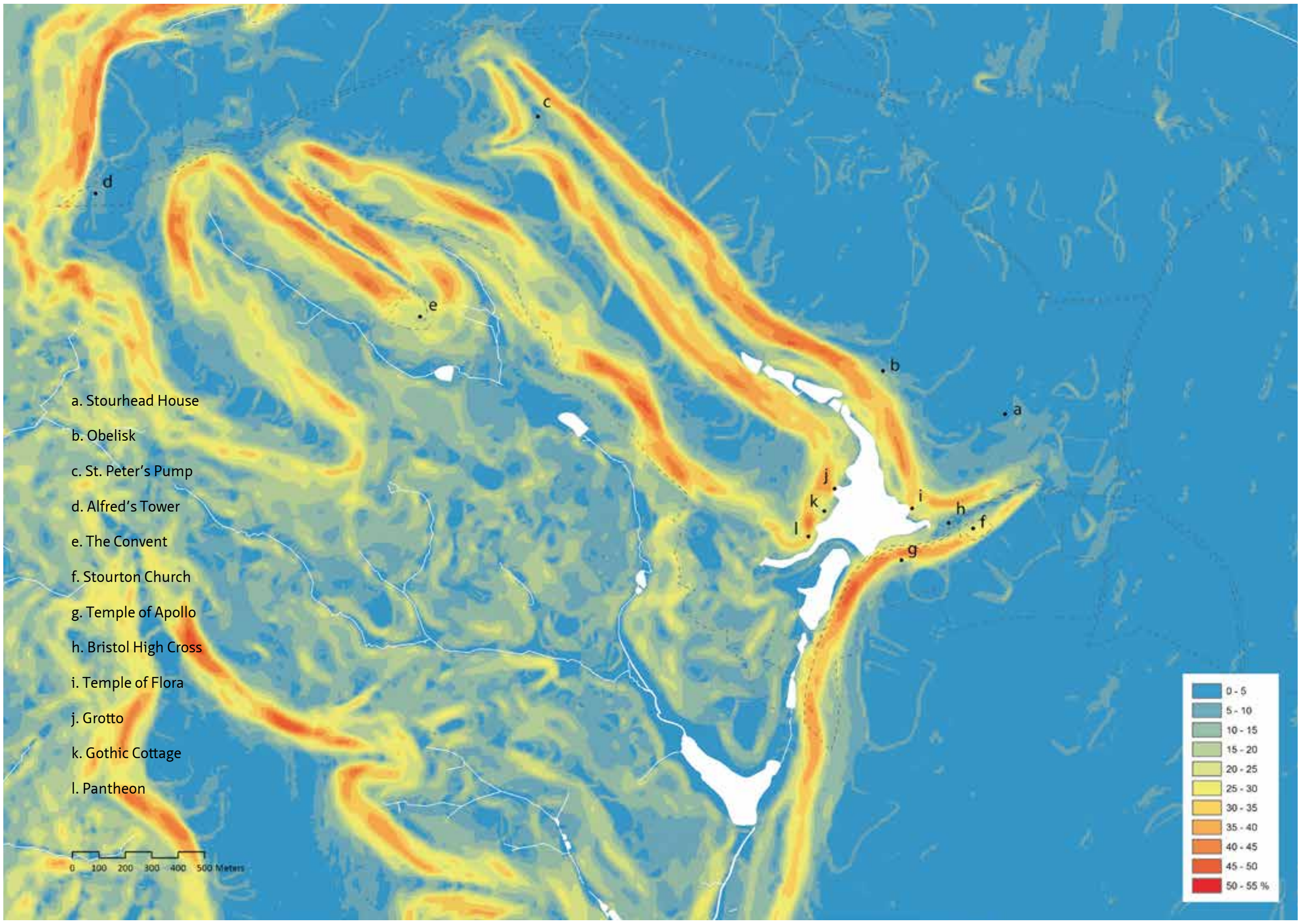

FIGURE 4.5 Slope. The variation in slopes expressed in percentages, with maxima varying from 28% to 47%.
→ GIS-based morphometric analysis of DEM 2010 using Spatial Analyst (map: Steffen Nijhuis)

On the edges, towards the valley (e.g. south of Stourhead House), steeper slopes can be found varying from 10% to 20%. The slopes in the valley correspond with the critical angles of repose related to the top soils present [500], with maxima ranging from 28% to 47%. The critical angle of repose indicates the maximum angle to which soils can be piled without sliding down. Steeper slopes (higher percentages) indicate rough, interlocking sands, while less steep slopes are an indication of smooth, rounded sand grains.

The analysis of slope orientation [Figure 4.6], the compass direction that a topographic slope faces (measured in degrees from north)[501], shows that the plateau's orientation varies from northeast to southeast. Combining this with slope angle indicates that the plateau is gradually sloping down to the southeast. The basic form of the valley has two branches: a western and an eastern branch. These are stream forms and come together in the central part of the valley that opens up to the south. The valley as such consists of a wide variety of different slope orientations and angles, resulting in asymmetrical valley forms. The shallow slopes are west and south facing and have a concave form. The steep slopes are the north-east facing slopes and have a convex form [Figure 4.7].

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[500] Neufert & Neufert, 2012, p. 428.

[501] Wade & Sommer, 2006, p. 10.

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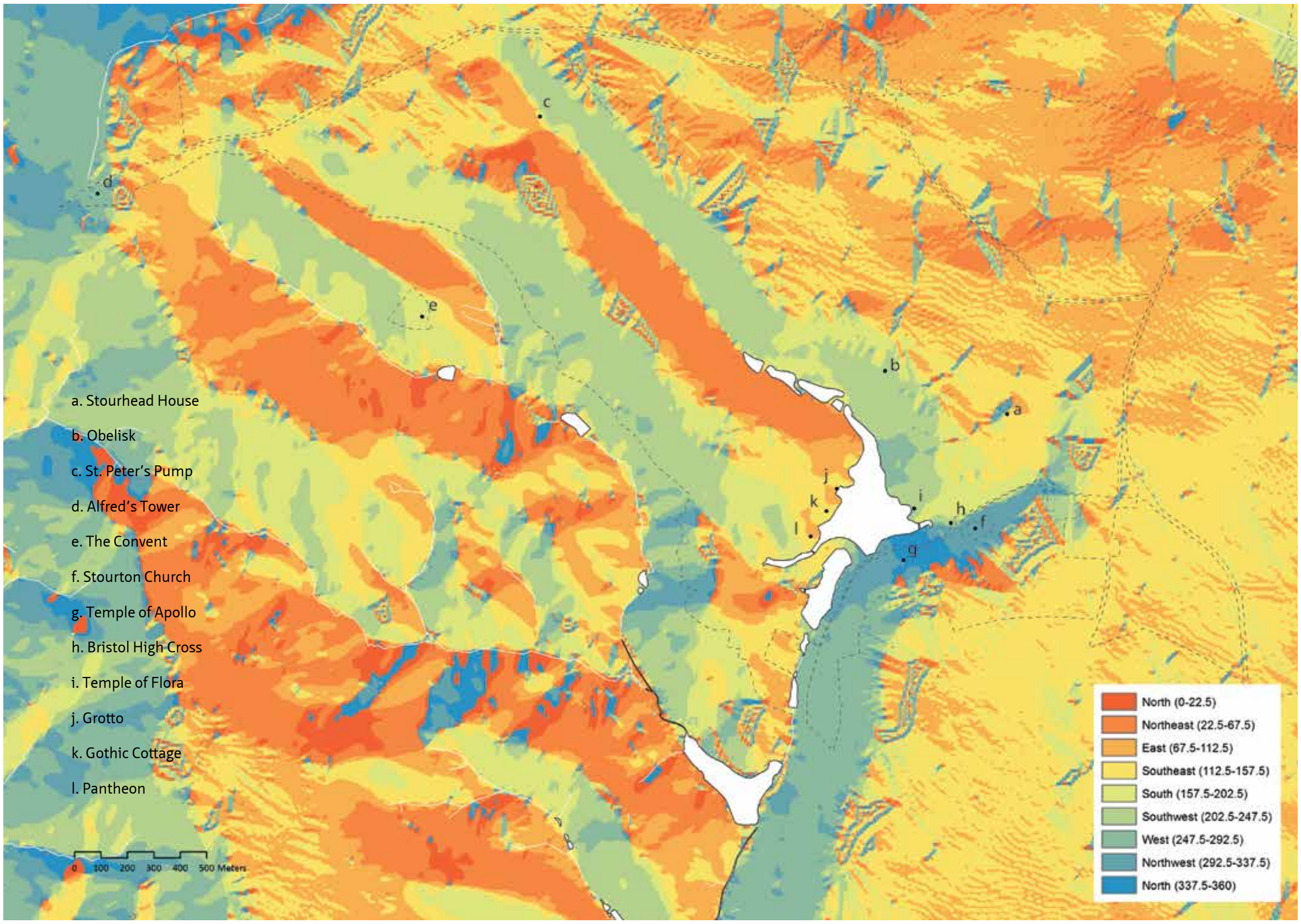

FIGURE 4.6 Aspect. Slope orientation expressed in compass direction a topographic slope faces, measured in degrees from north.
→ GIS-based morphometric analysis of the orientation of the slopes based on DEM 2010 using Spatial Analyst (map: Steffen Nijhuis)

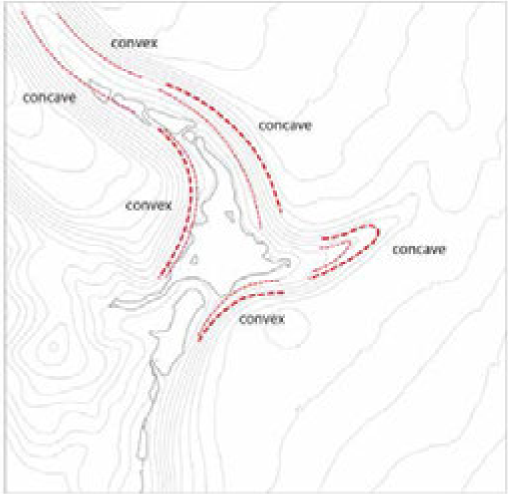

FIGURE 4.7 Close-up: The asymmetrical nature of the valley (drawing: Steffen Nijhuis)

The asymmetrical basic form of the valley is due to geomorphological processes of erosion and sedimentation by water, but also influenced by microclimatic differences determined by the orientation of the slopes, particularly regarding temperature.[502]

§ 4.2.3 Climate

Next to the physical conditions climate and microclimate have a big impact on natural patterns. Climate addresses slowly varying aspects of the atmosphere-hydrosphere-land surface system.[503] Meteorological variables such as long-term (average) patterns of wind, precipitation and temperature are important. Incoming solar radiation (insolation) is also an important determinant.

Stourhead landscape garden is located in a warm temperate humid region.[504] Maps generated from climatic GIS-data[505] show regional variations in precipitation patterns with averaged maxima between 784 and 894 mm annually [Figure 4.8]. Higher amounts of precipitation occur around the ridges in the west, due to high rates of evaporation from the forests located there. Lower amounts are associated with the lower parts of the region, such as the valley. The temperature in the warmest month is on average lower than 22°C, and for four or more months of the year remains above 10°C. A climatogram [Figure 4.9] based on a fifteen-year statistic from the nearest weather station at Yeovilton[506] provides a more detailed image of the seasonal variation in temperature. The coldest months are December, January and February, when the temperature is usually between 3 and 6°C. In July and August, the temperature averages between 16 and 21°C. The main wind comes from south-west [Figure 4.10].

For a deeper insight into solar radiation at Stourhead, the insolation has been calculated by means of solar radiation analysis tools.[507] The calculation is based on the DEM and involves atmospheric effects, site latitude and elevation, steepness (slope) and compass direction (aspect), daily and seasonal shifts of the sun angle, and effects of shadows cast by surrounding landforms.[508] The insolation is expressed in unit watt-hours per square metre (Wh/m2). The analysis points out that, throughout the year, the highest amounts of insolation can be found on the south and west facing slopes of the western ridge and the valley [Figure 4.11]. These places get the most sun and are warmer than others.

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[502] For example: Slope orientation affects the angle of sun rays hitting the ground. As a result west-facing slopes will be warmer than sheltered east-facing slopes. In the formation of the valley solifluction, a slow mass wasting slope process, was probably strongly influenced by this difference. Solifluction describes the slow down-slope movement of water-saturated sediment due to recurrent freezing and thawing of the ground. Affected by gravity, this process eventually produces smooth, gentle, concave forms on west and south facing slopes (Zonneveld, 1981; Easterbrook, 1999).

[503] American meteorological society, 2012.

[504] 'Cfb' according to the Koeppen & Geiger climate classification.

[505] Hijmans et al., 2005.

[506] Data from the weather station at Yeovilton derived from the National Climatic Data Center (NCDC).

[507] These tools calculate insolation across a landscape or for specific locations, based on methods from the hemispherical viewshed algorithm developed by: Rich, 1990; Rich et al., 1994, and further developed by Fu & Rich, 2000, 2002.

[508] Fu & Rich, 2000.

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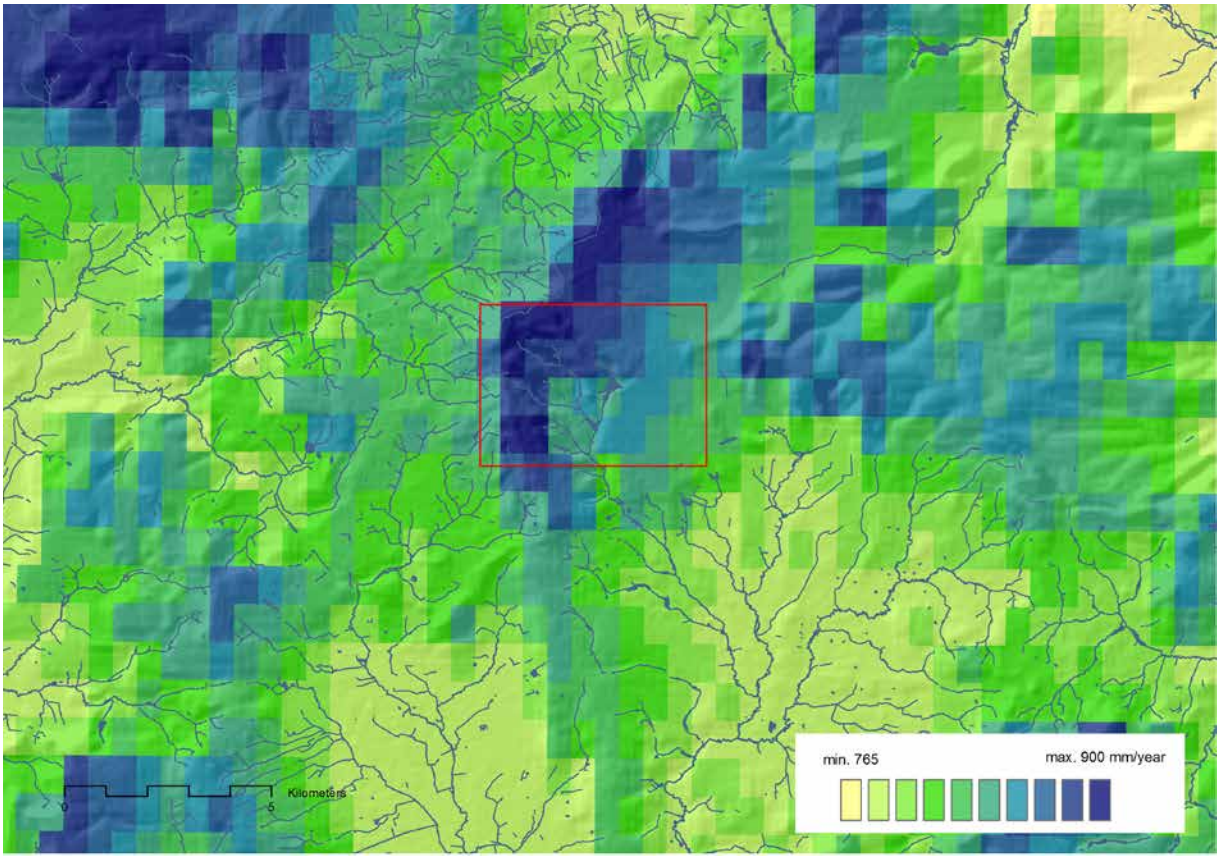

FIGURE 4.8 Annual precipitation based on geo-statistical analysis.
→ Composite GIS-map with overlay of precipitation pattern and water on shaded relief (map: Steffen Nijhuis, precipitation based upon Hijmans et al. 2005; hydrography based upon OS VectorMap District 1:25,000 with the permission of British Ordnance Survey)

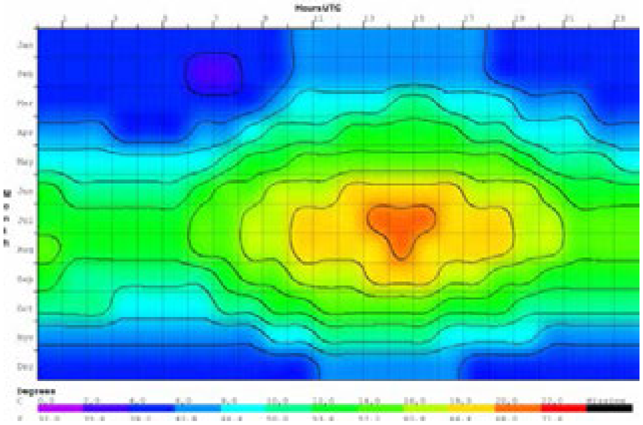

FIGURE 4.9 Climatogram, geo-statistical analysis of temperature at Stourhead landscape garden. Based on observations in the period 2000-2014 at the nearest weather station Yeovilton (source: NCDC-USA)

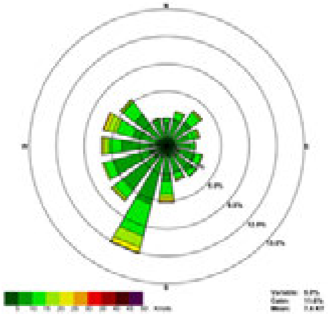

FIGURE 4.10 Wind rose, geo-statistical analysis of prevailing wind directions at Stourhead landscape garden.
Based on observations in the period 2000-2014 at the nearest weather station Yeovilton (image source: NCDC-USA)

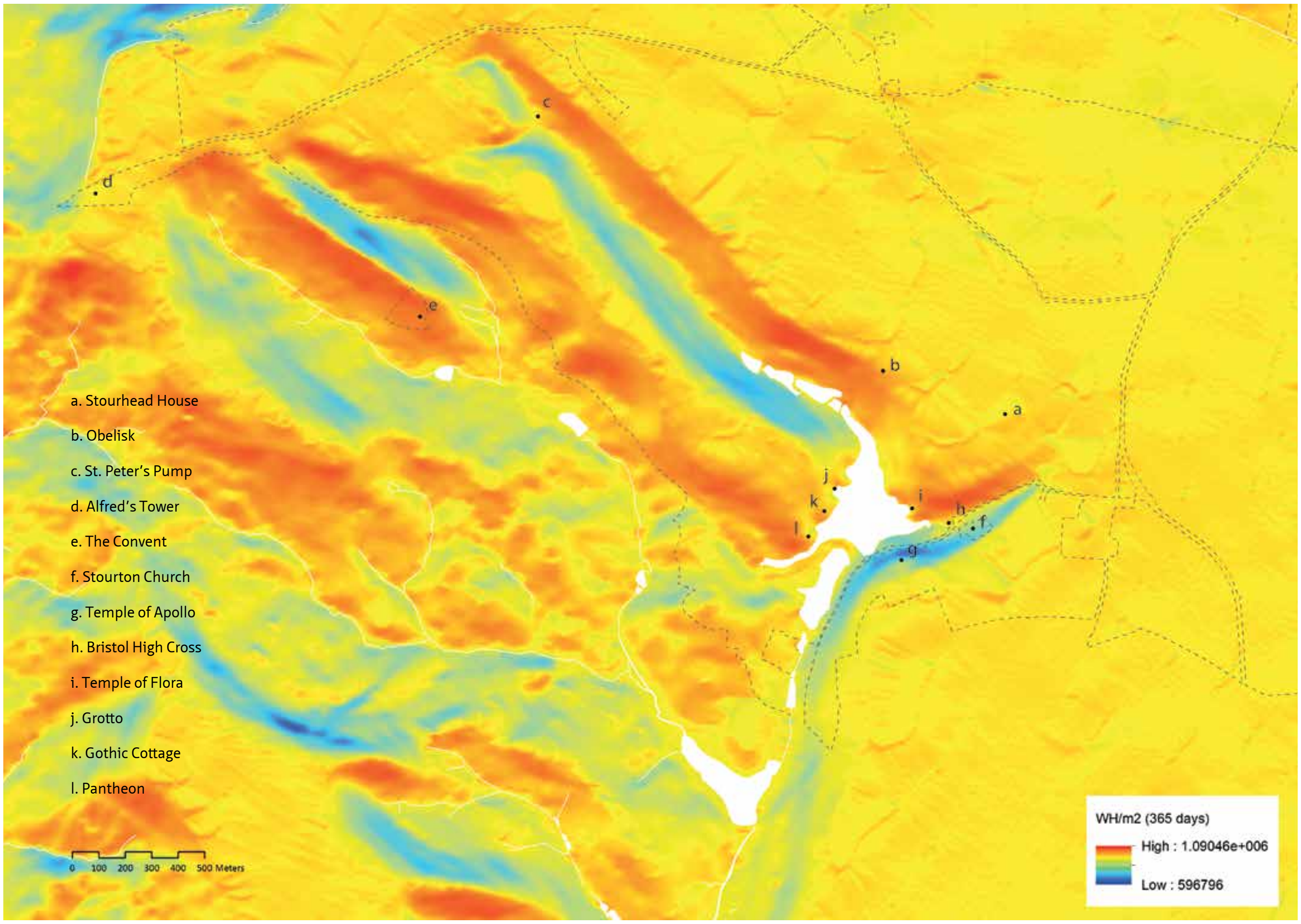

FIGURE 4.11 Insolation throughout the year 2013 with monthly intervals, based on DEM 1785-2010 (without vegetation). The warmest locations have the highest solar radiation (red), the coldest have the lowest solar radiation.
→ GIS-based calculation using Solar Analyst (map: Steffen Nijhuis)

§ 4.2.4 Water (incl. geohydrology)

The drainage pattern is closely related to the geomorphology on a regional level, as well as on the local level of the Stourhead grounds. From the high grounds drainage patterns radiate over the region [Figure 4.12]. Rivers and other streams drain the land and the lowest lying parts are swampy in nature and mostly devoid of settlement. As indicated by names such as Six Wells Bottom and Paradise Well, the valley at Stourhead landscape garden is characterized by a series of natural springs. These spring are fed by the Upper Greensand formation, which is a moderately productive aquifer yielding up to 25 L/s.[509] In the slopes near the junction with the Shaftesbury Sandstone, the water table hits the ground surface and feeds the (Dorset) Stour.[510]

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[509] Bristow et al., 1999; Geddes, 2000.

[510] Ibid.

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FIGURE 4.12 The Stour and Avon are the main rivers of the Stour-basin. The Stour is 97 kilometres long and flows through Wiltshire and Dorset to join the river Avon at Christchurch before entering the English Channel.
→ Composite GIS-map with overlay of hydrography, contour lines and multidirectional oblique-weighting hillshade (map: Michiel Pouderoijen & Steffen Nijhuis, based on OS Terrain 50 grid, OS Terrain 50 contour, OS District hydrography and ERC-river basin database)

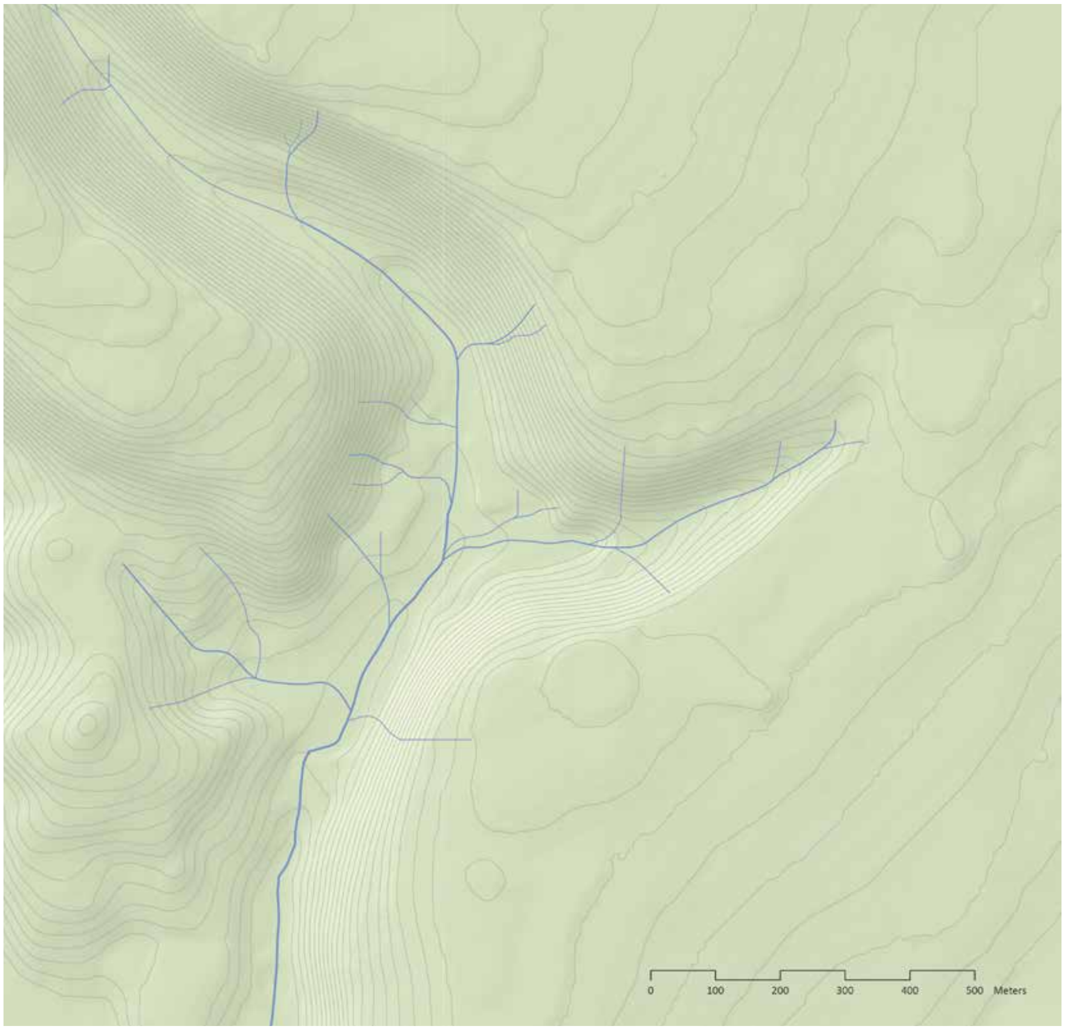

FIGURE 4.13 Calculation of the probable water pattern of the situation before 1722. The drainage pattern is generated by means of algorithms for hydrological analysis that generate water runoff patterns based on elevation, slope and orientation of the slopes of the DEM <1722. → GIS-based calculation using Spatial Analyst. Composite GIS-map with overlay of (simplified) water pattern on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

The Stour is a river of 97 kilometres long and flows through Wiltshire and Dorset to join the river Avon at Christchurch before it enters the English Channel. The water level of the Stour changes throughout the seasons. During winter the river often floods, facilitating the fertilization of the wide floodplains downstream. During summer low water levels make the river an important habitat for rare flora and fauna.

A series of artificial lakes are situated in the valley at Stourhead landscape garden, where the spring water is retained. In order to explore its natural basic form before human intervention, automated interpolation techniques were employed to generate the probable basic form of the valley, which resulted in DEM <1722 (Figure 3.21, Chapter 3). The DEM <1722 was used to perform a hydrological analysis in order to investigate the probable drainage pattern based on the natural terrain conditions before the fishponds have been created [Figure 4.13]. The drainage pattern is generated by means of algorithms for hydrological analysis, which generate water runoff patterns based on elevation, slope and slope orientation.[511]

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[511] For example: Jenson & Domingue, 1988.

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FIGURE 4.14 Interpretation of the basic form before 1722. Geometry and orientation of the natural water streams. Also indicated are the most important natural springs and their streams: Paradise Spring (a), Spring at Grotto (b), Six Wells Bottom (c) (map: Steffen Nijhuis)

In order to determine the importance of the water flows quantities and temporal differences in water supply via precipitation (surface runoff) and groundwater are decisive. As indicated on the historical maps, the main stream was in the upper part of the valley (in the western branch). Here the constant supply of groundwater via the natural springs at Six Wells Bottom ensured a constant flow of water. The eastern branch of the valley probably also carried a water stream as result of surface runoff after heavy rain storms, but it is not likely to have been a constant stream of water since there are no natural springs in the upper part of this valley branch.

Based on the natural basic form of the valley the water streams come together at the central part of the valley [Figure 4.14]. Here the main western stream merges with the eastern tributary as a two-forked stream form to the south. Smaller water streams related to the natural springs also meet the main water flow there.

Along with the possibilities offered by the basic form of the plateau and valley, geomorphology and water became the basis for a landscape architectonic composition that activated and articulated the natural forms and processes of the site and their use.

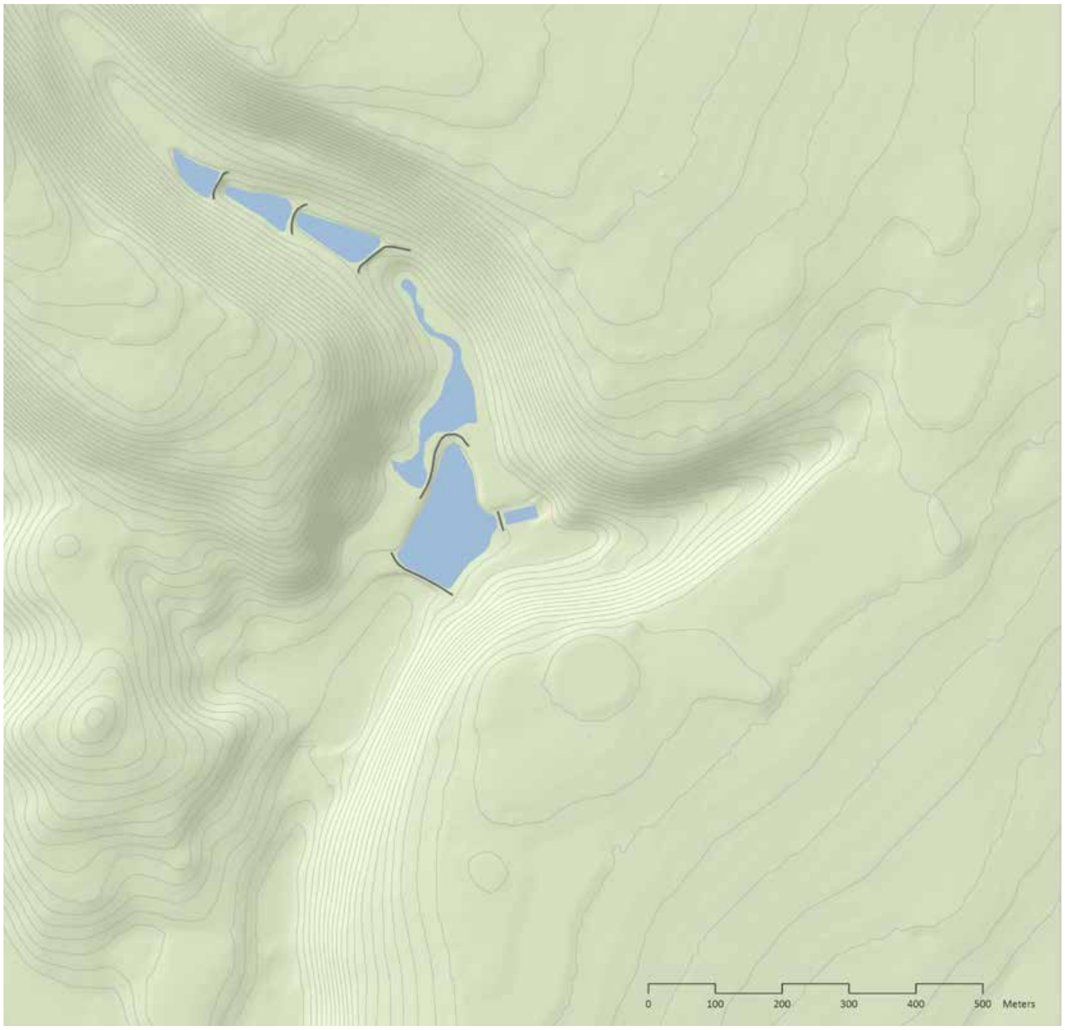

FIGURE 4.15 GIS-based reconstruction of the water bodies in 1722 (Stourhead t_0).
→ Composite GIS-map with overlay of medieval fishponds and dams on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

§ 4.3 Layout and development of Stourhead House and garden

The discussed features and processes of the natural landscape are mostly very stable resources and served as the basis for the development of a landscape architectonic composition. A major step in the development of the layout of Stourhead landscape garden can be found in the valley. Here the natural headwaters of the Stour are shaped and treated for functional and aesthetic reasons by creating dams with overflows. Nowadays the Great Lake is the centrepiece, where the Gault Clay and a dam across the southwest corner of the valley hold in the water. Other aspects of the basic form of Stourhead landscape garden are the allocation and orientation of the house, the layout of the garden around the house (including the Pleasure Garden and the Valley Garden), as well as the allocation of architectural features and the tracing of routes across the estate.

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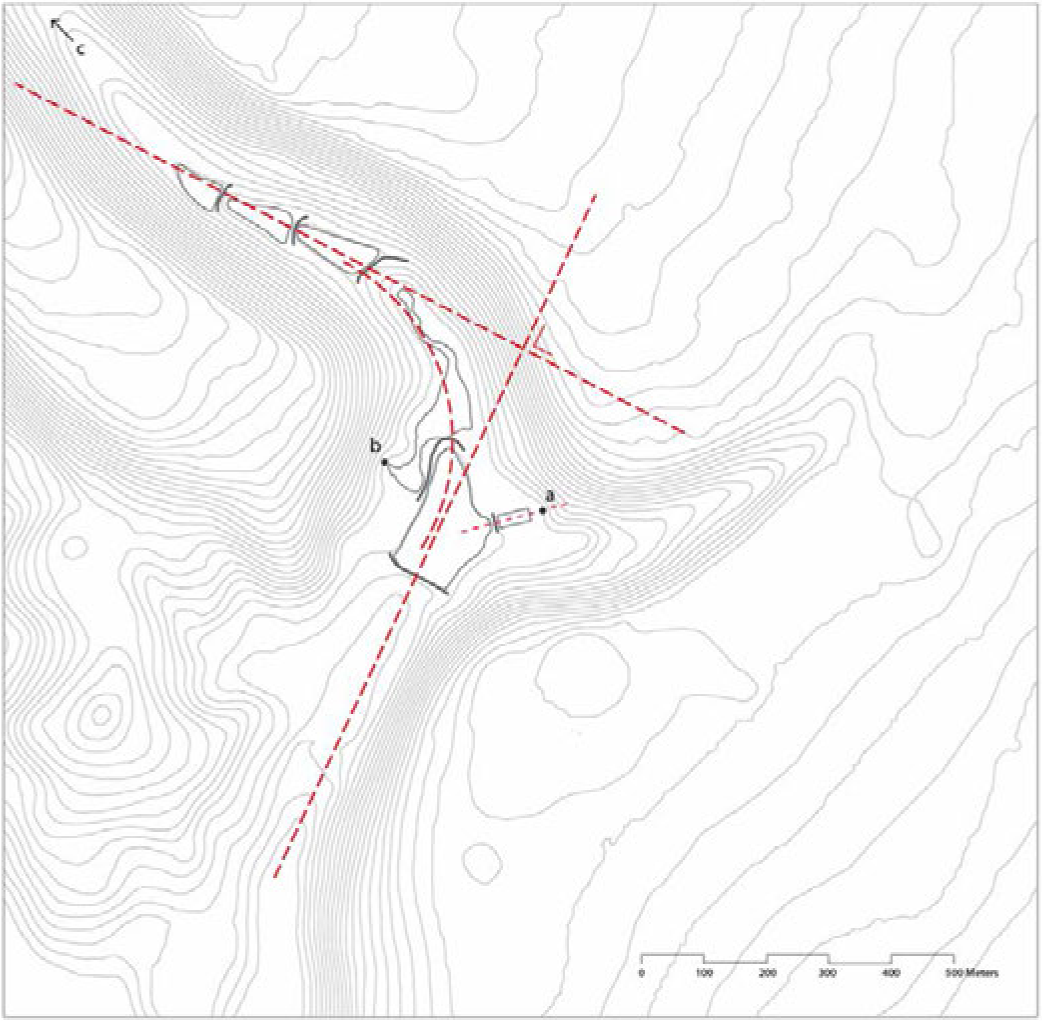

FIGURE 4.16 Interpretation of the basic form of the water bodies in 1722. Geometry and orientation of the water form. Indicated are the most important natural springs: Paradise Spring (a), Spring at Grotto (b), Six Wells Bottom (c) (map: Steffen Nijhuis)

§ 4.3.1 Formation of the Great Lake

As indicated on the 1722 map, there were five dammed fishponds and two other ponds in the valley in 1722[512] [Figure 4.15]. The cascading ponds in Six Wells Bottom were primarily fed by a spring upwards the valley, but also by a spring located at the Grotto, which produced a pool– a spring-fed withy bed.[513] The spring at Six Wells Bottom was most likely very active at that time, the 1722 and 1785 maps show a water stream, which indicates constant supply of water. The water of the ponds was retained by relative straight dams between two contour lines, forming a gorge.

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[512] It is likely that the headwaters of the Stour were already dammed before 1700 (Woodbridge, 1982/2002; Mayes, 1995).

[513] Woodbridge, 1982/2002; Mayes, 1995.

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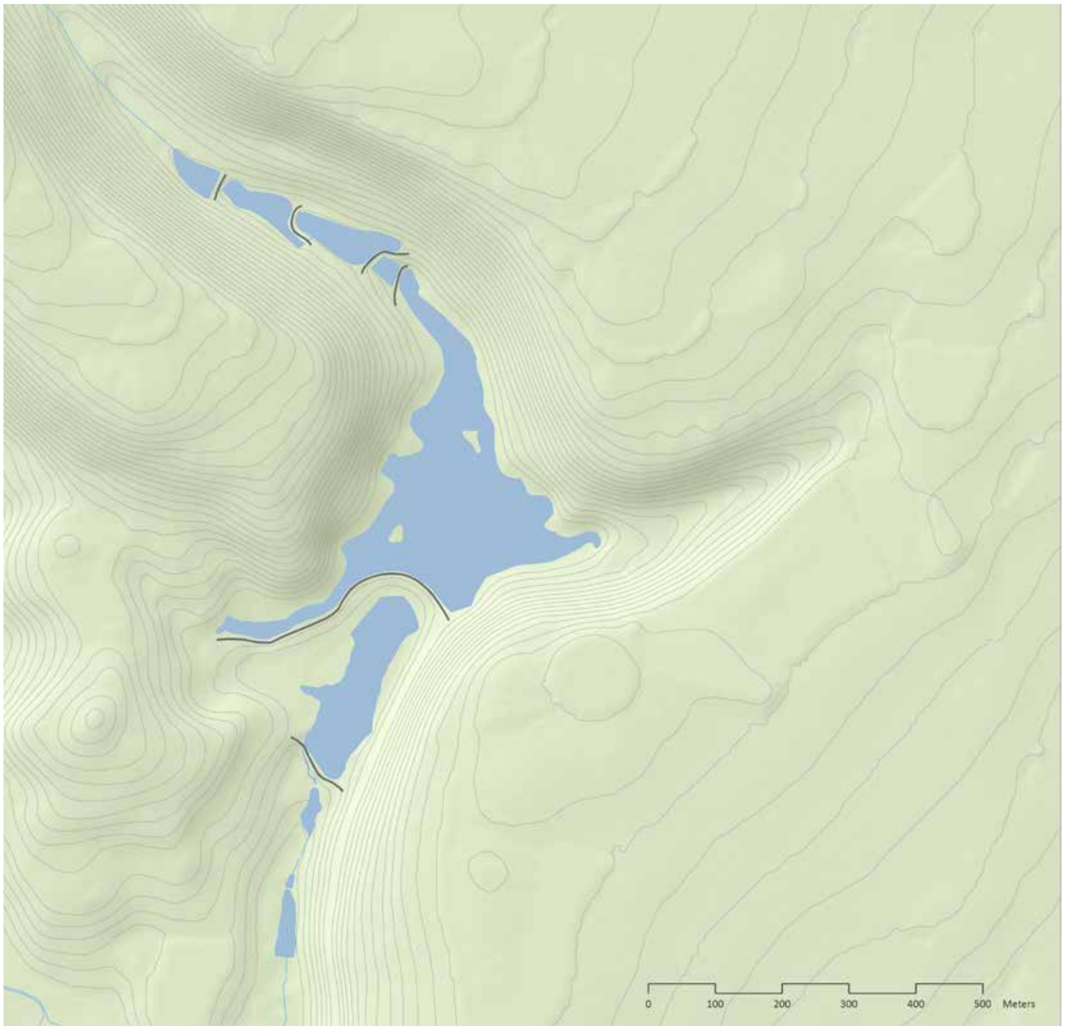

FIGURE 4.17 The water bodies in the valley in 1785-2010 (Stourhead t_1, t_2, t_3).
→ Composite GIS-map with overlay of the former fishponds, the Great Lake, Turners Paddock Lake and dams on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

The rectangular pond at the Paradise Well, where later the Temple of Flora was built, was either a drinking water reservoir for Stourton village or a stew pond for keeping live fish.[514] The southernmost dammed lake was a millpond that once powered a water-driven grist mill, which used to be located below the dam to process malt for brewing.[515]

The result is a series of water fragments which find their logic in the profile of the valley. The location and size of the ponds were strongly related to the form and orientation of the slopes of the valley and based on natural drainage patterns. They were primarily used for keeping fish and as a water power resource. The ponds form a continuous series of flow forms that curves around the slope in a south-west direction in an almost 90-degree bend. Their form and coherence is determined by the natural landscape setting and functional requirements [Figure 4.16].

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[514] Ibid.

[515] Ibid.

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FIGURE 4.18 The Great Lake with its triangular form and the dam (to the left) retaining the water (photo: Birdman photography, 2012)

The Great Lake

About 1757 the Great Lake as it is now was established as part of Hoare II's vision for the beautification of his grounds. This lake is an important part of the transformation of the natural landscape into an architectonic landscape for reasons that go beyond functional purpose. With help of the architect Flitcroft, Henry Hoare created the lake by means of a 'new' dam. Written sources point out that the dam of the southernmost pond was reconstructed and heightened, with construction beginning in 1754.[516] The new dam was also repositioned slightly to the south. The formerly straight dam was transformed into a horizontal arch with the convex side upstream. This shape helps transfer the force of the larger water body into the foundations in the rock. By raising the dam in this form the valley filled with water, converting it into a lake of about 7.4 hectares with a triangular form with three deep bays - as visible in DLM 1785-2010 [Figure 4.17 & Figure 4.18].

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[516] Ibid.

FIGURE 4.19 Interpretation of the basic form of the water bodies in 1785-2010. Geometry and orientation of the water. Important features related to water are: Paradise Spring (a), Spring at Grotto (b), Six Wells Bottom (c), Great Lake (d), Diana's Pool (e), Turners Paddock Lake (f) (map: Steffen Nijhuis)

FIGURE 4.20 Variation in curvature of the shoreline of the Great Lake (1785-2010) (map: Steffen Nijhuis)

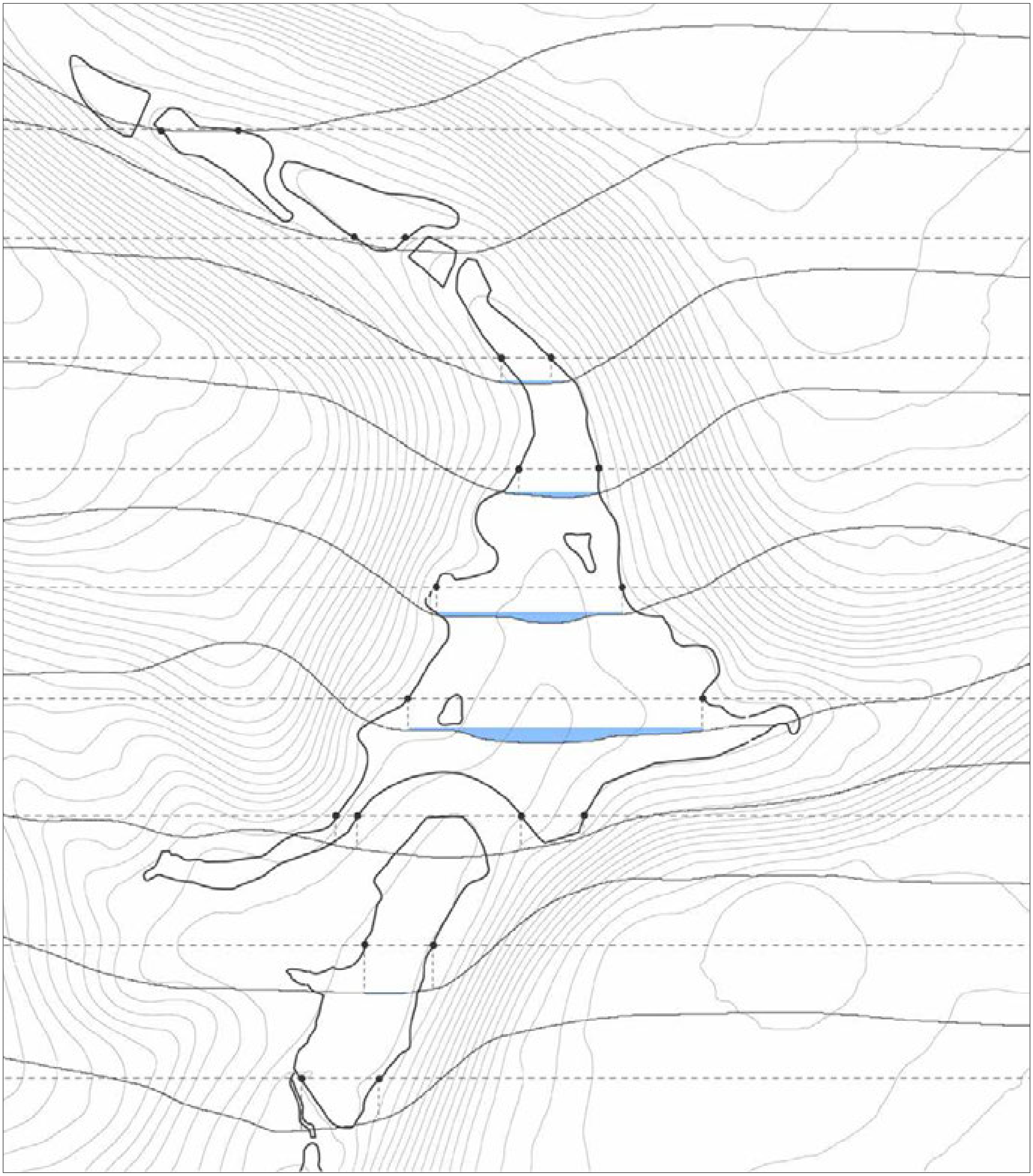

FIGURE 4.21 The form of the Great Lake (1785-2010) in the natural topography of the valley. The form of the water body is determined by the curvature of the slopes. The asymmetrical profile of the valley produces flat horizontal curves or straight lines on shallow slopes (west and south-facing) and more curvy lines on steep slopes (north and east-facing)

→ Map based on DEM 1785-2010 augmented with GIS-generated sections of the valley at regular intervals. The dotted lines indicate the location of the sections (drawing: Steffen Nijhuis)

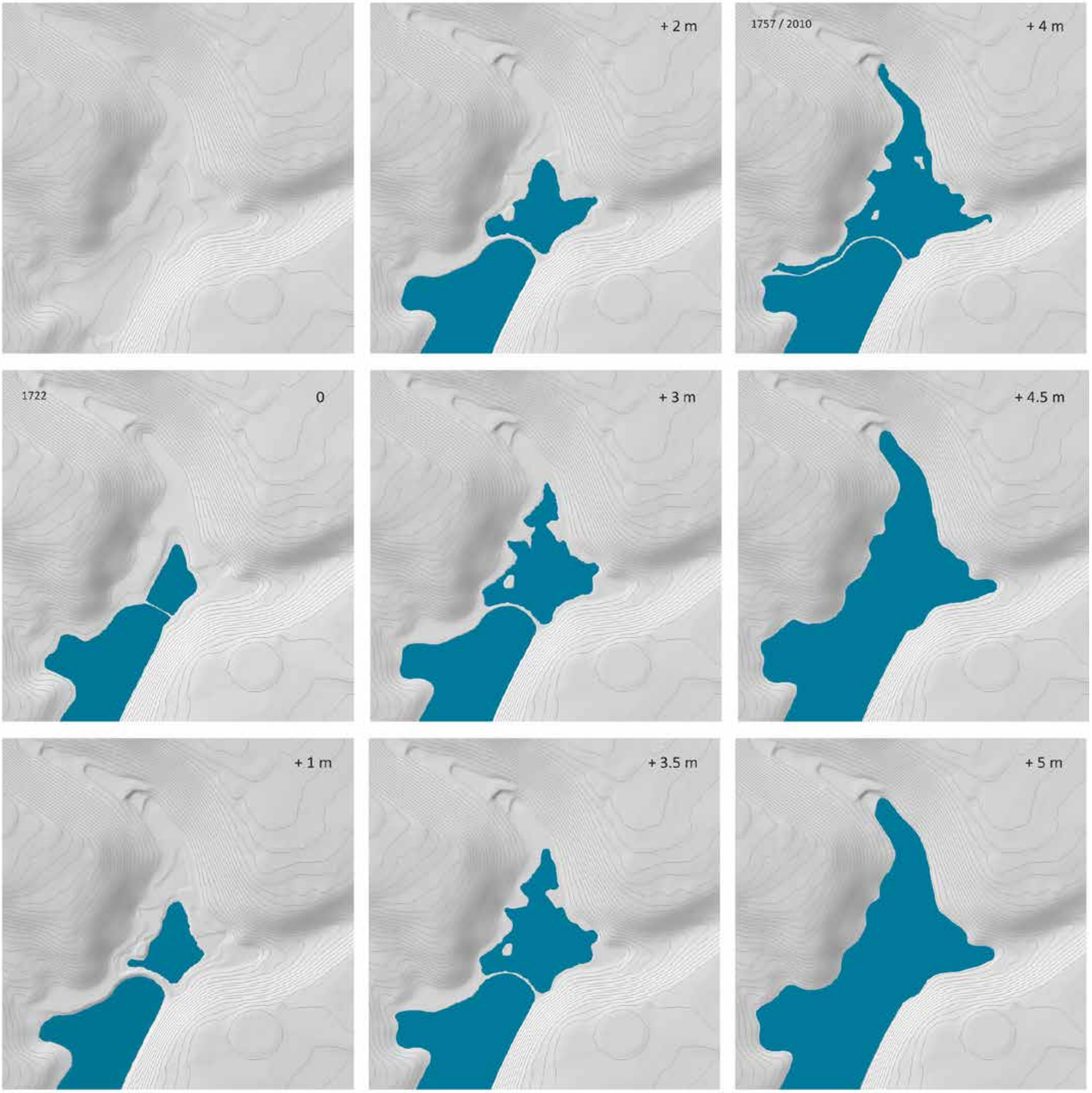

FIGURE 4.22 The water level and the variations of the slopes have greatly influence the curvature of the shoreline. The experiment shows that a 0.5 metre rise or drop in water-level (in this elevation range) has a considerable impact on the curvature of the shoreline.
→ GIS-based experiment based on DEM 1785-2010 using 3D Analyst, studying different water levels and their effect in an interactive way (maps: Steffen Nijhuis)

Geometrical analysis points out that the triangular form corresponds in principle with an isosceles triangle (with sides of about 410 metres). An important feature of isosceles triangles is that every side is of equal importance, which emphasises the lake as the central feature, retired in itself [Figure 4.19]. Nevertheless, the natural morphology of the lake differentiates its three sides and extends their edge length. The shore line curves as it were around the sides of the triangle [Figure 4.20], creating variety and

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a sequence of curves along the lake's edge. The curving northern, southern and western shorelines are respectively 600, 500 and 700 metres long. In shallow parts of the Great Lake, in the north and south, two islands were made, based on natural rises.

Further analysis reveals that the shoreline is determined by the asymmetrical profile of the valley, which produces flat horizontal curves or straight lines on shallow slopes (west and south-facing) and more curvy lines on steep slopes (north and east-facing) [Figure 4.21]. The shoreline curvature depends on the water level and changes constantly with different water levels.

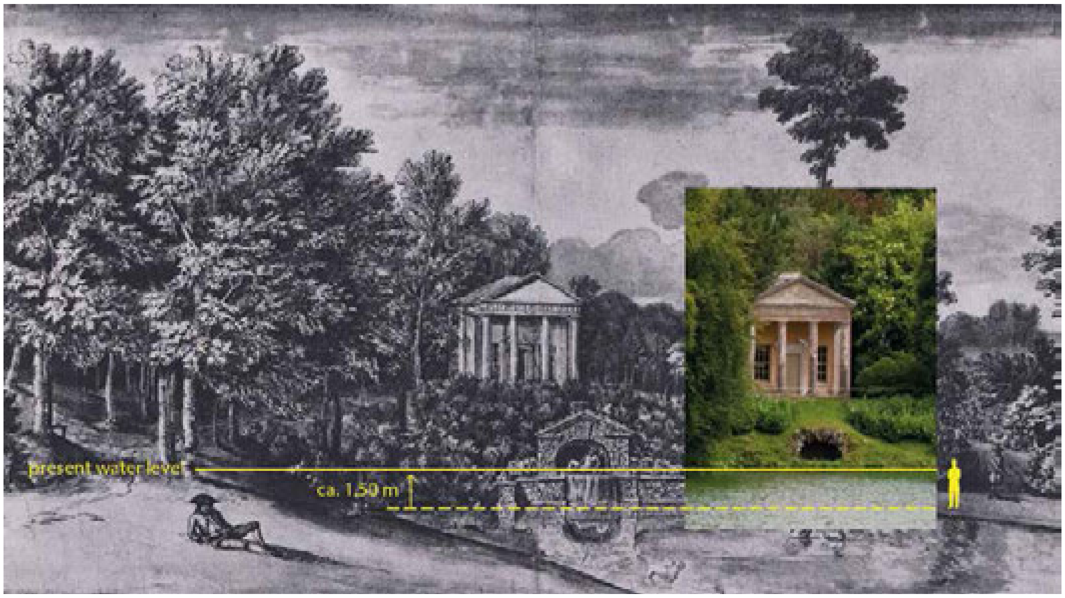

FIGURE 4.23 Comparison of the water level at the Temple of Flora in 1753 (before the establishment of the Great Lake in 1757) and 2010. At this location the water level was raised by about 1.5 metres (montage and photo by Steffen Nijhuis, based on a view by Bamfylde, 1753 and a present day photo)

Development of the curving shoreline

Since the lake was created for beautification, the form of the shoreline must have been an important point of attention. As Flitcroft was involved, it is likely that he consciously designed the form of the lake with the eye of a painter,[517] looking for an optimal curving shore line by altering the water level and adapting it to the variation of the undulating slopes on site.[518]

In order to study the interplay between the water level and valley morphology, and its effect on the form of the shoreline, an experiment was conducted altering the water level virtually using the DEM's [Figure 4.22]. The experiment shows that a 0.5-metre rise or lowering of the water level (in this elevation range) has a considerable impact on the curvature of the shoreline. By raising the water level of the southern basin by about 4 metres, the form of the Great Lake as it is now was established.

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[517] Flitcroft was as an engraver of William Kent, and very familiar with his work as an influential landscape designer and protagonist of the English landscape garden who designed landscapes with the eye of painter.

[518] Later the lake was drained (partly) several times for building and repairing works. Archival records point out that this happened in 1776, 1792, 1824 and 1968 (McKewan, 2006).

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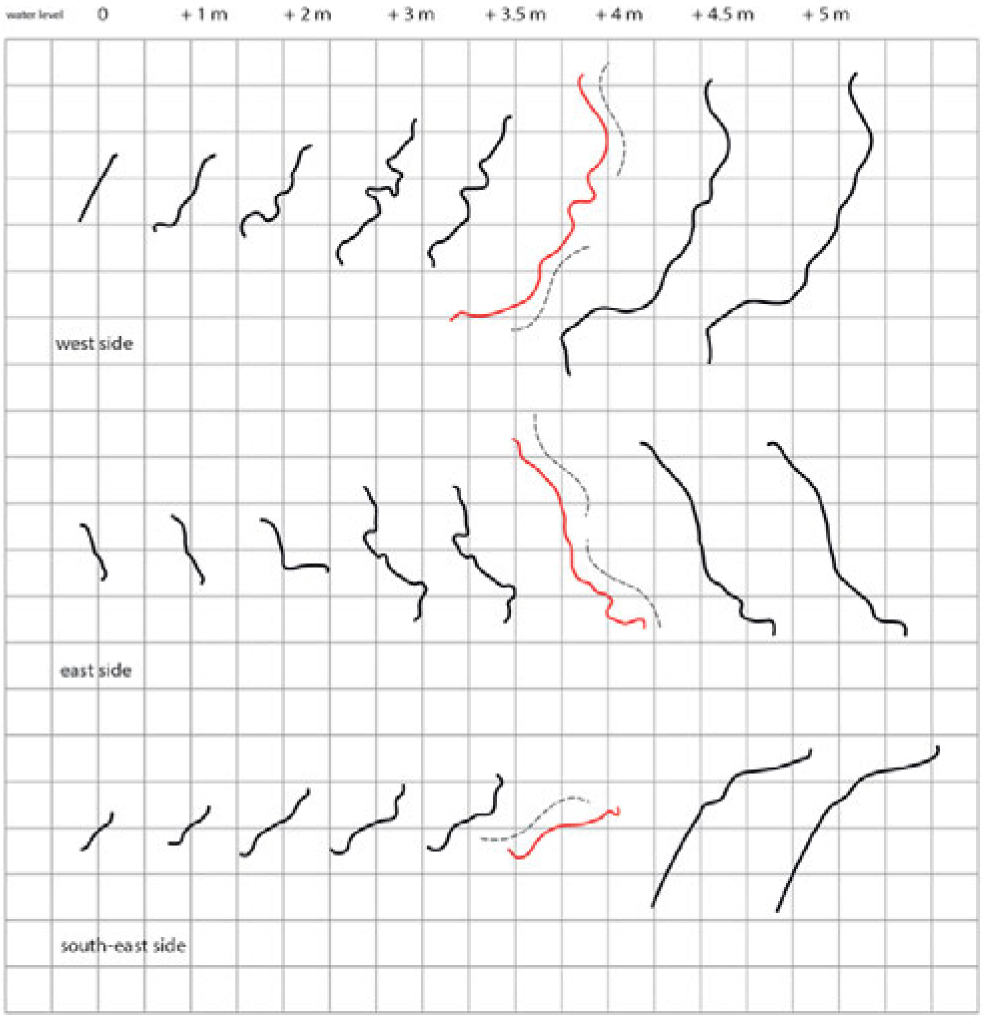

FIGURE 4.24 In search of the 'Line of Beauty' in relation to practical possibilities of water level rise and morphology of the valley. Changes of the Great Lake's shoreline curvature by raising the water level in the valley. The present situation is indicated in red (at 4 metres) and the shoreline shows a striking resemblance in curvature with William Hogarth's optimal theoretical 'Line of Beauty' (dashed line) (drawing: Steffen Nijhuis)

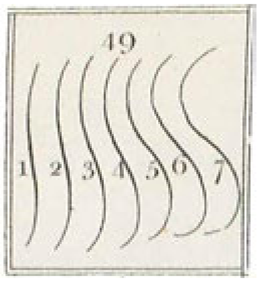

FIGURE 4.25 William Hogarth's depiction of attractive curving serpentine lines in his seminal work 'The Analysis of Beauty' (1753). Line no. 4 is considered the true Line of Beauty
→ Detail of Plate II, The Analysis of Beauty. The Whole Works of the celebrated William Hogarth, re-engraved by Thomas Cook (1812) (image courtesy of London Namur archive, ©Photo SCALA, Florence)

Most of the ponds were incorporated into the lake, except for the three northern dammed ponds that still exist. There was also an extra pond added, known as 'Diana's Pool'. The water level of the rectangular basin, which was located at a higher level, in front of the Temple of Flora, is raised about 1-1.5 metres.[519] It became part of the larger water body and flooded the cascade underneath it, as can be seen in the comparison of a view by Bampfylde with a photograph of the current situation [Figure 4.23]. The total depth of the lake is now about 5.1 metres. A new lake to the south – Turners Paddock Lake – was the result of the excavation of rock as building material for the new dam.[520]

The water level of the lake thus established a nice curving serpentine shoreline. According to Hogarth (1753/1997) an optimal curving serpentine line should meet the criteria of the 'Line of Beauty', which should be "*not too bulging in their curvature becoming gross and clumsy; nor too straight, becoming mean and poor*."[521] When comparing the changing shoreline with Hogarth's Line of Beauty there is a striking resemblance in the curvature of the new shorelines with these theoretical lines [Figure 4.24 & Figure 4.25]. This shows a sensitivity towards terrain conditions in the creation of the lake.[522] In this case it was not only a matter of the technical construction of a dam, letting the water find its own level. The shoreline became a formal landscape architectonic feature. The borders of the lake were also partly adjusted with stone shelving in the water.[523]

The basic form of the Great Lake increased the coherence in the pattern of flow forms, while dissolving the southern three ponds into a formal entity. The triangular form of the lake as a horizontal plane emphasises the natural morphology of the valley, transforming the north-south orientation of the former consecutive natural water courses into an undirected water mirror. The basic form of the valley as a landscape architectonic transformation was born. The basic form of the water plane, its dimensions, and its surrounding, curving shorelines, emphasised and accentuated by small islands, constituted an ideal basic condition for the stage of an intricate open-air-landscape theatre.

§ 4.3.2 Stourhead House

Stourhead House was constructed in 1720. It was built about two hundred metres west of the demolished Manor of Stourton, with the entrance on the east side. The house is built in Neo-Palladian style, designed by Colin Campbell (1676-1729) and presented in his influential design-catalogue '*Vitruvius Britannicus*'.[524] The Neo-Palladian style is an eighteenth century revival of the Palladian classical architectural style based on the architecture of the sixteenth century Italian architect Andrea Palladio, characterized by symmetry, perspective and elements of the formal classical temple architecture of the Ancient Greeks and Romans.[525]

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[519] As confirmed by McKewan, 2006, p. 51 & 55.

[520] In 1820 another lake was created near the village Gaspar, called Gasper Lake (now called 'New Lake').

[521] Hogarth, 1753/1997, p. 48. The research does not claim to establish a causal link between theory of Hogarth and the design of Stourhead, it uses the theory as a means to understand the composition of the park.

[522] The contemporary sensitivity towards the interplay of water-level and water-form in landscape design is well illustrated by, for example Meyer (1860, p. 154). Even earlier, in for example the work of Von Sckell (1825/1982, p. 140ff) we see water level alterations as tool for designing curving serpentine shorelines. See also his map studies for the shorelines of the Badenburger Lake at Nymphenburg (Munich, Germany) in the period 1801-1832 (Herzog, 2003, pp. 24-25).

[523] Woodbridge, 1982/2002, p. 13.

[524] Appeared in three volumes between 1715-1725.

[525] Curl, 2006, pp. 521, 551.

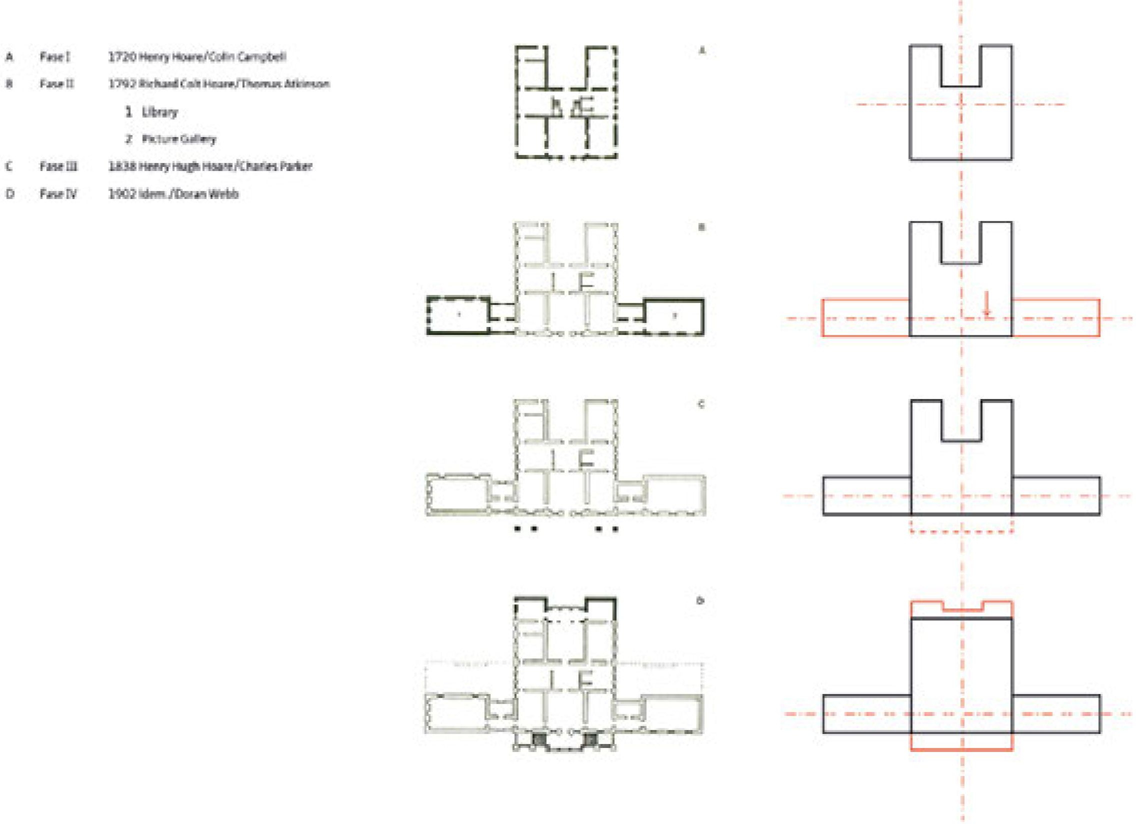

FIGURE 4.26 The typological development of Stourhead House. The basic form developed from a simple cubical form towards an architectural articulated form with an impressive front facade and protruding staircase portico. The drawings represent an idealized typological evolution of the main house, this does not correspond with the physical layout of the house and related buildings in the different time-slice snapshots as visible on the maps (drawing: Steffen Nijhuis, typological development of the house based on Reh, 1995)

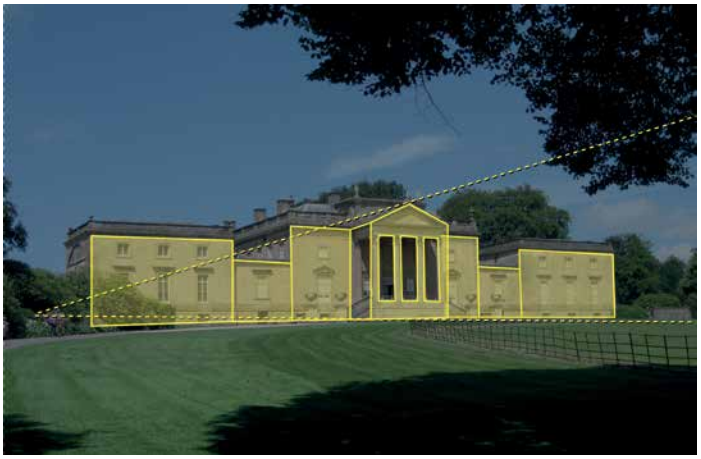

FIGURE 4.27 Explicit orientation of the facade with portico and wings. Stourhead House in 2011 (photo and drawing: Steffen Nijhuis)

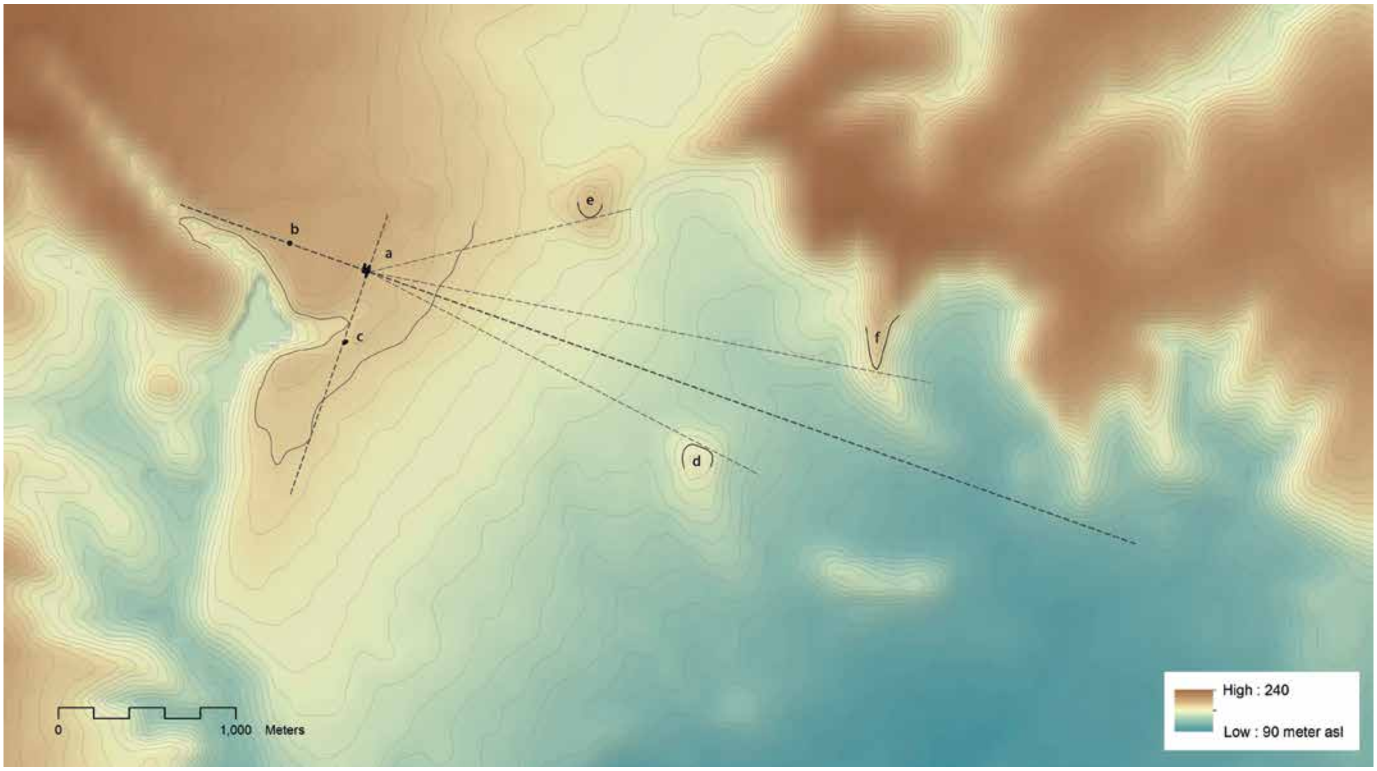

FIGURE 4.28 Allocation and orientation of Stourhead House in the landscape. Indicated are Stourhead House (a), Obelisk (b), St. Peter's Church (c) and related orientation lines mainly determined by natural features such as Zeal's Knoll (d), Beech Clump (e) and outliers of the chalky Kesley Down (f).
→ GIS-map with overlay of elevation zones on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

Though the basic design of the house was made by Campbell, various architects and master builders were involved in the evolution of the house.[526] Initially Stourhead House consisted of a cubical block with its entrance on the east façade. In 1792, two lateral wings, a library and a picture gallery were added. With this addition, the orientation of the building to the east was reinforced by the front façade, which acts as a screen in the landscape. In 1838 the staircase portico was added, according to Campbell's original design.[527] Through these architectural elaborations the basic form of the house developed in typological terms from a simple directed cubical form towards an architectural articulated form with an impressive frontage of about 70 metres wide facing the agricultural landscape. The protruding staircase portico is the centre of the composition and emphasises the orientation of the house and its main entrance [Figure 4.26 & Figure 4.27].

A topographical analysis points out that Stourhead House is located on a moderate rise on the plateau. The front façade of the house is oriented towards the downward sloping agricultural land to the southeast, and centred between Zeal's Knoll and outlying hills of the Kesley Down [Figure 4.28 & Figure 4.29]. In the transverse north-south direction the façade is aligned with the bell tower of St. Peter's Church in Stourton. This probably had to do with a common practice in land surveying, using vertical landmarks (fixed points) as reference points for measurement and alignment.

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[526] Such as: William Benson, Nathaniel Ireson, Francis Cartwright, William Wilkins, Charles Parker (Dodd, 1981; Colvin, 1997).

[527] Woodbridge, 1982/2002.

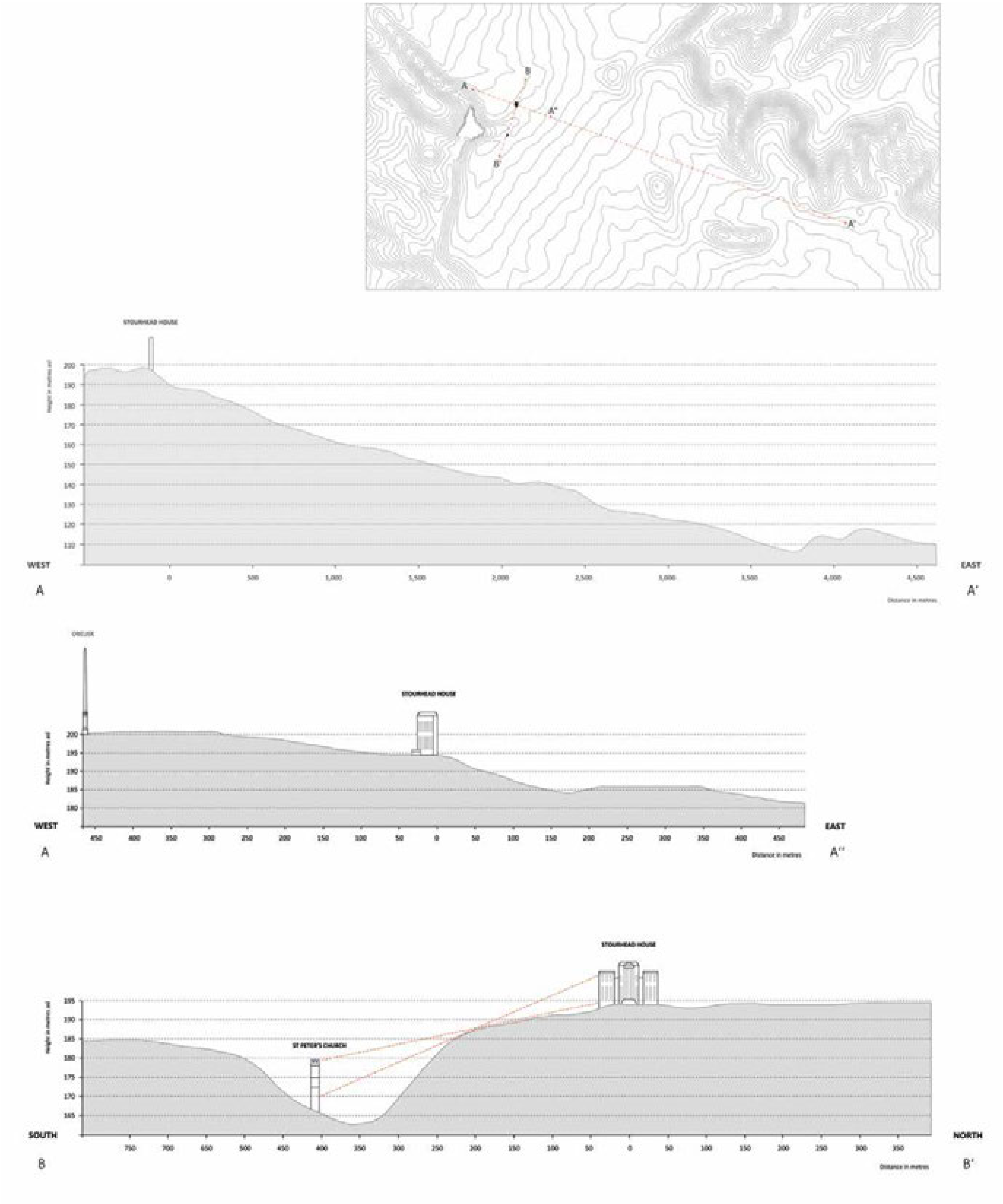

FIGURE 4.29 Longitudinal sections Stourhead House and environs. Sections derived from DEM 1785-2010 by means of GIS (drawings: Steffen Nijhuis)

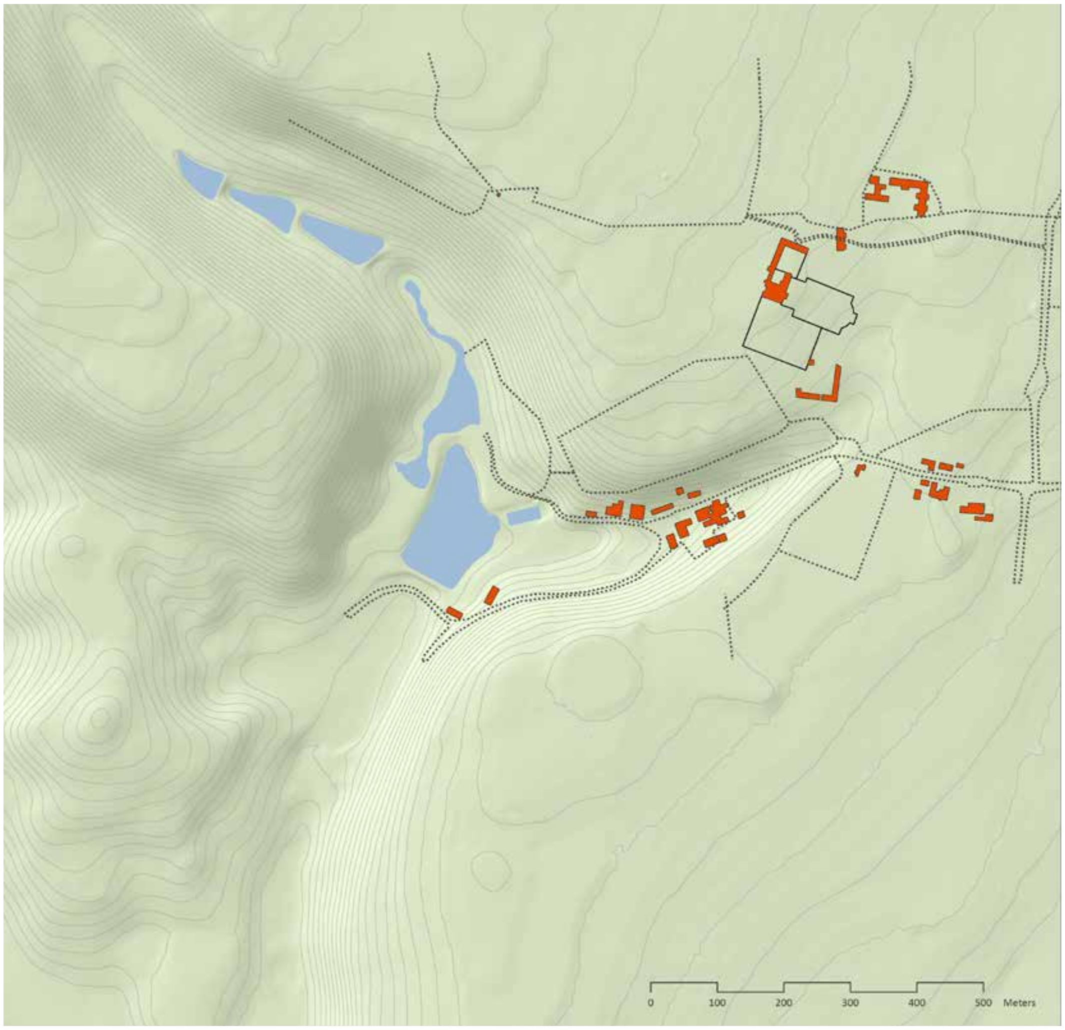

FIGURE 4.30 GIS-based reconstruction of Stourhead House with the forecourt and the walled kitchen garden in 1722 (Stourhead t_0).
→ GIS-map with overlay of buildings, garden elements, water and streets on shaded relief, augmented with contour lines
(map: Steffen Nijhuis)

The longitudinal sections derived from the DEM point out that a visual relationship between the house and the church tower is in principle possible. Thus in the positioning of the house the possibility of a connection between the plateau and valley was established.

In the basic form Stourhead House has a dominant position on the plateau. Due to its position the house can also function as a link between the two geomorphological complexes, the plateau and the valley.

§ 4.3.3 The Pleasure Garden

Stourhead House initially had a walled forecourt on the east-side with a traditional *base court*, and to the south walled gardens [Figure 4.30]. Both developed from the 1720s onwards and followed the orthogonal structure of the house, adapting to the gradient of the terrain [Figure 4.31].

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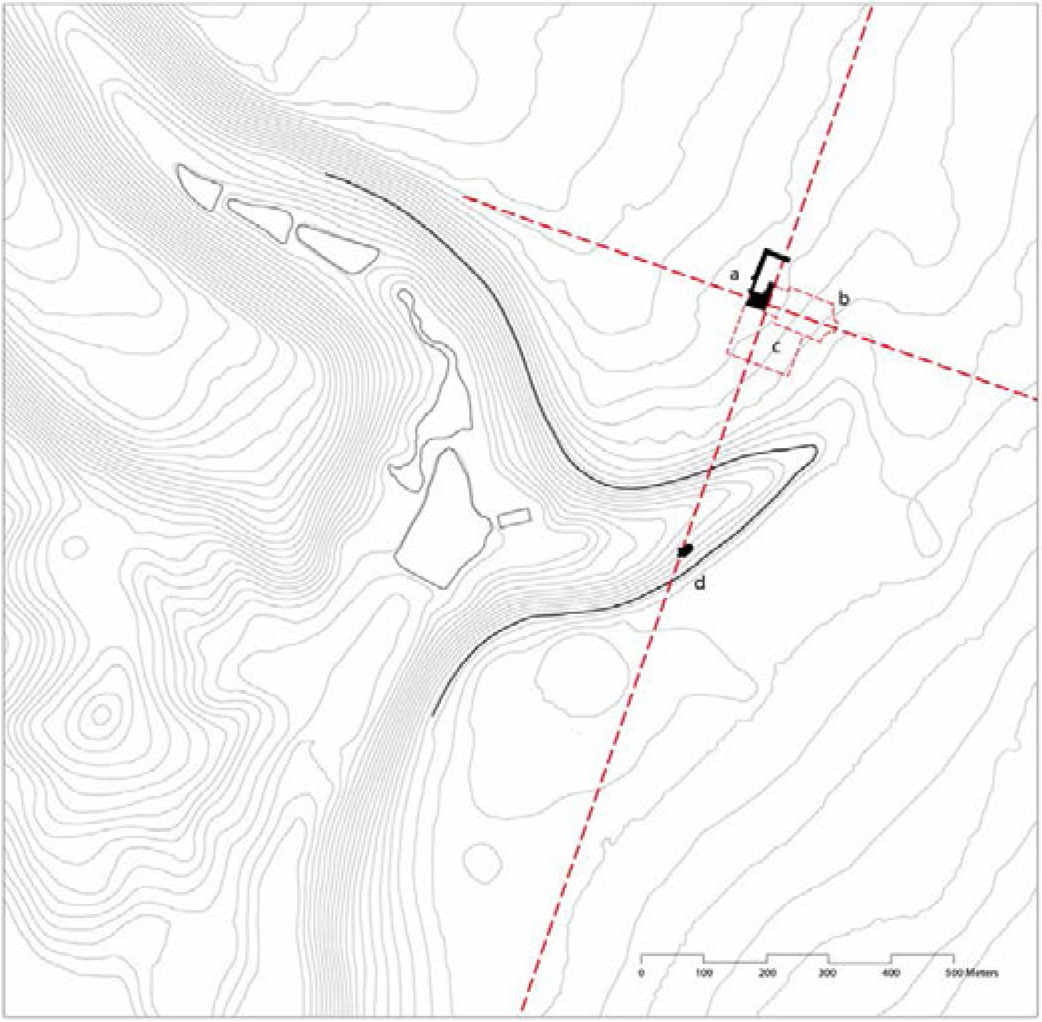

FIGURE 4.31 Interpretation of the basic form of the Pleasure Garden in 1722. Geometry and orientation of the house (a), forecourt (b), walled kitchen garden (c), and St. Peter's Church (d). The development of the Pleasure Garden followed the orthogonal structure of the house and adapted to the gradient of the terrain (map: Steffen Nijhuis)

From 1733 onwards the layout around the house was extended, and the walled garden turned into a bigger lawn, lined by trees [Figure 4.32] and probably a wall, as indicated on a watercolour view by Campbell, which was later removed [Figure 4.33]. At the end of the lawn the Statue of Apollo (1744, later removed) was placed as a focal point, emphasising the southward orientation of the garden. A bit further away, on the edge of the plateau, the Temple on the Terrace was located. Along the edge of the plateau the Fir Walk, initially a double lane of Douglas fir trees, was planted. The Fir Walk terminates at the Obelisk (1746), which is erected on a terrain elevation aligned with the centre of Stourhead House. These elements formed points of attraction and direct the walk around the Great Oar Pasture.[528]

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[528] According to Reh (1995) the Great Oar Pasture was completely surrounded by a sunken fence in the beginning. However, no evidence of that was found.

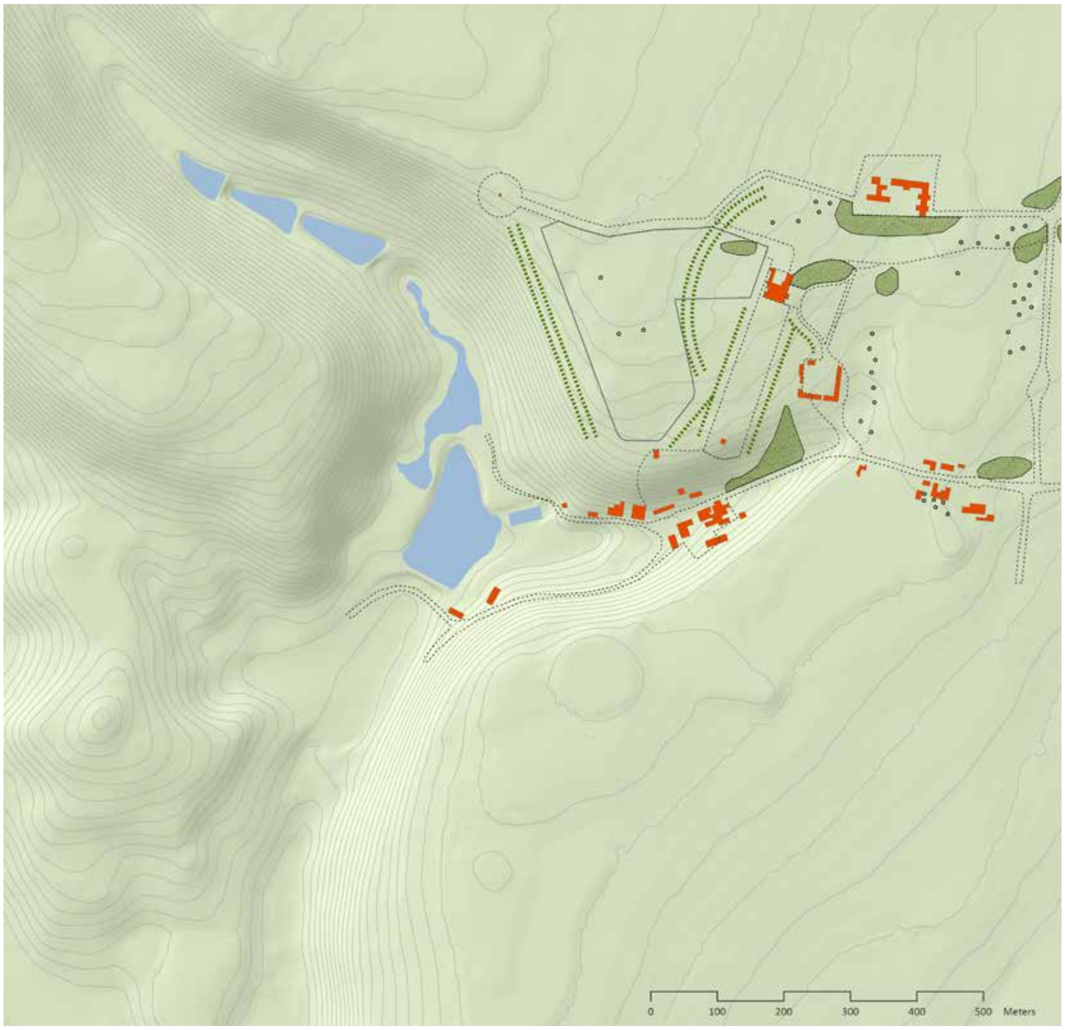

FIGURE 4.32 GIS-based reconstruction of Stourhead House with the Pleasure Garden 1733-1754.
→ GIS-map with overlay of buildings, garden elements, planting, water, and streets on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

FIGURE 4.33 The southern part of the Pleasure Garden. From 1733 the walled garden turned into a bigger lawn, lined by trees and most probably a wall, as indicated in this watercolour view by Colen Campbell (mid 1930s), and at the end of the lawn the Statue of Apollo (image source: Ackerman, 1990)

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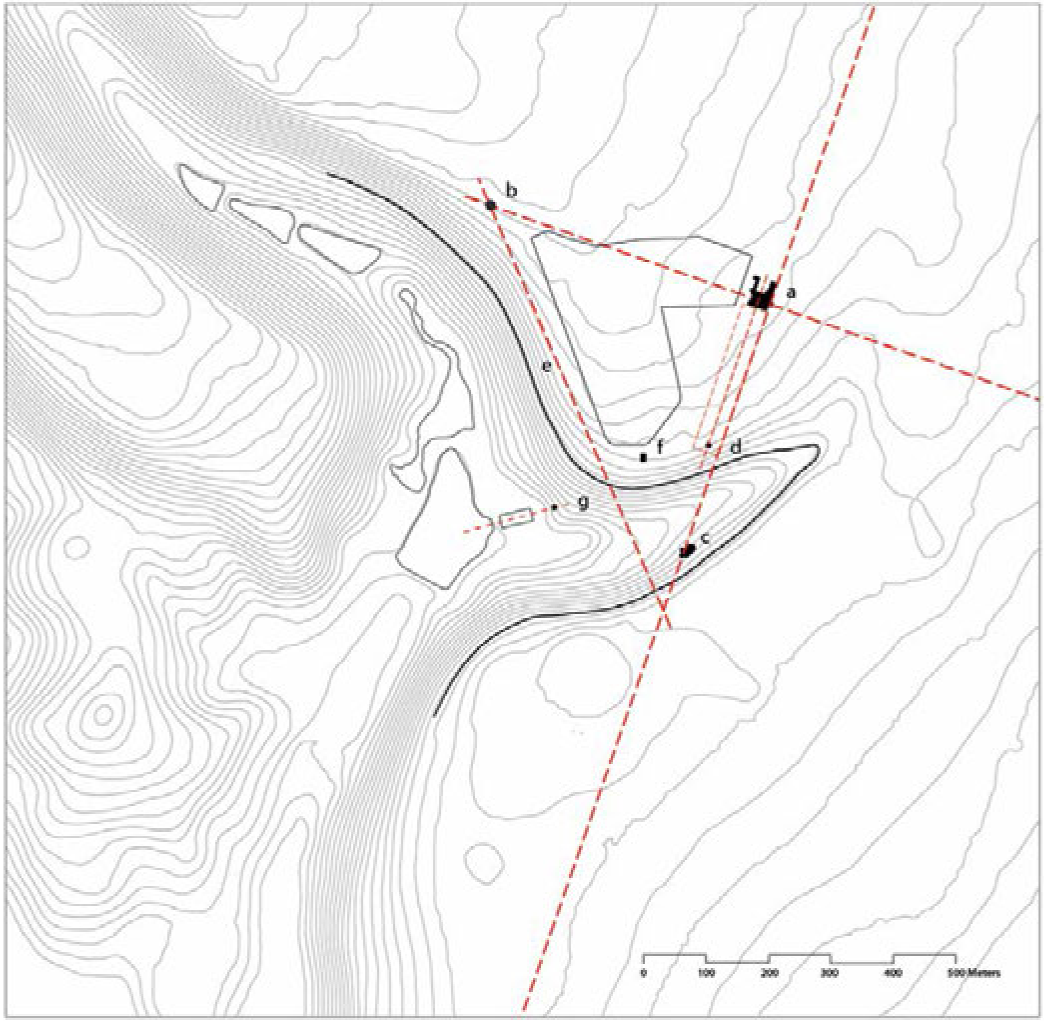

FIGURE 4.34 Interpretation of the basic form of the Pleasure Garden in 1733-1754. Geometry and orientation of the house (a), Obelisk (b),St. Peter's Church (c), Statue of Apollo (d), Fir Walk (e), Temple on the Terrace (f), and Temple of Flora (g). The Pleasure Garden developed into a triangular form on the plateau derived from elements in the natural morphology like local terrain heights and the valley edge. The architectural features at strategic locations integrated the house with the Pleasure Garden and articulated the initial relationship with the valley (map: Steffen Nijhuis)

In this way the basic form of the Pleasure Garden developed into a triangular form on the plateau derived from elements in the natural morphology, like local terrain heights and the valley edge. Elements such as the Obelisk, the Fir Walk, the Statue of Apollo and the Temple on the Terrace placed at strategic locations integrated the house with the Pleasure Garden and articulated the house's first relationship with the valley [Figure 4.34]. Via the placement of architectural features around the Great Lake the basic form of the valley became a landscape architectonic form in itself: the Valley Garden [Figure 4.35 & Figure 4.36].

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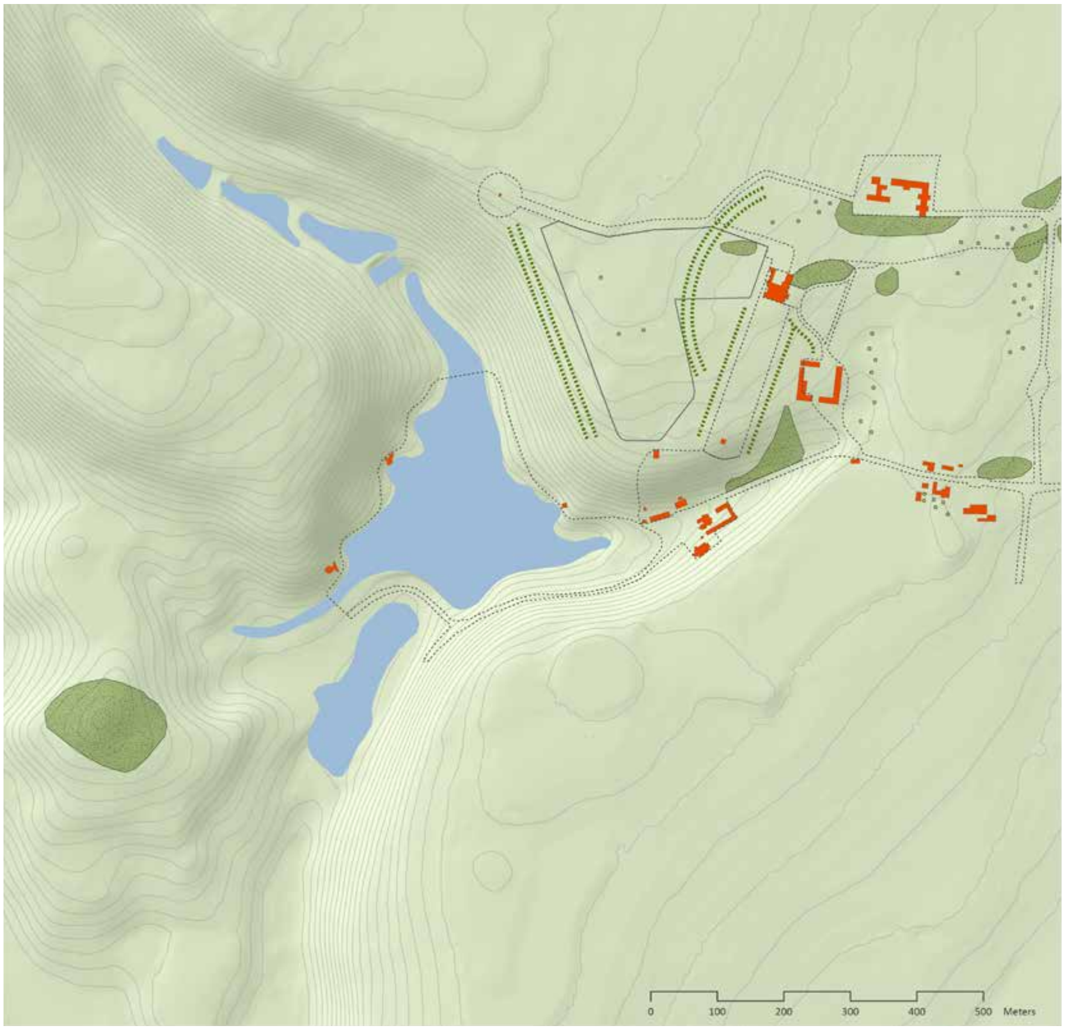

FIGURE 4.35 GIS-based reconstruction of Stourhead House with the Pleasure Garden and the Great Lake around 1757.
→ GIS-map with overlay of buildings, garden elements, planting, water and streets on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

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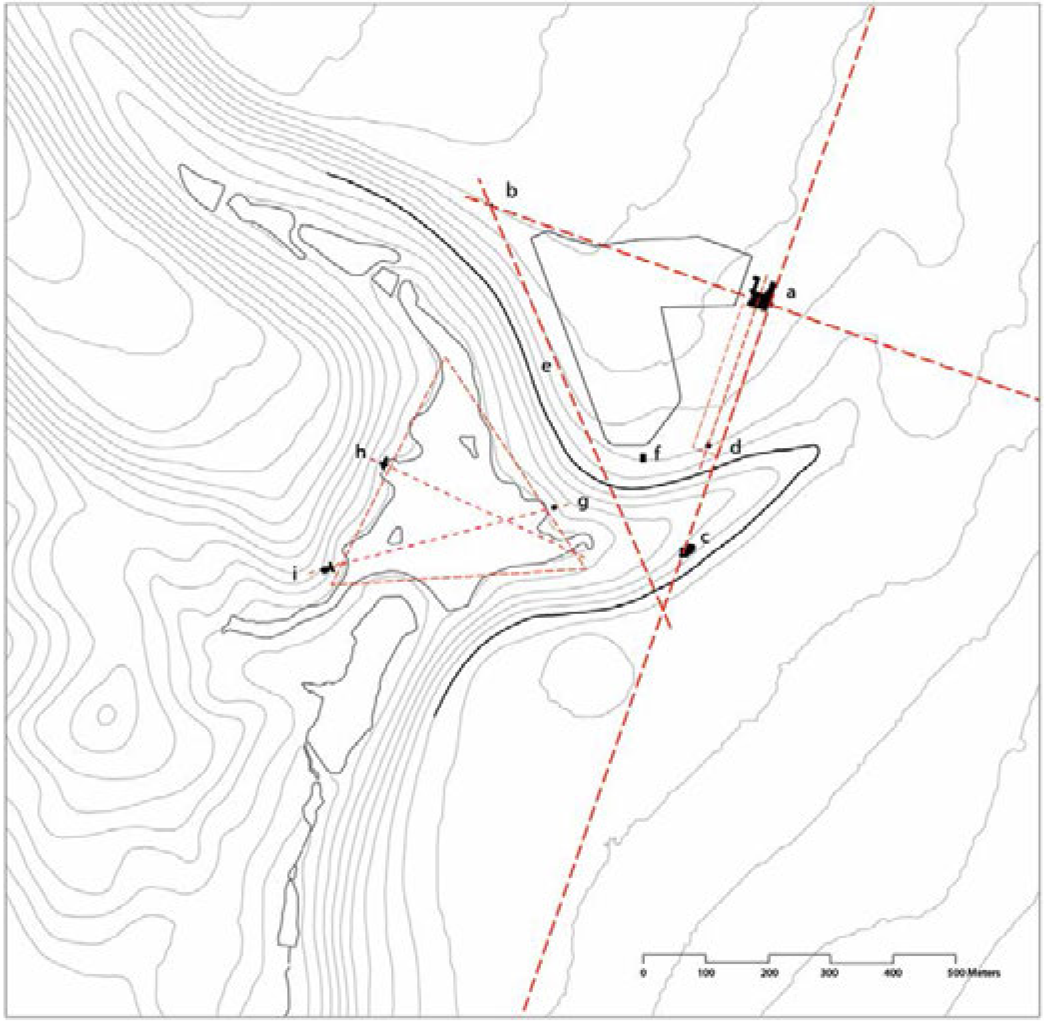

FIGURE 4.36 Interpretation of the basic form of the Pleasure Garden around 1757. Geometry and orientation of the house (a), Obelisk (b),St. Peter's Church (c), Statue of Apollo (d), Fir Walk (e), Temple on the Terrace (f), Temple of Flora (g), Grotto (h) and Pantheon (i). Via the placement of architectural features around the Great Lake the basic form of the valley became a landscape architectonic form in itself: the Valley Garden (map: Steffen Nijhuis)

§ 4.3.4 The Valley Garden

From 1744 onwards Henry Hoare II created, with the help of Flitcroft, classical, medieval (Gothic) and oriental features that in combination and in conjunction with the shape of the lake were placed in the valley. To trace the design of the features in chronological order attribute querying[529] is employed, helping to understand the successive development of its basic form. The architectural features are selected from the DLMs based on non-spatial descriptive properties assigned to the spatial objects. Here the fields with year of construction and demolition (in orange) are used [Table 4.1].

The analysis points out that the allocation and distribution of the architectural features in the Valley Garden is determined by the possibilities of the terrain form and the form of the Great Lake. Important

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[529] A request for records of features in a table based on their attribute values (Wade & Sommer, 2006, p. 11).

factors related to the terrain form are elevation, slope, and the curvature of the slopes in an upward direction. These formal landscape aspects can inform architectural motives and provide special positions for the architectural features to establish formal effects. In order to explore topological relationships between the features and landform, the features are selected according to the periodization of the time-slice snapshots and projected on the elevation, slope and curvature.

Stourhead 1785 (t_1)

The basic form of the Valley Garden in its most elaborate expression was established in 1785 [Figure 4.37]. The arrangement of the features follows the triangular form of the valley and the lake. The front facades of the features in the valley (particularly the 'rectangular' buildings) are oriented towards the lake and arranged on opposite sides in almost perpendicular lines, thereby forming virtual axes between paired counterparts across the lake. Some features in this way connected the valley with the plateau [Figure 4.38].

The development of the valley's landscape architectonic form began with the design of the Temple of Flora, with a cascade below. This temple is sited at Paradise Well, at the gentle sloping bottom of the valley's south facing slope, taking in the sun light [Figure 4.39 & Figure 4.40]. It is located on the transition from a concave to a convex upwardly slope, which dramatises its position and ensures its exposure by making the slope visually steeper and emphasising the Temple's facade [Figure 4.41 & Figure 4.42].

Feature's name	Year of construction	Year of demolition	Time-slice snapshot
Statue of Apollo	1744	unclear, but before 1800	t_1
Temple on the Terrace	1744	unclear, but before 1800	t_1
Temple of Flora	1744-46	-	t_1, t_2, t_3
Obelisk	1746	-	t_1, t_2, t_3
Grotto	1748, extended 1776	-	t_1, t_2, t_3
Rockwork Boathouse	1749	-	t_1, t_2, t_3
Wooden Bridge	1749	1798	t_1
Pantheon	1753-54	-	t_1, t_2, t_3
The Convent	1760-70		t_1, t_2, t_3
Palladian Bridge	1762	-	t_1, t_2, t_3
Rockwork Bridge	ca.1762-65	-	t_1, t_2, t_3
Grotto underpass	ca.1762-65	-	t_1, t_2, t_3
Bristol High Cross	1765	-	t_1, t_2, t_3
Temple of Apollo	1765	-	t_1, t_2, t_3
Turkish Tent	ca.1766	1792	t_1
St. Peter's Pump	1768	-	t_1, t_2, t_3
Hermitage	1771	1814	t_1
Alfred's Tower	1772	-	t_1, t_2, t_3
Chinese Alcove	unclear, around 1779*	unclear, but before 1800	t_1
Umbrella Seat	unclear, around 1779*	unclear, but before 1800	t_1
Gothic Cottage	ca. 1780 / 1806	-	t_1, t_2, t_3
Iron Bridge	1860	-	t_3

TABLE 4.1 Overview of the main architectural features in the database

The features indicated in orange are demolished

* *only indicated on map 1779*

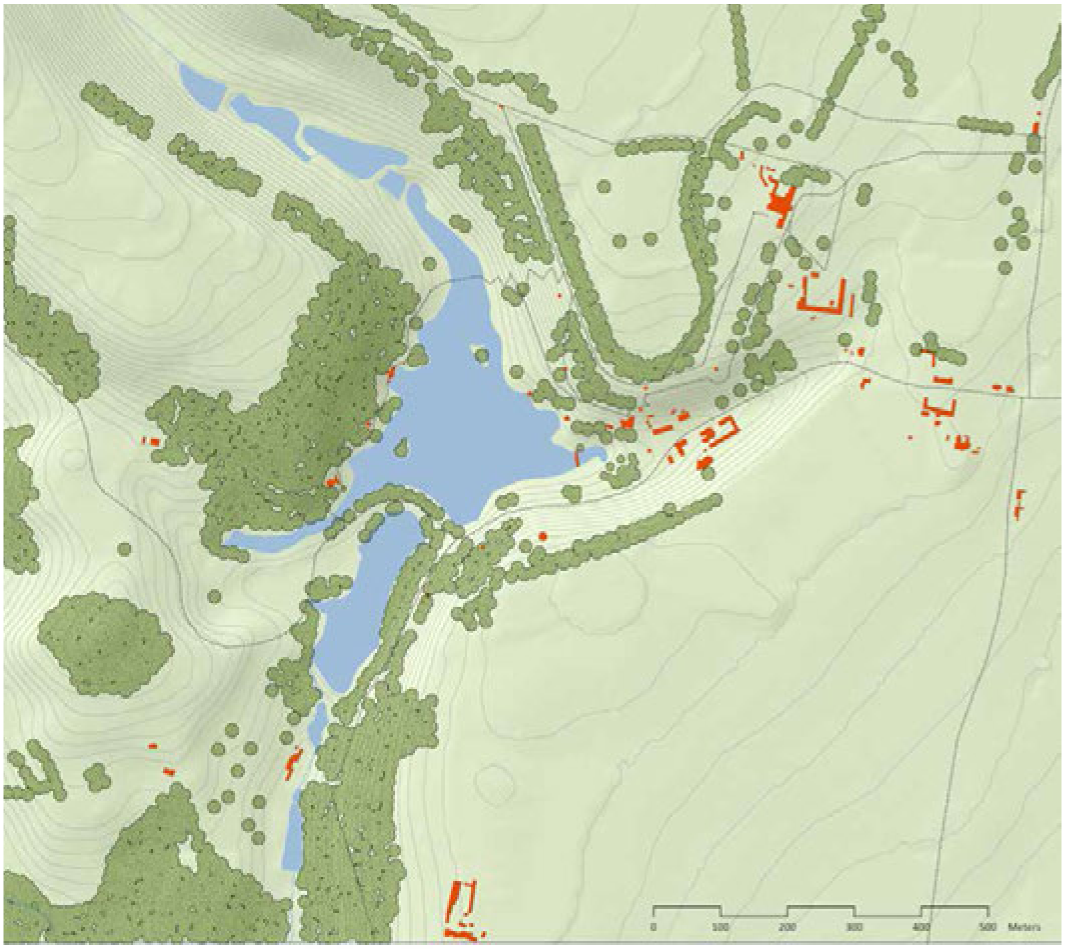

FIGURE 4.37 GIS-based reconstruction of Stourhead landscape garden in 1785 (Stourhead t_1). → GIS-map with overlay of architectural features, planting, water and routes on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

The next feature was the Grotto, which is also situated at the bottom of the valley. The Grotto's location is determined by another source of the Stour. It is located at a steep and shadowy side of the valley, in a concealed and dark place with an upwardly concave slope [Figure 4.41]. As visible in Figure 4.4, the Temple of Flora and the Grotto are both located in the lowest zones of the valley. These features are constructed before the water level was raised to create the Great Lake. The Grotto however was constructed above water level in anticipation of the planned water level rise.

The Pantheon is the next feature built in the lowest zone of the Valley Garden. It is located at a terrain elevation next to the steep east-facing slope of the valley [Figure 4.43]. The placement of the building takes advantage of the slope curvature. Just like the Temple of Flora, it is located at the transition from upwardly concave to convex slope, making the slope visually steeper and emphasising the façade. The north facing front façade of the Pantheon faces the Temple of Flora opposite on the south-side of the lake, which explains the building's angular displacement relative to the contour lines.

In the eastern branch of the valley, in the axis of the Fir Walk, as a counterpart of the Obelisk, the Bristol High Cross was placed on a small (artificial) hill relating the plateau to the valley. The Palladian bridge had no particular functional purpose but was a key element, strategically located in the centreline of the valley branch, while articulating the spatial relationship between the valley branch and the Great Lake.

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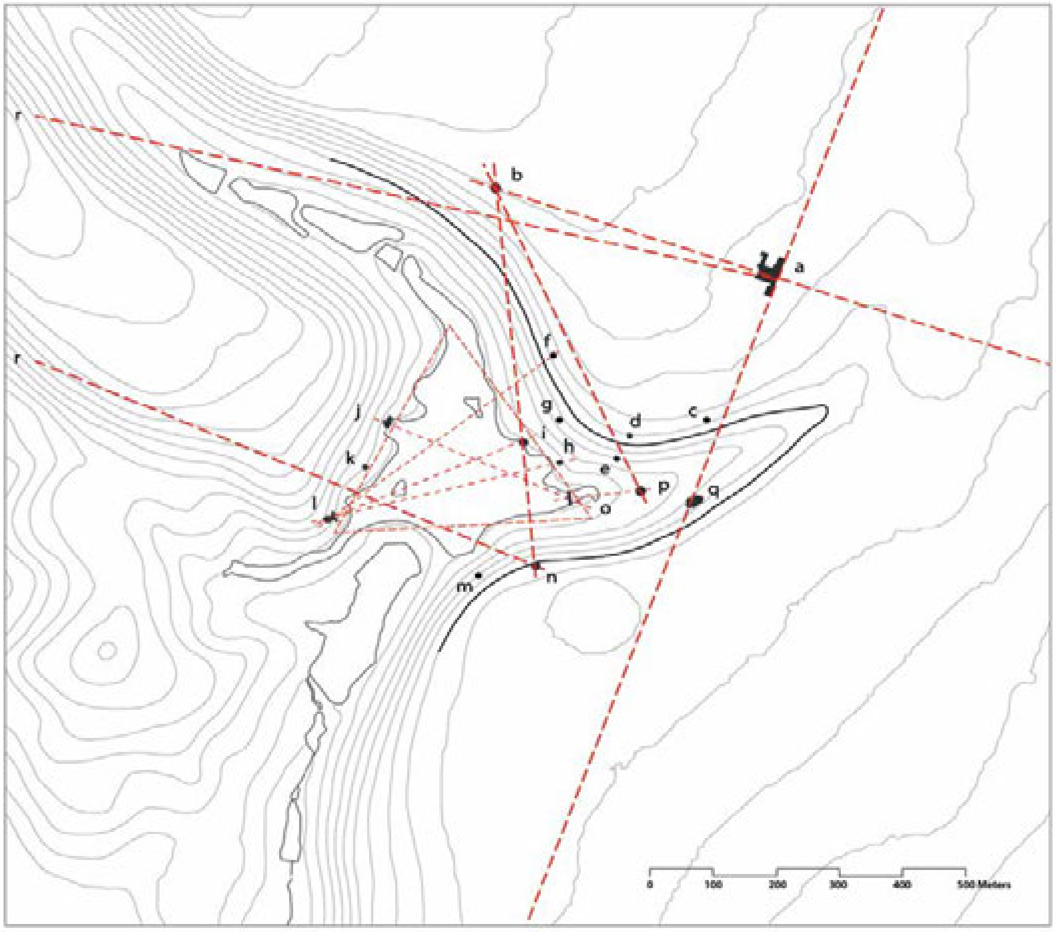

FIGURE 4.38 Interpretation of the basic form of Stourhead landscape garden 1785 (Stourhead t_1). Geometry and orientation of the house (a), Obelisk (b), Statue of Apollo (c), Temple on the Terrace (d), Umbrella Seat (e), Turkish Tent (f), Chinese Alcove (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Gothic Cottage (k), Pantheon (l), Hermitage (m), Temple of Apollo (n), Palladian Bridge (o), Bristol High Cross (p), St. Peter's Church (q) and Alfred's Tower (r). In 1785 Stourhead landscape garden appeared as an overall composition. Through the strategic topographic allocation, on edges, on rises and in axis related to the house, the features not only articulate the basic form of the valley, but also establish direct relationships between the lower and higher landscape (map: Steffen Nijhuis)

In the higher zones of the valley architectural features are located, which blend the formal systems of the valley and the plateau into one basic form. Near Church Hill, on the northwest-facing slope of the valley, the Temple of Apollo was constructed on the transition from the plateau to the valley, on the edge of a steep slope. Nearby, halfway up the slope, on an edge and concealed by planting, the Hermitage appeared. Near the Fir Walk, high up on the warm, sun-absorbing, south-facing slope, on the transition from the plateau to the valley the Turkish Tent arose on a small artificial rise called Diana's Hill. The Turkish Tent was oriented towards the Pantheon. Its location on a shoulder, a shallower sloping level on the steeper slope, with an upward concave slope as backdrop, dramatises the height difference and the interdependent relationship between the lower and upper elements of the valley. In this connection of the two landscape systems two other features also played a role. The Chinese Alcove, which was also placed on a shoulder, halfway up the steep slope as a place for repose, and halfway along the gradient from the higher situated Tent towards the lower situated Temple of Flora. To the east on the edge of the plateau, on a steep slope of the northern bay, the Umbrella Seat was sited to 'introduce' the valley.[530]

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[530] Although the Umbrella Seat is not indicated on a contemporary map, its location could be determined using a view from Piper, published in for example: Karling et al., 1981, p. 83.

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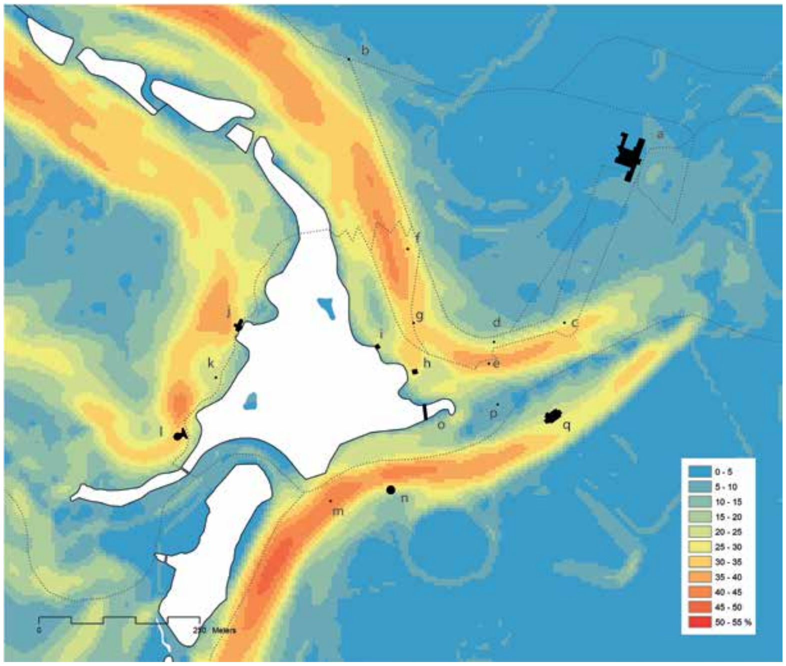

FIGURE 4.39 Correlation between architectural features in the Valley Garden1785 and the slopes (Stourhead t1). Stourhead House (a), Obelisk (b), Statue of Apollo (c), Temple on the Terrace (d), Umbrella Seat (e), Turkish Tent (f), Chinese Alcove (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Gothic Cottage (k), Pantheon (l), Hermitage (m), Temple of Apollo (n), Palladian Bridge (o), Bristol High Cross (p) and St. Peter's Church (q). The buildings take advantage of the valley's slopes dramatising and ensuring exposure by their placement.

→ Overlay of architectural features on GIS-based slope analysis (map: Steffen Nijhuis)

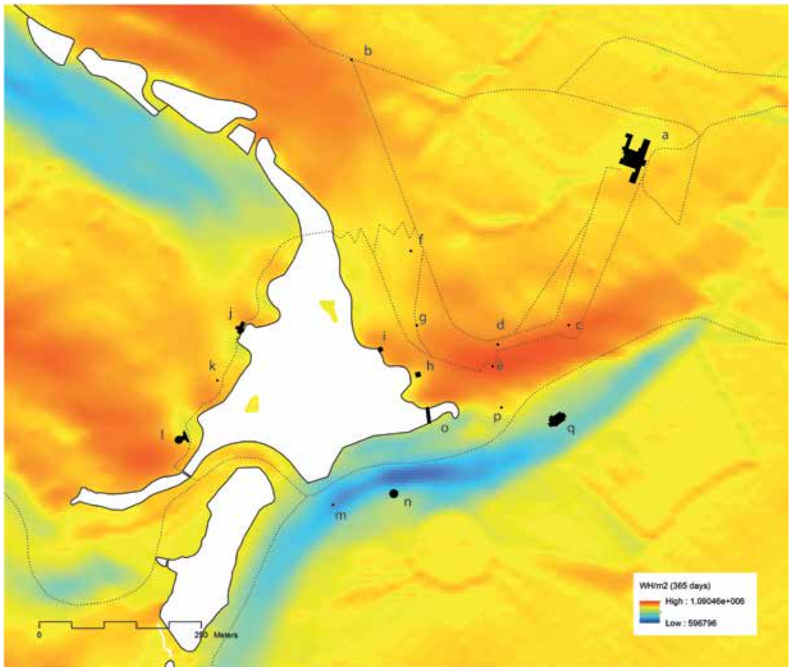

FIGURE 4.40 Correlation between architectural features in the Valley Garden1785 and insolation (Stourhead t1). Stourhead House (a), Obelisk (b), Statue of Apollo (c), Temple on the Terrace (d), Umbrella Seat (e), Turkish Tent (f), Chinese Alcove (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Gothic Cottage (k), Pantheon (l), Hermitage (m), Temple of Apollo (n), Palladian Bridge (o), Bristol High Cross (p) and St. Peter's Church (q). Some architectural features take maximum advantage of the warmest locations that have the highest solar radiation (red).

→ Overlay of architectural features on GIS-based insolation analysis (map: Steffen Nijhuis)

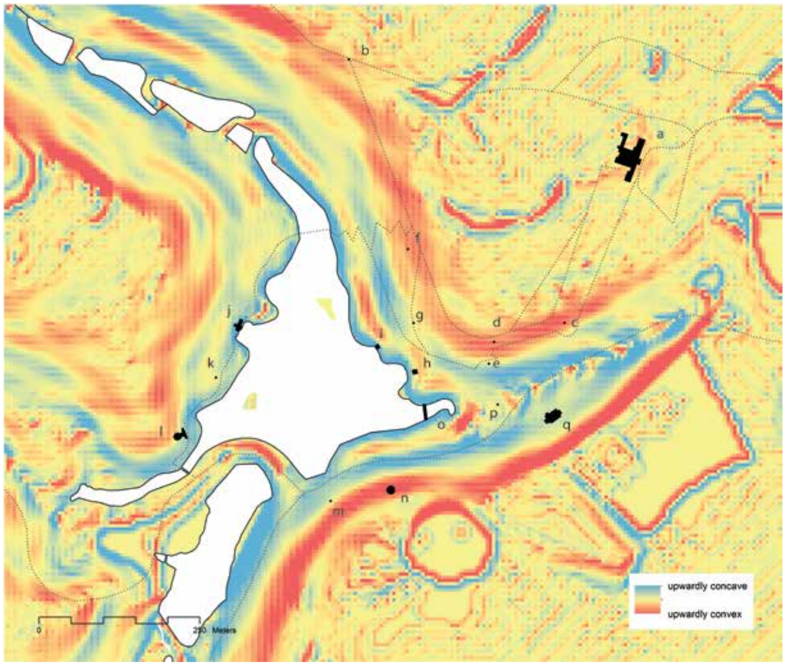

FIGURE 4.41 Correlation between architectural features in the Valley Garden 1785 with upward curvature of the slopes (Stourhead t_1). Stourhead House (a), Obelisk (b), Statue of Apollo (c), Temple on the Terrace (d), Umbrella Seat (e), Turkish Tent (f), Chinese Alcove (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Gothic Cottage (k), Pantheon (l), Hermitage (m), Temple of Apollo (n), Palladian Bridge (o), Bristol High Cross (p) and St. Peter's Church (q). Most architectural features take advantage of the valley's curvature dramatising and ensuring exposure by their placement.

→ Overlay of architectural features on GIS-based curvature analysis (map: Steffen Nijhuis)

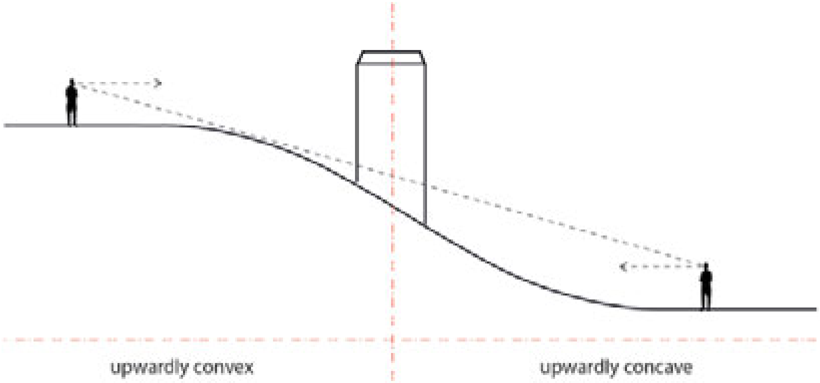

FIGURE 4.42 Upward curvature of the slopes. Building placed on the transition from a concave to a convex upwardly slope. This dramatises its position and by making the slope visually steeper ensuring the building's exposure (drawing: Steffen Nijhuis)

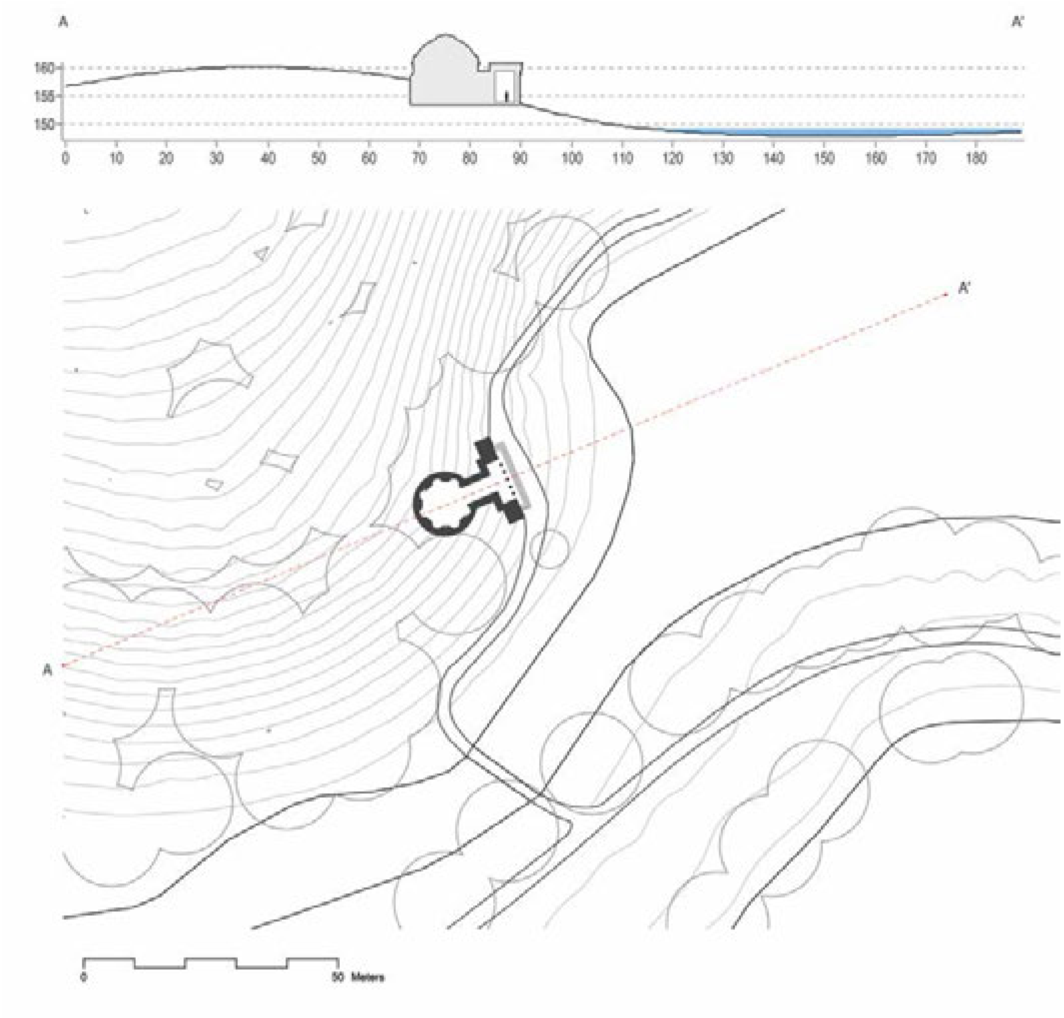

FIGURE 4.43 Allocation and orientation of the Pantheon.
→ Plan based on DLM 1785 augmented with a GIS-generated section derived from DEM 1785-2010 (drawing: Steffen Nijhuis)

Outside the Valley Garden, on the plateau at the highest point of the grounds, Alfred's Tower was located on the edge of the escarpment on Kingsettle Hill. It is a triangular tower of 49 metres high that virtually connects the valley with the plateau, the house, the domain as a whole and the regional landscape. In the upper zone of the western branch, named Six Wells Bottom, St. Peter's Pump was constructed to mark the most important source of the Stour, exactly on the border between the sand and the mudstone [Figure 4.3].

In 1785 the articulating elements of the valley were fully elaborated, with the Great Lake as the stage and nucleus. Together they form a formal system that can be seen as an extension of the Pleasure Garden around the house into the valley. Integrating the basic form of the plateau and the valley, Stourhead landscape garden appeared as an overall composition. Through the strategic topographic allocation, on edges, on rises and on axes related to the house, the features not only articulate the basic form of the valley, but also establish direct relationships between the lower and upper landscape. Such low-high paired features are: the Temple of Apollo and the Obelisk, the Obelisk and the Bristol High Cross, the Temple of Apollo and Alfred's Tower, Alfred's Tower and Stourhead House, the Obelisk and Stourhead House. The basic form of the plateau was further articulated with Alfred's Tower and St Peter's Pump integrating the western part of the grounds. Intermediate features articulate landscape transitions via the Statue of Apollo, the Temple on the Terrace, the Turkish Tent, the Umbrella Seat and the Chinese Alcove [Figure 4.38].

FIGURE 4.44 GIS-based reconstruction of Stourhead landscape garden in 1887 (Stourhead t_2).
→ GIS-map with overlay of architectural features, planting, water and routes on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

Stourhead 1887, 2010 (t_2, t_3)

The overall structure of Henry Hoare II's landscape garden's composition has been preserved by the subsequent owners [Figure 4.44 & Figure 4.45]. However, from the 1790's some architectural features were demolished such as the Turkish Tent, the Wooden Bridge, the Statue of Apollo, the Temple on the Terrace, the Umbrella Seat, the Chinese Alcove and the Hermitage, which changed the composition drastically. The result was that the basic form of the plateau and the valley became more autonomous parts of the composition, since the articulation of the transition between the two decreased through removal of these features. The Valley Garden also became the more dominant part of the landscape gardens' composition, because those architectural features, which in particular made up the 'former' Pleasure Garden, were demolished. Nevertheless the direct relationships established via the paired features still exist and make up the basic form as a whole [Figure 4.46].

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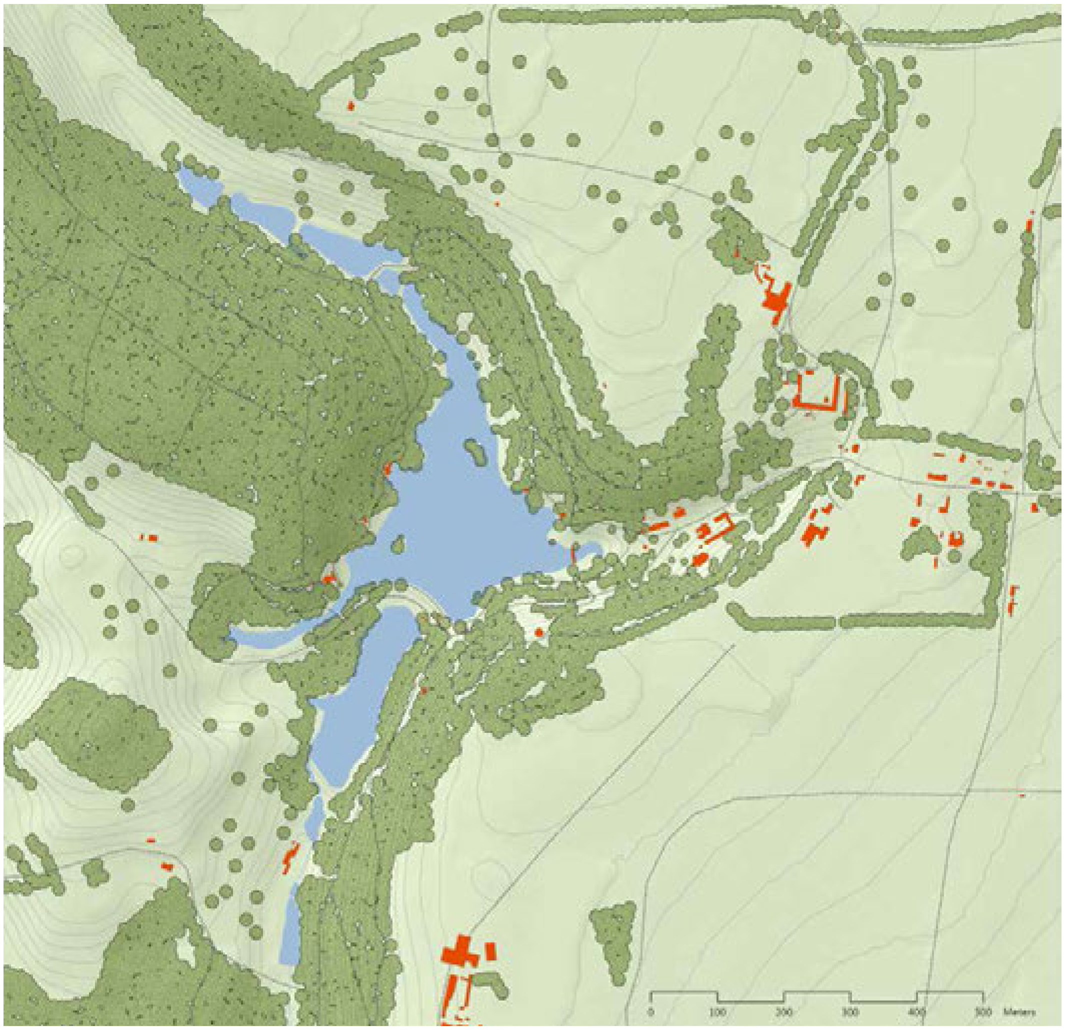

FIGURE 4.45 Stourhead landscape garden in 2010 (Stourhead t_3).
→ GIS-map with overlay of architectural features, planting, water and routes on shaded relief, augmented with contour lines (map: Steffen Nijhuis)

§ 4.3.5 Route pattern

According to Reh (1995) Stourhead landscape garden has three circular routes based on a constructed path network starting at Stourhead House: the route around the Great Oar Pasture and that around the Great Lake were footpaths, for walking, and the outer circuit to Alfred's Tower and the Convent were paths for horse riding or travelling by carriage. The routes link the house to the basic form of the different landscapes, guided by the architectural features, and take advantage of height differences and their slope gradient for allocation of functions and exposure of the geomorphology.

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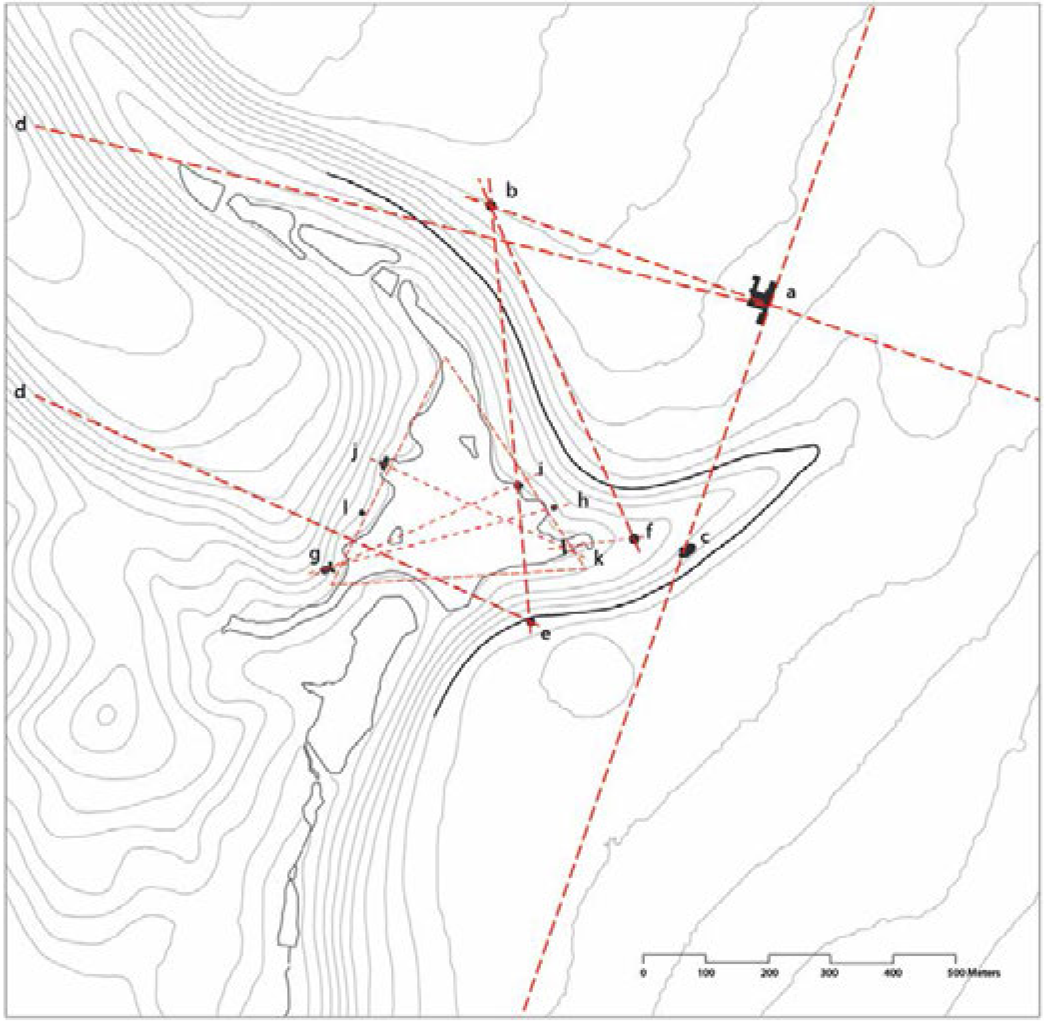

FIGURE 4.46 Interpretation of the basic form of Stourhead landscape garden 2010 (Stourhead t_3). Geometry and orientation of the house (a), Obelisk (b), St. Peter's Church (c), Alfred's Tower (d), Temple of Apollo (e), Bristol High Cross (f), Pantheon (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Palladian Bridge (k) and Gothic Cottage (l). The basic form of the plateau and the valley are more autonomous parts of the composition as the articulation of the transition between them decreased due to the removal of architectural features. The Valley Garden became the more dominant part (map: Steffen Nijhuis)

Terrain features like landform and water influence the possibility of and convenience for walking, and are thus important in explaining the route pattern.[531] As mentioned before, in the time that Stourhead landscape garden evolved, designing routes was an activity that took place on site and not on a drawing board.

There is a relationship between the sequential construction of the architectural features and the temporal development of the routes, addressing different parts of the landscape. Contemporary sources point out that routes usually were designed after the landscape garden's parts, features and scenes were shaped and planted. The construction of the routes logically followed the successive completion of the architectural features.[532] An example of this is the construction of the Wooden Bridge, which was built after the completion of the Grotto, as part of the route around the Great Lake.

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[531] This can be explained in terms of 'affordances', topographic properties that link perception and action (Gibson,1986).

[532] A common practice according to Hirschfeld, 1779-1785/2001, p. 252.

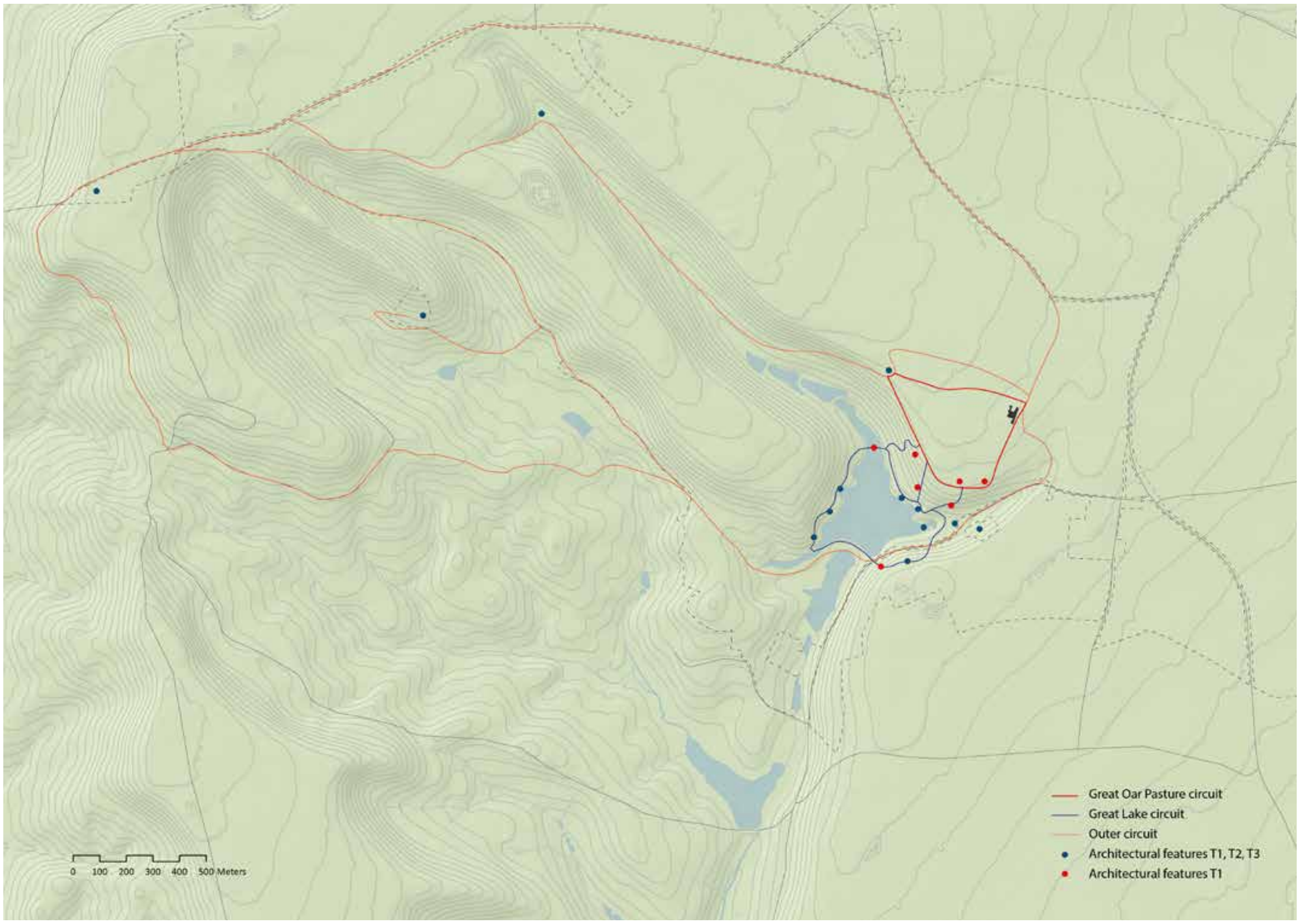

FIGURE 4.47 Three circular routes and the related architectural features.
→ GIS-map with overlay of architectural features, routes and water on shaded relief, augmented with contour lines (map: Steffen Nijhuis, routes based on Reh, 1995)

This means that the route structure gradually included different parts of the grounds, integrating them into a movement-induced architectural system that addresses different scale levels: from the house and Pleasure Garden, to the Valley Garden, and finally to the 'whole' estate. First, the route around the Great Oar Pasture was established (ca.1733-1754), addressing the Pleasure Garden in the direct environs of the house on the plateau. Second, the Valley Garden and its features were connected to the house via a route around the Great Lake (ca. 1744 onwards). In the third step the whole estate was connected to the sandstone articulated landscape via the Outer Circuit to Alfred's Tower and the Convent (ca.1760 onwards). The development of the routes corresponds with the development of the basic form as a whole integrating the plateau and the valley [Figure 4.47].

Route pattern Stourhead 1785 (t_1)

In order to analyse the basic form of the route pattern (and reconstructions) it is examined in relation to topographic features. As visible in the analysis, the path structure is responding to the landform and their possibilities in various ways [Figure 4.48]. In 1785 there was a route directly from the house to the Temple of Flora in an almost straight line, connecting the plateau to the valley. This relatively flat terrain could be walked across at an even pace as it gradually intersected the top contours of the valley.

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At the Statue of Apollo the choice could be made to descend into the valley or to continue the walk around the Great Oar Pasture along the valley to the Obelisk. The path descended towards the lake with an steady incline (e.g. going up- or downhill evenly), in a line diagonal to the slope of the valley. The line the path traced is the maximum steepness of a path that is comfortable for walking.[533]

The Great Oar Pasture-circuit, via the Fir Walk, first followed the contour line of the plateau. At the Turkish Tent the valley was introduced again. Here the route zigzaged down the steep slope, directly along the contour gradient, in order to reach the Wooden bridge (later a ferry boat) and cross the western bay of the lake. The zigzag pattern dramatised the relatively steep slope of the valley. The regular changes in direction, called 'kick turns', were to confirm the direction, introduce the contours of the valley and to allow one to catch one's breath.[534] After crossing the western branch of the valley, the path followed the contour lines of the slopes at the bottom of the valley and, directed by the serpentine curvature of the shoreline of the lake, interacted with the natural undulations of the slopes.[535] From the Pantheon on the route first continued via Zeal's Road to the Inn at Stourton.

The Outer Circuit [Figure 4.47] articulated the basic form as a coherent landscape integrating the plateau and the valley, first addressing the highest part of the grounds via Alfred's Tower and later the Great Lake, as the lowest part of the grounds.

The 1785-route system (t_1) as a whole reflects a sensitivity towards a different tactile integration of the route on the plateau and the valley, dramatising the effect of walking on the plateau by long straight structures, descending into the valley mostly by crossing contour lines perpendicularly or diagonally, and dramatising the effect of water in the valley by a continuous winding route around it [Figure 4.49].

Route pattern Stourhead 1887 (t_2)

Later the path structure changed considerably [Figure 4.50]. Around 1887, and in accordance with the shift of importance within the composition to the Valley Garden, visitors were mainly guided from the house via the eastern branch of the valley towards the Great Lake avoiding steep slopes. Stourton village became the public entrance of the Valley Garden, to disappointment of Colt Hoare.[536] Around the lake the paths were broadened and levelled for the convenience of visitors and the foot-ferry was removed so one had to make a detour along the northern bay of the lake (Diana's pool).

The route around the lake was elaborated in the direction of the Temple of Apollo, which could now be reached by crossing Zeal's Road via the Rockwork Bridge, followed by a steep zigzag climb directly on the contour gradient of the southern slopes of the valley [Figure 4.51]. Arriving at the edge of a steep slope, the path continued along the contour line towards Church Hill where the Temple of Apollo is located. From here the path descended towards the village with an steady incline, in a line diagonal to the slope. There was also a possibility to go directly to Zeal's Road. As Zeal's Road was fenced the road could be crossed via the Grotto's underpass. North of the road a new path was created that made it possible to walk there, along the shores of the lake.

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[533] Which is about 10% (cf. Neufert & Neufert, 2012).

[534] Cf. Loidl & Bernard 2003, p.108.

[535] This is in accordance with Repton's observation of great beauty, where the lines of the path and the shore diverge: "*as where the water sweeps to the left, and the path to the right*" (Repton, 1803, p. 135; cf. André, 1879, p. 387).

[536] "*...frequently the garden are visited from the Inn, on which account we recommend the starting from the House and not from the Inn*" (Hoare, 1818, p. 27).

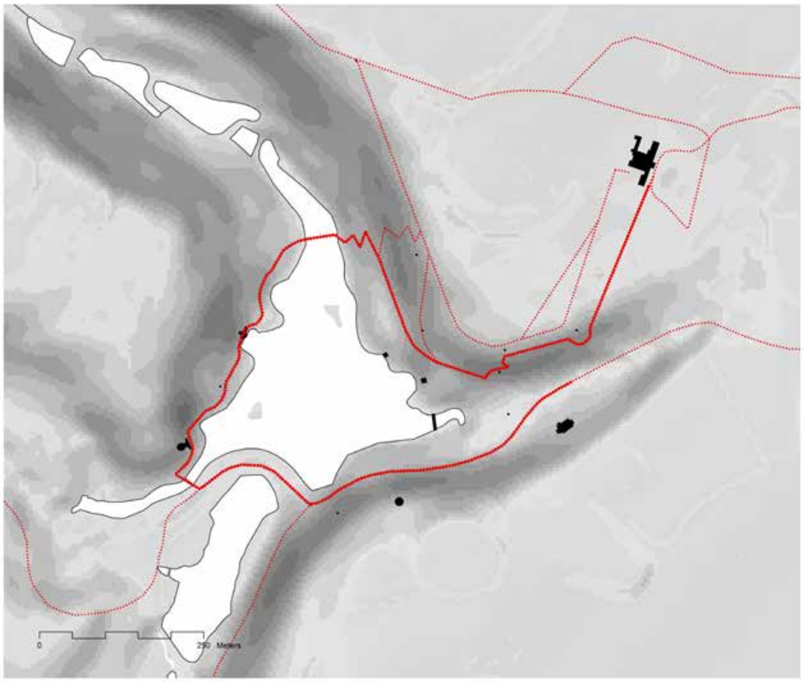

FIGURE 4.48 Route pattern Stourhead 1785 (t_1) in relation to slope and architectural features. Main route in thicker line.
→ Overlay on GIS-based slope analysis (map: Steffen Nijhuis)

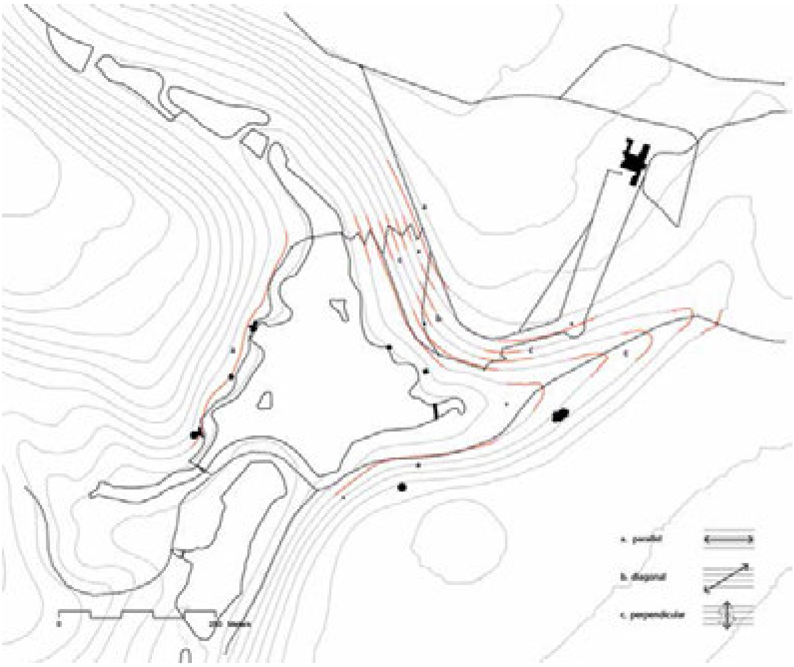

FIGURE 4.49 Basic form of route pattern 1785. The 1785-route system (Stourhead t_1) as a whole reflects a sensitivity towards a different tactile integration of the route on the plateau and the valley, dramatising the effect of walking on the plateau by long straight structures, descending into the valley mostly by crossing contour lines perpendicularly or diagonally, and dramatising the effect of water in the valley by a continuous winding route around it (map: Steffen Nijhuis)

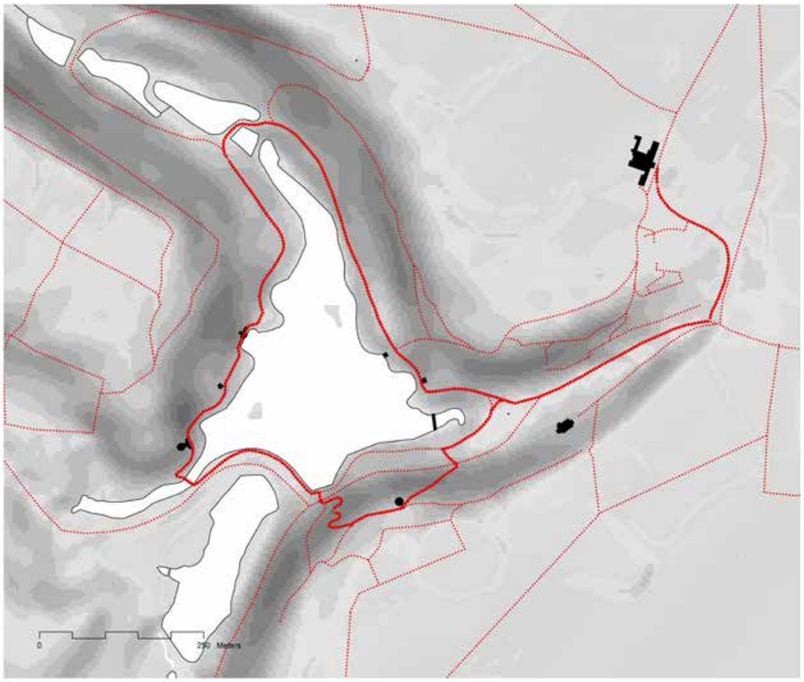

FIGURE 4.50 Route pattern Stourhead 1887 (t_2) in relation to slope and architectural features. Main route in thicker line.
→ Overlay on GIS-based slope analysis (map: Steffen Nijhuis)

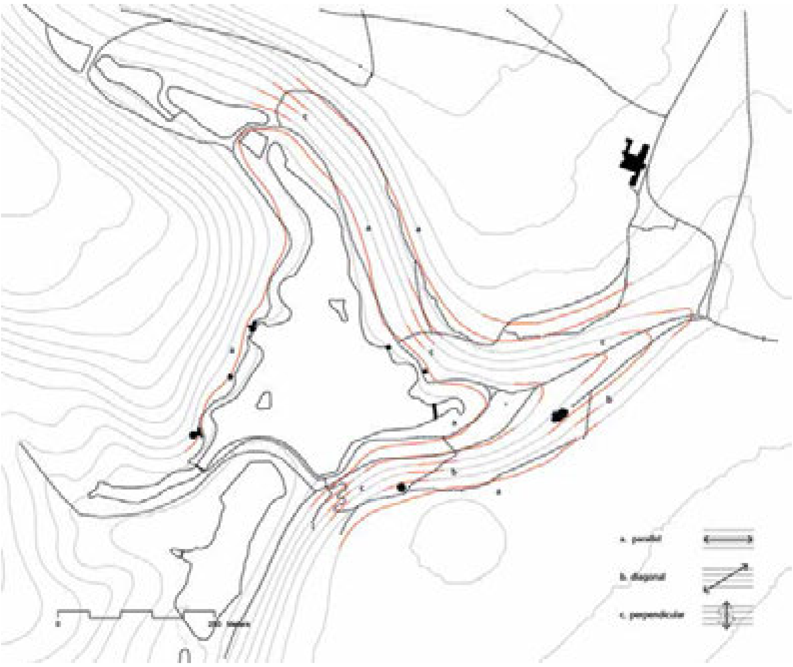

FIGURE 4.51 Basic form of the route pattern in 1887. The 1887-route system (Stourhead t_2) changed the transition from the plateau to the valley and shifted from the eastern plateau edge towards eastern valley branch. The dramatic effect of crossing height differences on this transition was toned down to follow the smooth gradient from the eastern valley branch (map: Steffen Nijhuis)

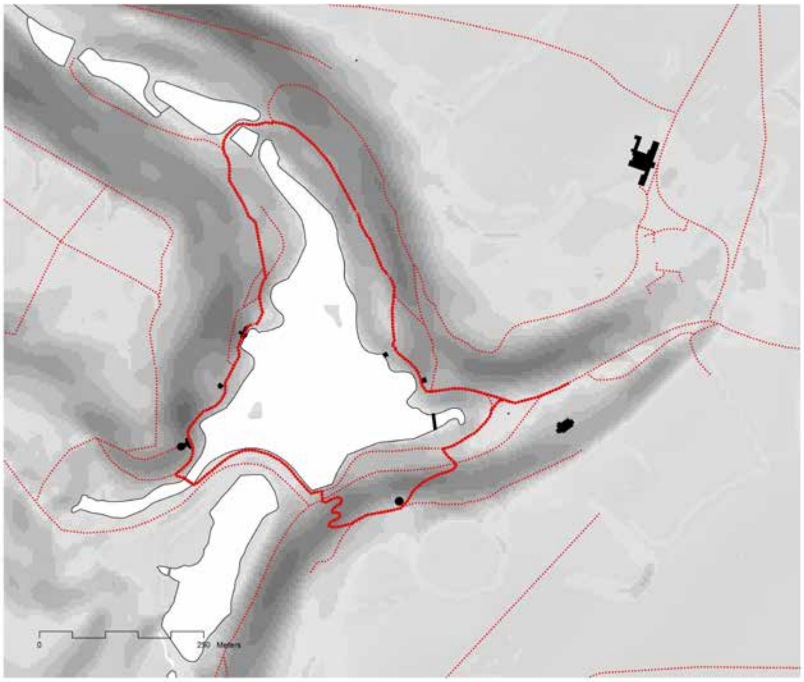

FIGURE 4.52 Route pattern Stourhead 2010 (t_3) in relation to slope and architectural features. Main route in thicker line. → Overlay on GIS-based slope analysis (map: Steffen Nijhuis)

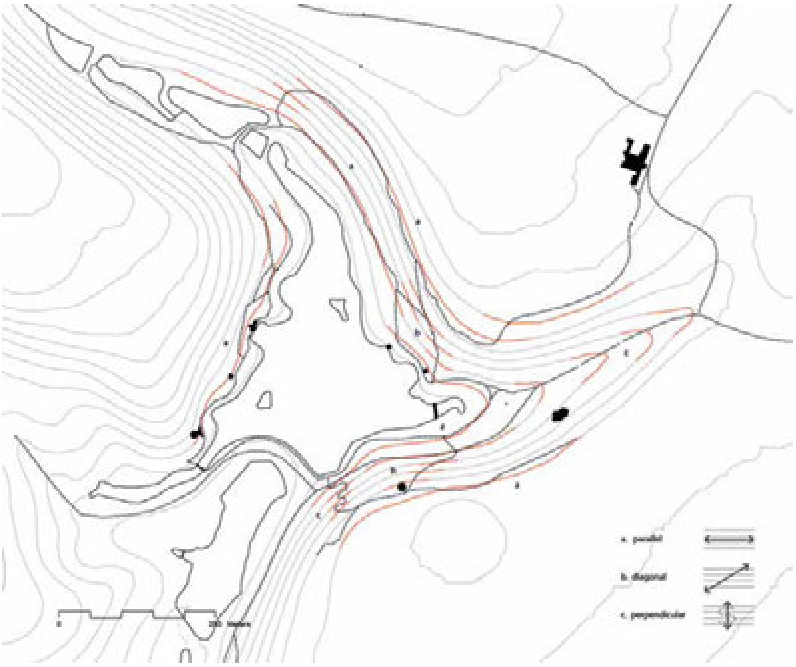

FIGURE 4.53 Basic form of the route pattern in 2010. The 2010-route system (Stourhead t_3) reflects the continuous tendency of toning down height differences to make it a less energetic descent or climb. The route focus' is more on the valley itself and articulate its differentiated, intricate and rich natural form with a circular walk around the lake (map: Steffen Nijhuis)

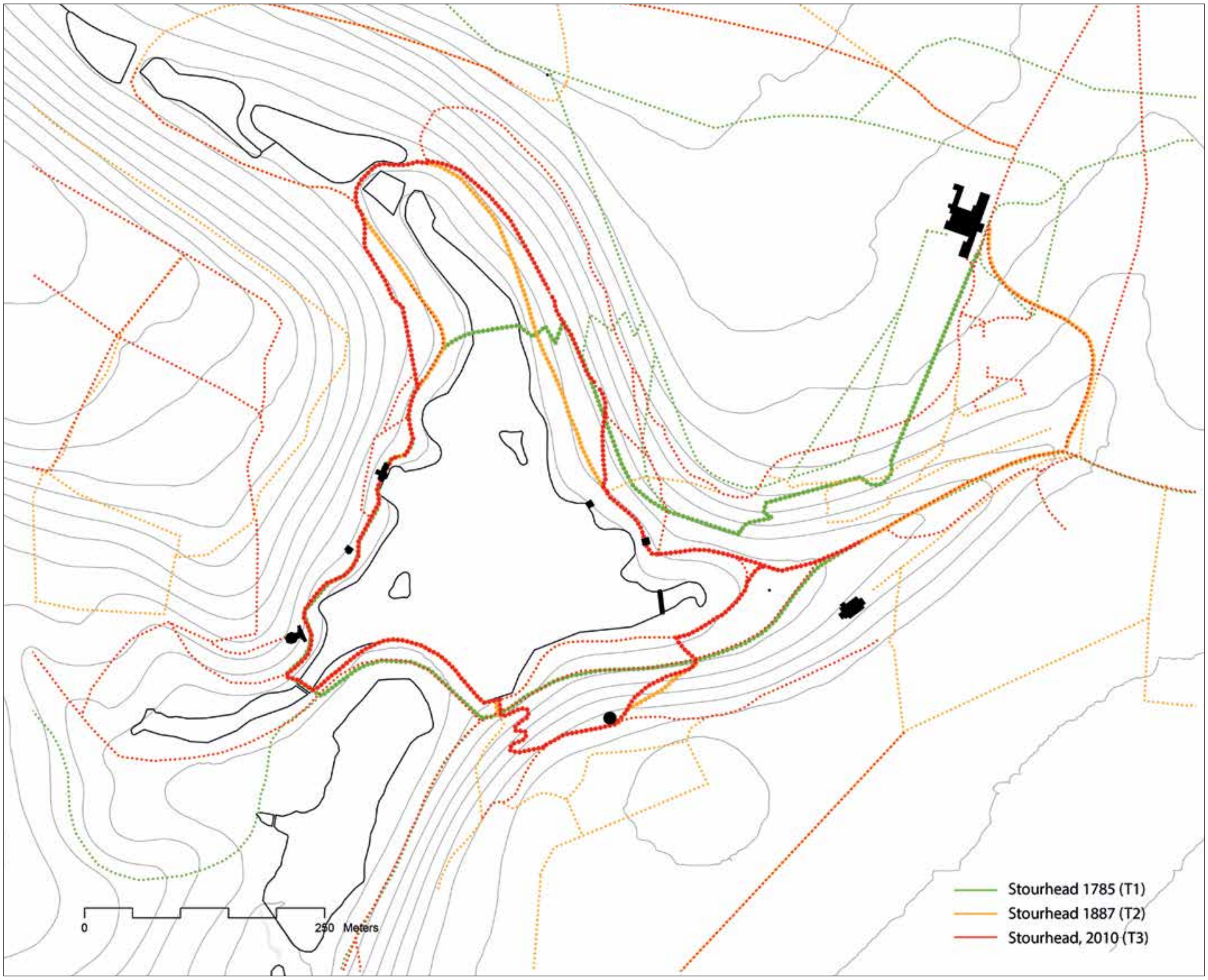

FIGURE 4.54 Development of the route pattern (Stourhead 1785 (t_1), 1887 (t_2), 2010 (t_3)) (map: Steffen Nijhuis)

The basic form of the route system of the plateau changed considerably. Since the focus was on the development of the Valley Garden, the Great Oar Pasture-circuit was not used anymore and became derelict. However, below the Fir Walk an alternative route to the valley evolved, entering the valley at Diana's pool. There was still also the possibility of entering the valley at the Temple of Flora directly from the house. The outer circuit remained unchanged.

The 1887-route system (t_2) changed the transition from the plateau to the valley, and shifted from the eastern plateau edge towards the eastern valley branch. The dramatic effect of crossing height differences on this transition was toned down, by following the smooth gradient of the eastern valley branch. Hence the relationship in the basic form between the plateau and valley became weaker. The changes in the route structure on the plateau caused the loss of the Great Oar Pasture-circuit and weakened the basic form of the Pleasure Garden around the house. The basic form of the Valley Garden was strengthened. Around the lake the route was extended into the western branch and came closer to the eastern shore of the lake. The added route towards the Temple of Apollo with its dramatic height difference stresses the autonomy of the valley as a complex geomorphological landform with different branches.

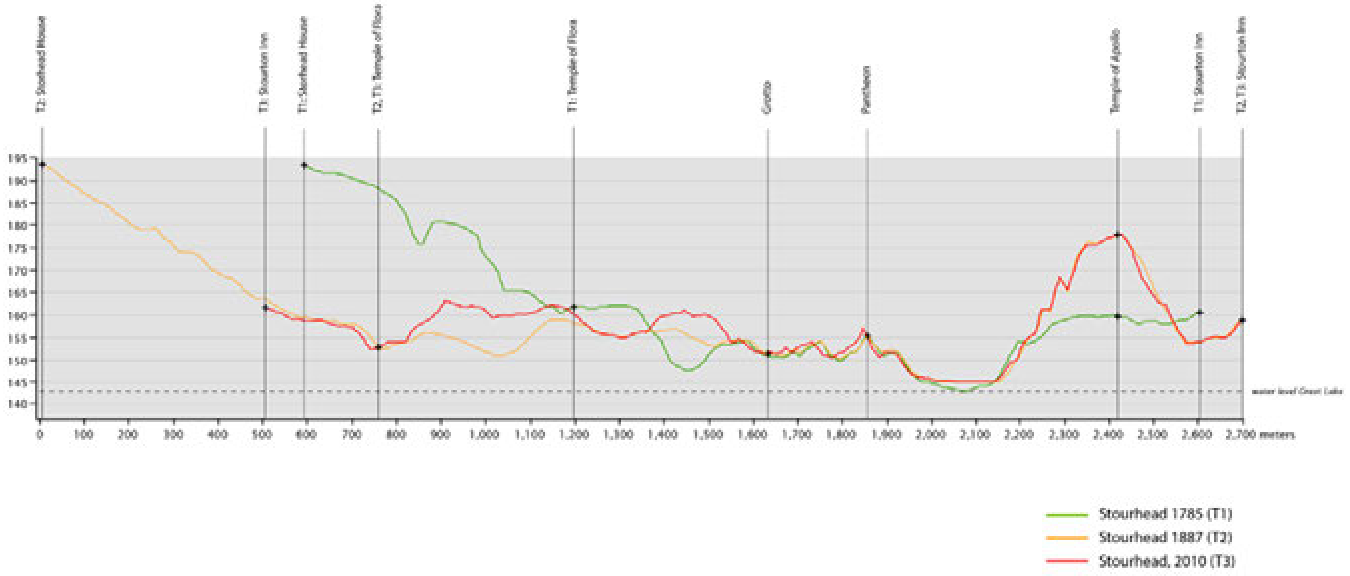

FIGURE 4.55 Analysis of the routes and their height gradient.
→ GIS-based analysis of height gradient along the route derived from DEM 1785-2010 using 3D Analyst (drawing: Steffen Nijhuis)

Route pattern Stourhead 2010 (t_3)

The 2010-route system (t_3) reflects the continuous tendency of toning down height differences to make it a less energetic descent or climb. Nowadays the circuit route along the lake can be followed on a path on a more or less level stretch along the same contour line. It is also possible to enter the valley from the house via the Temple of Flora or Diana's pool, again following the edge of the plateau and descending into the valley following contour lines and crossing them diagonally [Figure 4.52 & Figure 4.53].

The development of the route system expresses a gradual change in the relationship between the route and the terrain [Figure 4.54 & Figure 4.55]. The initial route dramatised the differences between the basic form of the plateau and the valley and at the same time tied them together. The later routes focus more on the valley itself and articulate its differentiated, intricate and rich natural form with a circular walk around the lake with the Temple of Apollo as the climax at the top of its natural longitudinal axis.

§ 4.4 Characteristics of the three-dimensional composition

An important aspect of Stourhead landscape garden is the form and functioning of the three-dimensional composition, which determine the spatial form and the experience of the design. The characteristics of the three-dimensional composition can be described in terms of corporeality. The corporeal form addresses the physical three-dimensional (Euclidean) space and can be described in terms of spaces, boundaries, volumes and screens. A space is a surface with hardly any visually obstructive elements, and can be defined by textures, height differences and ('solid') boundaries or volumetric elements higher than eye level. As it is barely possible in landscape architecture to create strictly defined spaces like those in architecture, space is actually created by mentally completing components that can be perceived incompletely.[537] The location and relation of the boundary solids to each other are crucial for the potential of an area to be summed up as a 'space'.[538] Boundaries or volumes are space-defining elements and consist of landforms, vegetation (forest and shrubbery), buildings or infrastructure. Screens refer to the concept of transparent boundaries and can consist of lines of trees that define space but at the same time freely create random connections with the surroundings.

§ 4.4.1 The spatial form of the plateau and valley

The physical terrain conditions of the natural landscape were 'the canvas on which the landscape garden is painted'.[539] The landscape architectonic composition is largely determined by the basic form of the plateau and valley and articulated by patterns of vegetation (i.e. lines, clumps of trees and solitary trees, woodland and shrubbery), the lake and the placement of architectural features [Figure 4.56]. The plateau is characterised by a vast open space with a clear and abrupt change of height towards the Valley Garden, which is accentuated with planting on the edge creating a transition zone from the plateau to the valley. Around Stourhead House, the open space is articulated with randomly placed clumps of trees, lanes, and hedges opening up and closing views. The valley can be considered as an almost enclosed space, determined by the undulating slopes, and planted ridges on three sides, which constitute a winding frame around the heart of the composition: the Great Lake. The planting on the slopes of the valley dramatises and diversifies the formal system by following or opposing the landform. To the south the valley opens up, with the dam as a horizontal line.[540] The lake is the plane that reflects the various scenes of the surrounding wooded and grassy slopes ornamented with architectural features. These spatial characteristics are the result of a succession of landscape architectonic transformations.

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[537] Loidl & Bernard, 2003, p. 58.

[538] Ibid.

[539] To speak in the words of Hirschfeld, 1779-1785/2001, p. 203.

[540] According to Von Sckell (1825/1982, p. 60) one open side is ideal in the composition of a lake in a valley, in order to see the 'free horizon' and enhance the spatial effect of the water.

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FIGURE 4.56 Stourhead landscape garden from the east. The Valley Garden left and the plain with Stourhead House and Pleasure Garden on the right are the two main spatial entities (photo: Birdman photography, 2012)

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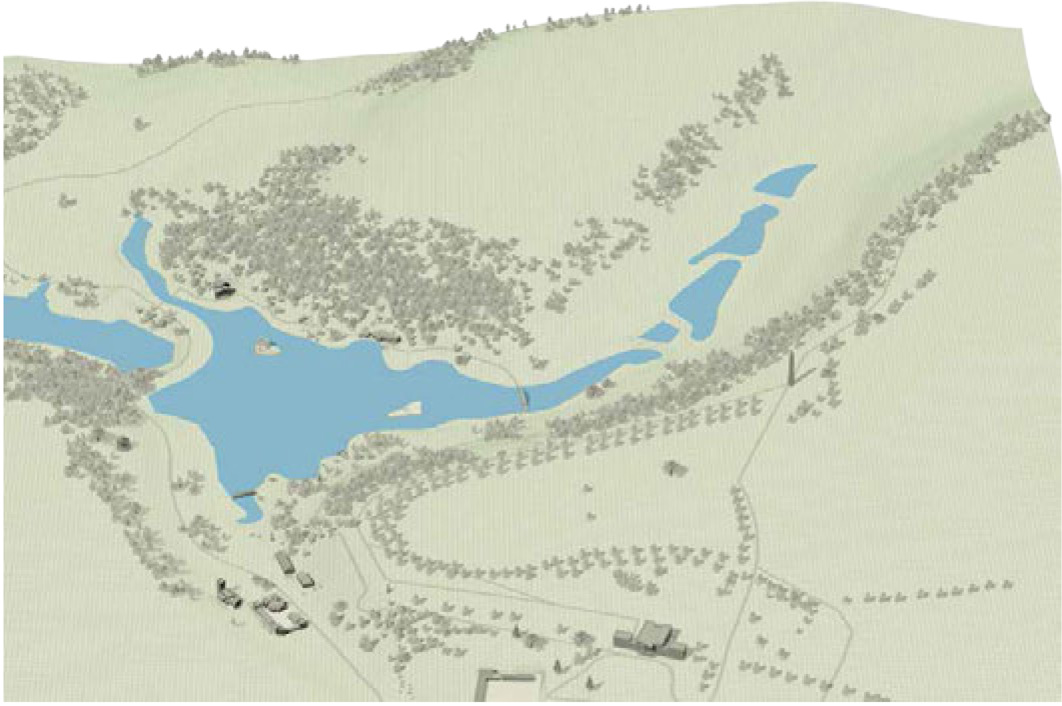

b

FIGURE 4.57 Schematic-iconic representation of Stourhead 1785 (t_1), view from south (a) and northeast (b) (model by Steffen Nijhuis & Joris Wiers)

§ 4.4.2 The development of the three-dimensional composition

The successive spatial evolution of the garden can be studied using GIS-based three-dimensional visualisations of Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3).

Corporeal form Stourhead 1785 (t_1)

As visible in the three-dimensional representation of the time-slice snapshot Stourhead 1785 (t_1) [Figure 4.57] the Fir Walk was planted along the edge of the plain, which emphasised the boundaries of the terrace and articulates the transition in height. Initially this was a double lane of Douglas fir that acted spatially as a balcony over the Valley Garden and embraced the Great Oar Pasture. Due to the transparent nature of the lane it was in space-defining terms a transparent screen. From the valley the Fir Walk spatially retained the relief. The house is oriented towards the open agricultural landscape. In front of the house groups of beech, poplar and evergreen oak were present,[541] acting as coulisses in the open agricultural landscape. Here the planting followed the spatial pattern of the agricultural landscape, integrating the landscape garden into its surroundings. To the back the Obelisk as vertical accent marks the axial orientation to the landscape, but its visual relationship to the house was blocked by a screen of trees. This continuous belt of trees created an elongated space oriented towards the valley. Here the Statue of Apollo and the Temple on the Terrace polarize the 'transition space' between the house and the valley and give direction. Along the edge of the terrace the Umbrella Seat and the Turkish Tent introduced the Valley Garden by opening up vistas and acting as rest points.

In the valley the planted tree-mass diversified the open space created by the natural form of the valley. The planting mass sometimes met the Great Lake and sometimes not, dramatising the slopes by almost completely covering them or keeping them partly open. Broadleaved trees dominated (e.g. oak, ash, beech, alder), with some conifers intermixed,[542] and provided a backdrop for the architectural features. The green tones were arranged in large masses "*as the shades are in the painting to contrast the dark masses with light ones*."[543] According to this principle, parts of the northeast slope were afforested and blended with the slopes making it heavier in visual terms. However, at Diana's Hill the slope downwards stayed open as a vista, with the converging contours of the tree-mass guiding the eye towards the Turkish Tent. The Turkish Tent was then accentuated, by its placement on a small terrain elevation. The shores were largely unplanted, except for some clumps of trees, creating a spatial transition from the slopes to the water. At Flora's Temple the planting met the water and embraced the building. Halfway up the slope there is a small semi-concealed space with the Chinese Alcove.

The western slope of the valley was completely afforested, with the extensive use of laurel underwood creating a green mass visually emphasising the steep slope. At this side the trees came down to the lake and served as the backdrop for the Grotto and Pantheon as main architectural features. The water form in the bays narrows and bends around the planted slopes, creating the illusion of a river mouth.[544] The top of the ridge remained open. The islands and dam were planted with shrubs.

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[541] Woodbridge, 1976, p. 88.

[542] Ibid.

[543] Henry Hoare cited in Woodbridge, 1976, p. 104.

[544] In 1814 the eastern branch of the lake was extended in the direction of the village, presumably to strengthen this effect.

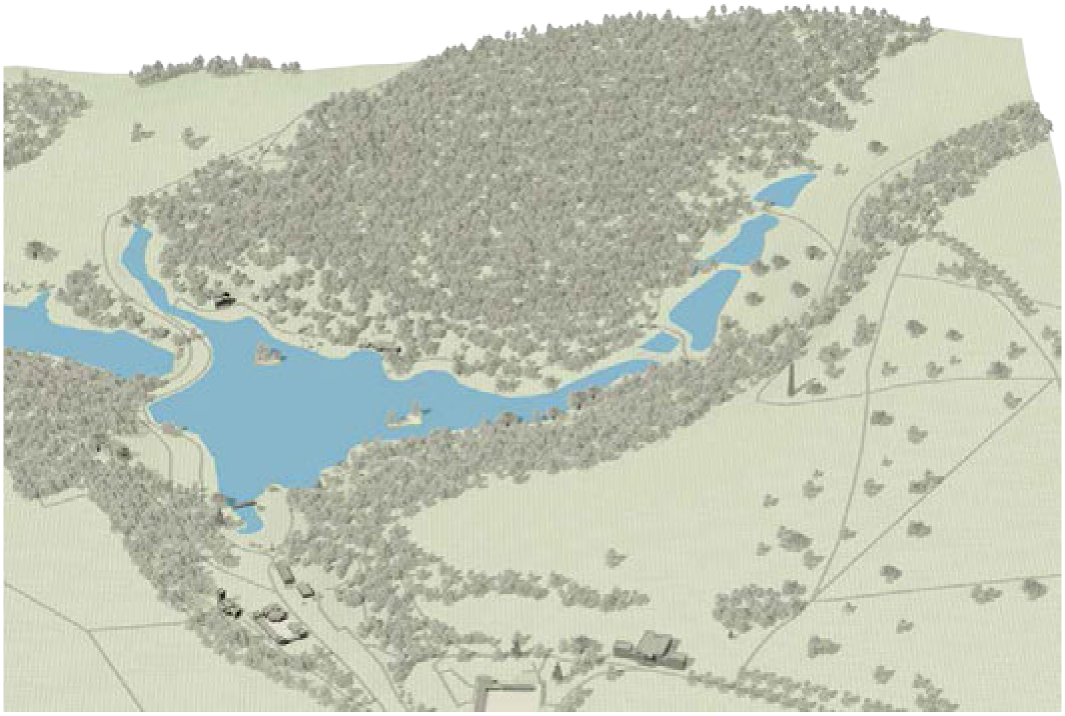

FIGURE 4.58 Schematic-iconic representation of Stourhead 1887 (t_2), view from south (a) and northeast (b) (model by Steffen Nijhuis & Joris Wiers)

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The water of the lake in northern and eastern bay is crossed by the Wooden Bridge and Palladian bridge respectively. These played an important role in the various views around the lake and function as coulisses in the scenery.

The south side of the northern bay remained largely open, except for a belt of trees that was planted along the edge of the terrace. This visually heightened the relief and emphasised the edge of the terrace. Here below the Temple of Apollo the slopes remained mainly unplanted besides a few clumps of trees along the shore. The foliage in the southern part of the slope hid the Hermitage as a transition zone between the bottom of the valley and the Temple of Apollo.

Though the planting was still young and often transparent it acted as a spatial interface between the plateau and valley. The planting and the architectural features along the edges of the plateau articulated the relationship between the higher and lower parts of the composition. The transparent Fir Walk in particular acted as a balcony from which the valley could be seen. The Pleasure Garden was extended into the valley via the creation of transitional spaces that were accentuated by the Statue of Apollo, the Temple of the Terrace, the Umbrella Seat and the Turkish Tent. At the same time these features established spatial relationships by attracting people towards them and opening up vistas to the valley. The geomorphological form of the grounds was architectonically elaborated by strengthening the corporeality of the landform and articulation of the open spaces, like the water plain and the open slopes, and contrasting tree-masses. The asymmetrical nature of the valley was emphasised by the contrast of the completely afforested western slope and the open southern slope with a planted edge.

Corporeal form Stourhead 1887 (t_2)

Stourhead 1887 (t_2) [Figure 4.58] shows considerable changes as brought about by removal of architectural features and the introduction of a planting programme by Richard Colt Hoare, but also by the maturation of trees and shrubs. To the rear of the house the belt of trees was cleared, opening up the space towards the Obelisk. The increased amount of scattered solitary trees and clumps of trees in the pastureland surrounding the house increased the spatial diversity as well as strengthened the visual depth of the space as coulisses in a theatre would. Trees guide the driveway and other roads towards the house. These lines of trees function as screens and divide the vast open space of the plain into chambers.

The Fir Walk was replaced and thickened with broadleaved trees and under-planting. Due to the foliage the valley was no longer visible from the edge of the terrace. The transparent Fir Walk turned into an opaque green mass, making a clear division between the plain and the valley and at the same time creating a transition zone. Masses of planting also appeared on the south facing slope of the northern bay of the valley, ‘hiding’ the village of Stourton from the house. Here, on the terrace side, a funnel-formed space directs visitors from the house to the Valley Garden. The Statue of Apollo, the Temple on the Terrace, the Turkish Tent and the Umbrella Seat, as well as the Chinese Alcove were removed, as were the Wooden Bridge and Hermitage. Some cottages in the village that obscured the view of the church and the gardens were also demolished. Spatially this meant that the visual variety in architectural features was toned down.

The balance between space and mass in the valley also changed substantially due to an extensive planting programme. The northeast slope became completely planted, filling in the vista and bare shore, covering the whole area down to the water shrubbery and with some trees. The slope and shore on the south side of the lake were also planted with trees and laurel, creating continuous massive spatial boundaries that together made the valley space seem smaller.

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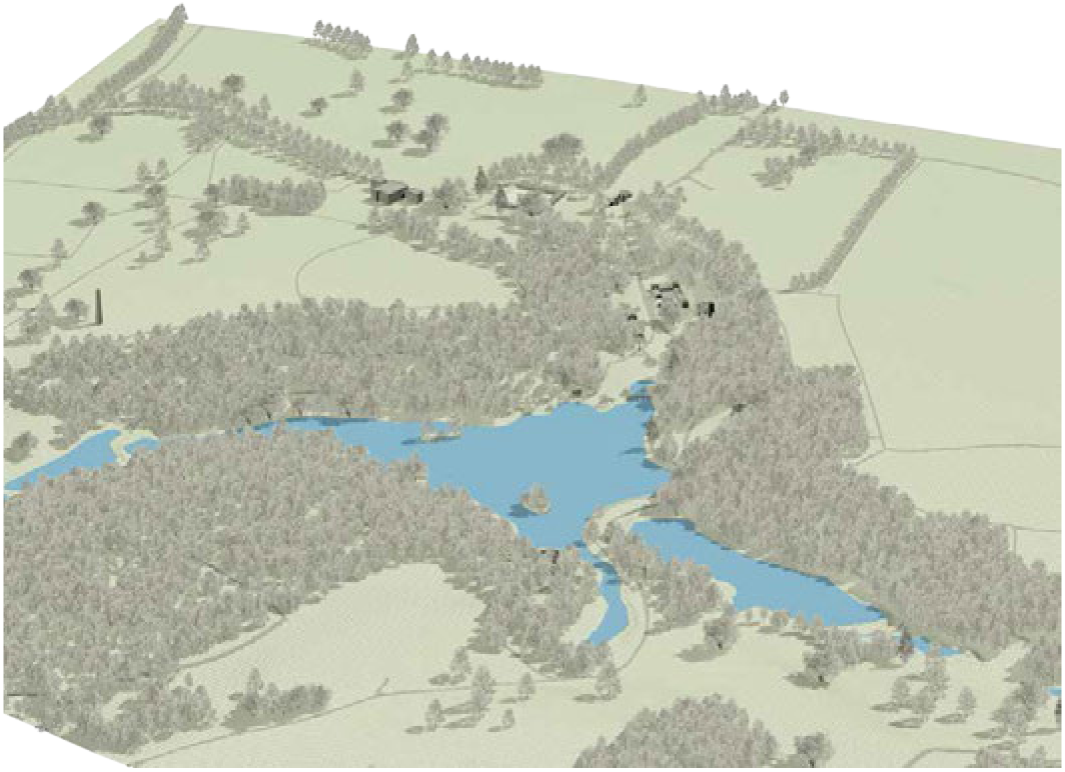

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FIGURE 4.59 Schematic-iconic representation of Stourhead 2010 (t_3), view from south (a) and northeast (b) (model by Steffen Nijhuis & Joris Wiers)

The belt along the edge of the terrace too was extended and thickened, completing the space-embracing boundary of the valley. The slope below the Temple of Apollo remained open, but the lower part was later planted with some shrubbery, setting the temple in a 'sea of green'.

Around the lake ornamental planting was introduced in the form of exotic trees and shrub species. Most notable is the introduction and extensive planting of rhododendron (*Rhododendron ponticum*)[545] throughout the Valley Garden. This planting mass with soft mauve, lilac and red colours in May-June, had a significant impact on the visual effect, and was in great contrast to the former planting mass, which mainly consisted of green tones. Within the lake, the islands with added trees and shrubs 'blocked' or 'hid' the course of the water in the bays, just as the Palladian Bridge in the north hid the second bend of the water course, creating the illusion of a continuous water flow.

The extensive planting programme changed the corporeal form drastically. The spatial form of the plateau and the valley became more autonomous parts of the composition due to the decreased articulation of their transition through the transformation of the Fir Walk into an opaque green mass, the removal of architectural features in the transitional zone, and the almost complete afforestation of the slopes on all sides leaving only some clearings framing and directing views. The Valley Garden became the more dominant part of the composition due to the retained architectural features and the introduction of exotic trees and under planting. In general the asymmetrical nature of the valley was toned down due to the planted slopes becoming continuous massive spatial boundaries, which enforced the central position of the lake and the introvert character of the Valley Garden. The open space on each slope became densified by planting that both created small enclosed spaces as well as opened up vistas towards and across the lake. The spatial extremes of the open lake and the closed afforested slopes became articulated via spatial diversification at a local level in the transition zone between the slope and the water.

Corporeal form Stourhead 2010 (t_3)

The spatial composition of Stourhead 2010 (t_3) [Figure 4.59] can be characterised by a further densification of the spaces on the plateau and a further densification of the Valley Garden. The construction of visitor facilities in particular changed the open character of the plain at the entrance of the northern branch of the valley. Buildings and related planting created sub-spaces and densified the open character of the plain. The spatial variety in the Valley Garden levelled out due to additional planting and natural growth of the planting in the last century. The slopes became almost completely afforested and the planting masses do not articulate the slopes anymore but covers all sides of the valley, mostly to the water. As a result the intricate spatial system with transition zones from the slope to the water disappeared, and decreased the spatial variety in the sense that open was more open and the closed more closed. The spatial extremes were emphasised, with the Great Lake as the most open space, and the slopes and shores as the almost closed. In relation to that, the framing of the views became more pronounced, and views were emphasised selectively, particularly the views on the Pantheon and the village. Other views are (partly) overgrown, like the view on and from the Temple of Apollo. The dominant position of the Valley Garden in the composition is further emphasised by the construction of the visitors facilities, which guide individuals directly to the Valley Garden, and the proliferation of exotic species there. Accumulation of detail due to collecting and planting of individual species, and the introduction of notes of strong colour in the scene (e.g. flowering shrubs, leaf colours), caused fragmentation in the visual effect of the planting mass.[546]

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[545] First introduced in 1791 but extensively planted in the period 1828-1830 (Woodbridge, 1976, p. 100).

[546] See also: Woodbridge, 1976, p. 105.

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The development of the corporeal form expresses a gradual change in the relation between the plateau and the valley, between landform and planting. The initial planting and architectural features integrated the higher and lower parts of the composition. Gradually the corporeal form was architectonically elaborated by an intricate system of open and closed spaces creating transition zones between the plateau and the valley, between the slopes and the water. Initially the asymmetrical nature of the valley was emphasised by the contrast of the completely afforested western slope and the open southern slope with the planted upper edge. Over time both the plateau and the valley became densified and more autonomous through an extensive planting programme and removal of architectural features. The Valley Garden became the more dominant part of the composition due to the remaining architectural features and the introduction of exotic trees and under planting. At this stage the relation between the open lake and the closed afforested slopes was articulated via spatial diversification at a local level in the transition zone between the slope and the water. However, further densification transformed the corporeal form of the valley into spatial extremes of space and mass, but emphasised its overall introverted character and the central position of the lake. The Valley Garden was transformed into an arboretum with the emphasis on the variety of individual plants rather than the variation in spaces and masses.

§ 4.5 The visual manifestation of the three-dimensional composition

As discussed earlier, the visible form is something quite different from the corporeal form. The visible form refers to the appearance of the composition to an observer within it from a horizontal perspective and is a visual treatment of the potential perceived space. Not only do the three-dimensional aspects of space play a role in the visible form; other conditions related to visual observation are also determining factors, such as: the physiology of visual perception (field and range of vision), observation conditions such as position (altitude, proximity and angular size of the objects), viewing direction, and atmospheric conditions.[547] Routes are also important, since these guide the visual and kinaesthetic experience that emerges only via movement. Movement determines the sequential unfolding of visual information as observers pass through the designed landscape.

Both virtual 3D-landscapes from eye-level and viewshed analysis are employed to explore the visual manifestation of the three-dimensional composition. They make it possible to portray the landscape architectonic composition objectively from the perspective of the viewer. Essentially the aim is to describe, analyse, and map the visible form determined by the relative position(s) of the individual in relation to the spatial patterns consisting of open spaces, surfaces, screens, and volumes within the composition. The virtual 3D-landscapes mimic the experience of the composition from the inside out and are helpful in getting a grip on the scenography of the routes and in identification of visual relationships and connections by means of close observation and interpretation of the renderings. With the help of viewshed analysis, the observer's field of vision can be automatically analysed from many different angles.[548] The potential of 'being able to see' is mapped out; this has to do with the plausible and/or probable visible space.[549] The product is a morphological description of spaces and

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[547] Duntley, 1947; Nicolai, 1971; Antrop, 2007.

[548] Llobera, 1996, 2003; Wheatley & Gillings, 2000.

[549] Fisher, 1995, 1996; Weitkamp, 2010.

elements and their position in their surroundings, removed to the greatest degree possible from symbolic, cultural, and personal elements. In this way, the visible form can be analysed from single or multiple observation points covering the entire 360 degrees of the viewing circle or any part thereof. The visible portion of the viewing circle is thus calculated.[550] The part that is immediately visible to an observer is called the breadth of view, or viewshed. Viewing angle, viewing distance, and eye level (viewing height) may all be set as variables in the analysis [Figure 4.60]. It is possible to carry out the analysis from routes (cumulative and sequential viewsheds) to assess relative space visibility, open-close ratio, and visual dominance of the composition's fabric (woodland/trees, grassland, water) along the main routes, but also from individual positions (single viewsheds) to analyse particular views and visibility ranges from high vantage points.

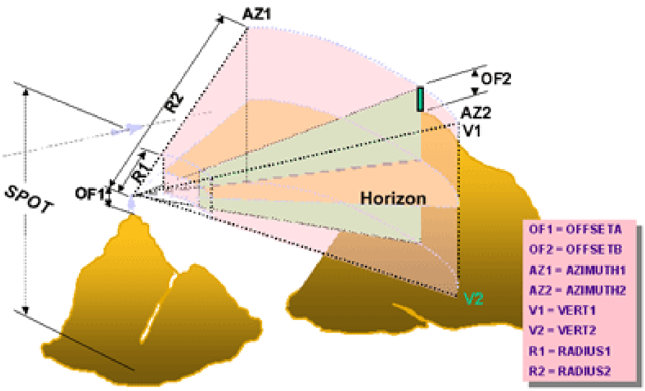

FIGURE 4.60 Parameters for controlling the viewshed analysis. It is possible to limit the region of the raster inspected by specifying various items in the feature attribute dataset, such as observation point elevation values, vertical offsets, horizontal and vertical scanning angles, and scanning distances (source: ESRI)

§ 4.5.1 Relative visibility from the main routes at eye level

Relative visibility is an important index for determining the visual form of the landscape architectonic composition and concerns the fundamental question of what can and what cannot be seen from certain viewpoints.[551] Relative visibility is an indicator of visual scale describing perceptual units ("landscape rooms") in relation to their size, shape and diversity, and openness.[552]

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[550] Technically the viewshed identifies the cells in an input raster that can be seen from one or more observation locations.

[551] Higuchi, 1975/1988, p. 4.

[552] Cf. Tveit et al., 2006; Ode et al., 2008.

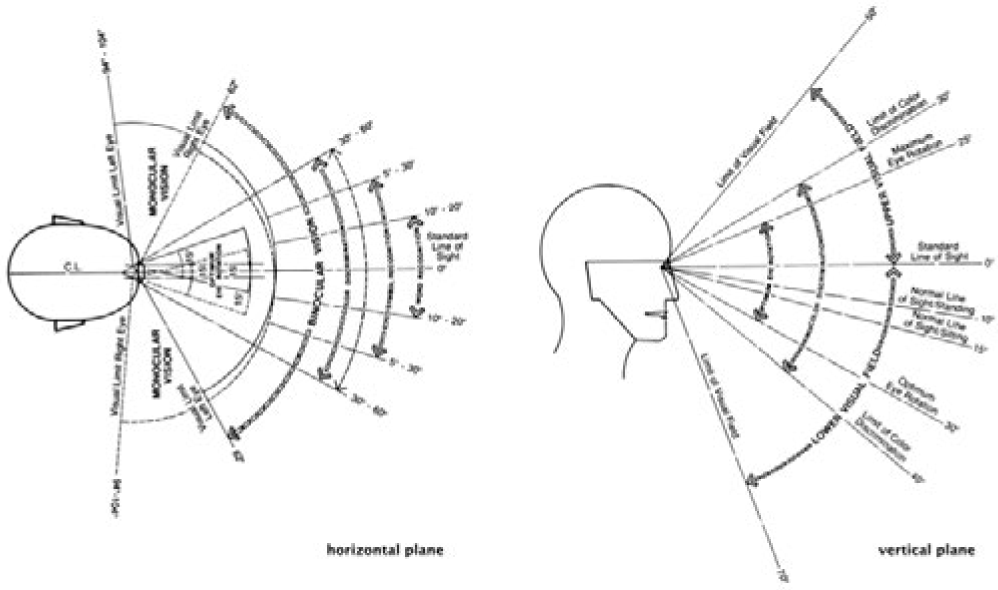

FIGURE 4.61 Field of vision in the horizontal and vertical plane (image source: Panero & Zelnik, 1979)

Openness in this sense is an integrated concept and can be understood as a derivative of patterns of screens and volumes in the designed landscape.[553] Each perceptual unit has its own characteristic open/closed ratio and is related to the notion of mystery. In landscape architecture terms, mystery refers to "*a pleasant challenge to the imagination which sets the observer to trying to determine for himself by closer investigation what is concealed from his first glance, or if this be impossible, to filling in and completing the unseen landscape according to the play of his own fancy.*"[554] In other words, mystery describes the degree to which a viewer is drawn into the landscape architectonic composition by the intrigue of what lies ahead, which in turn is related to the ability of the individual to see the landscape, or the impossibility of complete perception, and hence is a function of openness and has to do with screening, enclosure, and routing.[555] Relative visibility is also related to movement. An open environment affords movement in any direction, and an environment with surfaces, screens and objects only at openings does not.[556] Research in wayfinding indicates that route choice behaviour is 60% dependent on spatial aspects such as space perception, spatio-visual attractiveness, arousal, and orientation.[557] Thus, relative visibility is an important aspect of visible form because it affords movement via openings, offers a sense of direction via spatial orientation, and offers arousal or attraction via visual composition.

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[553] From the perspective of landscape physiognomy, open space is present where elements such as trees, houses, dikes etc. (visual limits) that rise above the observer's eye level are absent across a specific surface area. In other words, openness is present where the landscape is 'empty' or 'open' (De Veer, 1977). The degree of openness is directly related to landscape preferences and is therefore an important indicator (Nasar et al., 1983; Hanyu, 2000). However, landscape openness has a very low correlation with scenic beauty (Palmer, 1996).

[554] Hubbard & Kimble, 1917, p. 82.

[555] Kaplan & Kaplan, 1989, p. 55-57; Tveit et al., 2006.

[556] Gibson, 1986.

[557] Korthals Altes & Steffen, 1988.

Relative visibility is analysed by employing cumulative and sequential viewsheds from the main routes at eye-level and focuses on the Valley Garden. Cumulative viewshed analysis combines visual coverage (the area that can be seen) with accumulation of visibility (how many times the area is seen) relative to the tracing of the route and the number of viewpoints along the route (every 5 metres, t_1, n=411; t_2, n=544; t_3, n=440) expressed in percentages.[558] Combining the resulting cumulative viewshed-analysis with the composition's fabric, the visual dominance can be calculated to give an impression of the type of fabric that dominates the visible area (how many of which fabric can be seen). Sequential viewsheds give insight into the amount of visible area between the viewpoints along the route. This analysis quantifies the open-close ratio along the route. The following assumptions are the basis of the analysis: eye-level is 1.60 metres above ground level[559], a horizontal viewing angle of 360 degrees (the entire viewing circle) and vertical angle of 70 degrees below and 50 degrees above the standard line of sight are given [Figure 4.61].

Relative visibility Stourhead 1785 (t_1)

The visibility analysis points out that the western and southern slopes of the valley, as well as the western part of the lake, visually dominated the experience along the main route (visible from > 45% of the viewpoints) [Figure 4.62 & Figure 4.63]. This means that the combination of route tracing and planting emphasised the asymmetrical nature of the valley in terms of visible form and softened the central position of the lake by drawing attention to the completely planted western slope and to the open southern slope. While following the route in a counter-clockwise direction, the planting mass first dominates the view, which is later interrupted by the open slope on the south side. This open slope with its planted top edge directs the eye to the Temple of Apollo and to the northern branch of the valley with the Palladian Bridge, Bristol High Cross and Stourton Church. While continuing further along the route, the western side of the valley again becomes important, drawing attention to the open western branch.

The measurements show that the transition zones from the house to the valley and from the slopes to the water are a mixture of low and high relative visibility, which indicates a high degree of mystery and sense of spatial variety via partial screening, enclosure, and opening up. The natural winding of the path is sometimes parallel to the shoreline and sometimes not, gradually and progressive changing views and enhancing the impression of spaciousness. Most architectural features are located in the areas with low visibility (visible from <15% of the viewpoints) (except for the Temple of Apollo), which means that those are only visible from particular viewpoints and are concealed by planting.

As experienced from the route, the composition had a rather open and diverse character expressed by the almost 58 hectares of visible open space out of a total of 80 hectares of visible area (70.1%). Grassland is the visually dominant fabric (42.64%), followed by woodland (36.65%) and water (20.15%) [Table 4.2 & Figure 4.68]. As the sequential viewshed analysis points out, the size of the visible open spaces along the route varied greatly, indicating a rich spatial variation in terms of openness and enclosure [Figure 4.67].

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[558] 50% means the area is visible from 50% of the viewpoints along the route.

[559] Eye-level height ranges from 1.43 to 1.74 metres amongst male and female adults (Panero & Zelnik, 1979, p. 98). In this study, the average of 1.60 is used. Others propose 1.65 metres (Haak & Leever-Van den Burgh, 1994, p. 12).

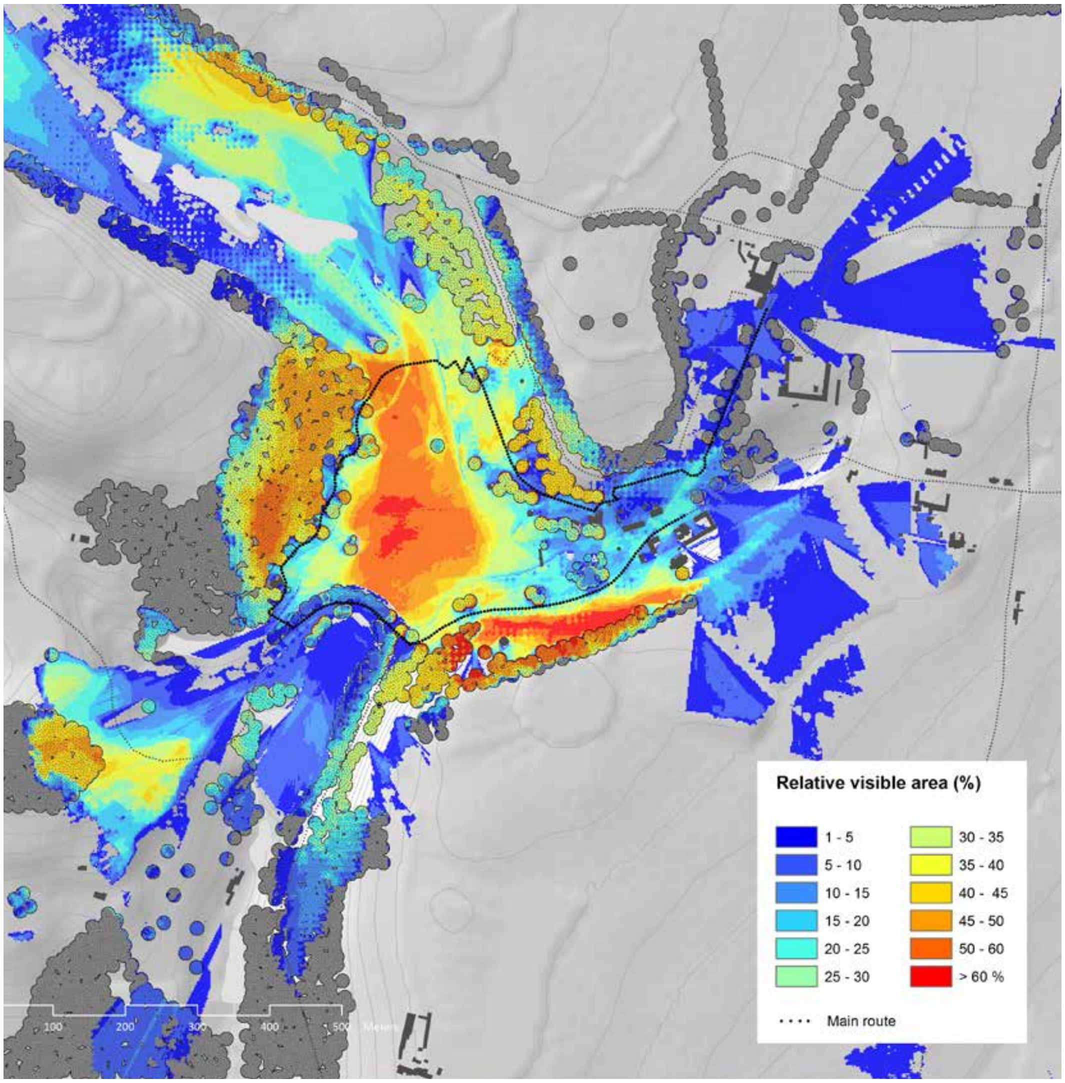

FIGURE 4.62 Relative visibility at eye-level following the main route, Stourhead 1785 (t_1).
→ Composite GIS-map with DLM 1785, the main route and cumulative viewshed analysis (map: Steffen Nijhuis)

FIGURE 4.63 The south facing slope remained unplanted and played an important role in the spatial experience of the valley. View from the Pantheon, C.W. Bampfylde, ca. 1770 (image source: Woodbridge, 1970)

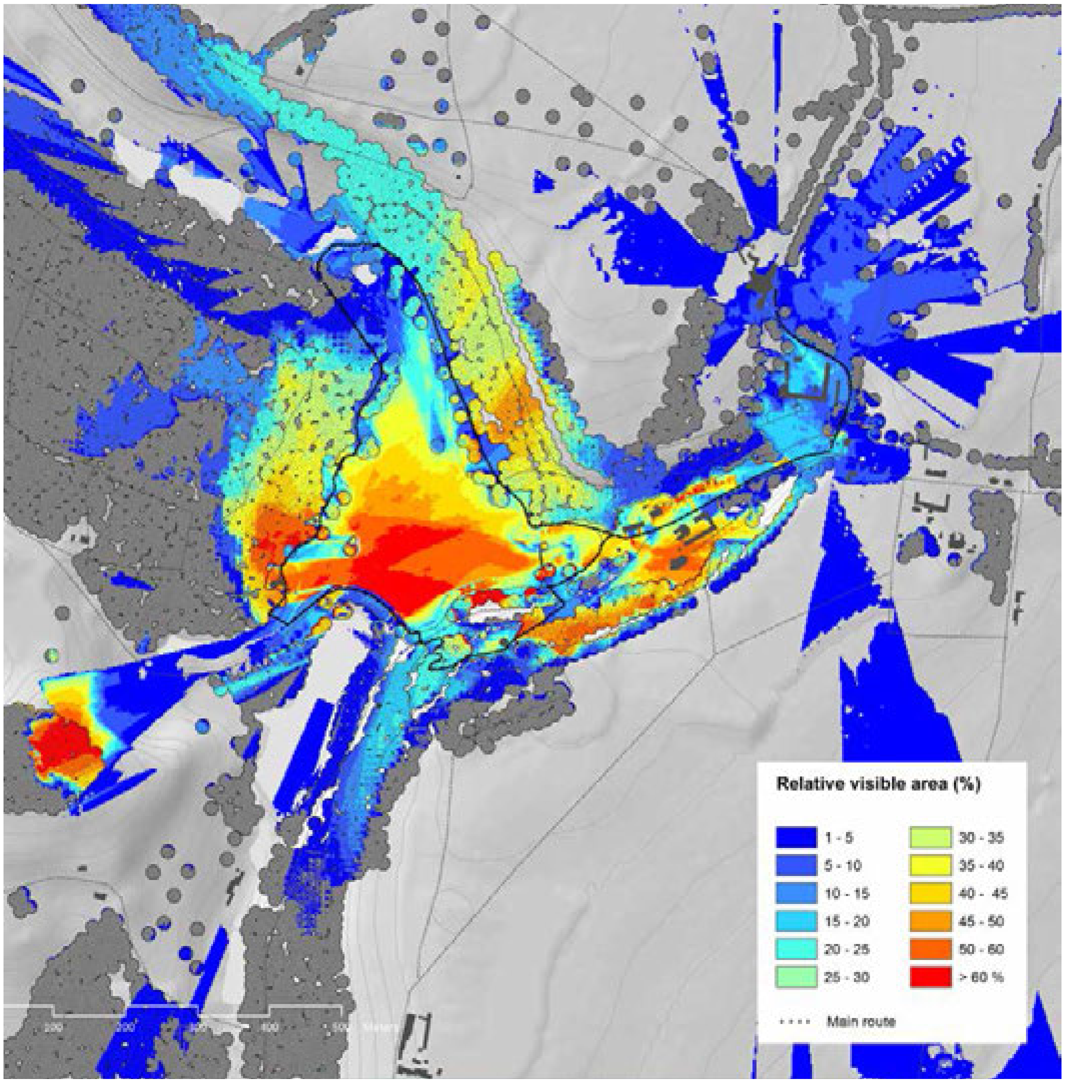

FIGURE 4.64 Relative visibility at eye-level following the main route, Stourhead 1887 (t_2).
→ Composite GIS-map with DLM 1887, the main route and cumulative viewshed analysis (map: Steffen Nijhuis)

FIGURE 4.65 The valley is spatially densified by the masses of planting on the south-facing slope. View from the Dam, F. Nicholson, c. 1813 (image source: Woodbridge, 1982/2002)

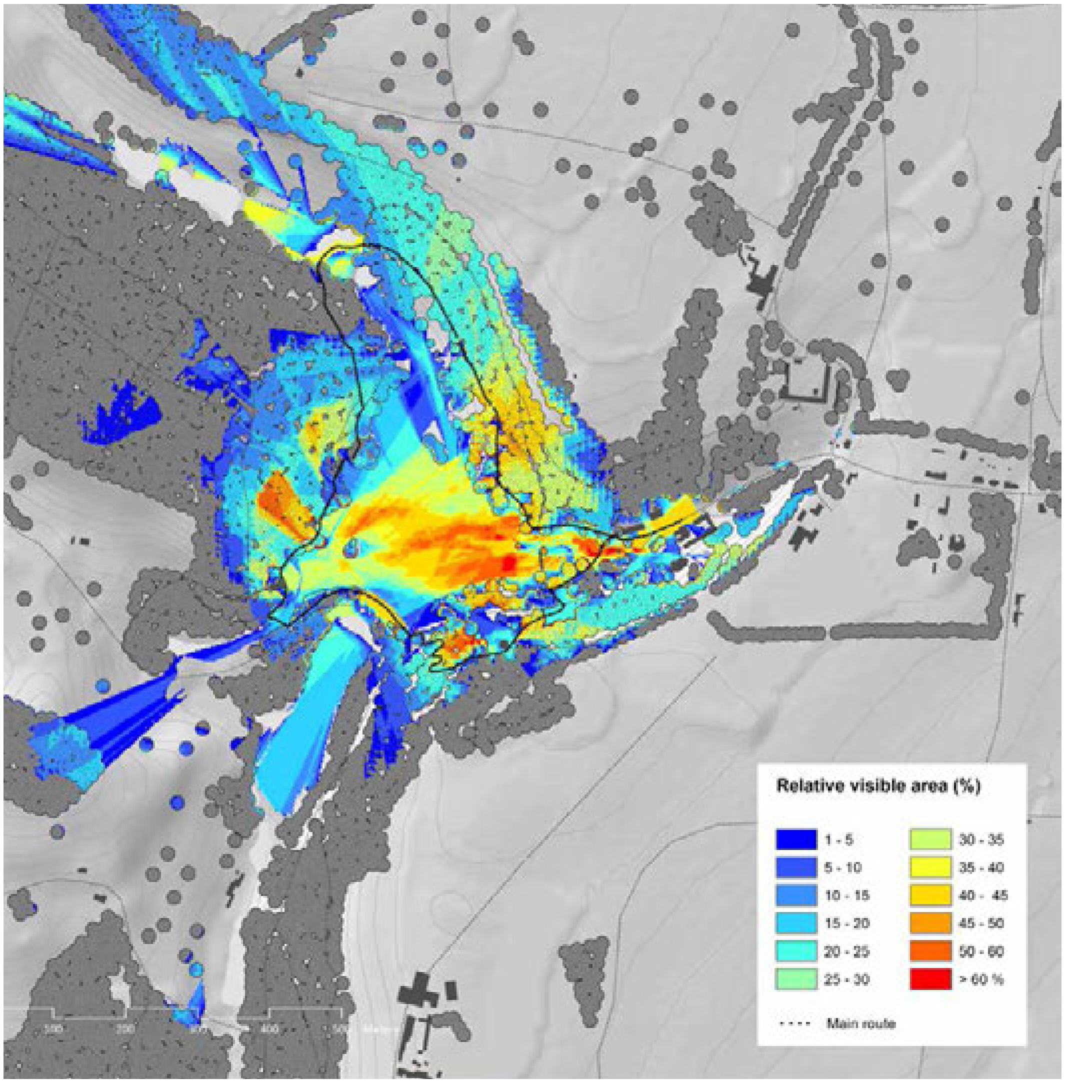

FIGURE 4.66 Relative visibility at eye-level following the main route, Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010, the main route and cumulative viewshed analysis (map: Steffen Nijhuis)

The visible form of the valley can be characterised as a double-folded directed space in which the two opposite sides of the Valley Garden counterbalance each other using openness and planting mass, and in which the central position of the lake was visually enforced. The composition showed a rich variety alternation between open and closed spaces and different visible fabrics along the route, with open grassland as the predominate fabric.

Relative visibility Stourhead 1887 (t_2)

Due to the further densification by planting and changes in the route, the relative visibility changed considerably in this time-slice snapshot [Figure 4.64 & Figure 4.65]. The southern and northern slopes have turned into green planting masses. Hence, the valley had become more symmetrical and views more pronounced and directed. The area around the Pantheon as well as the area with the Palladian Bridge, Bristol High Cross, and St. Peter's Church became the prevailing features in the visible form (visible from > 45% of the viewpoints). The Temple of Apollo was still visibly surrounded by a green planting mass but was less visually dominant. Due to the changing relative visibility, the southern part of the lake had emerged as an

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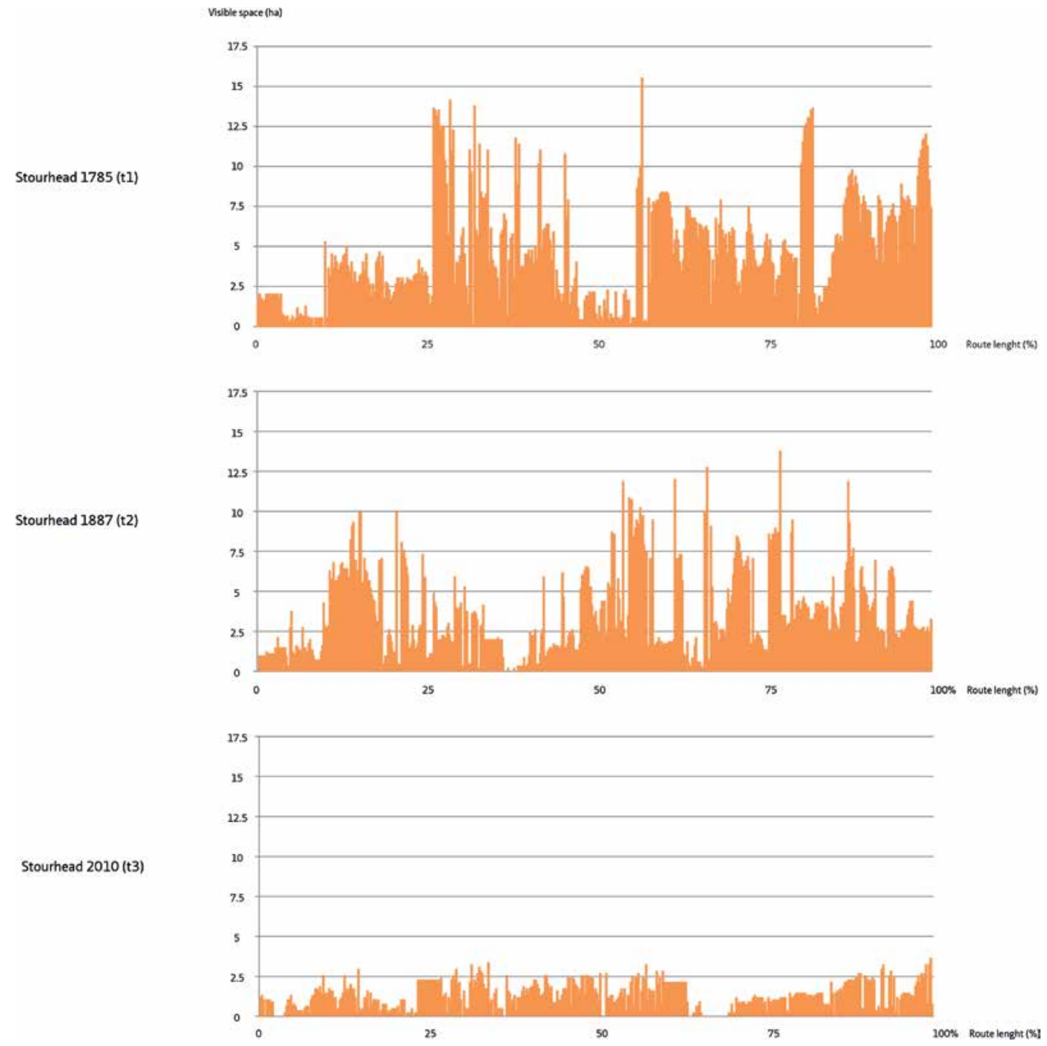

FIGURE 4.67 Comparison of amount of visible space along the main routes in Stourhead 1785 (t_1), 1887 (t_2), and 2010 (t_3) based on sequential viewsheds (image: Steffen Nijhuis)

important part of the Valley Garden's experience. In this stage of development, the transition zones from the house to the valley and from the slopes to the water were mainly characterised by low relative visibility rates (visible from <15% of the viewpoints), indicating a more constant open-close experience along the route.

In this stage of Stourhead's development, analysis shows a measured reduction of circa 20% visible open space when compared with Stourhead 1785 (t_1). At this stage, 44 hectares were visible open space, out of a total of 82 hectares visible area (53.8%). Relatedly, woodland had become the principal visible fabric (54.47%), followed by water (24.41%) and grassland (20.11%) [Table 4.2 & Figure 4.68]. The sequential viewshed analysis shows that the open-close variety was still there, but that the diversity in the size of visible spaces had levelled off [Figure 4.67].

The visible form of the Valley Garden had changed and transformed into an elongated space from the Pantheon to the village and its related architectural features. The valley had become more symmetrical in nature, emphasising the southern side of the lake. The spatial variation had levelled and developed into a balanced open-close experience along the route. Woodland and water had become the prevailing visible fabrics.

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Relative visibility Stourhead 2010 (t_3)

In Stourhead 2010 (T_3) the eastern sides of the lake and valley are the most-seen parts of the Valley Garden from the main route (visible from > 45% of the viewpoints) [Figure 4.66]. The balance in relative visibility has shifted towards the village with the Temple of Flora, Palladian Bridge, Bristol High Cross, and Stourton Church. Since big stretches of the route go through woodland and are planted on both sides, the experience of open spaces is concentrated on only a few locations. The result is that the spatial variety and the related sense of mystery in the transition zones is marginal and culminates at certain places where views open up across the lake. The sequential viewshed analysis also points out that the alternating open-close experience has changed into a more monotonous one, with some sudden changes [Figure 4.67].

In terms of relative visibility, the Valley Garden has transformed into a closed variant expressed by a reduction of about 53% in its visible area (from 80.29 to 42.34 hectares), and only 15 hectares thereof is visible open space (35.9%). Woodland is the most dominant fabric (59.59%) and water as a visible fabric has increased in importance (29.32%) [Table 4.2 & Figure 4.68].

	Stourhead 1785 (t_1)		Stourhead 1887 (t_2)		Stourhead 2010 (t_3)	
	ha	%	ha	%	ha	%
	Visible area					
	80.29		81.70		42.34	
	Visible space					
	57.65	71.81	43.94	53.78	15.21	35.93
	Visual dominance					
Grassland	1295.56	42.64	334.83	20.11	37.63	10.72
Water	612.42	20.15	406.44	24.41	102.89	29.32
Buildings	19.83	0.65	16.88	1.01	1.31	0.37
Woodland & trees	1110.83	36.56	906.88	54.47	209.14	59.59
Total	*3038.64*		*1665.03*		*350.97*	

TABLE 4.2 Space visibility and visual dominance

The visible form of the valley has developed into a space where the Great Lake and the afforested slopes are equivalent in visible open space and mass. The routes in the transition zones from the slopes to the water are almost completely covered by planting, thus diminishing the spatial variety. Only where views open up is the lake visible along with the architectural features in the background on the opposite side. In general, the eastern side of the lake and the related branch of the valley are visually the most dominant.

The development of the visible form shows a gradual transformation of the open/closed ratio as experienced from the route, which is related to the notion of mystery. The landscape architectonic composition has transformed from a rich variety of open-closed spaces, and their alternation, into a more levelled and balanced open-close experience, which is finally almost completely covered by planting and opens up only at particular points. In general, the Valley Garden has developed from a double-folded directed and asymmetrical space with the lake in a central position into a more elongated, symmetrical space with the emphasis to the southern side of the lake, which later shifted towards the eastern side. The spatial variation has been diminished by the visual effect of the amended routes in combination with the addition of new planting and growth thereof. The different visible fabrics have also changed considerably from a more diverse experience with grassland as the predominant fabric, to a more monotonous one with woodland and water as the most important fabrics [Figure 4.67, Figure 4.68 & Figure 4.69].

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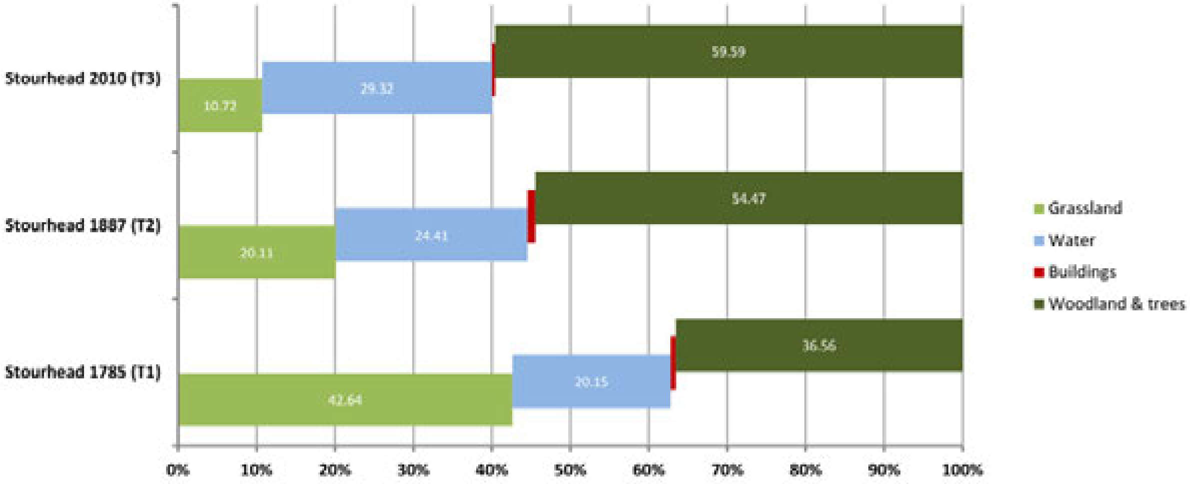

FIGURE 4.68 Comparison of visual dominance at eye level from main routes (image: Steffen Nijhuis)

§ 4.5.2 Scenography of the routes

In the time period that Stourhead landscape garden evolved, the layout of routes paid the most careful attention to the point of view from which architectural features strike the eye. The routes were not mainly constructed with attention to logistics, but to "*conduct people to notable scenes with no need for retracing one's steps*."[560] Hence the practice of laying out routes should "*not only allow for variation and diverseness but also for the most advantageous disclosure of the best views and vista's, sometimes suddenly, sometimes gradually.*" [561] In this respect, the landscape garden can be regarded as a 'walkscape' or 'gardenesque score', a spatial succession of configurations linked to the steps of the walker and consisting of routes that lead and circulate, as well as of deliberate points of view and resting points.[562] Hunt (2003, 2004) called this type of intentional relating of movement and visible form a 'stroll'.[563] A stroll is a sort of movement with a sense of destination and its ultimate purpose within the site. Strolling also implies a defined route between whatever incidents punctuate and give rhythm to the movement. In that respect, the route guides visitors through the composition in response to or in accordance with the designer's intentions.

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[560] As described by: Hirschfeld, 1779-1785/2001, p. 252.

[561] Ibid.

[562] Lefaivre &Tzonis, 1992, p. 54. The term 'walkscapes' is derived from the book of the same name by: Careri, 2002.

[563] Other types in this taxonomy are procession and ramble. The procession is a ritual movement that follows both a preordained path and purpose and is determined by implicit or explicit guidelines constituting the performance of that ritual laid down in formal records such as social or religious conventions or written text. The ramble is a type of movement without an external prompt, they are promoted largely by the will or curiosity of an individual. Rambles are for the pleasure of movement itself (Hunt, 2003, 2004).

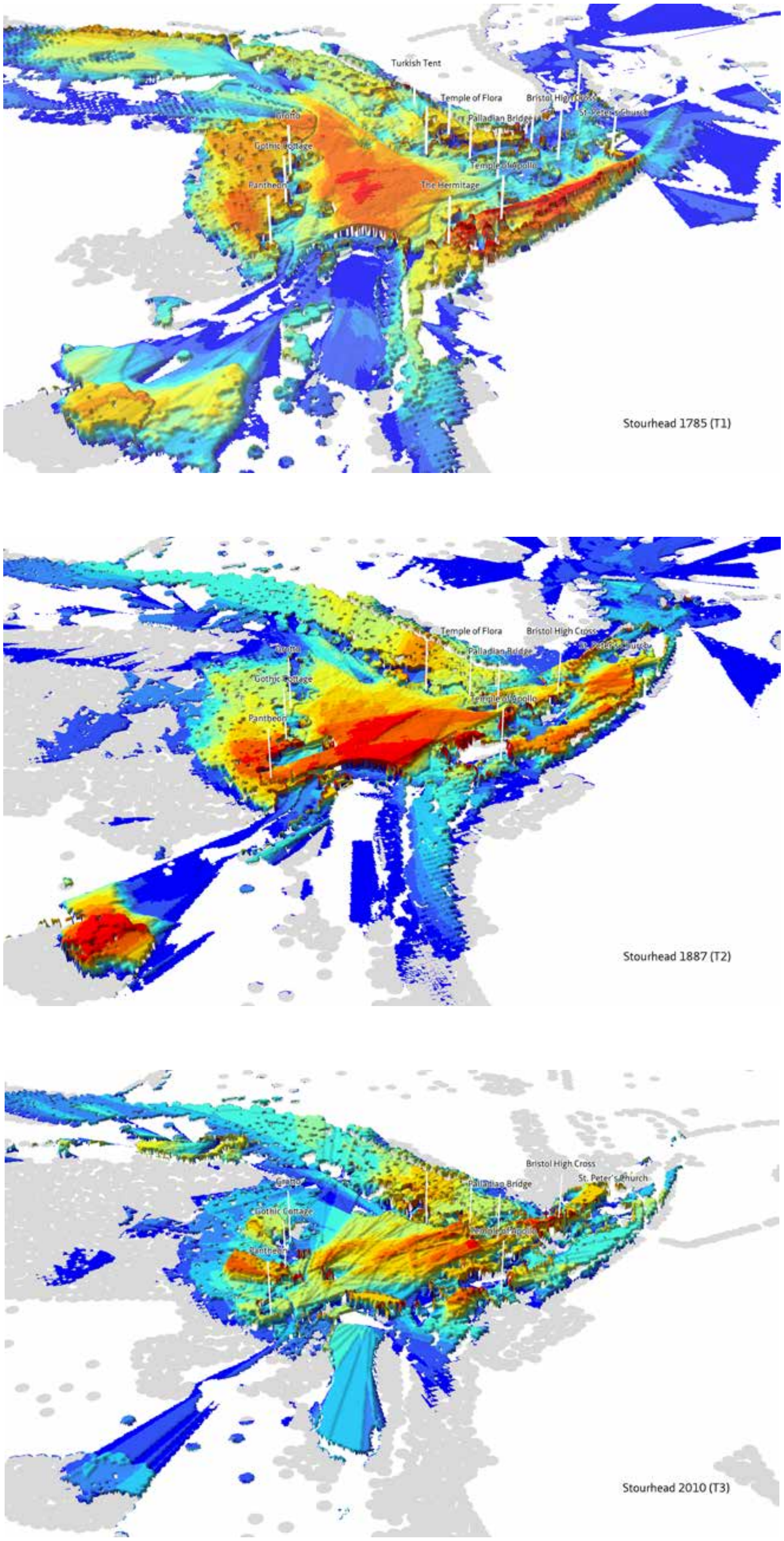

FIGURE 4.69 Development of relative visibility at eye-level following the main route, Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3).
→ GIS-based 3D-visualisation of the cumulative viewshed analysis (map: Steffen Nijhuis)

At Stourhead the routes link the house to the architectural features and create a movement-induced architectural system. In such a system, routes and landmark-based piloting are important modes of initiating visually controlled movement. Landmark-based piloting refers to the act in which the observer relies on sequentially organised knowledge: a landmark is associated with direction and distance information that leads to another.[564] In this case, the architectural features function as orientation points or attractors, and induce and direct movement.[565] They act as strategic foci in a scene and attract the attention more than other areas of the landscapes' face, thus functioning as 'magnets' or destinations[566] [Figure 4.70]. These focal points offer conscious or unconscious motives for continuing the route: having arrived at a certain destination, one sees another that stimulates the stroller to move on.

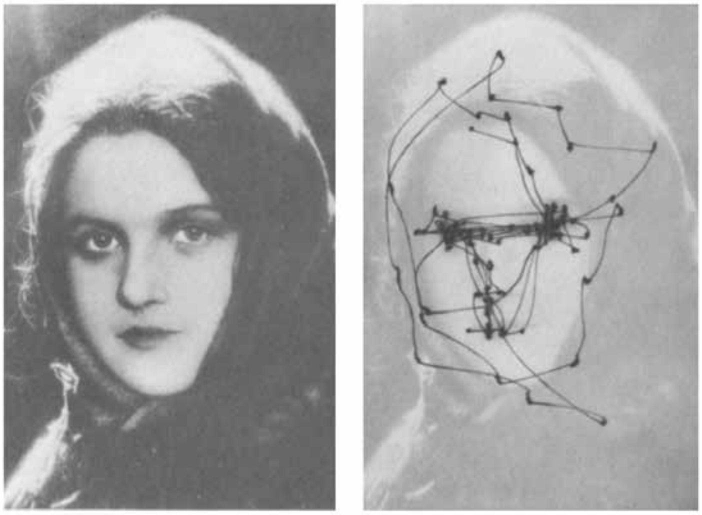

FIGURE 4.70 Recording of eye movement during free examination of a photographed face. The eye fixates mainly on the eyes and mouth as anchor points in the 'landscape of the face' because they provide important information on the internal state of mind of the person on the picture and are the basis for action (image source: Yarbus, 1967)

In order to analyse the relation between the scenes, the visual links (or sightlines), and the routes, three-dimensional visualisations of Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3) were employed. To simulate the experience of an individual standing in the composition perspectives were generated at eye-level (1.60 metres) with a 35mm camera perspective, which corresponds to a 62 degree binocular field of vision. The analysed routes and viewpoints are indicated in Figure 4.74.

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[564] Allen, 1999.

[565] Golledge & Spector, 1978; Golledge, 1999; Hillier et al., 1993. For applications in landscape architecture see: Loidl & Bernard, 2003, pp. 102 ff.

[566] More precisely: they provide more information than others elements and carry useful or necessary information for recognition and understanding of spatial relationships (Yarbus, 1967).

FIGURE 4.71 The relationship between the main route, the walking direction and architectural features, Stourhead 1785 (t_1).
→ GIS map with overlay of main architectural features and main route on DLM 1785 (map: Steffen Nijhuis)

FIGURE 4.72 View from Umbrella Seat with the Temple of Apollo, the Palladian Bridge and the Pantheon, F.M. Piper, 1779 (image source: Woodbridge 1982/2002)

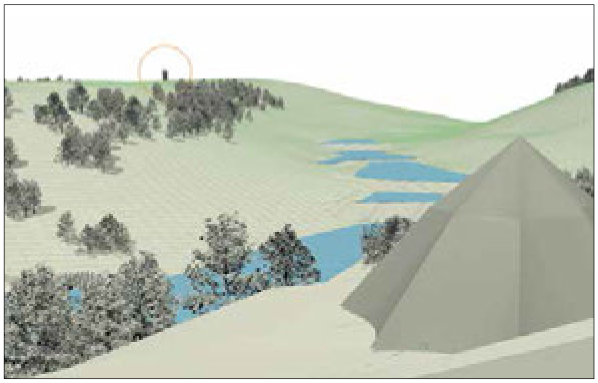


FIGURE 4.73 View from Turkish Tent with Alfred's Tower in the background.
→ Schematic-iconic representation of Stourhead 1785 (t_1) (model by Steffen Nijhuis & Joris Wiers)

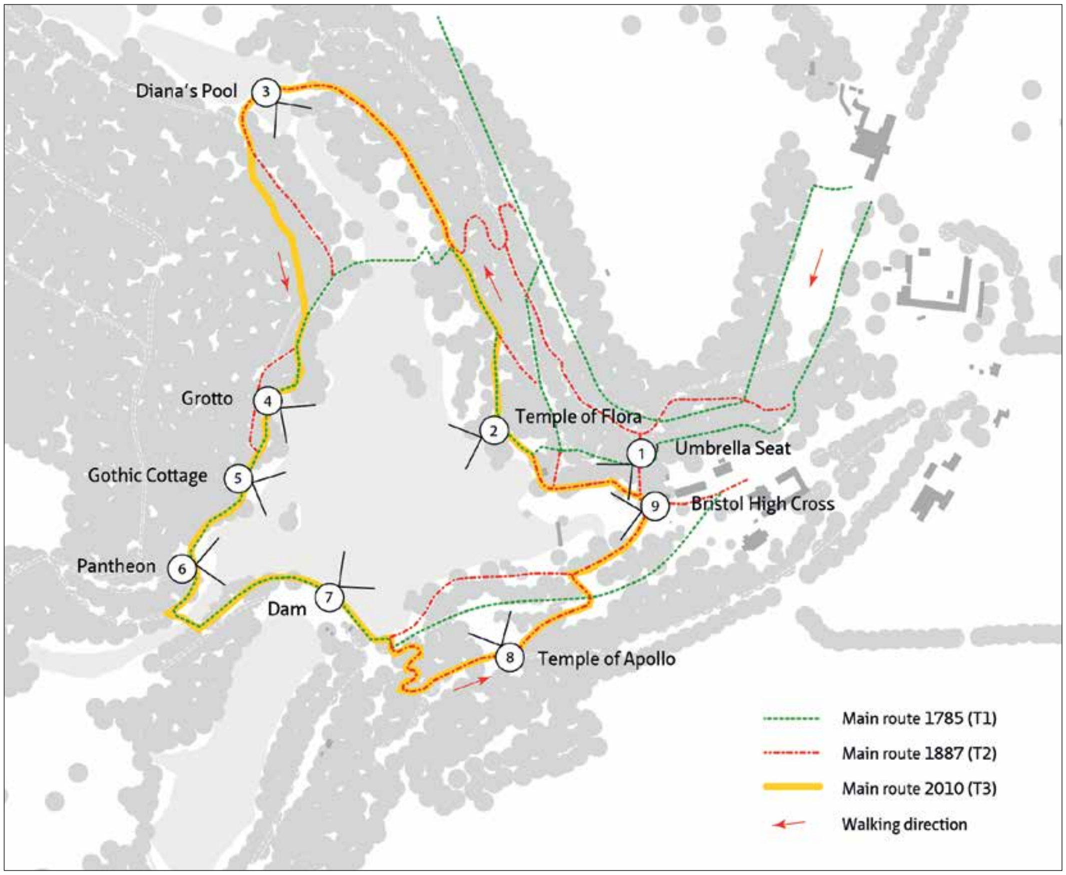
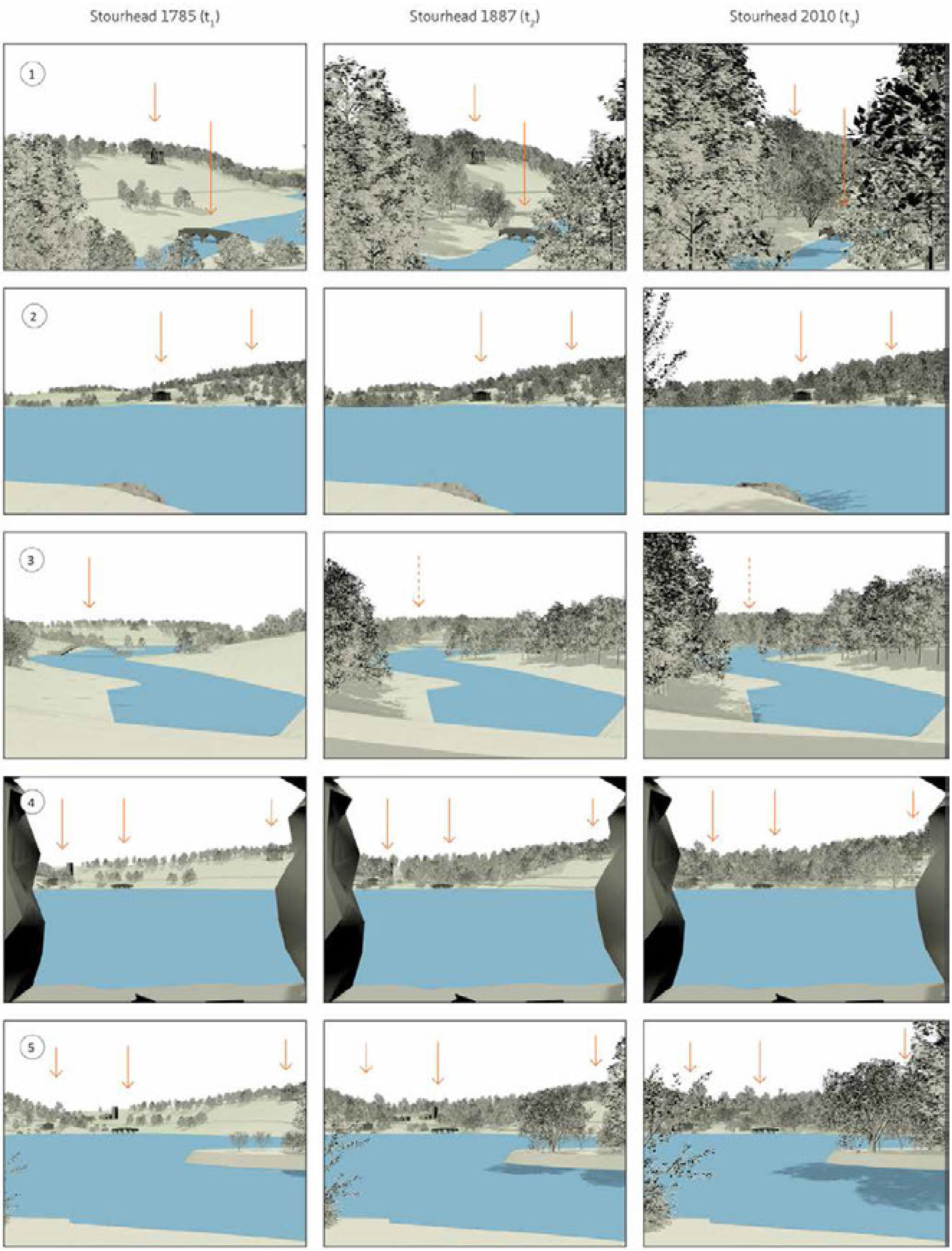


FIGURE 4.74 Important viewpoints related to the pictorial circuit of Stourhead landscape garden throughout the ages (map: Steffen Nijhuis)

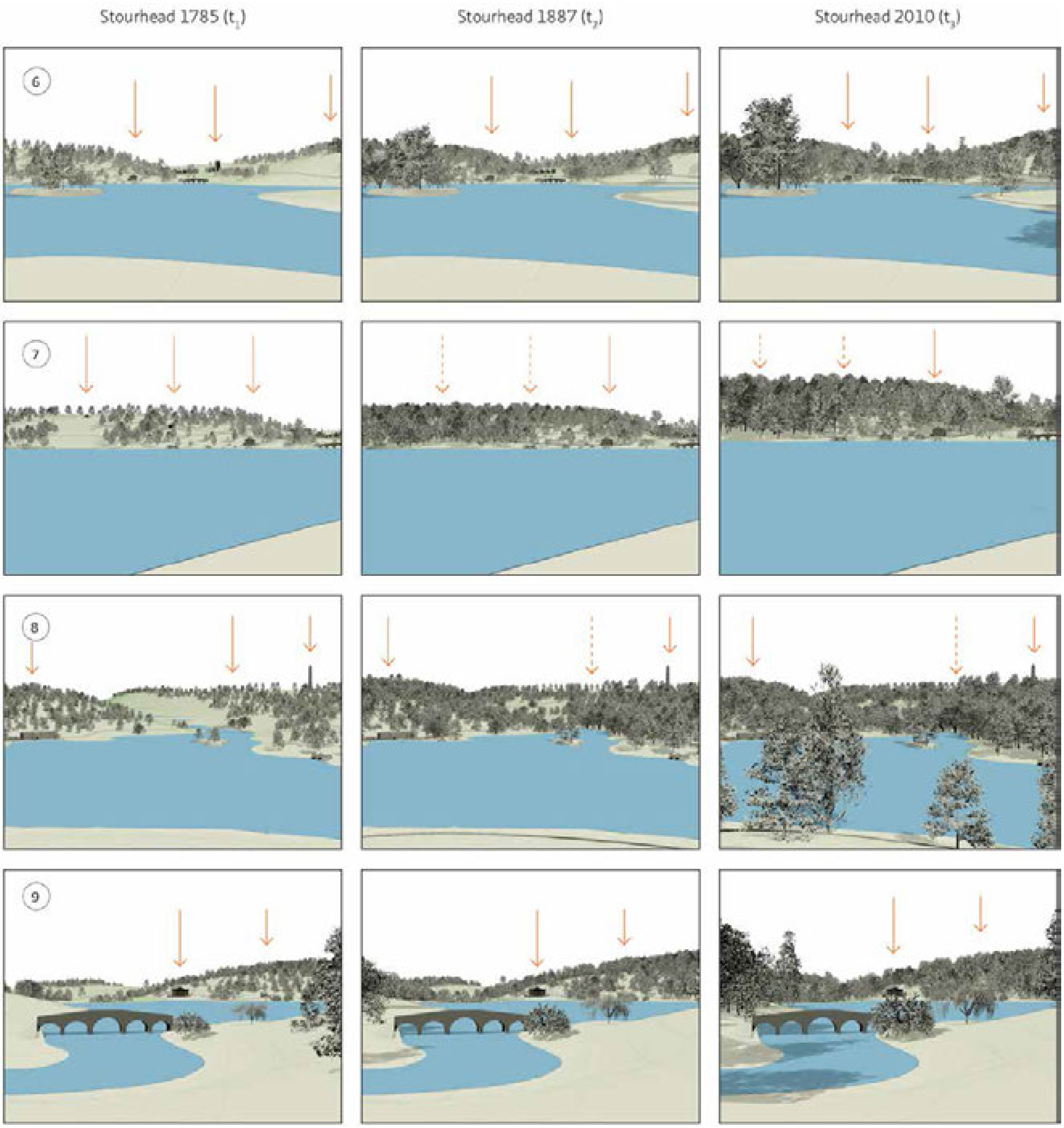
Route scenography Stourhead 1785 (t_1)

The circular walk around the Great Oar Pasture was the first stage in the elaboration of the architectural system, where the route sequentially connected Stourhead House → Statue of Apollo → Temple on the Terrace → Umbrella seat → Turkish Tent → Obelisk → Stourhead House [Figure 4.71]. The features dictate the scene, are visible as intermediate destinations, and can be reached directly because the route is in line with movement to the goal. However, from this circular walk, lateral visual relations to the Valley Garden are also established via deliberate resting points that are, at the same time, fixed viewpoints that visually connect the Pleasure Garden (on the plateau) to the Valley Garden. Visual connections are: Temple on the Terrace → Stourton and Bristol High Cross; the Umbrella seat → Palladian Bridge and Temple of Apollo [Figure 4.72]; and the Turkish Tent → Wooden Bridge, Grotto and Pantheon. From the Turkish Tent, Alfred's Tower was also visible [Figure 4.73]. The architectural features become reasons to descend into the Valley Garden guided by the circular path structure.



Stourhead 1785 (t_1)
Stourhead 1887 (t_2)
Stourhead 2010 (t_3)
1
2
3
4
5

TOC



Stourhead 1785 (t_1)

Stourhead 1887 (t_2)

Stourhead 2010 (t_3)

FIGURE 4.75 The development of the views with the architectural features as focal points. Arrows indicate important focal points, dashed arrows indicate focal points that have disappeared. The viewpoints are indicated in Figure 4.74.
→ Schematic-iconic representation of Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3) at eye-level (1.60 metres). The views are rendered though an 35 mm camera objective, which corresponds with the 62 degree angle of binocular view (model by Steffen Nijhuis & Joris Wiers)

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FIGURE 4.76 Panorama from the hills between the Temple of Apollo and the Hermitage, F.M. Piper, 1779 (image source: Woodbridge, 1970)

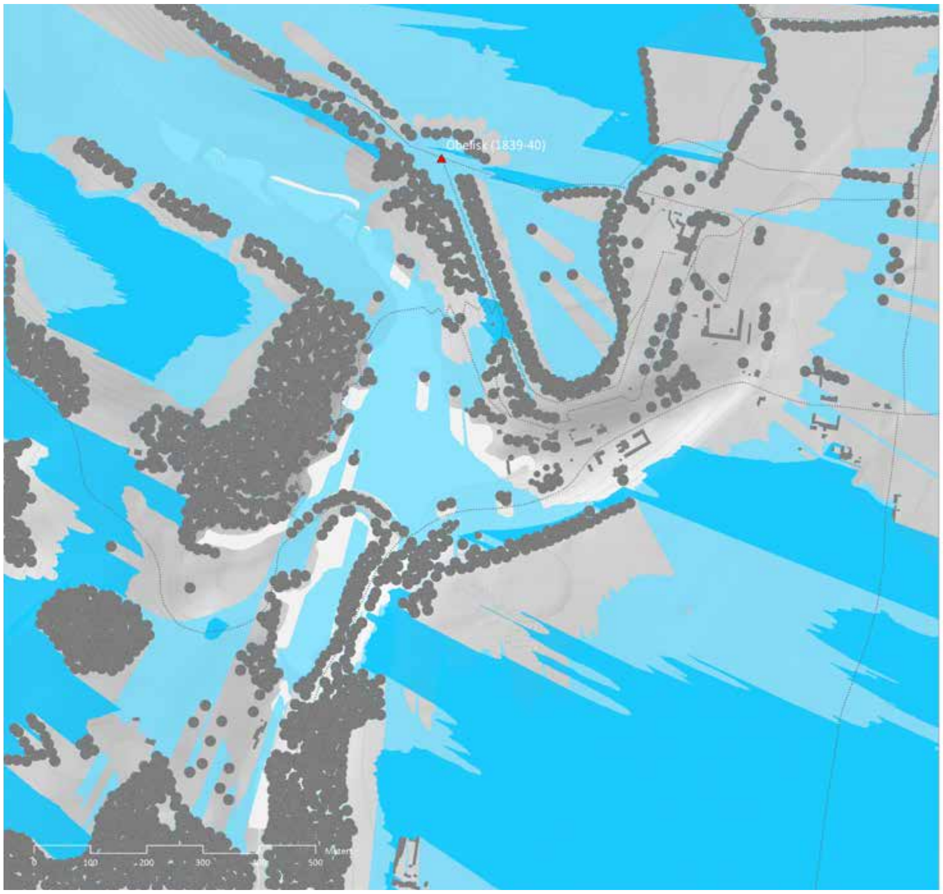

FIGURE 4.77 Stourhead 1785 (t_1): visibility at eye-level (1.60 metre) of the top 2 metres of Alfred’s Tower (49 minus 2 metres; dark blue) and the top 2 metres of the Obelisk (41 minus 2 metres; light blue).
→ Composite GIS-map with DLM 1785 and viewshed analysis from Alfred´s Tower and Obelisk (map: Steffen Nijhuis)

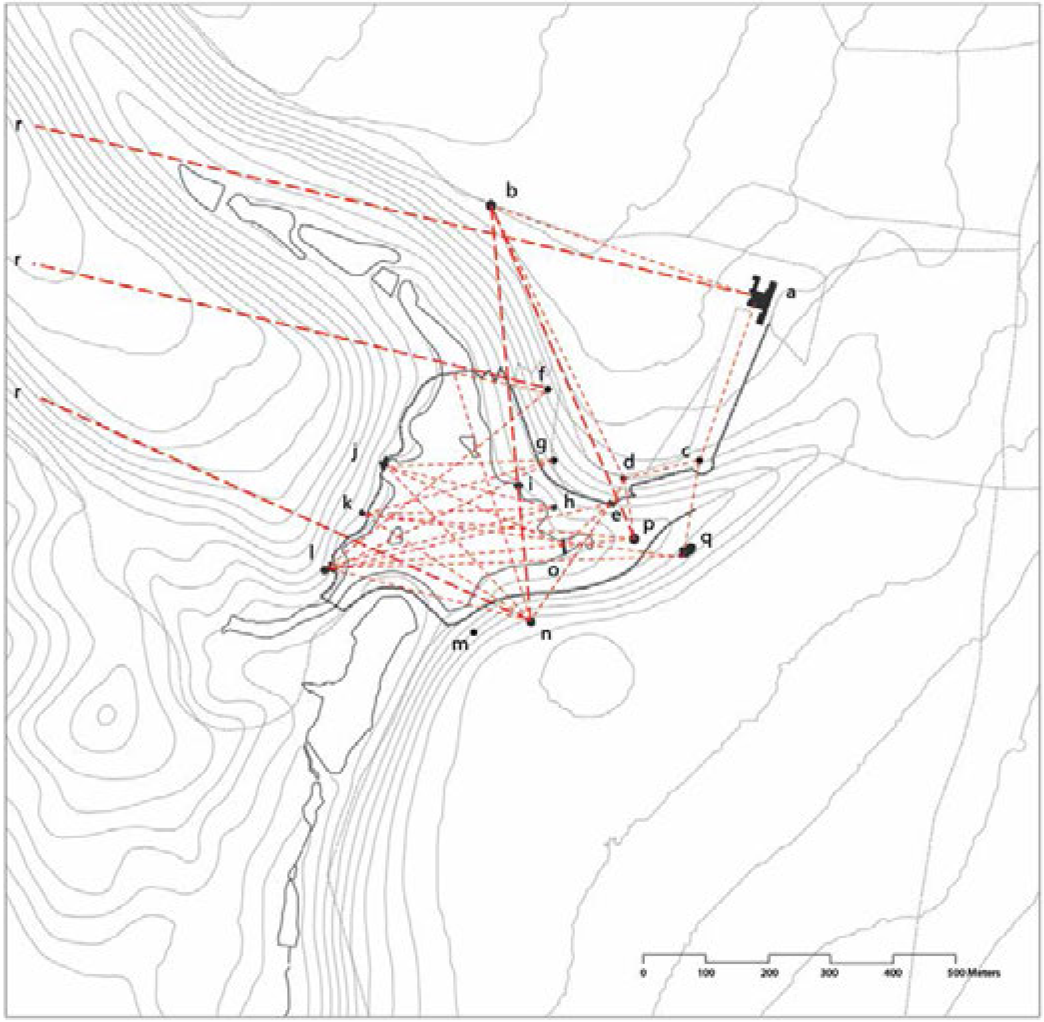

FIGURE 4.78 Interpretation of visual connections related to the routes and architectural features, Stourhead 1785 (t_1). House (a), Obelisk (b), Statue of Apollo (c), Temple on the Terrace (d), Umbrella Seat (e), Turkish Tent (f), Chinese Alcove (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Gothic Cottage (k), Pantheon (l), Hermitage (m), Temple of Apollo (n), Palladian Bridge (o), Bristol High Cross (p), St. Peter's Church (q) and Alfred's Tower (r) (map: Steffen Nijhuis)

The circular walk around the lake was the next elaboration of the composition and is considered to be the most important, as affirmed by Henry Hoare II and Colt Hoare themselves.[567] The recommended route started at the house, followed the edge of the plain via the Statue of Apollo and the Temple on the terrace and descended downward in the direction of the Temple of Flora. From there, the route continued along the water edge to the Grotto. This initial route was later complemented by another possibility, entering the valley from the Fir Walk at the location where the Turkish Tent was located. From there, the route continued crossing the northern bay by the Wooden Bridge via the Grotto, to the Pantheon and ending at Stourhead's Inn.

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[567] For instance, Colt Hoare's second guide book guides the visitor directly to the Valley Garden by stating: *"At a short distance from the Mansion-House* [(Stourhead House)], *we descend under the shade of a thick grove of tall august trees, into the gardens, and catch, most unexpectedly, the first view of a spacious vale beneath, embosomed in wood, the uniform tints of which are most happily relieved by a handsome Temple, called the Pantheon; from its resemblance* [(in miniature)] *to the one of the same name in Rome. Our walk leads us on the side of this lake to a passage over it, which in past times was effected by a lofty bridge, but now by simple ferry-boat. From hence we are conducted by a well-planed approach to the Grotto..."* (Hoare, 1818, pp. 22-23).

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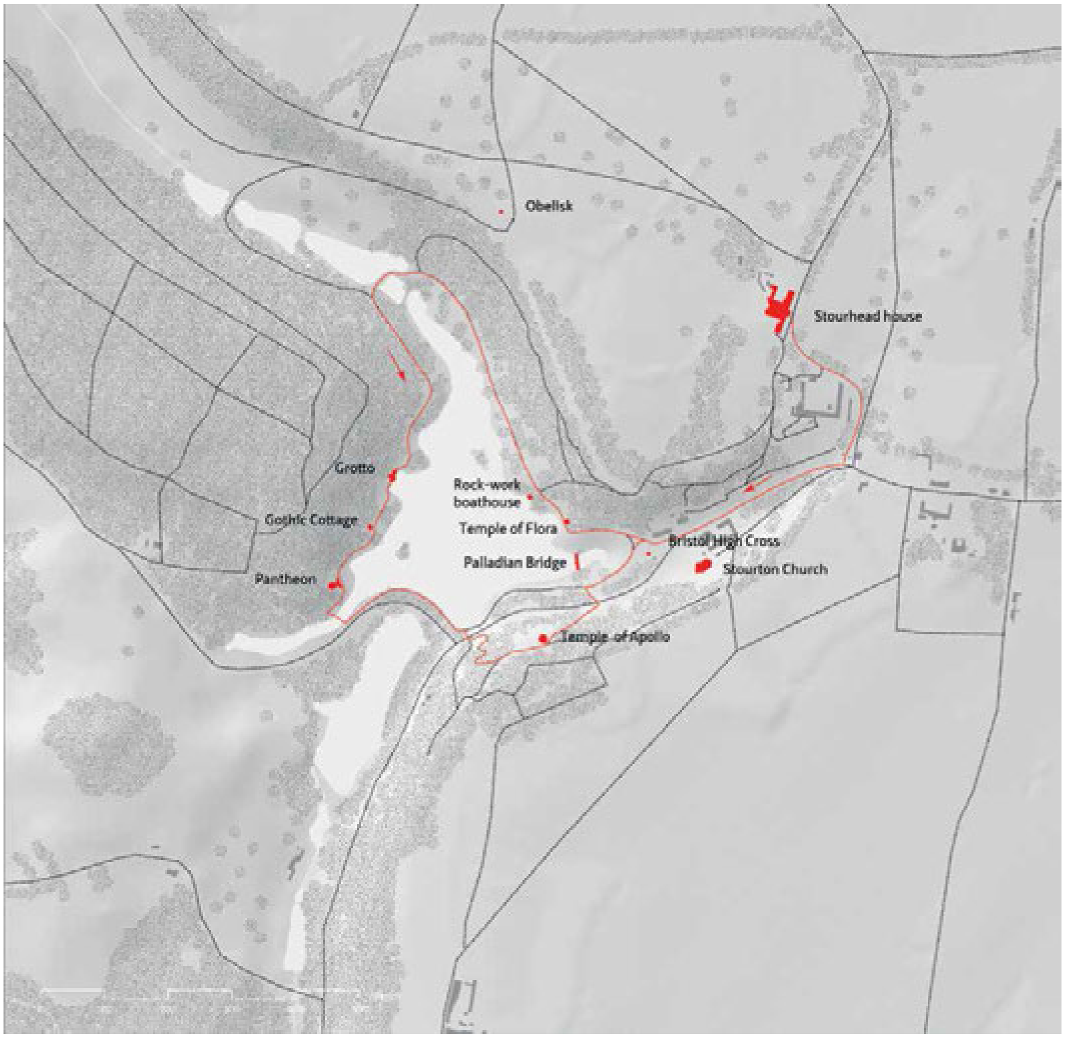

FIGURE 4.79 The relationship between the main route, the walking direction and architectural features, Stourhead 1887 (t_2).
→ GIS map with overlay of main architectural features and main route on DLM 1887 (map: Steffen Nijhuis)

At the lower level of the Valley Garden there are views determined by openings in the planting mass or framed by clumps of trees. The strategic foci in the scenery are formed by visual pairs of architectural features at both sides of the lake, with these being the most important: Temple of Flora ↔ Pantheon, Gothic Cottage [Figure 4.74 & Figure 4.75, t_1, view 2]; Grotto ↔ Temple of Flora, Palladian Bridge, Bristol High Cross and St. Peter's Church Tower (view 4); Gothic Cottage ↔ Turkish Tent, Temple of Flora, Palladian Bridge, Bristol High Cross, and St. Peter's Church Tower (view 5); Pantheon ↔ Chinese Alcove, Umbrella Seat, Temple of Flora, Palladian Bridge, Bristol High Cross, and St. Peter's Church Tower (view 6); Bristol High Cross ↔ Palladian Bridge, Pantheon, and Gothic Cottage. Connecting the Valley Garden to the higher parts the important pairs are: Wooden Bridge ↔ Temple of Apollo (view 3); Grotto ↔ Temple of Apollo (view 4); Pantheon ↔ Turkish Tent; Pantheon ↔ Temple of Apollo (view 6); Temple of Apollo ↔ Grotto and Wooden Bridge (view 8). From the Temple of Apollo the Obelisk and Alfred's Tower are also visible, connecting the Valley Garden to the rest of the grounds. As depicted in a drawing by Piper [Figure 4.76], the viewshed analysis also indicates that Alfred's Tower was visible from the Temple of Apollo and the Turkish Tent [Figure 4.77].

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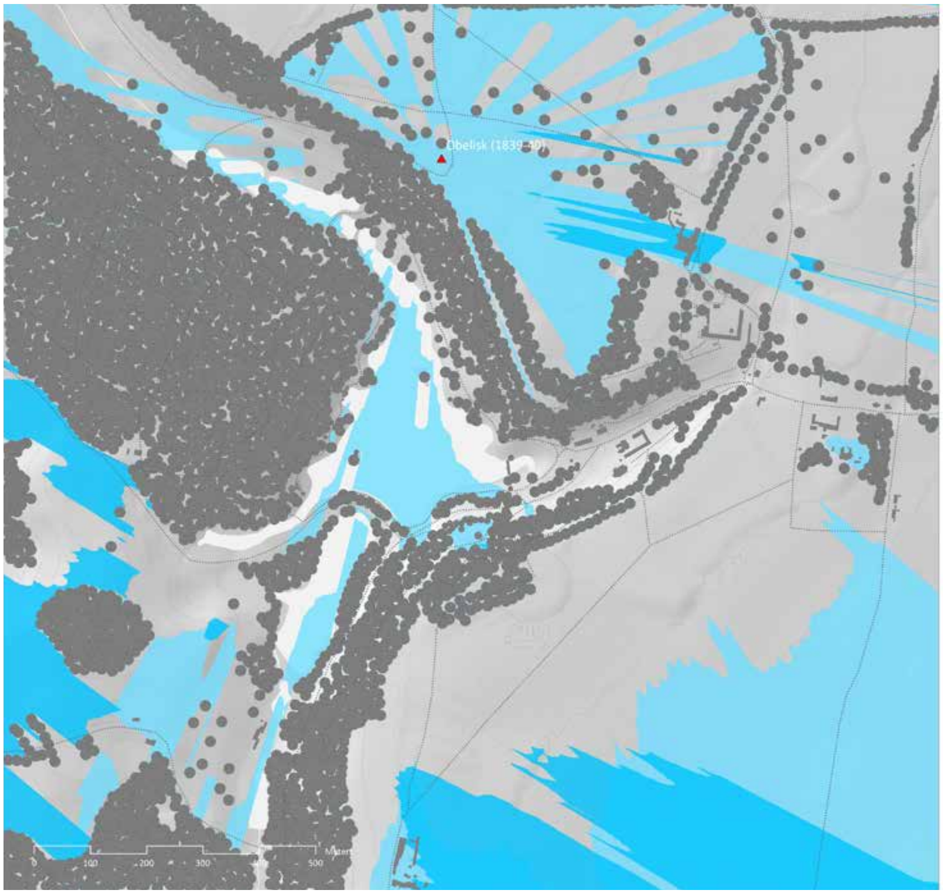

FIGURE 4.80 Stourhead 1887 (t_2): visibility at eye-level (1.60 metre) of the top 2 metres of Alfred's Tower (49 minus 2 metres; dark blue) and the top 2 metres of the Obelisk (41 minus 2 metres; light blue). The Obelisk is still visible from the Temple of Apollo; Alfred's Tower is not. Alfred's Tower is visible from Stourhead House.
→ Composite GIS-map with DLM 1887 and viewshed analysis from Alfred´s Tower and Obelisk (map: Steffen Nijhuis)

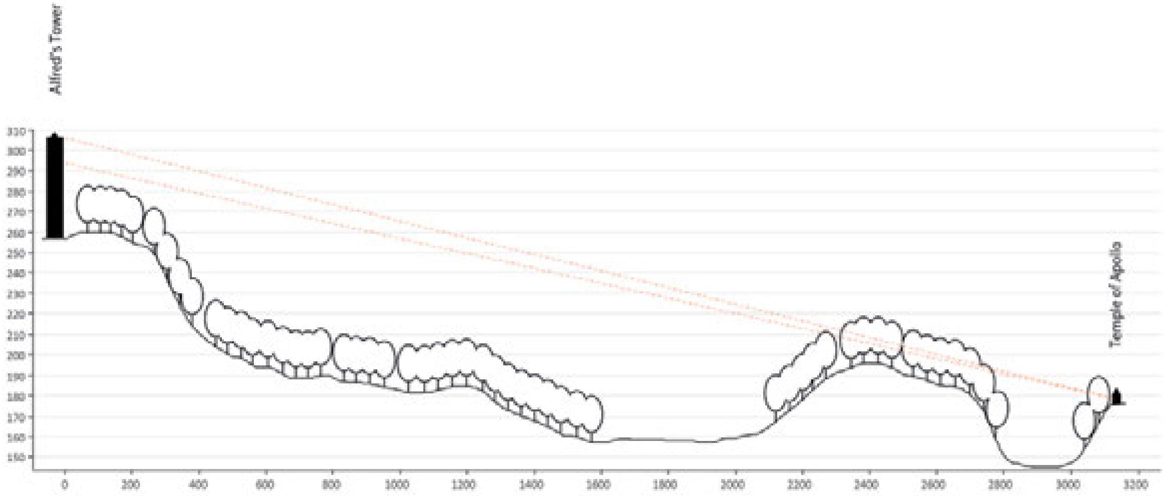

FIGURE 4.81 Because of the height of the trees Alfred's Tower is not visible from the Temple of Apollo anymore from 1887 onwards.
→ Longitudinal section from Alfred´s Tower to the Temple of Apollo. Section derived from DEM 1785-2010 by means of GIS (drawing: Steffen Nijhuis)

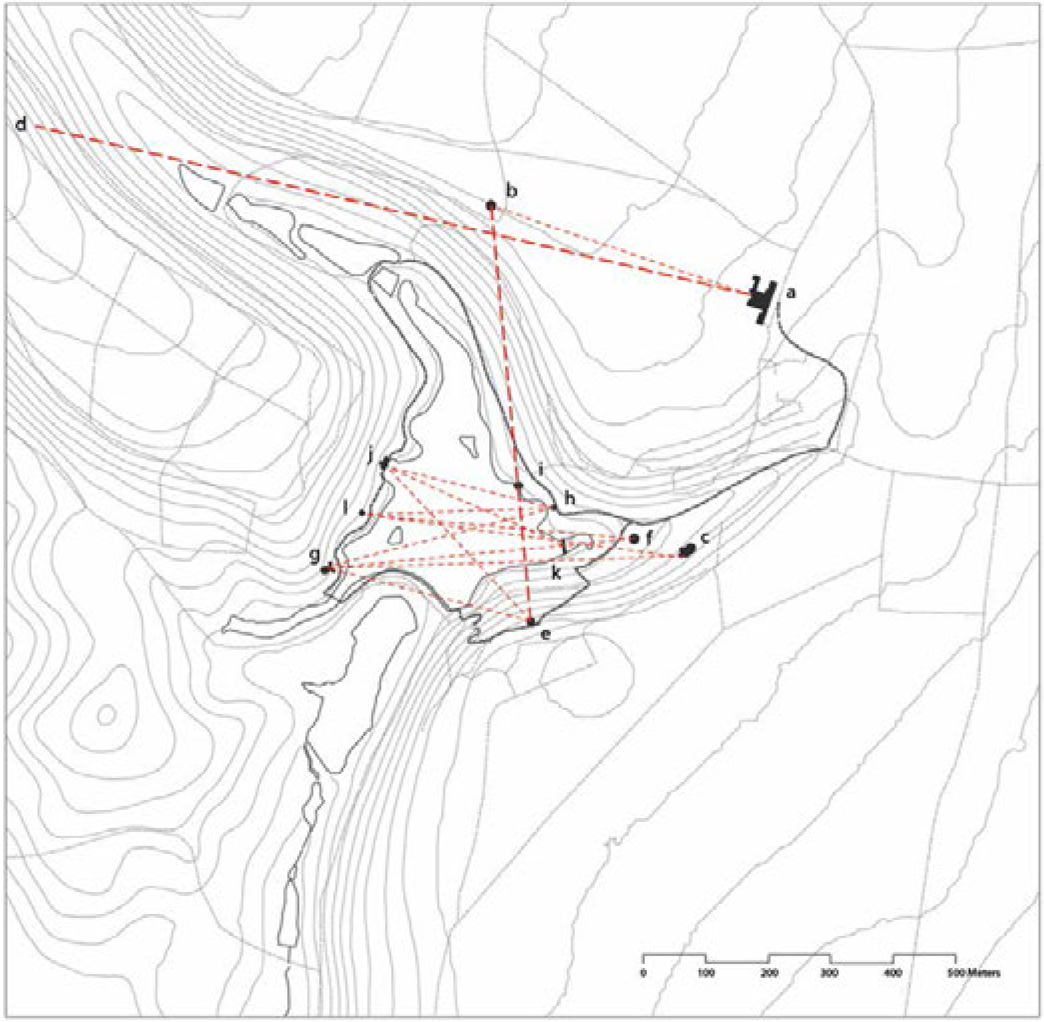

FIGURE 4.82 Interpretation of visual connections related to the routes and architectural features, Stourhead 1887 (t_2). Stourhead House (a), Obelisk (b), St. Peter's Church (c), Alfred's Tower (d), Temple of Apollo (e), Bristol High Cross (f), Pantheon (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Palladian Bridge (k) and Gothic Cottage (l) (map: Steffen Nijhuis)

The visible form is characterised by a sophisticated system in which architectural features dictate the views and act as attractors that induce movement regulated by routes. Every architectural feature is a deliberate point of view and reveals new views with focal points as potential destinations within and between the Pleasure Garden, the Valley Garden, and the western part of the estate. From the house, the route and visual destination have the same direction and guide individuals through the Pleasure Garden in a direct, frontally oriented way. The Valley Garden is introduced by strategically located features that establish visual links between the higher and lower parts of the composition. Here, the direction of the route and the visual destination deviate and have an indirect, lateral relationship. The Valley Garden consists of a complex system of sightlines across the lake with visual linkages to the higher parts towards the Obelisk and Alfred's Tower. The circular route of the Valley Garden depends mainly on indirect, lateral relationships where the route is not directly oriented to the destination. This increases the sense of intrigue and surprise at what lies ahead [Figure 4.78].

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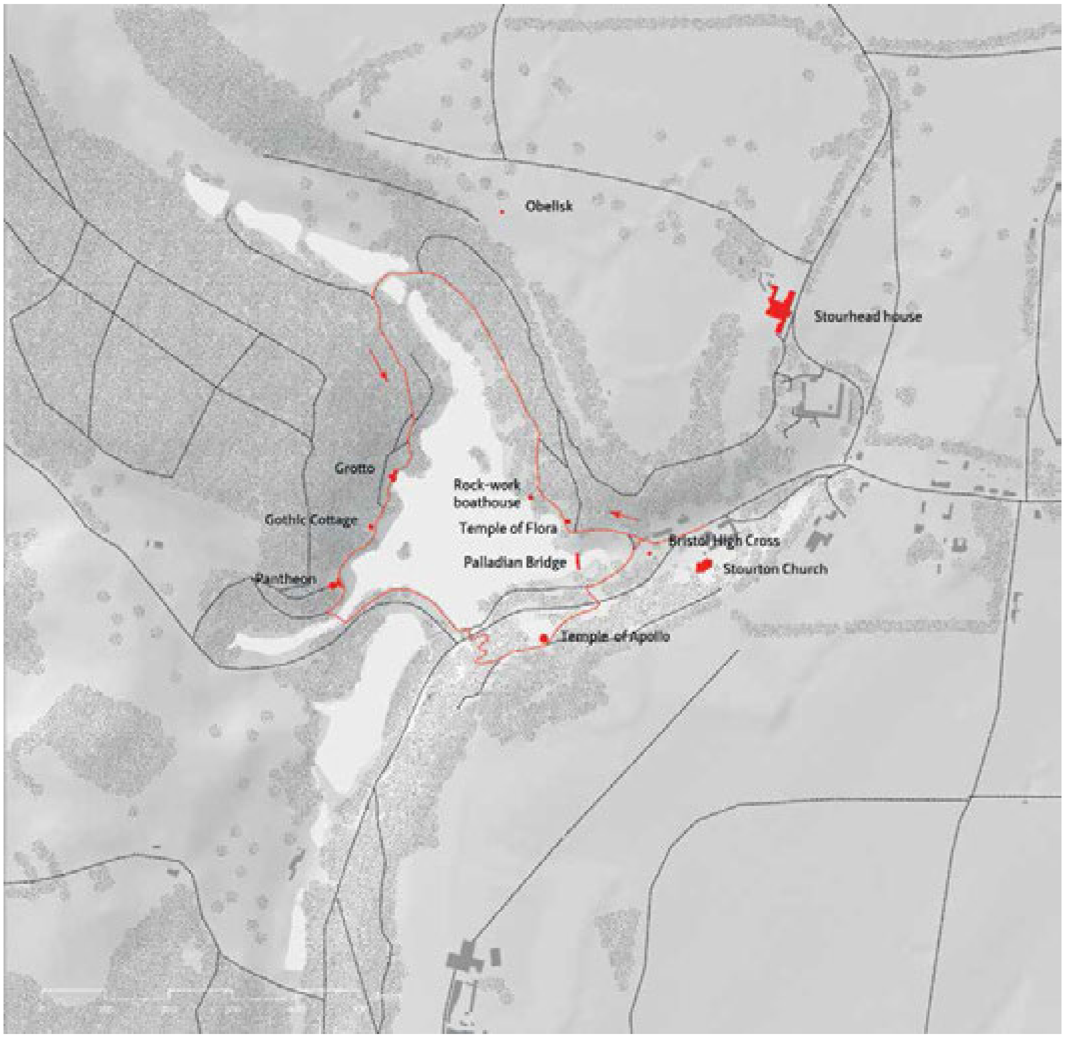

FIGURE 4.83 The relation between the main route, the walking direction and architectural features, Stourhead 2010 (t_3).
→ GIS map with overlay of main architectural features and main route on DLM 2010 (map: Steffen Nijhuis)

Route scenography Stourhead 1887 (t_2)

Due to the modification of the route structure and the removal of several architectural features, the movement-induced system had changed substantially by this point in time [Figure 4.79]. The removal of the Statue of Apollo and the Temple on the Terrace particularly diminished the circular route system around the Great Oar Pasture, as did the removal of the architectural features in the transition zone between the plateau and the valley that had established visual relationships. The Valley Garden became the most important part of the composition with Stourton Village as the starting point of the circular route around the Great Lake.

At the lower level of the Valley Garden, important visual pairs remained the same, but by the introduction of greenery and the growth of planting, the framed views became more pronounced [Figure 4.74 & Figure 4.75, t_2]. The Wooden Bridge was no longer visible as an iconic feature (views 3 & 8), nor was the Turkish Tent, which had also vanished. Most visual links from the Valley Garden to the middle and higher parts of the composition disappeared as a result of the almost complete forestation and removal of features at the northern slope of the valley (most significantly, the Turkish Tent). Viewshed analysis reveals that Alfred's Tower was also no longer visible from the Temple of Apollo due to the growth of trees [Figure 4.80 & Figure 4.81]. From Stourhead House, Alfred's Tower was still visible.

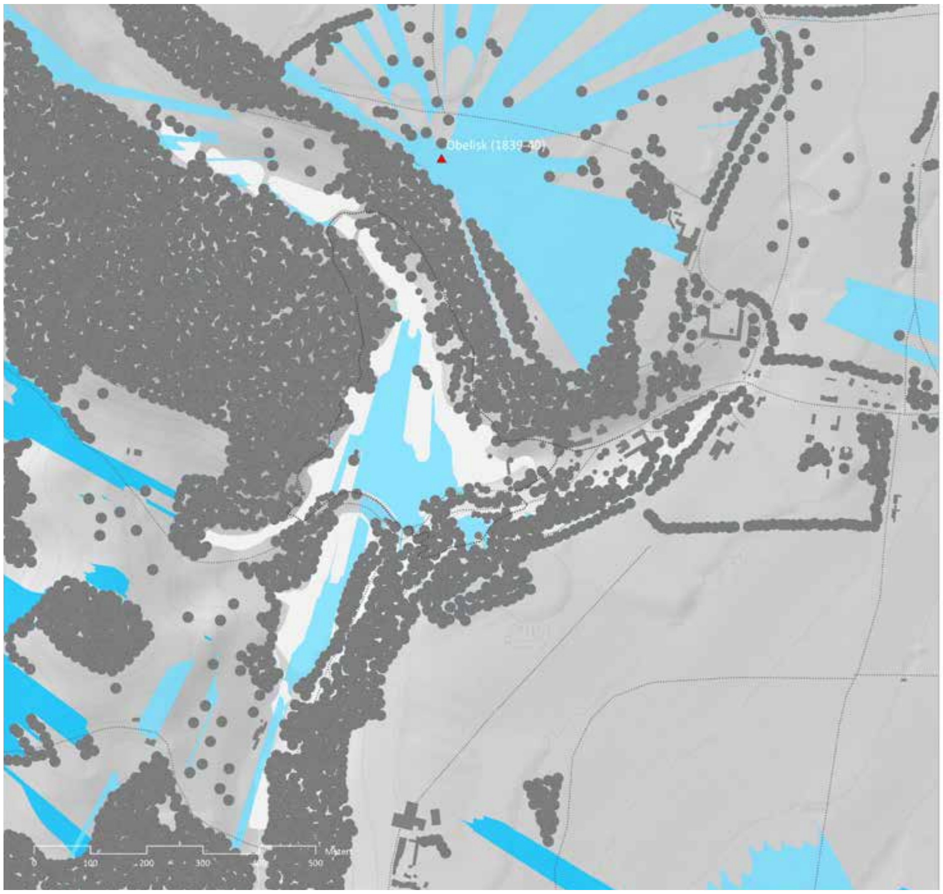

FIGURE 4.84 Stourhead 2010 (t_3): visibility at eye-level (1.60 metre) of the top 2 metres of Alfred's Tower (49 minus 2 metres; dark blue) and the top 2 metres of the Obelisk (41 minus 2 metres; light blue) The Obelisk is still visible from the Temple of Apollo and the house; Alfred's Tower is not anymore.
→ Composite GIS-map with DLM 2010 and viewshed analysis from Alfred´s Tower and Obelisk (map: Steffen Nijhuis)

The Valley Garden became the nucleus of the composition as a result of wide-ranging changes in the route system and removal of architectural features in the transition zone between the plateau and the valley. Though simplified in terms of fewer visual connections, the circular route and the related views still depend on indirect, lateral visual relationships across the lake [Figure 4.82].

Route scenography Stourhead 2010 (t_3)

The stroll at Stourhead was further simplified by changes in the route structure [Figure 4.83]. The densification and growth of the planting masses towards the lake cut off some visual relationships and selectively emphasised the importance of certain views related to the circuit walk. From the Grotto [Figure 4.74 & Figure 4.75, t_3, view 4], the Temple of Flora is no longer visible and the Temple of Apollo is hardly visible from the Pantheon (and vice versa, views 6 & 8). Alfred's Tower is also not visible from the house, as the viewshed analysis points out [Figure 4.84]. However, the Obelisk remains visible from the Temple of Apollo and is the only visual link left that connects the Valley Garden with the rest of the upper parts of the landscape. The result is that the network of visual linkages concentrates on the Valley Garden as the main part of the composition. Here, the clearly defined views from the Temple of Flora (view 2), Grotto (view 4), Pantheon (view 6), Temple of Apollo (view 8) and Bristol High Cross (view 9) persist as the main important scenes with visual linkages to architectural features across the lake [Figure 4.85].

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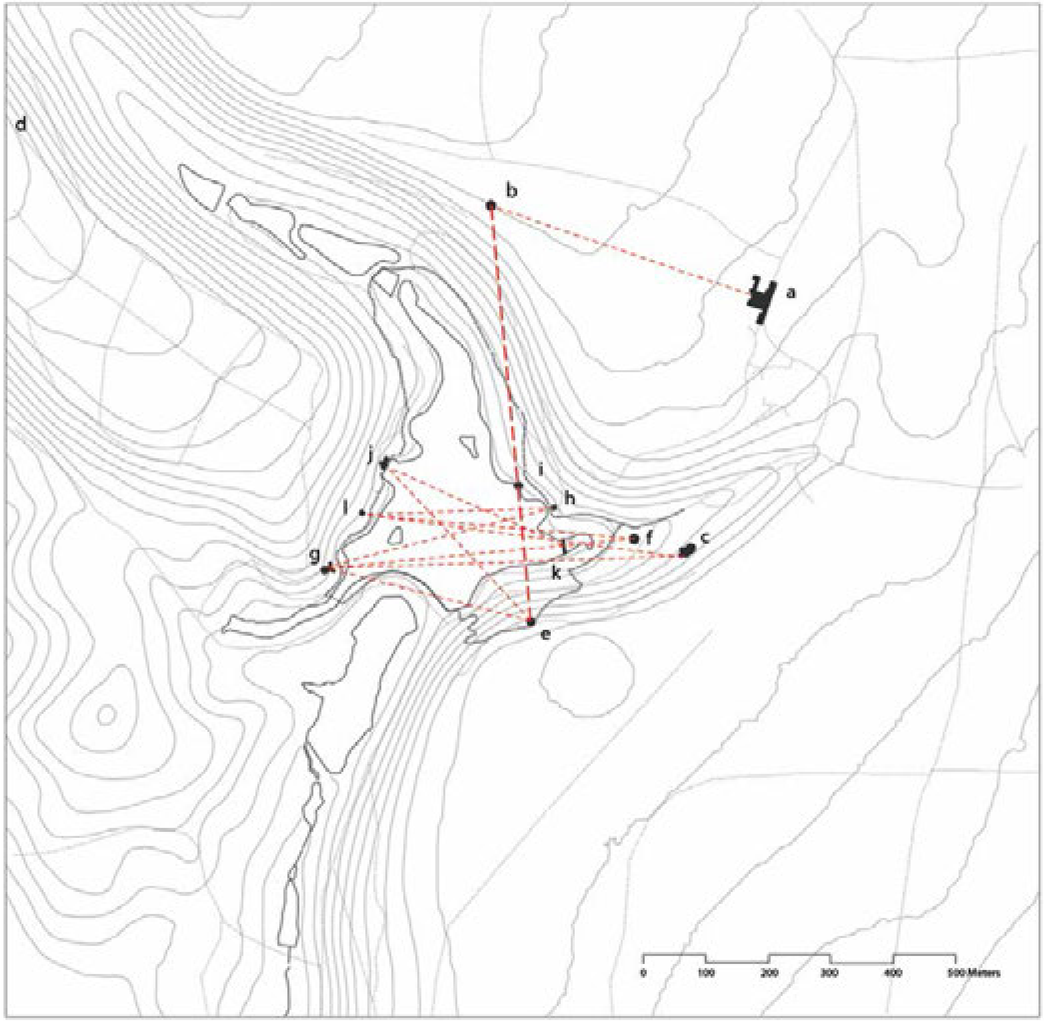

FIGURE 4.85 Interpretation of visual connections related to the routes and architectural features, Stourhead 2010 (t_3).Stourhead House (a), Obelisk (b), St. Peter's Church (c), Alfred's Tower (d), Temple of Apollo (e), Bristol High Cross (f), Pantheon (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Palladian Bridge (k) and Gothic Cottage (l) (map: Steffen Nijhuis)

The visible form of Stourhead and its visual logic is determined by the views and sightlines related to the routes, as well as the visibility and sequence of the architectural features. The routes and the related architectural features generate visually controlled movement, since they draw individuals into the landscape architectonic composition and direct them through it. The slow-motion vision when following the path offers sequential frontal and lateral perception of scenes and a gradual discovery of the various features involved. This gradual change offers a sense of scenic intricacy that arouses and sustains curiosity. These successive acts of perception and recognition also influence one's sense of time. Observers in motion perceive change successively and adjust their knowledge. For instance, individuals can tell the length of their walks by the rhythmic spacing of recurring elements. The more spatial variation, the shorter the walk seems; but recalling from it memory, the walk seems longer.[568] Upon arrival, the architectural features are used for enjoyment and repose for those walking through the composition and become viewpoints for other views as stages in the circuit walk. The circuit walk around the lake, in particular, is now architectonically the most articulated part of the composition. The lake is the plane of symmetry for the various scenes, divided by the backdrop of the groups with

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[568] Bosselman, 1998.

tree-planted islands and surrounded by the grassy and (later mainly) wooded slopes. The Valley Garden is a landscape theatre with a double visual structure, with both axially related views and circuitous, serial views with the lake as the reflecting pool mirroring the scenes. The first is about stationary vision and framed views across the lake, providing scenes with oriental, classical, and Gothic emblems dramatically juxtaposed. The second is about the counter-clockwise route that directs the observer by means of slow-motion vision and tactile experience (going up and down) through a series of shifting views, offering a sequential and gradual discovery of the various features involved.

§ 4.5.3 Designed views superior to *landskip* paintings

In the era that Stourhead landscape garden evolved, scenic composition was an art of gardening and landscape paintings were models for landscape design.[569] Three-dimensional space was organized by merging topography with the formal codes of landscape painting. Terrain disposition, light and shadow, colour, and perspective were translated into a three-dimensional setting composing scenes and illusionary space.[570] A scene refers to an extensive piece of the composition that can be seen from a single viewpoint as in a painting or stage of a theatre with a foreground, middle ground, and background.[571] Moreover, it is about views (vistas) as composed landscape unities within the field of vision. According to contemporary landscape design theorists, the views should not be completely open at all points or observable from all parts of the garden and brought in harmony with other scenes.[572] Thus, view-making involves demarcating, organising, and the framing of scenes with architectonic objects (e.g. by using buildings, porches and porticos), planting, and barriers such as walls, fences and hedges. Alongside natural elements, an ideal view consists of a composition of landform, wood, and water, but augmented with architectural features such as buildings and sculptures as an expression of the cultivation of nature.[573] The views should enable perception of relationships in terms of oppositions, deviations, and gradual progressions. Though the landscape garden was intended for viewing as a spatio-visual apparatus, it was anything but static. The views incited the viewer to move into space and become incorporated as a 'spectator-in-the-text'.[574] The viewer entered the picture and was both actor and spectator. The movement of the water, the moving leaves of the trees, and diurnal and seasonal changes were also important dynamics in the views. Hence, Whately (1772/1982, p. 1) states that the creation of landscape gardens was "*superior to landskip painting, as a reality to a representation.*"[575]

The formal relationship of objects in a three-dimensional view is visible as a scene on the retina and determined by the binocular field of vision and visual depth.[576] The field of vision consists of an up-down and sideways dimension, and visual depth is related to distance perception.

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[569] See for an elaboration: Hauck, 2014, pp 89ff.

[570] Hunt, 1992, p. 107.

[571] Repton, 1803; O'Malley et al., 2010.

[572] Cf. Hirschfeld, 1779-1785/2001, p. 204.

[573] Cf. Whately, 1772/1982; Hirschfeld, 1779-1785/2001.

[574] Bruno, 2002, p. 195.

[575] 'Landskip' as used by Whately refers to the 16th century meaning of 'landschap' or 'landscape', being a picture representing a view of natural scenery (Claval, 2004). The word landscape was also used in other contexts to designate a small territory (Olwig, 2002).

[576] Sekuler & Blake, 2006; Ware, 2008.

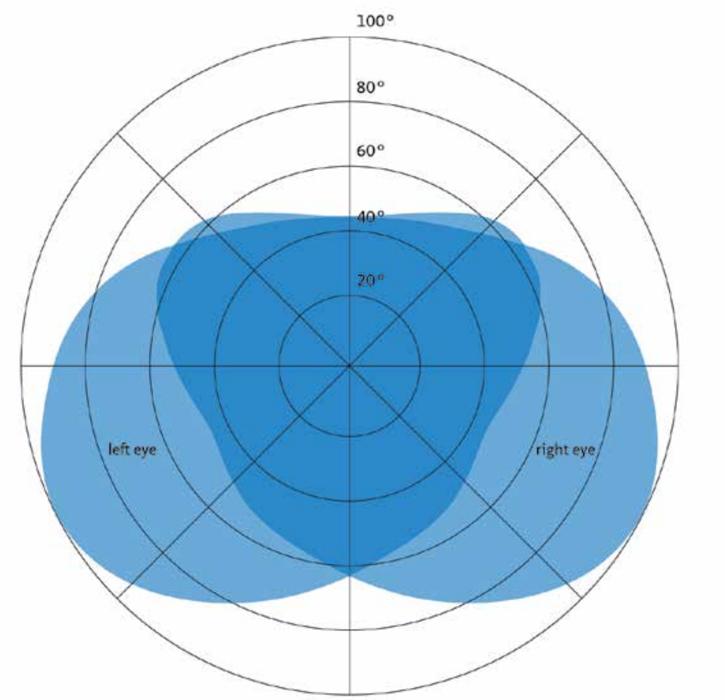

FIGURE 4.86 The field of view for an individual looking straight ahead. The irregular boundaries of the left and right fields are caused by facial features such as the nose. Pattern recognition concentrates in the region of binocular overlap (dark blue) (image source: Ware, 2004, graphic redrawn by Steffen Nijhuis)

The up-down/sideways dimension addresses visual pattern processing and colour discrimination and is the basis for recognition of objects and their relationships [Figure 4.86]. The up-down dimension can be explained in terms of vertical viewing angles and the sideways dimension in terms of horizontal viewing angles [Figure 4.61]. Pattern recognition is primarily focused on contours (shape), regions, spatial grouping (based on: nearness, continuity, similarity, enclosure, shape and common direction), and visual distinctness.[577] Visual distinctness describes the degree of feature-level contrast between the object and its surroundings (e.g. figure-background).

As discussed earlier, there are multiple views related to the circuit walk around the Valley Garden and are organized mainly via axial relationships between architectural features on both sides of the lake, and function as focal points within the view. These views are regarded as the most important in the development of the landscape garden in the last century (Stourhead 2010 (t_3)) and are subject to further analysis: Temple of Flora (viewpoint 2), Grotto (viewpoint 4), Pantheon (viewpoint 6), Temple of Apollo (viewpoint 8) and Bristol High Cross (viewpoint 9) [Figure 4.74]. The views are framed by extensive use of trees and laurel for under-planting on the slopes of the valley and the islands. The plantings as well as the porticos and windows (grotto) of the architectural features in the foreground are used to direct the gaze. Also important in directing the gaze are the planted islands. By utilising single GIS-based viewsheds, it was possible to analyse the visible area from these viewpoints and to measure the horizontal and vertical angular extent of the views and the objects within [Figure 4.87, Figure 4.88, Figure 4.89, Figure 4.90 & Figure 4.91].[578]

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[577] Ibid.

[578] The results of the horizontal angular analysis are also published in: Nijhuis, 2011, 2014a.

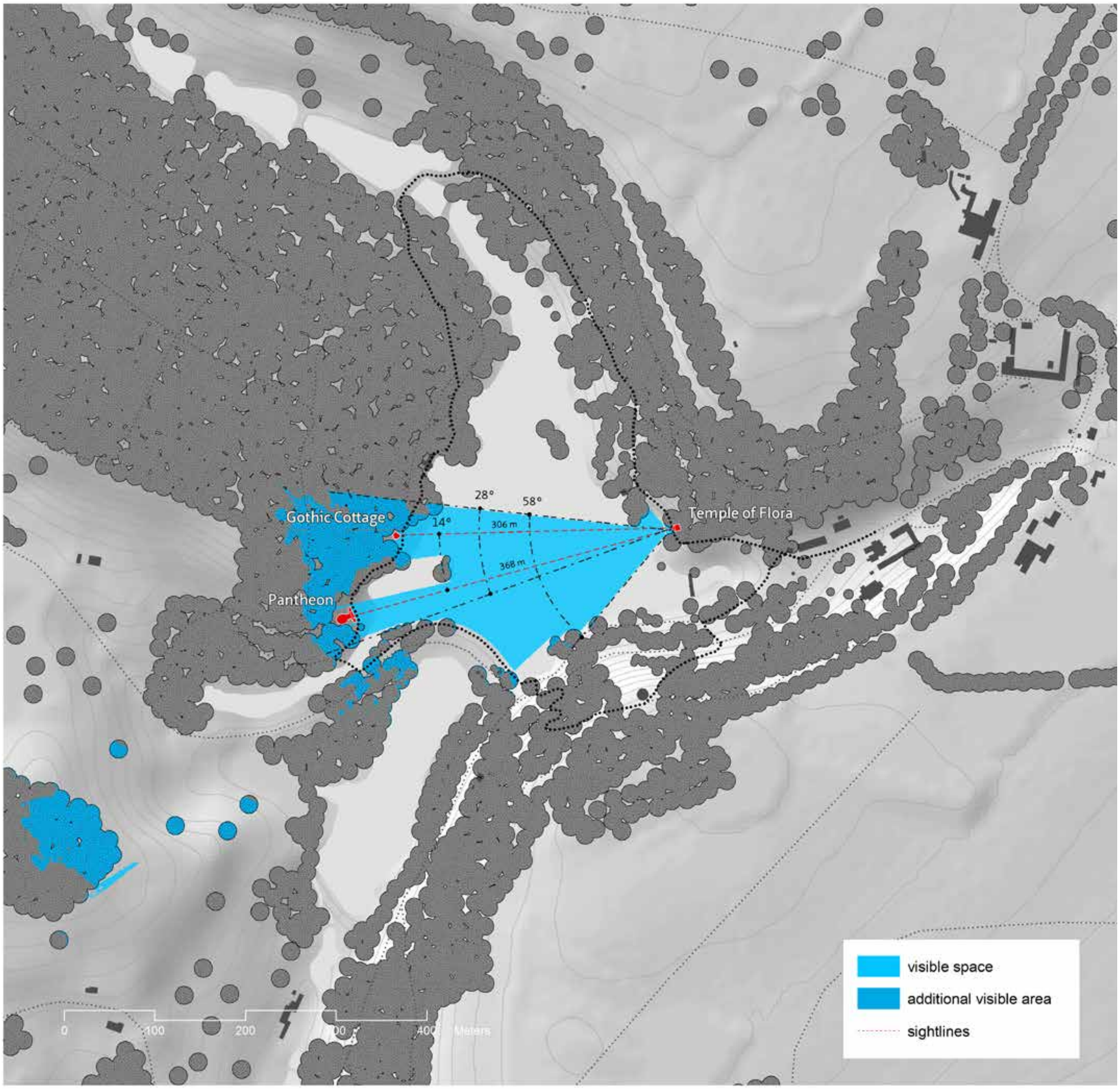

FIGURE 4.87 Visibility analysis from the Temple of Flora (viewpoint 2), Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010, viewshed and angular analysis from Temple of Flora at eye-level (1.60 metres) (map: Steffen Nijhuis)

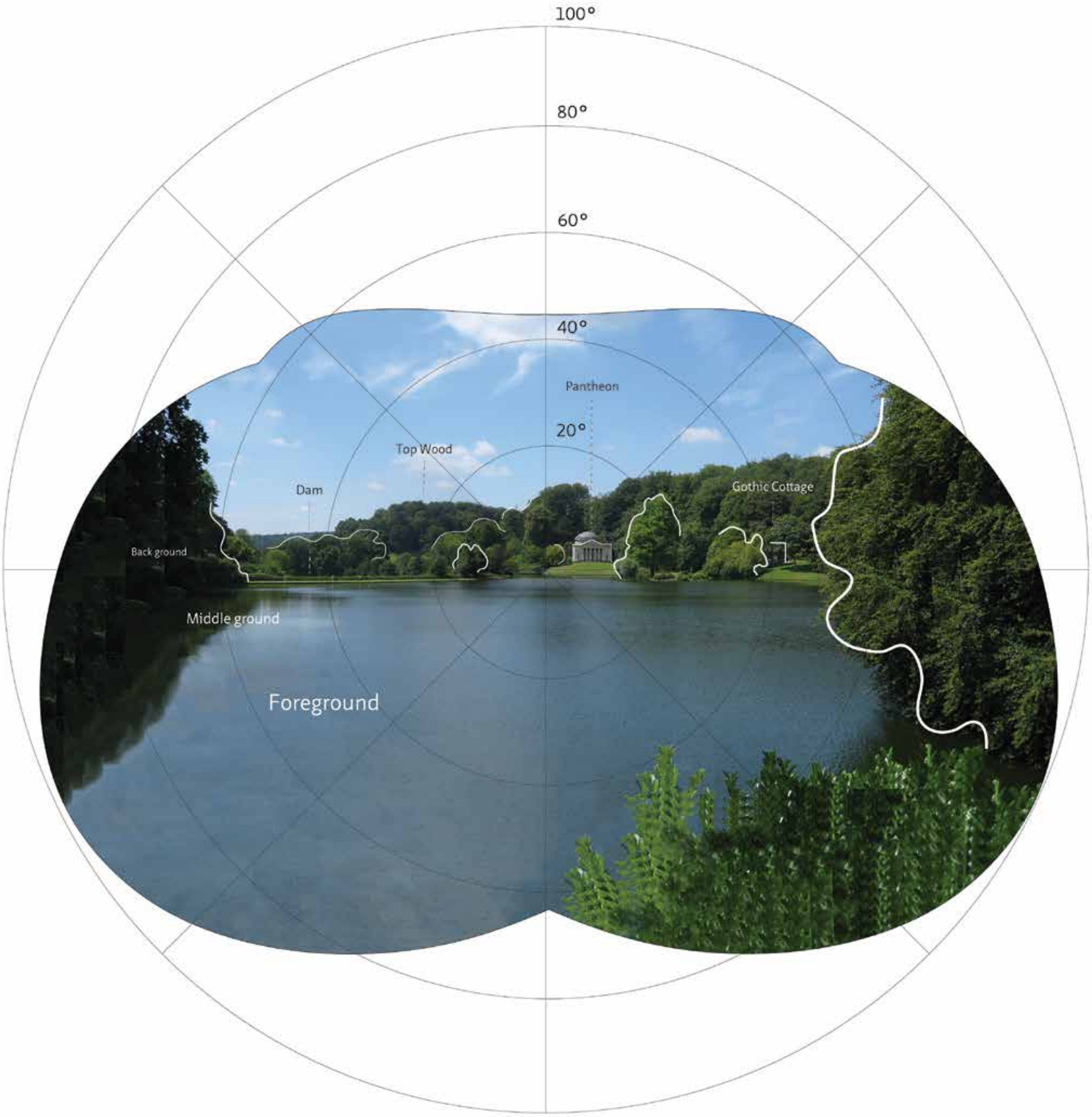

FIGURE 4.88 The field of view gazing straight ahead from the Temple of Flora (viewpoint 2) at eye-level (1.60 metres), Stourhead 2010 (t_3). The Pantheon and the Gothic Cottage are important foci in this view (graphic: Steffen Nijhuis)

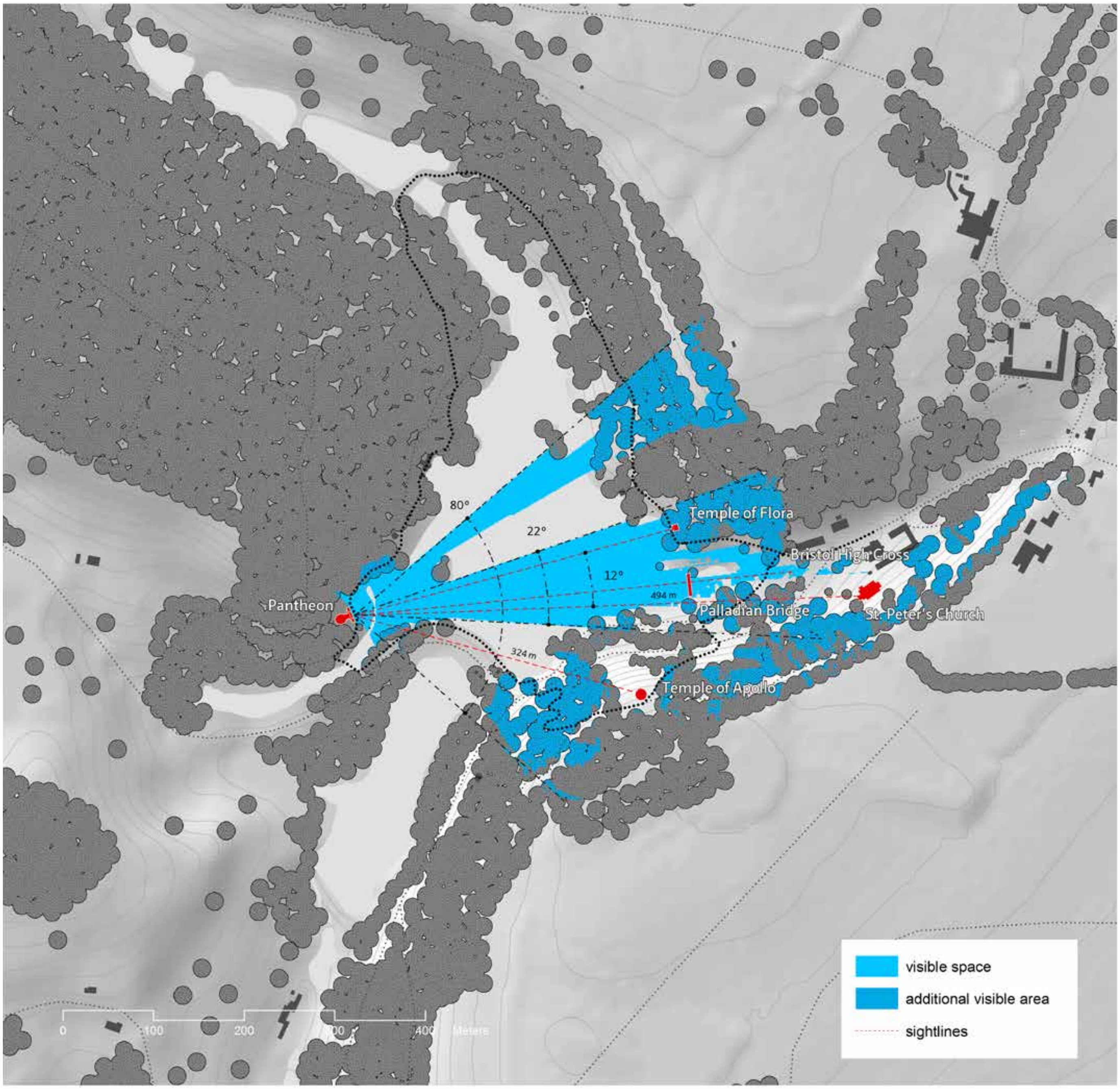

FIGURE 4.89 Visibility analysis from the Pantheon (viewpoint 6), Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010, viewshed and angular analysis from the Pantheon at eye-level (1.60 metres) (map: Steffen Nijhuis)

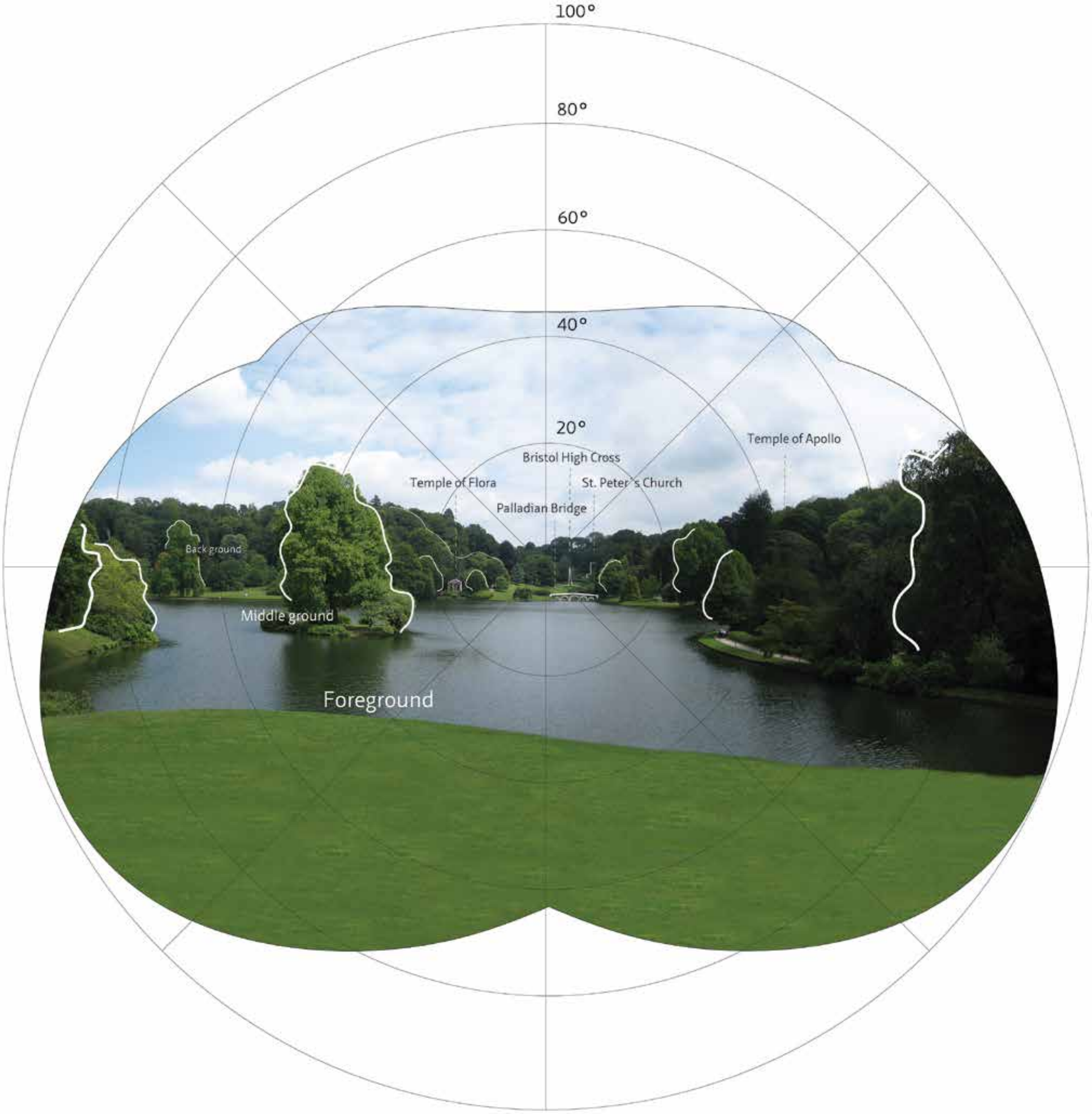

FIGURE 4.90 The field of view gazing straight ahead from the Pantheon (viewpoint 6) at eye-level (1.60 metres), Stourhead 2010 (t_3). The Temple of Flora, the Palladian Bridge, Bristol High Cross and St. Peter's Church are important foci in this view. The Temple of Apollo was also an important focal point in this view but is now overgrown (graphic: Steffen Nijhuis)

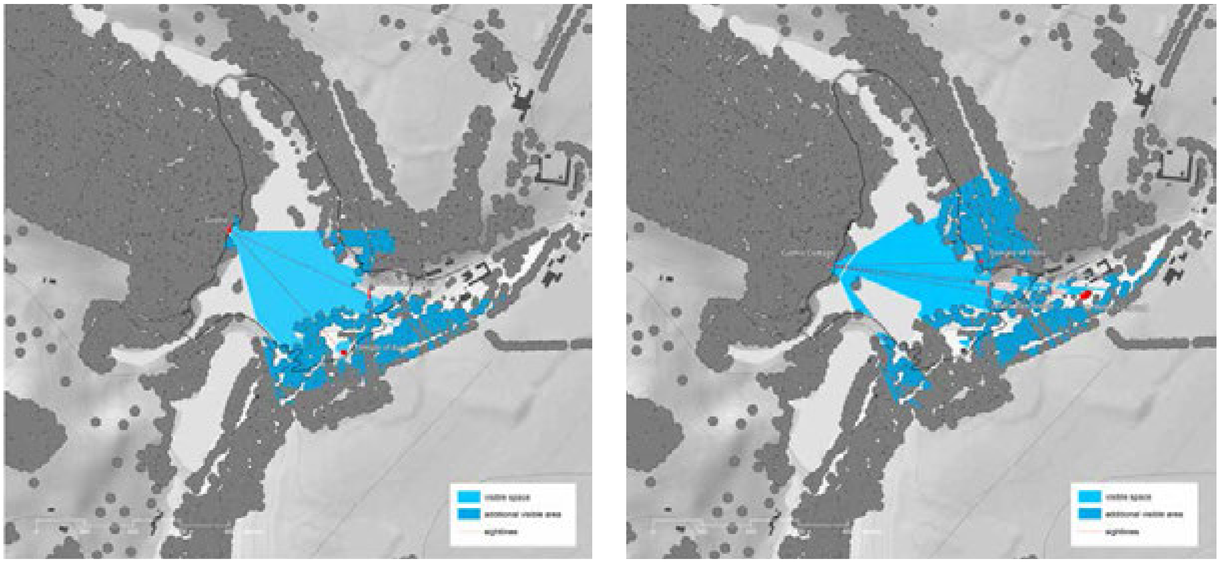

FIGURE 4.91 Visibility analysis from the Grotto (viewpoint 4) (left) and the Gothic Cottage (viewpoint 5) (right), Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010 and viewshed analysis from the Grotto and Gothic Cottage respectively at eye-level (1.60 metres) (map: Steffen Nijhuis)

viewpoint	Temple of Flora	Grotto	Cottage	Pantheon	Temple of Apollo	Bristol High Cross	Mean	Std.dev.
	viewpoint 2	*viewpoint 4*	*viewpoint 5*	*viewpoint 6*	*viewpoint 8*	*viewpoint 9*		
maximum horizontal angular extent of the view (degrees)	58	76	85	80	86	36	*70.17*	*19.58*
optimum horizontal angular extent of the view (degrees)	28	29	27	22	32	24	*27.00*	*3.58*
angular extent between foci (degrees)	14	23	12	12 (30*)	60	12	*22.17*	*19.02*
maximum distance viewpoint - focal point (metres)	368	343	497	494	3120**	478	*436.00*	*74.37*
minimum distance viewpoint - focal point (metres)	306	318	305	324	320	90	*277.17*	*92.01*

TABLE 4.3 Comparison of horizontal angular and metrical distances

Measurements based on calculated viewsheds, decimal figures converted to an integer
* *incl. Temple of Apollo*
** *outside the valley garden*

Horizontal angular extent

The viewshed analysis shows that the (optimum) horizontal angular extent of the views, as well as the angular extent between the foci, corresponds with the centre of the field of vision in the range to 30 degrees binocular view [Table 4.3].[579] This corresponds with the zone with the highest degree of acuity in the field of vision.[580] The analysis outcome suggests that this is the decisive factor for framing the view and (visual) grouping of the focal points in a view, as affirmed by Schubert (1965) and Pechère (2002).[581] It underlines that these views were designed 'by eye' as a three-dimensional painting or theatre, rather than using rulers and a compass.

The perceptual order of the views is also expressed in the metric length of the sightlines between the focal points across the lake establishing the axial relationships. The average distance is about 430 metres making sure that the artefacts and their characteristics can be recognized. The maximum distance for recognition of characteristic elements in a landscape is about 500 metres.[582]

Vertical angular extent

Maertens (1877) and Higuchi (1975/1988) argue that vertical viewing angels are important for the sense of distance and appearance of objects in terms of spatial-positional relationships [Figure 4.92]. The notion of 'here' and 'there' is particularly related to the angle of depression.[583] 'Here' refers to the foreground and is sensed as being immediately in front of the observer and ranges from 10 to 30 degrees below the horizon. Except when one is standing on a high building or terrain elevation, the sense of 'here' and 'there' becomes a matter of vertical distance.[584] On a more or less horizontal plane, 'there' refers to the range of 0 to10 degrees downward and can be characterised as the middle ground. This zone corresponds with the normal line of sight and individuals normally do not gaze fixedly at objects outside this range.[585] From this follows that the process of looking up, related to the angles of elevation, involves a certain amount of stress, which connotes the idea of paying reverence as a result of its visual effort.[586] The area from 0 to 9 degrees has visual importance as background.[587]

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[579] The optimum angular extent is determined by the occluding objects in the fore/middle ground, framing the view that contains the focal points.

[580] Humans have an almost 120 degree forward-facing horizontal, binocular field of vision. Within this field sharp images are transmitted to the brain, depth perception and colour discrimination is possible. However, the ability to perceive shape (pattern recognition), motion, and colour vary across the field. Pattern recognition concentrates in the centre of the field of vision and covers about 20-60 degrees binocular view. The highest degree of acuity is found in the range of about 20-30 degrees binocular view. This is due to the much higher concentration of cone cells (type of photoreceptors) in the fovea, the central region of the retina, which corresponds with a visual angle of 12-15 degrees per eye (= ca. 20-30 degrees binocular view), from there the acuity of the eye rapidly falls off (Snowden et al., 2006; Ware, 2004; Panero & Zelnik, 1979).

[581] Schubert (1965) discovered the sequence of 20, 30, 33 and 42 degrees in urban design with the emphasis on 20 and 30 degrees for important ensembles, and Pechère (2002) points out that 22 degrees is a common used angle to determine appropriate views in landscape design.

[582] Van der Ham & Iding, 1971.

[583] Higuchi, 1975/1988, p. 46. Cullen, 1961, p. 35ff.

[584] Higuchi, 1975/1988, p. 46.

[585] Panero & Zelnik, 1979.

[586] Higuchi, 1975/1988, p. 46.

[587] Ibid., p. 59.

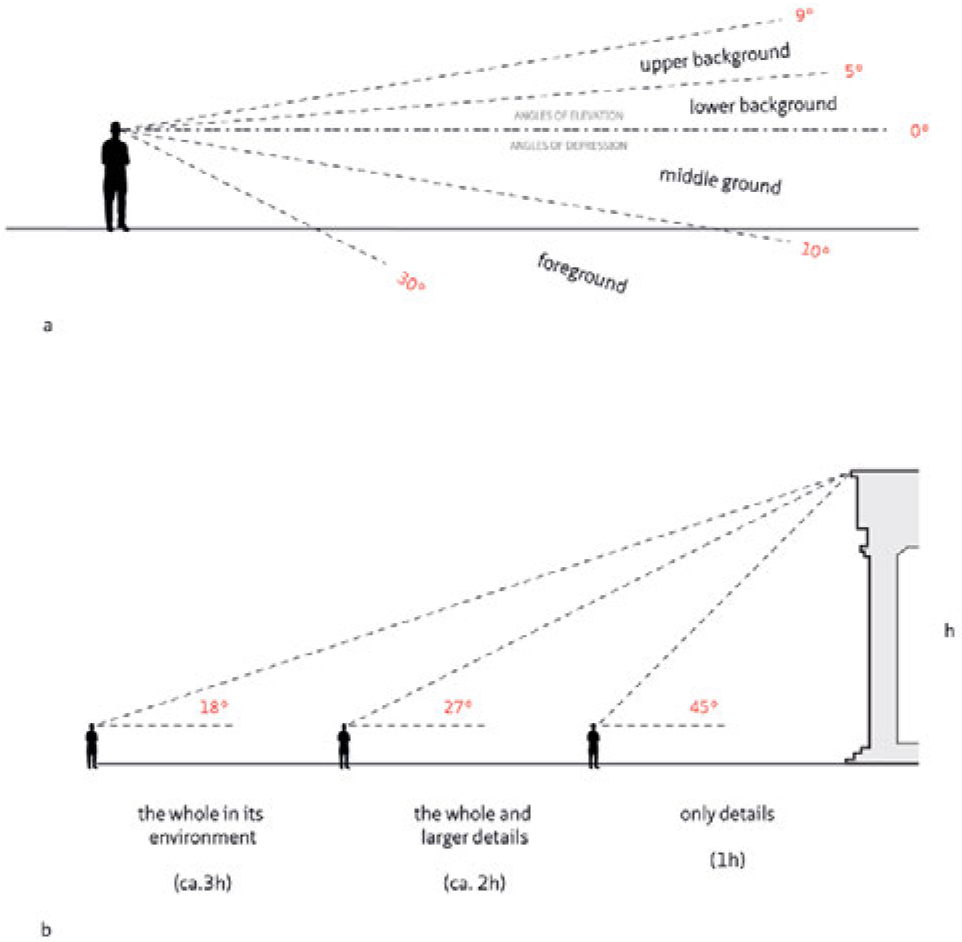

FIGURE 4.92 Angles of depression/elevation and sense of visual nearness in an open view (a), and angles of elevation and change of appearance of buildings related to viewing distance (b) (drawing: Steffen Nijhuis, data adapted from Maertens, 1877 & Higuchi, 1975/1988)

The analysis demonstrates that the views at Stourhead 2010 (t_3) in the foreground are dominated by the planting, which demarcate the views and the grassy shores, which open up the views [Table 4.4 & Figure 4.93, Figure 4.88 & Figure 4.90]. The middle ground is determined by the water plane and the planted islands, which direct the gaze. The background consists mainly of planting masses of light and dark toned trees and under-planting. As discussed earlier, this palette was later extended with more exotic species, which now dominate the views with sometimes colourful accents (in the flowering season). Interestingly, the architectural features are all located in the lower background, the zone between 0 and 5 degrees. In this zone, visual significance is defined by the fact that individuals can view objects without raising or lowering their head.[588] Movement of the eyeballs is sufficient. This is an optimal range for architectural features to stand out via their distinct form and colour, and can act as foci in the visual field. The upper background (5-9 degrees) affords interesting 'landscapish' views with an important role for the skyline and landform, and can only be seen by raising the head slightly.[589]

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[588] Ibid.

[589] Ibid.

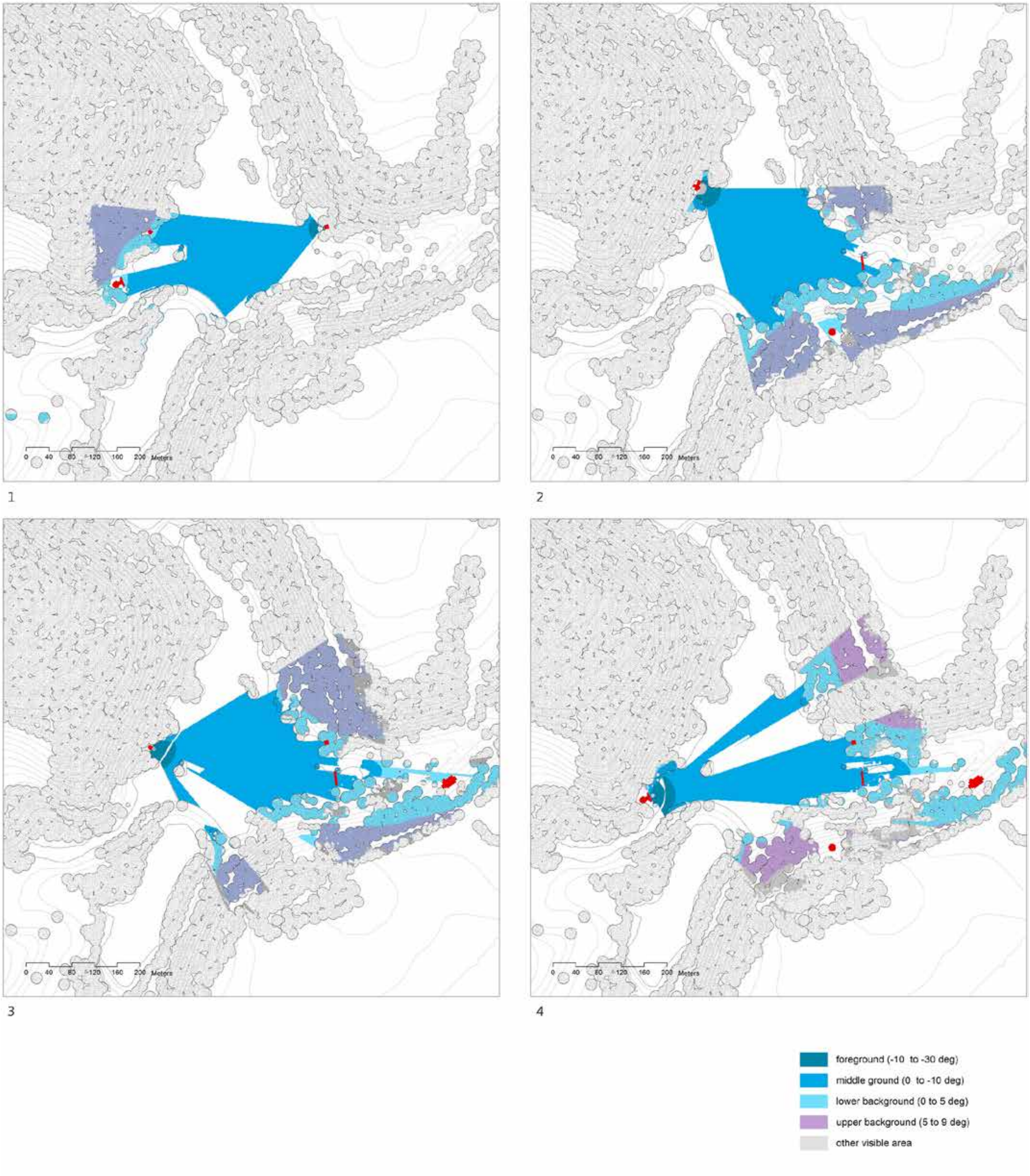

FIGURE 4.93 Analysis of angles of depression/elevation and sense of visual nearness from the Temple of Flora (viewpoint 2) (1), the Grotto (viewpoint 4) (2), the Gothic Cottage (viewpoint 5) (3) and the Pantheon (viewpoint 6) (4), Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010, viewshed and angular analysis from various viewpoints at eye-level (1.60 metres) (maps: Steffen Nijhuis)

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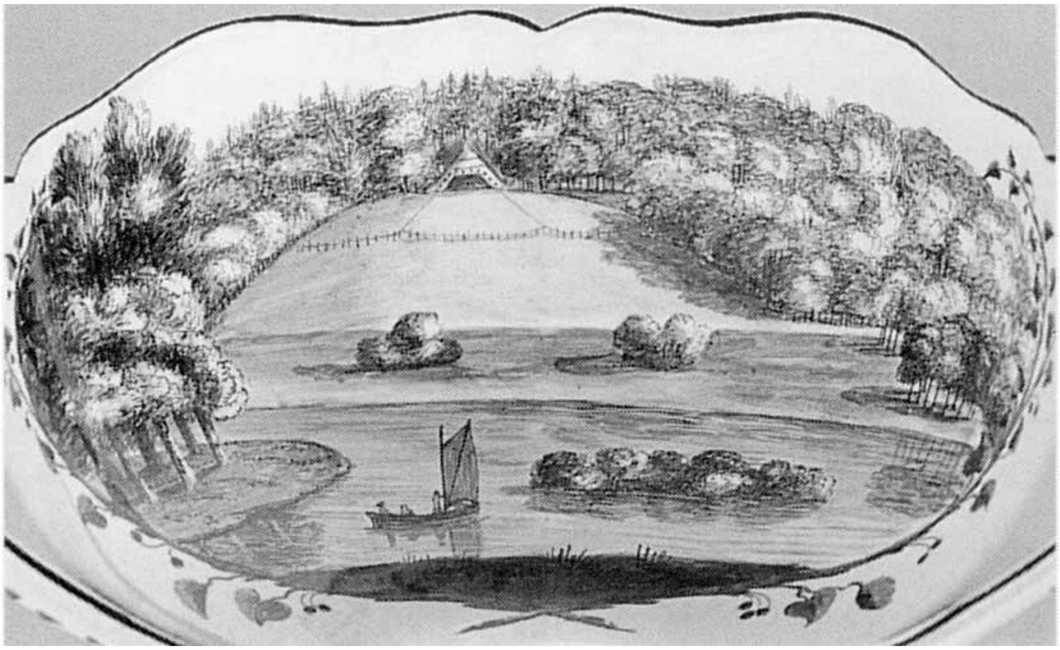

FIGURE 4.94 View from the Pantheon, Stourhead 1785 (t_1). To the fore the Great Lake, in the background the Turkish Tent on Diana's Hill is visible, which is the only known depiction of the Tent in its context. The tent was regarded as an important feature since it is exaggerated when compared with the real time proportions as visible in Figure 4.95 (image source: Raeburn et al., 1995)

FIGURE 4.95 Panoramic view from the Pantheon with (from left to right): the Turkish Tent, the Temple of Flora, the Palladian Bridge, Bristol High Cross, St. Peter's Church and the Temple of Apollo. Schematic-iconic representation Stourhead 1785 (t_1) (model by Steffen Nijhuis & Joris Wiers)

In terms of space-position relationships, the view from the Pantheon deserves special attention. From here, the Temple of Apollo is visible in the upper reaches of the lower background (3.8 degrees), increasing the building's significance by hinting at respect through the need for visual effort to look up. From the Temple of Apollo (and the Turkish Tent), the Pantheon is located in the middle ground, looking downward and referring to it as 'there we were'. In Stourhead 1785 (t_1) the Turkish Tent had a similarly high placement as the Temple of Apollo, and hence was also an important feature in the view from the Pantheon underlining its significance in early stages of the composition's development [Figure 4.94 & Figure 4.95].

viewpoint	Temple of Flora	Grotto	Gothic cottage	Pantheon	Bristol High Cross	Turkish Tent
maximum vertical angular extent (degrees)	1.68	4.48	1.3	3.57/3.8	minus 1.55	minus 3.57
maximum height difference between foci (metres)	10.83	26.88	10	27.93/23	13	27.93
distance (metres)	368	343	440	447/338	478	447
focus point	*Pantheon*	*Temple of Apollo*	*Bristol High Cross*	*Turkish Tent/ Apollo*	*Pantheon*	*Pantheon*

TABLE 4.4 Comparison of vertical angular and metrical distances

As the space-position relationships gradually change while following the route, architectural features become destinations, gradually emerging from the background and begin to visually fill the field of vision. The appearance changes as the angle of elevation changes and is relative to the height of the building or sculpture. Maertens identified the range 18, 33 and 45 degrees as significant vertical elevation angels [Figure 4.92].[590] From 18 degrees elevation, which corresponds to a distance of circa three times the height (ca. 3h), monumental characteristics become visible, to see the whole in its environment. From 33 degrees (ca. 2h) onwards, the range of vision is filled and detailed recognition is possible, and 45 degrees (1h) is the best place from which to observe small details. Since several architectural features in the Valley Garden, like the Temple of Flora or the Pantheon, are frontally oriented to the lake and sideways to the route, it is hardly possible to see the whole and the larger details in a frontal view.

Visual depth cues and optical illusions

Since the metrical depth of the views in the Valley Garden does not exceed the critical seeing distance of 1,200 – 1,400 metres, one can perceive optical depth.[591] Beyond this distance individual (common) objects are barely recognizable and merge with their background. In visual perception, depth cues and size constancy provide information about distance and can be employed to create optical illusions (e.g. visual exaggeration of the real size).[592] The views at Stourhead are also subject to optical illusions.

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[590] Maertens, 1877, p.30ff. Schubert (1965, p. 37) comes up with a more detailed range of 6, 20, 27, 33, 42 degrees.

[591] Antrop, 2007; Nijhuis et al., 2011b.

[592] See for applications in landscape design: Koch, 1915; Hubbard & Kimball, 1935, pp. 102ff.

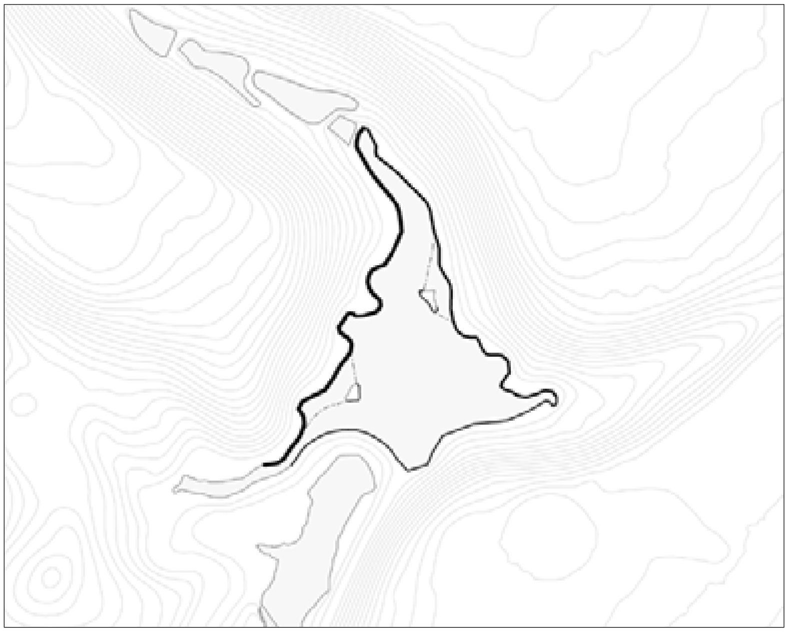

FIGURE 4.96 Edge length of the shorelines virtually extended by islands (map: Steffen Nijhuis)

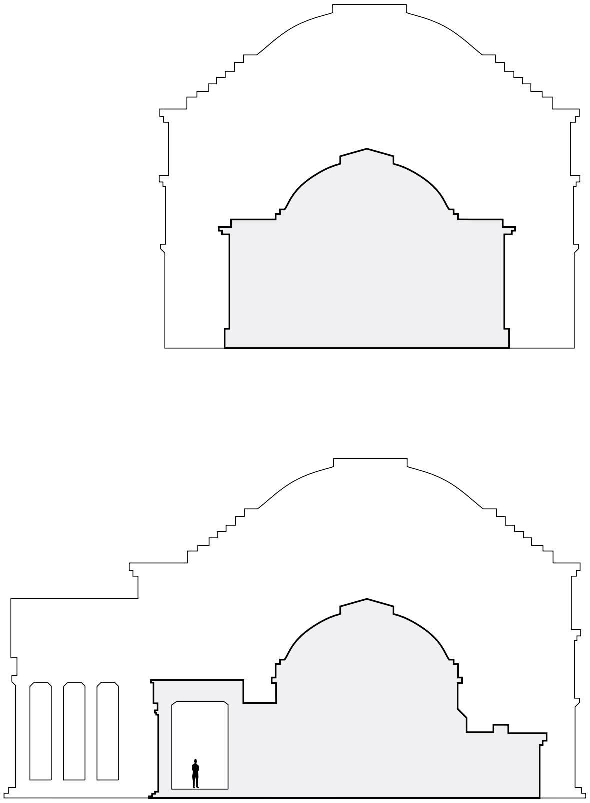

FIGURE 4.97 The Pantheon at Stourhead is a miniaturized version of the Roman original and is located on an elevation of the terrain, taking the eye for a run. Frontal (top) and longitudinal (bottom) comparison of the Pantheon (grey) and the Roman original (drawing: Steffen Nijhuis)

Occlusion in the middle ground by e.g. the planted islands and the Palladian Bridge are the most powerful depth-cues involved, exaggerating the perceived distance. The planted islands in the lake serve as requisites in a theatre, framing the views interrupting the empty flatness of the water and creating the illusion of space. By creating islands, the edge length of the lake is extended virtually (north-eastern and western shore line, resp. +6% and +1%) [Figure 4.96]. The western shore is most dominant in terms of length; the island here does not contribute significantly in extending the edge length. Depth cues like size relative to known objects and height on the picture plane are also design principles that play an important role. By slightly diminishing the size of distant objects, or using trees in the distance that are smaller than might be expected, they seem to be more distant.[593] For example, the Pantheon is a miniaturised version of the Roman original [Figure 4.97] and is located on a terrain elevation, taking the eye for a run since "*the human eye tries to see the object as being large as the mind knows it be*." [594] In general, the restful green-blue toned planting masses in the background suggest distance by simulating aerial perspective, where saturation and contrast decreases with distance and objects take on the cool colours of the atmospheric haze. The introduction of planting with stimulating warm colours (e.g. red and orange leaves and flowers) in the background makes it come forward and undermines the optical illusion of distance. The incidence of light and shadow also provides for a sense of depth.

The composed views around the lake form an important aspect of the visible form. The rules of visual optics were employed to arrange the view so that they are visually and proportionally effective, as in a three-dimensional painting or stage of a theatre. The zone with the highest degree of acuity in the field of vision was decisive for the horizontal angular extent of the views and the grouping of features. The average metric length of the sightlines between the focal points across the lake that establish the axial relationships make sure that the features' characteristics can be recognized. The vertical angular dimensions determine the foreground, middle ground, and background. The Great Lake dominates the middle ground and the architectural features are placed in the lower background. This is the optimal visual range for the features to stand out. The views in the Valley Garden are subject to optical illusions by subdividing the foreground, middle ground, and background, and using occluding elements in combination with smaller-sized architectural features. Whether consciously applied or not, these visual characteristics of the views demonstrate a rich wealth of tacit knowledge of spatial design and suggest that they were designed on-site.

§ 4.5.4 Visual integration of the estate and its surroundings

Views were not only valued as aesthetically pleasing, but were also equated with ownership and control of one's domain.[595] This is most apparent at two locations: Stourhead House and Alfred's Tower. Both locations provide possibilities for perspective (extensive views) and visually extend the landscape garden into the surrounding landscape.

Stourhead House is located on a moderate rise that provided for an overview of the downward sloping agricultural land to the east. It offered the possibility of gazing across the distant landscape and overseeing the property, "*as well as providing an impression of superiority and dignity for distant travellers.*"[596]

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[593] Hubbard & Kimball, 1935, pp. 102ff.

[594] Higuchi, 1975/1988, p. 60.

[595] O'Malley et al., 2010, pp. 539 & 641.

[596] In the words of Hirschfeld, 1779-1785/2001, p. 264.

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FIGURE 4.98 Alfred's Tower (image courtesy of The National Trust, photo: Stephen Robson)

The view to the east, the front of the house, is framed by forested hills like Zeal's Knoll in the south and Beech Clump and White Sheet Hill in the north. Outliers of the chalky Kesley Down and Mere Down ridge near the Great Bottom (north of Mere) also refined the angle of the front façade of the house, as discussed previously [Figure 4.28].[597] The view to the west transformed from a more closed, to an open view towards the Obelisk, which is aligned with the centre of the house. Artificial boundaries were carefully hidden so as not to obstruct the view and provide for a natural atmosphere. The sunken fence (called: ha-ha, blind fence, or deer wall[598]) on the north and east sides of the Great Oar Pasture is an example of such a design solution. This ditch combined with a steep bank was to prevent cattle and deer from entering the direct environs of the house without interrupting the view. On the southwestern side, the Great Oar Pasture was closed off by a belt of woodland and shrubbery.

Alfred's Tower is located at the highest point of the grounds [Figure 4.4]. It is a triangular tower 49 metres (top of the roof 51 metres) in height designed by Flitcroft and completed in 1772 after his death [Figure 4.98]. It was located and raised at Kingsettle Hill to honour King Alfred, since this was the supposed mustering place of Alfred the Great's Anglo-Saxon army near the battlefield where he defeated the Danes in 878, an important moment in the establishment of England as a nation.[599] The visually strategic nature of the location is underlined by the fact that, in earlier times, this high spot functioned as a beacon where fires were lighted to alarm the surrounding area to the approach of an enemy.[600]

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[597] See paragraph 4.3.2.

[598] O'Malley et al., 2010, p. 341.

[599] Woodbridge, 1982/2002.

[600] Hoare, 1812.

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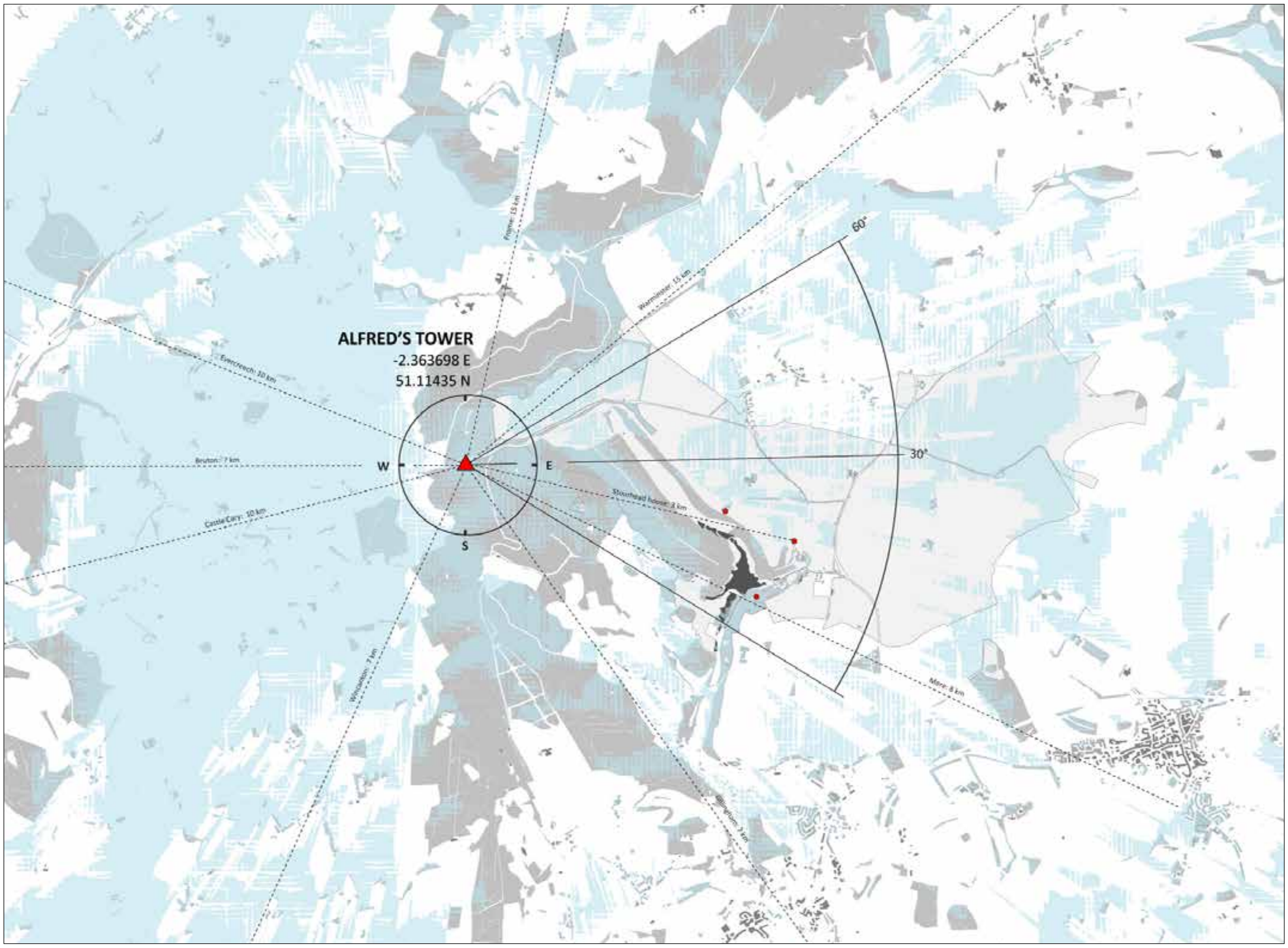

FIGURE 4.99 Analysis of the panorama from Alfred's Tower at eye-level (49 plus 1.60 metres), Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010 and viewshed analysis from Alfred´s Tower (map: Steffen Nijhuis)

The triangular prospect tower or belvedere ("place with a beautiful view") was raised in a period in which tower building and climbing to see one's self from the perspective once reserved for God and kings had emerged as the fundamental drive from which the Panorama as a mass medium took its form.[601] It was a place where anyone at the railing of the observation platform had an equal view in correct perspective of anything as near or far as they might wish to observe.[602]

As the viewshed analysis shows, the observation platform provides, due to its visually strategic position, a magnificent panorama over the veins of Glastonbury against the background of the Bristol Channel and the plain of Somerset [Figure 4.99 & Figure 4.100]. The theoretical range of vision (horizon) is approximately 44 kilometres.[603] However, the maximum visual range depends on atmospheric circumstances, and is referred to as the meteorological optical range.

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[601] Oetterman, 1997, p. 14ff.

[602] Ibid.

[603] The theoretical horizon can be calculated using the formula: 3,827√ h (eye-level in metres) = range in kilometres. Here the optical range is relative to the height of the eye-level and the curvature of the earth. In this case, the height of the tower is 49 metres +

northwest view

east view

south view

FIGURE 4.100 Panorama from Alfred's Tower, 2010 (photos from: http://www.alfredstower.info/)

This meteorological range decreases the visual optical range by 30 to 70 %.[604] The actual visibility of distant objects depends on the apparent contrast between the object and its background, the angular size of the object, its shape and vertical area, the contrast threshold at the level of luminance (type of day), the conditions and techniques of observing, and the eyelevel and related curvature of the earth[605] [Figure 4.101]. That means that the church towers of, for example, Frome (15 km), Warminster (15 km), and Everchreech (10 km) are visible in optimal atmospheric circumstances. Nearer by, only woodland and grassland of the landscape garden is visible [Figure 4.102]. Stourhead House and other architectural features are no longer visible from the tower due to the placement and growth of the trees. As the viewshed analysis points out, the Temple of Apollo and the Turkish Tent were visible from the tower in Stourhead 1785 (t_1). In 1887 (t_2) only the house and the Obelisk were visible [Figure 4.103]. Thus, over the centuries, the tower's visual connections with the Valley Garden, the Pleasure Garden, and the related architectural features vanished and stressed its importance as a prospect tower providing extended views over the region.

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eye-level 1.60 metres + average difference elevation location tower 82 metres = 132.6 metres. Theoretical range 3.827* √132.6 = 44.06 kilometres.

[604] Observations from the Royal Netherlands Meteorological Institute (KNMI) show that the meteorological optical range in full daylight varies from nearly zero up to several tens of kilometres (KNMI, 2010). Average ranges of 12 kilometres (50% of the time), 20 kilometres (25%) and 28 kilometres (10%) are typical for Dutch circumstances.

[605] Duntley, 1948; Middleton, 1952.

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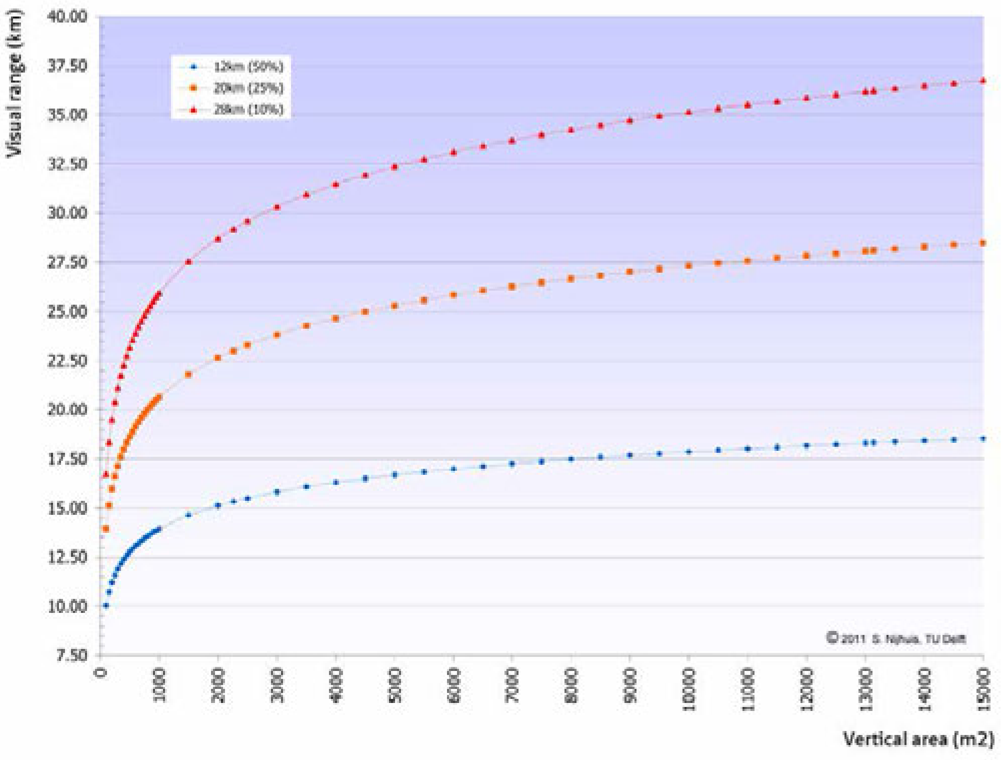

FIGURE 4.101 Visibility of distant objects at different meteorological ranges in full daylight (Lenght-width proportion vertical area<5; contrast value object-background ≥ 2%) (source: Steffen Nijhuis)

The prospects at Stourhead House and Alfred's Tower visually integrate the estate as a whole and its surrounding landscape. The eye-catching tower in particular offers a dramatic panorama over the region. It holds not only symbolic significance but also visually connects the valley with the plateau, the house with the estate as a whole, and the estate with the wider regional landscape. Over time, by the loss of visual connections with architectural features in the landscape garden itself, the tower's function as a visual hinge between the different scales of the landscape architectonic composition was marginalized and instead placed a new emphasis on its function as an autonomous belvedere.

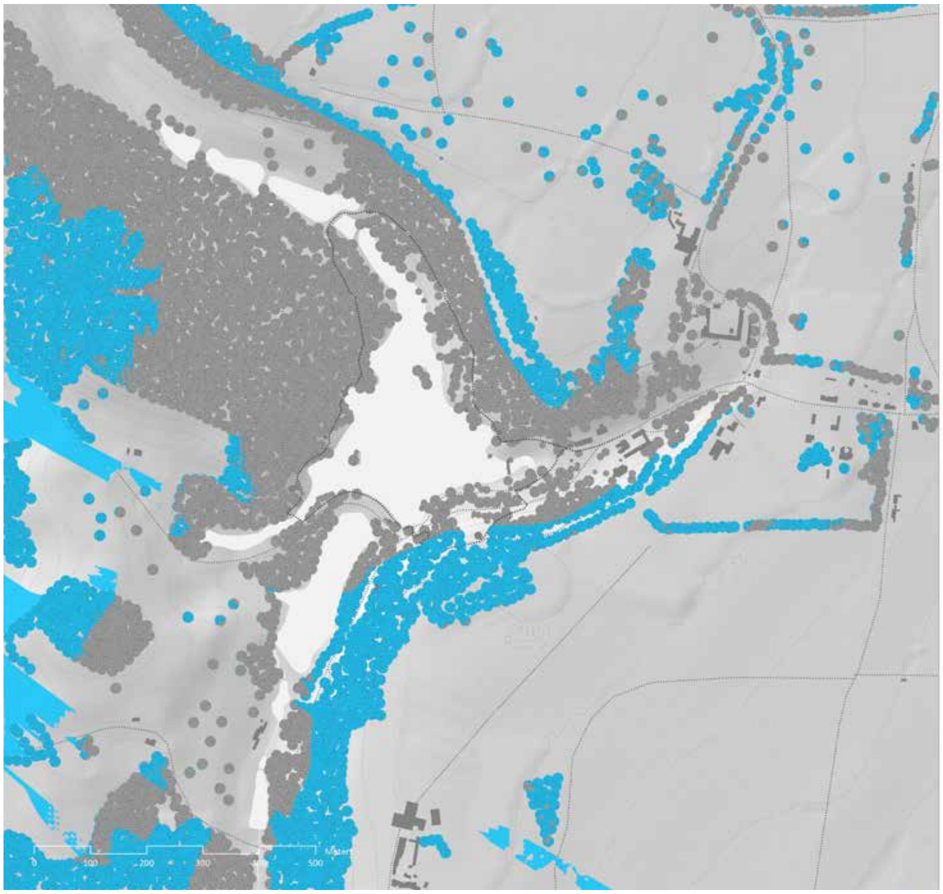

FIGURE 4.102 Visibility of the grounds from Alfred's Tower at eye-level (49 plus 1.60 metres), Stourhead 2010 (t_3).
→ Composite GIS-map with DLM 2010 and viewshed analysis from Alfred´s Tower (map: Steffen Nijhuis)

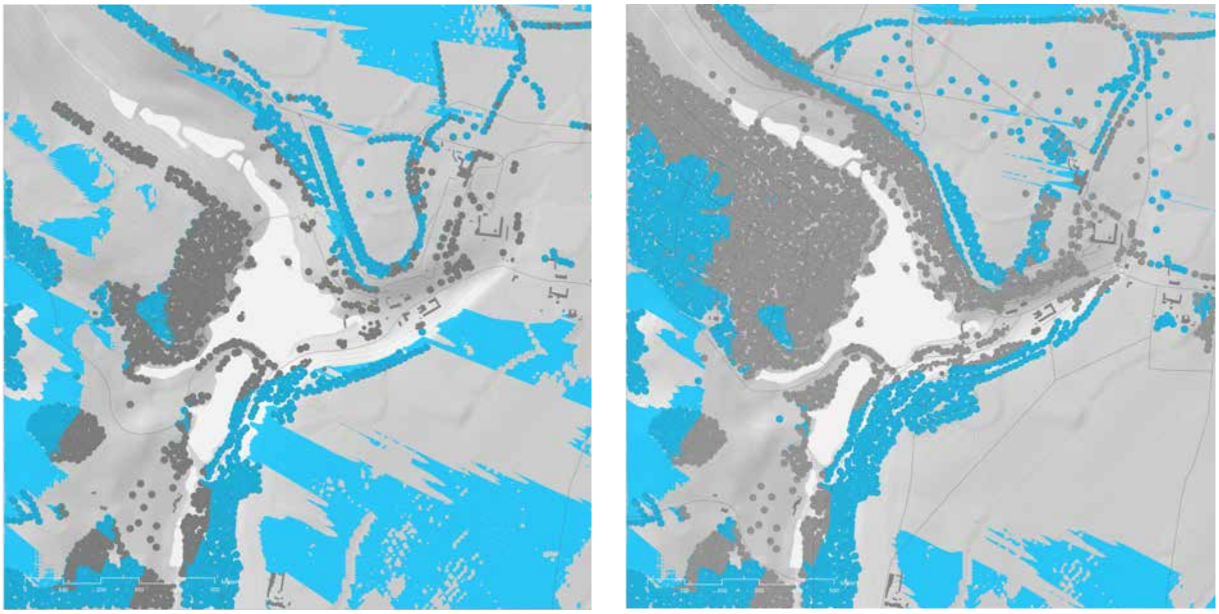

FIGURE 4.103 Visibility of the grounds from Alfred's Tower at eye-level (49 plus 1.60 metres), Stourhead 1785 (t_1) (left) and 1887 (t_2) (right).
→ Composite GIS-map with respectively DLM 1785 and DLM 1887, and viewshed analysis from Alfred´s Tower (map: Steffen Nijhuis)

§ 4.6 The potential relationship between space and meaning

According to contemporary landscape garden design theorists, the essence of the landscape garden is in the experience of it, in the way it responds to individuals and their expectations.[606] Experience is an occurrence (or event) that leaves an impression on someone and affects feelings and emotions. Next to its visible form and the role of movement, the symbolic form is important in the experience of the landscape garden. The symbolic form refers to the parts of the composition that have the potential to mean or symbolise something (e.g. emblematic architectural features in framed views). Meaning is defined here as the implied or explicit significance of signs, symbols, context, and other external phenomena that relate or give rise to internal mental activity.[607] The forms, spaces, and objects that constitute the composition can have a referential or symbolic function but do not *contain* meaning. The designer can *intend* meaning for what is designed, but users *attach* meaning to what they experience.[608] In that respect, the landscape architectonic composition functions as an interface between the intentions of the designer and the reception of the user.

Since the study of meaning is in the field of semiotics and cognitive sciences, it is hardly possible to generate definitive answers to questions of symbolic form in this study. Here, GIS is applied to study some morphological conditions with the potential to evoke certain feelings, emotions, or narratives. It offers an actual (non or a-historical) and formal reading of the site. From that perspective, two aspects of symbolic form will be addressed: representational and responsive.[609] The representational aspect (1) of symbolic form refers to (a) presentational and (b) referential elements of the composition.[610] Presentational elements refer to the implicit, contextual aspects of symbolic form, such as the proportion of space, light, and shadow and the tactile structure of the routes. These aspects exert great influence on the experience and can activate certain feelings, thoughts, and emotions. Referential elements point to the more explicit aspects of symbolic form and act as signs or symbols. Examples include inscriptions, sculptures and architectural features. The latter ones serve as iconographic elements (e.g. grotto representing the underworld) that together can make up an allegorical structure. They have strong referential importance and can evoke certain concepts, ideas, and narratives. The responsive aspect (2) of symbolic form points to its reception, which is about evaluation and affection by individuals and results in an observable human response.

The following analysis is focused only on the aspects that could be operationalized by means of GIS and reveals elements of the sensorial and tactile potential as a basis for the performance and attribution of meaning.

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[606] Introduction by Parshall in: Hirschfeld, 1779-1785/2001, p1 ff.

[607] Hershberger, 1970, p. 40.

[608] Ibid., p. 39, cf. Ferrari, 2010.

[609] Categories adapted from: Hershberger, 1970, p. 44.

[610] In psychological terms called the stimulus, a thing or event that evokes a specific reaction.

§ 4.6.1 Presentational elements of the symbolic form

The spatial composition, space definition and the experience of light and shadow are (implicit) presentational aspects of the symbolic form. These contextual aspects influence attribution of meaning since they have the power to evoke certain feelings, thoughts, and emotions.

Spatial composition

As discussed before the spatial composition was subject to changes and deliberate alterations over the centuries. The landscape garden changed and particular architectural features were also removed to obtain a kind of stylistic purity. Statements like *"ill accorded with the different Grecian Buildings"*[611] by Colt Hoare exemplify that the imposed meaning of the landscape garden changed and was edited by the owners themselves.

In a spatial sense, the previous GIS-based analyses already showed that the landscape garden changed from a park landscape with a rich variety of open-closed spaces with pastures into a forest landscape emphasising the Great Lake. The Valley Garden in particular transformed over time as an expression of different Arcadian dreams. In this respect one could interpret Stourhead 1785 (t_1) as pastoral scenery with open meadows and grassland, with a backdrop of trees and water. It was an Arcadia where classical, medieval (Gothic), or oriental features co-existed and provided a world landscape with numerous associations and stories. In Stourhead 1887 (t_2) the landscape garden had been transformed into a forest landscape. Arcadia was now defined in terms of trees and water, and the main route circles around the Great Lake. The scenery is more natural, embellished with some classical and medieval architectural features. The composition seeks the effect of the functioning of nature and landscape itself. Oriental features were found superfluous. The meaning of the landscape garden changed, which is also evident in the many horticultural additions such as the rhododendrons and other exotic species. In Stourhead 2010 (t_3), the landscape garden has become primarily a tourist landscape, where horticulture, the tourist's gaze (with directed views) and related touristic logistics define its development. This is exemplified by the construction of the huge visitor centre at the entrance of the Valley Garden and the adjustment of the route structure. Here Arcadia is a 'product' – a place for an 'authentic' historical experience, arboriculture and daydreaming – focused on the visual nature of the visitor's experience (sites become sights) and providing some sense of competence, pleasure and structure to those experiences.[612]

The constantly changing spatial composition of the landscape garden illustrates changing Arcadian dreams and suggests that it is not possible to impose a fixed meaning. The richness of the site lays in its multiple layers and the wide range of possible interpretations framed by its spatial composition.

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[611] Hoare, 1800, p. 45.

[612] See for backgrounds on the tourist gaze: Urry, 1990/2002; Waterton & Watson, 2014.

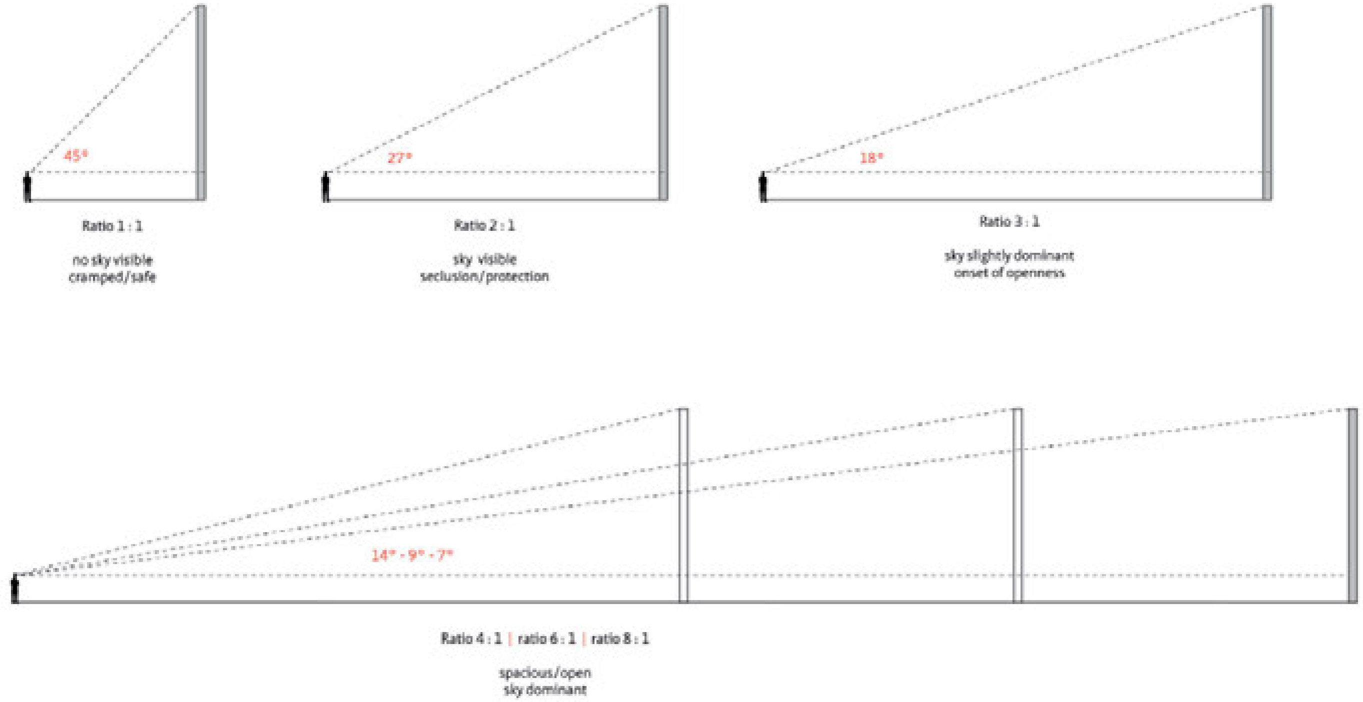


FIGURE 4.104 Space means experience of proportion and is about the ratio between the observer´s distance from a spatial boundary. The greater the distance, the more strongly the sky will dominate (drawing: Steffen Nijhuis, data adapted from Maertens, 1877 and Loidl & Bernard, 2003)

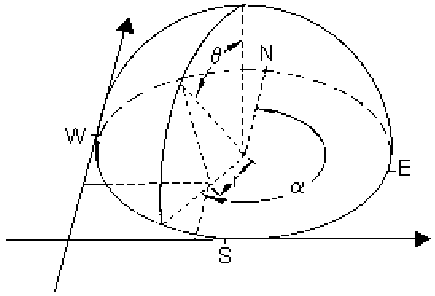


FIGURE 4.105 Hemispherical visibility analysis at eye-level looking upward; fisheye perspective (image source: ESRI)

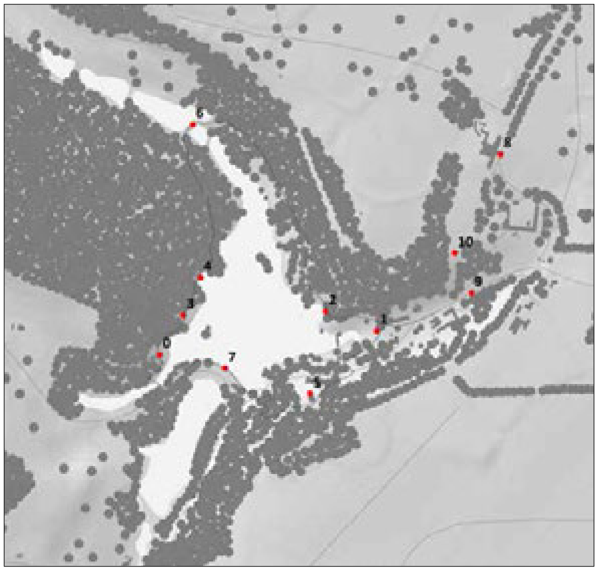
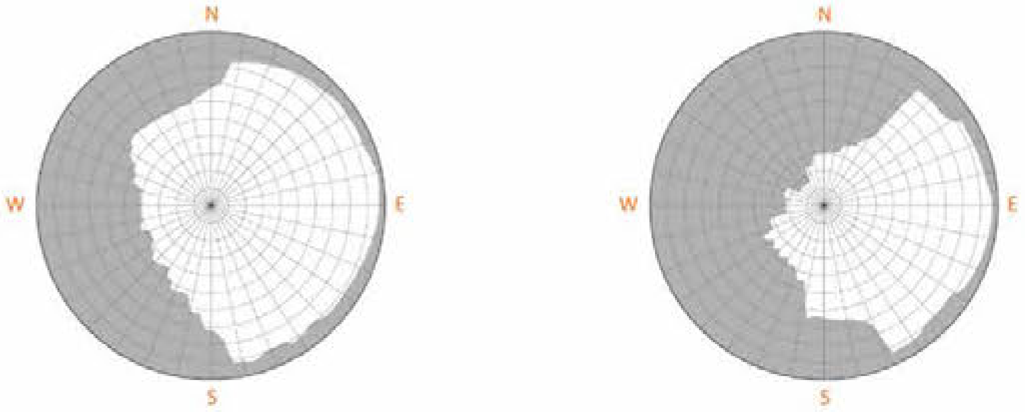
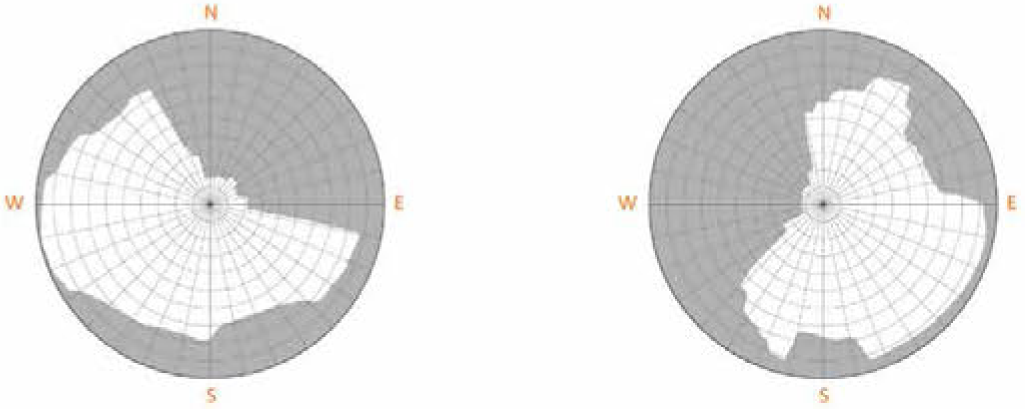


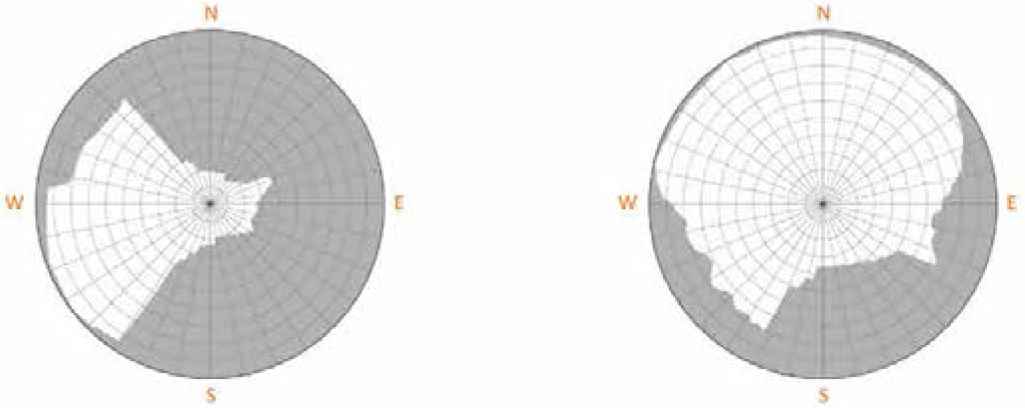
FIGURE 4.106 Viewpoints for the analysis of spatial proportion and edge-effect (map: Steffen Nijhuis)



Pantheon (0) Gothic Cottage (3)

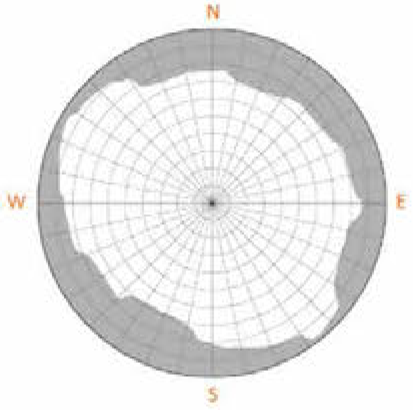


Bristol High Cross (1) Grotto (4)

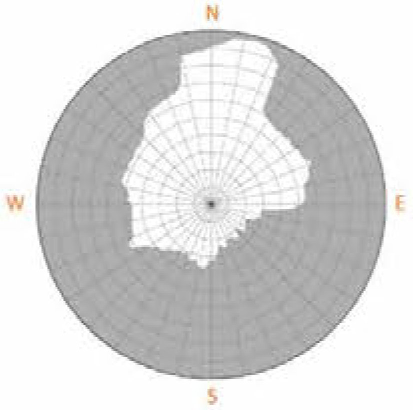


Temple of Flora (2) Temple of Apollo (5)

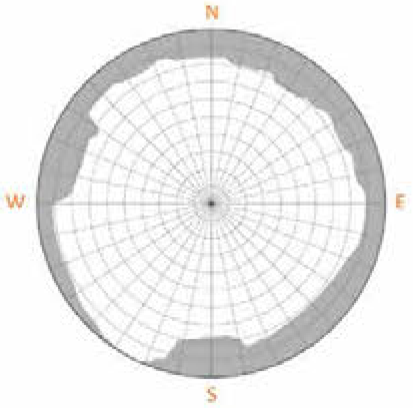
FIGURE 4.107 GIS-based hemispherical analysis of the proportion between vertical boundary and open sky at eye-level. Also showing the direction of the space. White: open sky, grey: vertical boundary. The circles depict visual angle in steps of ten degrees (drawing: Steffen Nijhuis)



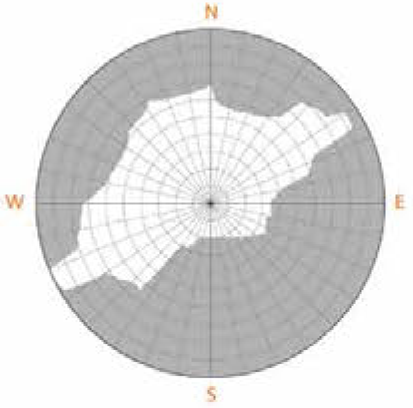
Alfred's Pump (6)



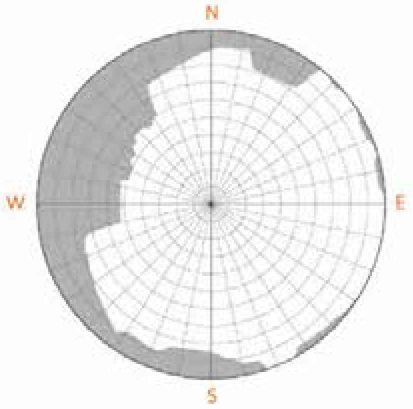
Valley (9)



Dam (7)



Terrace (10)



Stourhead House (8)

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Space definition

Alongside the changes in the composition, certain spatial effects important for the experience of the landscape garden also changed. An important denominator in spatial effects is space definition, as it determines spatial size, degree, and nature of enclosure.[613] Spatial size is determined by the ratio between the viewer's distance from a spatial boundary and the distance between the point of sight and height of the boundary.[614] This ratio defines the spatial size and the degree of enclosure. The greater the difference between distance (d) and height (h) becomes, the more strongly the sky will dominate the space and the feeling of enclosure reduces.[615] When the ratio is 1:1 (h : d) no sky is visible and the space is fully enclosed and evokes a feeling of safety, or of being in a cramped space. The space is partially enclosed and the sky is visible at a ratio of 2:1. This evokes feelings of seclusion and protection. At a ratio of 3:1 the sky is slightly dominant and the space feels minimally enclosed. In a space with a ratio of 4:1 or more, the sky dominates and the space is characterised as spacious, which feels unenclosed. In this respect one could say that space is actually about the experience of proportion [Figure 4.104].[616]

In order to assess the spatial effect of space definition, a hemispherical viewshed analysis was performed at several locations in Stourhead 2010 (t_3) [Figure 4.105 & Figure 4.106]. This GIS-based analysis measured the proportion between the vertical boundary and open sky at eye-level [Figure 4.107]. The analysis outcomes indicate that most spaces are asymmetrically enclosed with a ratio of less than 6:1 (< 9 degrees). From a protected backdrop of green foliated mass, one can experience the visually prominent open space that is, in most cases, formed by the Great Lake. In this way, the definition of space directs the visual experience to views opening up towards the lake, providing a sense of spaciousness and at the same time offering a feeling of safety and seclusion. This also corresponds with the notion of an ideal tourist landscape, directing the gaze of the visitor towards the most significant picture-perfect views the landscape garden has to offer (as presented on postcards and in brochures).[617] However, the assumption is that in the earlier stages (Stourhead 1785 (t_1), 1887(t_2)) of the composition's development, space definition was characterised by a greater variety of undirected, open spaces related to the half-open park landscape that later turned into a forest landscape with the Great Lake in a central position.

Light and shadow

The experience of (day)light and shadow is also an important presentational element of the symbolic form, as it is more than a question of comfort. Light and shadow provoke emotions and atmosphere. They can make a space pleasant or unpleasant, and influence the spatial experience of scale.[618] Light and shadow effects are important for the scenery as they can emphasise masses and spaces while delineating and accentuating forms and edges.[619] Hence the experience of light and shade was important to the contemporary landscape designers.[620]

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[613] Motloch, 2001, p. 184ff; Loidl & Bernard, 2003: p. 48ff.

[614] Ibid.

[615] Ibid.

[616] Ibid.

[617] See for the importance of photography for visitors and heritage sites: Urry, 1990/2002, p. 124ff.

[618] Von Meiss, 1990, p 121-126.

[619] Hubbard & Kimball, 1935, p. 111-112.

[620] Cf. Whately, 1772/1982; Hirschfeld, 1779-1785/2001.

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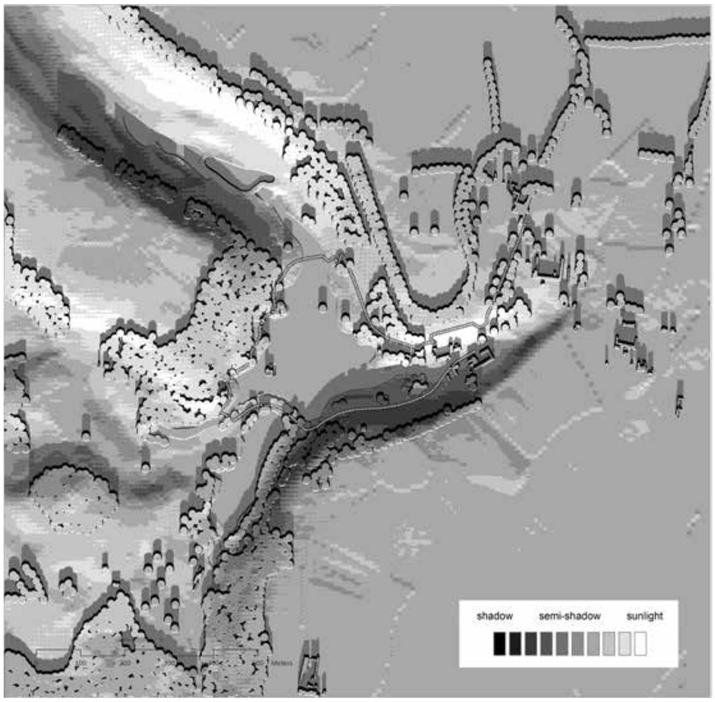

FIGURE 4.108 Light-and-shade experience at Stourhead in 1785 (t_1).
→ GIS-based analysis of light and shade based on the average between summer solstice (21 June; sun altitude 62 degrees) and winter solstice (21 December; sun altitude 15 degrees) from South (azimuth 180 degrees from North) (map: Steffen Nijhuis)

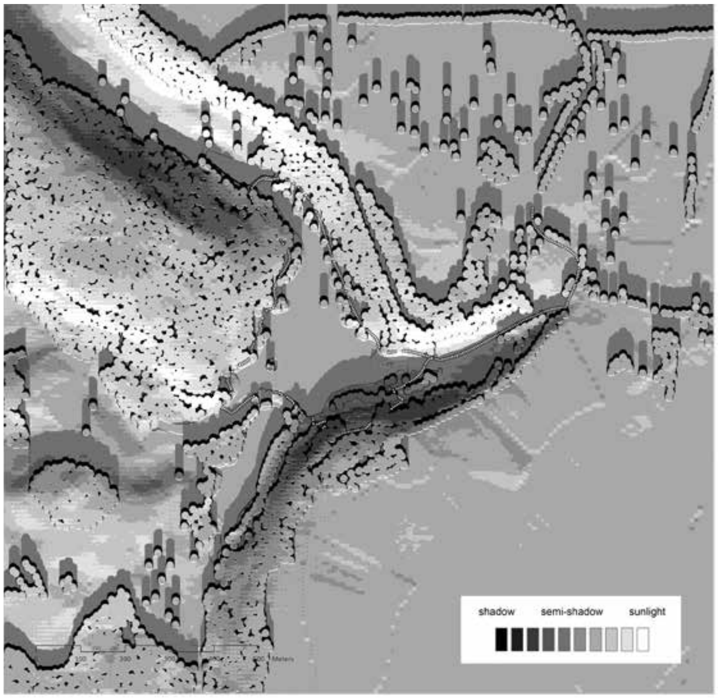

FIGURE 4.109 Light-and-shade experience at Stourhead in 1887 (t_2).
→ GIS-based analysis of light and shade based on the average between summer solstice (21 June; sun altitude 62 degrees) and winter solstice (21 December; sun altitude 15 degrees) from South (azimuth 180 degrees from North) (map: Steffen Nijhuis)

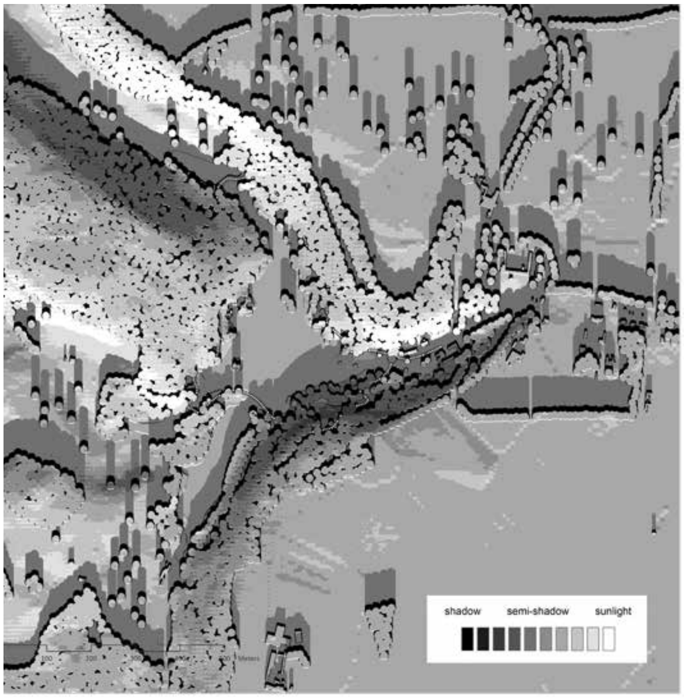

FIGURE 4.110 Light-and-shade experience at Stourhead in 2010 (t_3)
→ GIS-based analysis of light and shade based on the average between summer solstice (21 June; sun altitude 62 degrees) and winter solstice (21 December; sun altitude 15 degrees) from South (azimuth 180 degrees from North) (map: Steffen Nijhuis)

In order to analyse the effects of light and shadow, sun cast shadow was calculated based on the average between summer solstice (21 June; sun altitude 62 degrees) and winter solstice (21 December, sun altitude 15 degrees) from the south at 12 o'clock in the afternoon (azimuth 180 degrees from North) based on Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3) [Figure 4.108, Figure 4.109 & Figure 4.110]. Based on the geographical context it is no surprise that the north facing slopes of the valley have the most shade projection.[621] The south-facing slopes, as well as the lake and the open grasslands on the terrace catch the most daylight. On a more detailed level the light-shade experience is mainly determined by the planting masses of trees and shrubbery. The contrasts between open spaces and masses are emphasised in the views by effects of light and shadow, like the contrast between the shady tree-masses and open light-absorbing Great Lake. The colour of the architectural features too is lighter and brighter than the planting in the background, reinforcing their importance as focal points. The corporeality of architectural features is also strengthened by light and shadow contrasts, such as the Pantheon. The Pantheon is oriented with its rear to the prevailing direction that the sun shines in, resulting in backlight throughout the day, which underlines the corporeality of the building and the contrasting light and shadow in its front façade.

The analysis of the light-shade experience from the main routes points out that the development of the composition in terms of light-shade follows a similar pattern as discussed in the development of the visible form [Figure 4.111]. It shows a gradual transformation from a diverse palette of light-shade contrasts in an alternating pattern along the route, into a more levelled and determined light-shade experience, where the woodland is the equivalent of shade [622], and where views open up, the lake serves as a large light and open surface reflecting the scenes.

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[621] Hence names like the 'Shady Hanging' in the Six Wells Bottom.

[622] Nowadays called 'The Shades' to characterise the shady paths (Garnett, 2006, p. 10).

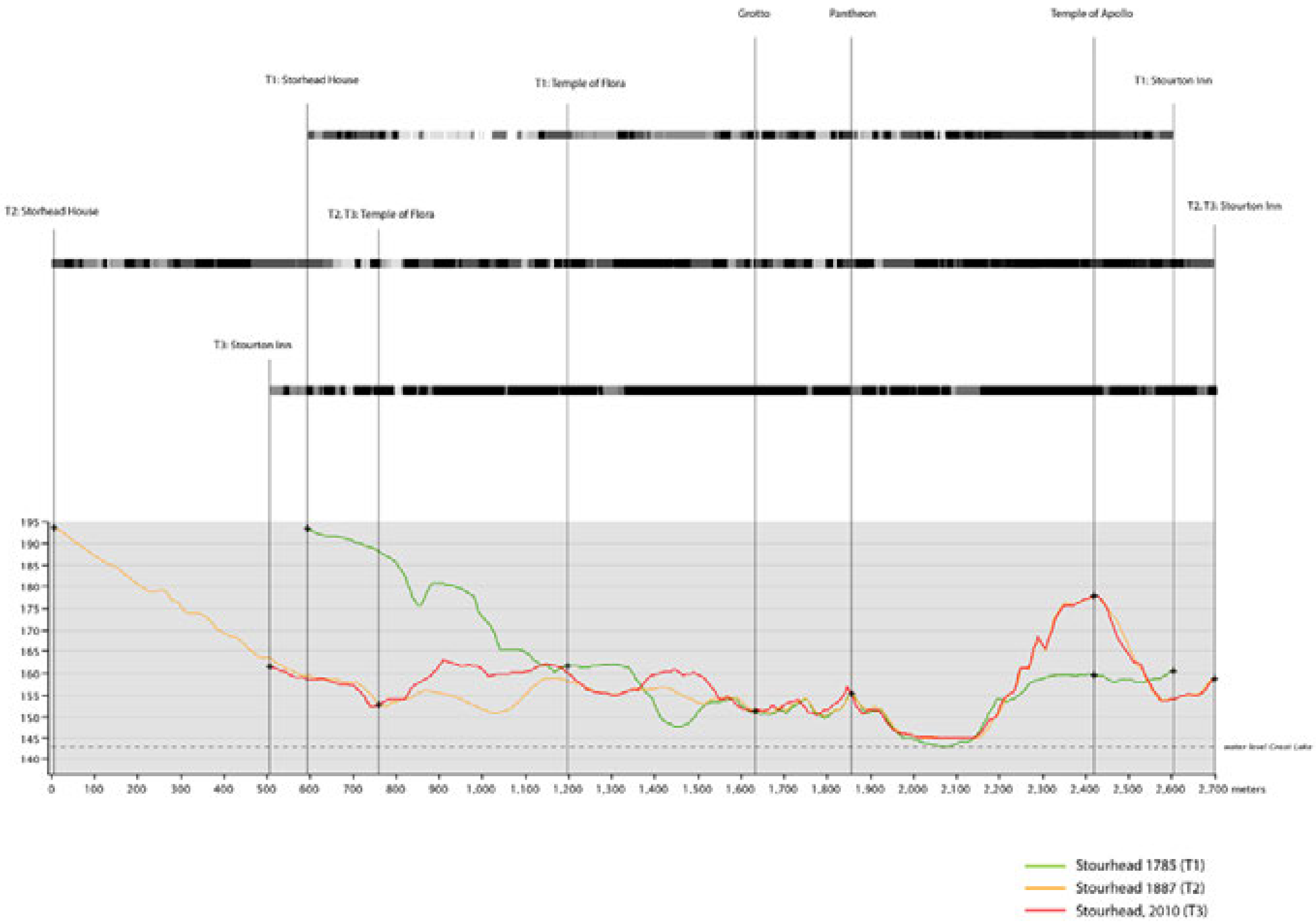

FIGURE 4.111 Comparison of light-shade experience along the main routes in Stourhead 1785 (t_1), 1887 (t_2), and 2010 (t_3).
→ GIS-based analysis of height gradient along the route derived with 3D Analyst from DEM 1785-2010 in relation to light and shade along the route (drawing: Steffen Nijhuis)

§ 4.6.2 Referential elements of the symbolic form

At Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3) the most explicit referential elements of the symbolic form are the architectural features that dictate the views. The temples, grotto, obelisk, etc. have a particular classical, medieval (Gothic), or oriental connotation as a result of their architectural expression [Figure 4.112 & Figure 4.113]. The various temples and the Gothic Cottage, for instance, could also be used for repose or as a shelter from sun and rain. However, according to contemporary writers, the main purpose of these objects is beautification of the scenery, to activate or intensify the site's character, and as monuments.[623]

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[623] Whately, 1772/1982; Hirschfeld, 1779-1785/2001.

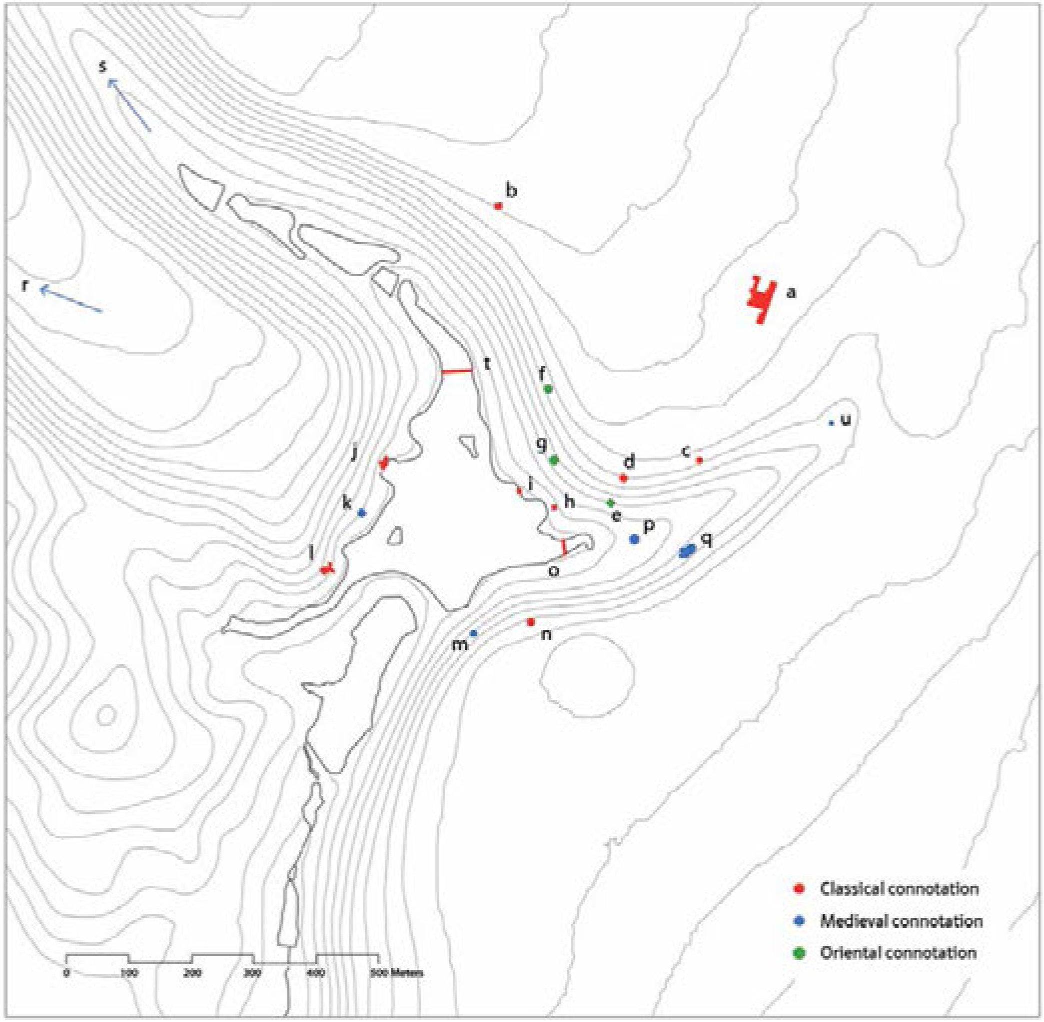

FIGURE 4.112 The architectural-iconographic elements and their classical, medieval or oriental connotation. House (a), Obelisk (b), Statue of Apollo (c), Temple on the Terrace (d), Umbrella Seat (e), Turkish Tent (f), Chinese Alcove (g), Temple of Flora (h), Rockwork Boathouse (i), Grotto (j), Gothic Cottage (k), Pantheon (l), Hermitage (m), Temple of Apollo (n), Palladian Bridge (o), Bristol High Cross (p), St. Peter's Church (q), Alfred's Tower (r), St. Peter's Pump (s), Wooden Bridge (t) and the Gate (u) (map: Steffen Nijhuis)

They were there *"to enlighten the minds"*[624] by their reference to paradise or certain myths (e.g. the foundation of Rome) and to commemorate notable historical events or persons. They gave local form to memories of the Grand Tour or were expressions of passion or political perspective.[625]

As discussed earlier, the architectural features act as focal points in sequential frontal and/or lateral views, creating a pictorial sequence organised by the circuitous route in the Valley Garden. This stroll seems to be allegorical in nature and designed as a series of compositions dissolving into each other, and is called a pictorial circuit.[626] The cinematic experience is a reflection of the visual story being told; the storyline becomes a physical construction, starting at Stourhead House and ending at Stourhead's Inn.[627]

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[624] Hirschfeld, 1779-1785/2001, p. 285.

[625] Hunt & Willis, 1988; Hunt, 1992a.

[626] Paulson, 1975.

[627] Woodbridge, 1976.

FIGURE 4.113 Overview of the most important architectural-iconographic features with a particular classical, medieval or oriental connotation in Stourhead 1785 (t_1) (models by Steffen Nijhuis & Joris Wiers)

FIGURE 4.114 Eighteenth century replicas of the Temple on the Terrace and the Wooden Bridge at Wörlitz, Dessau (Germany) (photos: Steffen Nijhuis)

Decoding this alleged allegorical structure has been the focus of several art historians and literary scholars who have addressed Stourhead in a wide range of interpretive writings.[628] Usually referring to the existing features, these scholars have imposed divergent allegories upon the garden that range from Aeneas' journey to found Rome, to evoking England's historical past, to Hercules' choice at the crossroad , to the Christian's pilgrimage through life. However, Magleby (2009) points to the lack of attention to the dismantled exotic pavilions such as the Turkish Tent and Chinese Pagoda in these studies, and proposes a more inclusive reading that includes the British discourse about the Ottoman Empire.

Though this is not an iconographic analysis, investigating the pictorial and tactile structure by means of GIS can provide some clues for others to refine insights or offer alternative readings. The views that are identified as the most important in the development of the landscape garden in the last century (Stourhead 2010 (t_3)) are the basis of this analysis, including: Temple of Flora (viewpoint 2), Grotto (viewpoint 4), Pantheon (viewpoint 6), Temple of Apollo (viewpoint 8) and Bristol High Cross (viewpoint 9) [Figure 4.74]. However, it is important to recall that since Stourhead 1785 (t_1) several features have been removed, some sight connections have vanished due to tree growth, and the route structure has changed considerably. To have an idea of their significance for the symbolic form, it is interesting to see contemporary replicas and modern temporary reconstructions of the removed features[629] [Figure 4.114 , Figure 4.115 & Figure 4.116].

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[628] See paragraph 2.4.4 'Stourhead as allegorical structure' for an overview. Regarding iconographic or semiotic readings of the landscape garden Hunt (2004) puts forward an important issue concerning the undefended assumption that Stourhead is to be grasped 'as a whole', and that the whole picture can somehow be made apparent to us either on site or retrospectively by commentaries of art historians and literary scholars. As Hunt argues this assumption of or search for unity, for wholeness in any explanation of the garden's meaning doubtless follows from these authors' training to read poems, novels or paintings as complete and coherent works of art that add up to more than the sum of their details. But it is not an assumption that works well for gardens. As Hunt points out, gardens and landscapes are constructed over time, with new insertions of trees, plants and buildings not necessarily observing or even having knowledge of an original sense of the whole; there is also the 'insertion' into the garden of visitors in many later generations whose responses complicate any search for holistic readings (Hunt, 2004).

[629] The 'Stourhead Revisited-project' in 2002 was a project where the most important removed features were temporarily recreated (Higgs, 2003).

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FIGURE 4.115 In the project 'Stourhead Revisited' in 2002 the demolished features were recreated on a temporarily and placed in the garden. Left: Wooden Bridge printed on a life-size banner and erected at its original position. Right: Modern reconstruction of the Turkish Tent and sited at its original position (image source: Higgs, 2003)

The viewshed analyses demonstrated that the views contain juxtaposed classical and medieval objects [Table 4.5]. Though classical objects dominate the views, they are counterbalanced by medieval objects. This suggests an allegorical dialogue between historical events, especially due to the fact that there is a more or less balanced number of symbols within a given view.

The landscape garden was a place for relaxation and pleasure, it asked to be explored, its surprises and unsuspected corners were to be discovered on foot.[630] Therefore it is also important to consider the relationship between the viewpoints and course of the route, since it guides visitors through the landscape architectonic composition in response to the designer's intentions. The route is articulated three-dimensionally, in forward direction and in up and downward directions and establishes horizontal and vertical relationships between the architectural features as iconographic elements. In the horizontal direction, there is a certain timing, with varying intervals, between the major views. In the vertical direction, the relationship is defined by going upward or downward, e.g. descending to the Grotto, ascending to the Pantheon, and the steep climb to the Temple of Apollo [Figure 4.117].

Whether or not a specific iconographic programme was in the mind of its creators, they designed an Arcadian landscape inhabited by the gods and heroes of classical antiquity and England's history. As MacDougall (1985) suggests, it is likely that such a landscape architectonic composition was a device for creating a memory system rather than a story with a deeper meaning. It was not a place to contemplate deep philosophical or religious questions. Memory could be developed by establishing a mental image of a place inhabited by or 'decorated' with views.[631] In this respect, it is important to acknowledge that the interpretation of every single view that one receives from different viewpoints are not ends in themselves but are parts in a series of views that draw together the mental image of the composition.[632] From this it follows that symbolic form is about the construction of time-space relationships between routes, views, and iconographic elements in terms of sequence and timing.

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[630] According to Hunt, 1989.

[631] MacDougall, 1985.

[632] See Chapter 2, note 143.

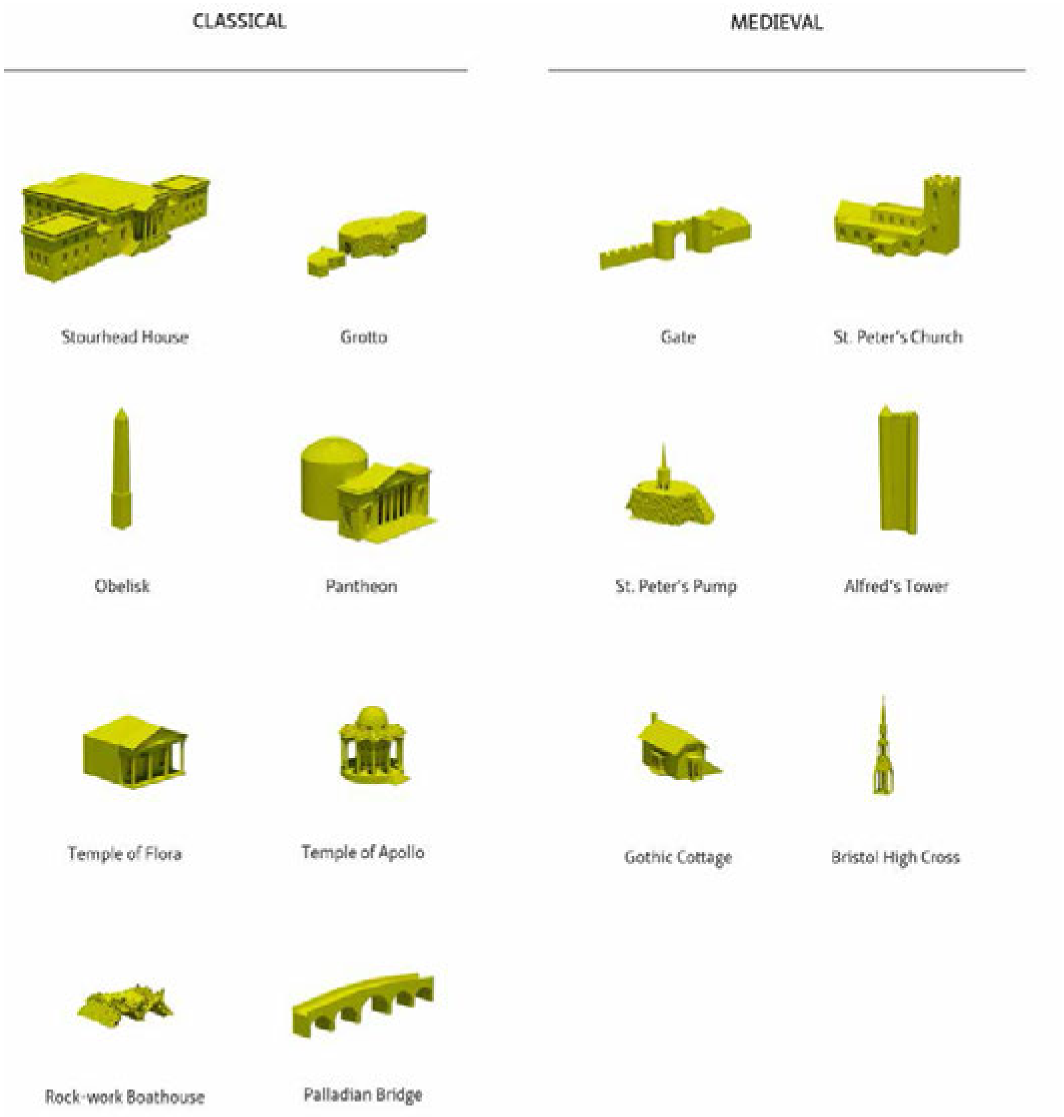

FIGURE 4.116 Overview of the most important architectural-iconographic features with a particular classical or medieval connotation in Stourhead 1887 (t_2) and 2010 (t_3) (models by Steffen Nijhuis & Joris Wiers)

Viewpoint	Focal points with emblematic character
Temple of Flora (1)	Pantheon (C), Gothic Cottage (M)
Grotto	Temple of Apollo (C), Palladian Bridge (C), Temple of Flora (C), Bristol High Cross (M), St. Peter's Church (M)
Gothic Cottage	Temple of Flora (C), Palladian Bridge (C), Bristol High Cross (M), St. Peter's Church (M)
Pantheon (2)	Temple of Flora (C), Palladian Bridge (C), Bristol High Cross (M), St. Peter's Church (M), Temple of Apollo (C)
Bristol High Cross (3)	Palladian Bridge (C), Pantheon (C), Gothic Cottage (M)
Temple of Apollo	Grotto (C), Obelisk (C), Alfred's Tower (M), Pantheon (C)

TABLE 4.5 Focal points with emblematic character per view, Stourhead 1887 (t_2), 2010 (t_3)

The features indicated in orange are not visible anymore because of growth of planting
(C) indicates classical connotation
(M) indicates medieval connotation
(1) The Temple of Flora was originally called Temple of Ceres
(2) The Pantheon was originally called the Temple of Hercules
(3) The Bristol High Cross derived from the High Street of Bristol

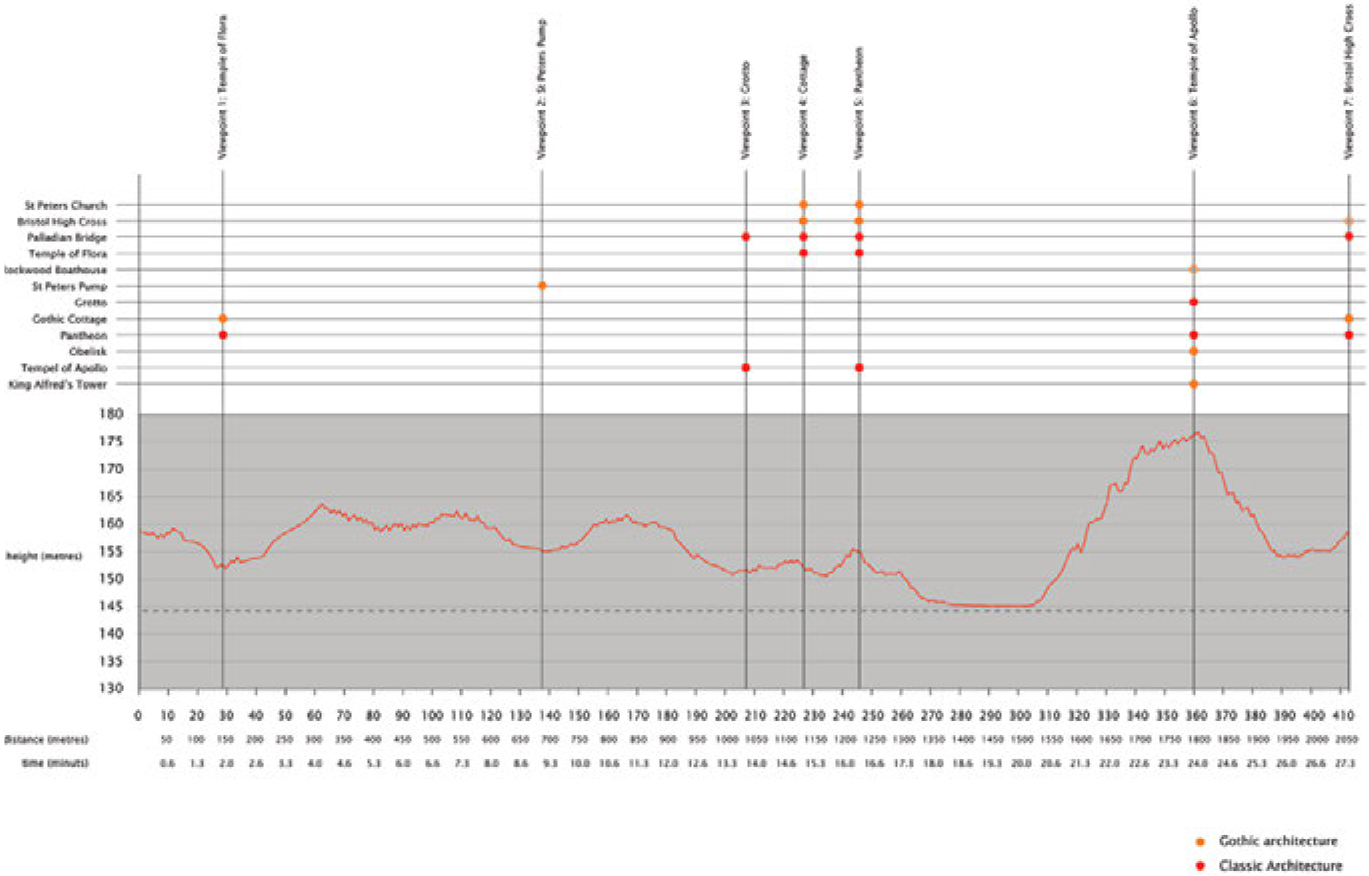

FIGURE 4.117 The stroll explored at Stourhead in 2010 (t_3). The sequence of the views in relation to distance, time and height of the path.
→ GIS-based analysis of height gradient along the route derived with 3D Analyst from DEM 1785-2010 (drawing: Steffen Nijhuis)

Hunt (2004) sums it up as follows: "*Stourhead comes to exist, it seems, in contested claims for meanings that can be shown to have been embedded in the original design by Henry Hoare on the basis of some tendentious reading of the cultural context… [However,] the richness of [the site] lies in [its] ability to provoke and promote a wider sea of emotions, ideas, stories than was ever anticipated by Henry Hoare [and its successors].*"[633] Though the alleged allegorical structure of Stourhead was simplified over the centuries by removal of features and the growth of trees, the presented analysis puts forward that the site won in greater richness, promoting and provoking a wide range of emotions, ideas, and stories with its symbolic form. The changing meanings of the Arcadian nature of the park, evoked by the changes in the landscape itself in relation to the sequence of images with iconographic elements organised by the composition and the imposed routes in particular, connects tactile experience and visual appearance as conditions for the attribution of meaning.

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[633] Hunt, 2004, p. 204.

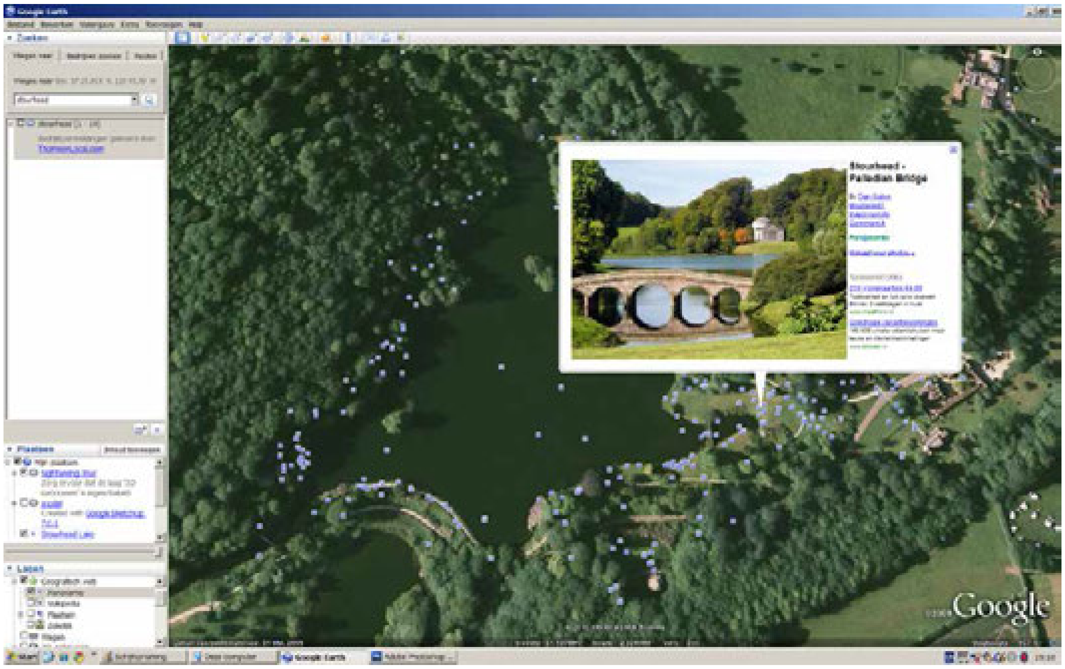

FIGURE 4.118 Crowdsourcing by making use of geotagged photographs as an indicator of the level of interest of visitors (image retrieved from: http://www.panoramio.com [accessed September 2010])

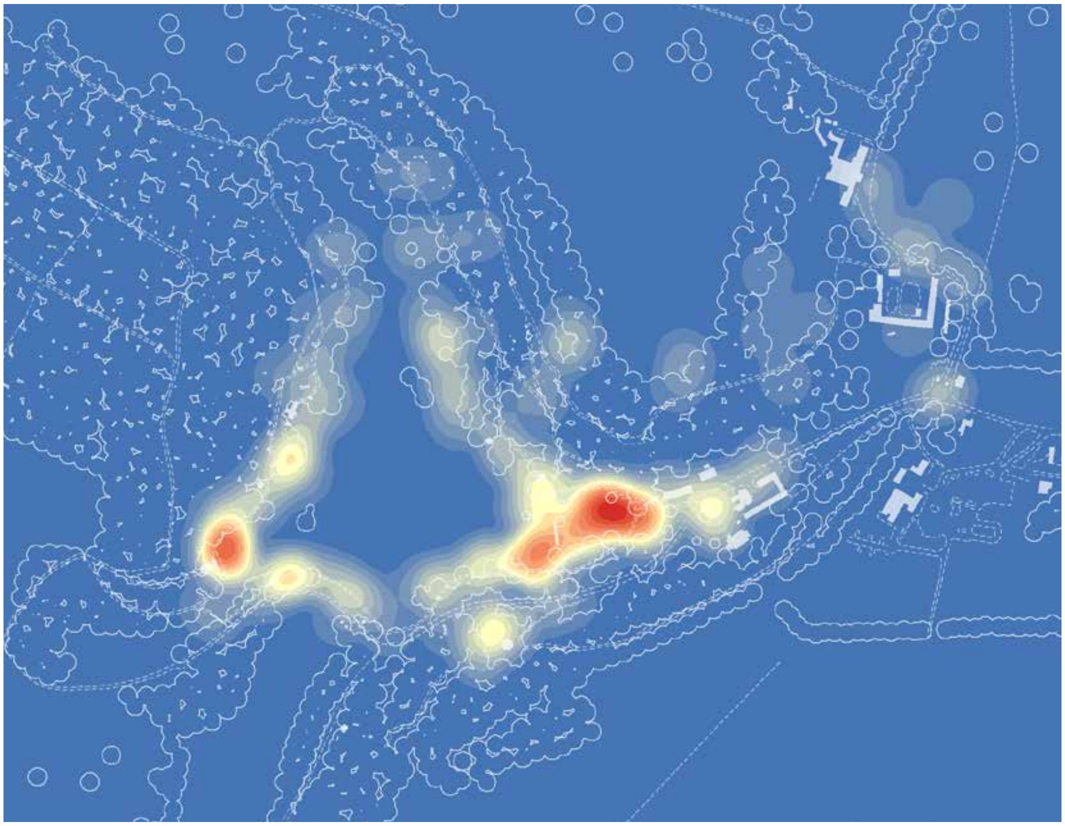

FIGURE 4.119 GIS-based density analysis of the amount of geotagged photographs (*n* = 279). In 2010 the most popular is the view towards the Pantheon (viewpoint Bristol High Cross) (38.35%), followed by the view towards Bristol High Cross (viewpoint Pantheon) (map: Steffen Nijhuis)

§ 4.6.3 Responsive aspects of the symbolic form

The responsive aspect of the symbolic form can be addressed by the analysis of observable human behaviour as an indication of their appreciation and affection. To photograph is nowadays an important way of seeing and recording, but also a way to appreciate a scene or object.[634] It gives shape to travel and site visits, and is the reason for stopping to take a picture and then to move on.[635] People feel that they must not miss seeing particular scenes – informed by guides, postcards, brochures, etc. – as otherwise the photo-opportunity would be missed.[636] Photography also involves the democratisation of all forms of human experience, both by turning everything into photographic images and by enabling anyone to photograph them.[637] This suggests that photographs can be used to measure 'observable appreciation' in terms of quantity (e.g. how much is a particular scene or object photographed) and quality (e.g. which scenes or objects are photographed). In this respect photo-sharing communities on the Internet are useful sources for acquiring such data. Web 2.0-applications such as Panoramio[638] allow users to upload their photos with their geographic location, and are thus a powerful means for crowdsourcing.[639]

For Stourhead 2010 (t_3) the level of appreciation of certain points within the landscape garden was analysed through GIS-based density analysis of geotagged photographs (n=279) [Figure 4.118 & Figure 4.119].[640] The analysis points out that the viewpoint at Bristol High Cross [Figure 4.74: viewpoint 9], the view towards the Pantheon, is the most popular (38.35%), followed by the viewpoint at the Pantheon (viewpoint 6), the view towards Bristol High Cross. It is interesting to notice that these views are often presented in visitors guide books, postcards, websites, etc. indicating that visitors track down and capture attractive images for themselves that they have already seen in these media.[641] However, earlier contemporary sources show similar patterns of appreciation, like the etchings, drawings and paintings of Bampfylde (1770), Grimm (1790), Nicholson (1813), which often depict these views too.[642] The 1779 map of Piper also provides clues in that direction. As discussed in Chapter 3, the map appears to have proportional distortions in positional accuracy, despite the skills Piper had as a land surveyor, which indicates that the map highlights particular areas of interest. As the map presents important views and visual relationships at eye-level it is striking to see that the bottom-right corner in particular seems to be most exaggerated, which corresponds with the viewpoint at Bristol High Cross [Figure 4.120]. Thus, when one regards this distortion to be a measure of importance, the view towards the Pantheon seems to be important in historical times as well.

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[634] Urry, 1990/2002, p. 128.

[635] Ibid.

[636] Ibid.

[637] Ibid.

[638] See: http://www.panoramio.com/.

[639] The process of obtaining needed services, ideas, or content by soliciting contributions from a large group of people, and especially from an online community.

[640] Retrieved from: http://www.panoramio.com/ [accessed September 2010].

[641] Cf. Urry, 1990/2002, p. 129.

[642] For overviews of their depictions see for example: Woodbridge, 1970, 1982/2002; White, 1995.

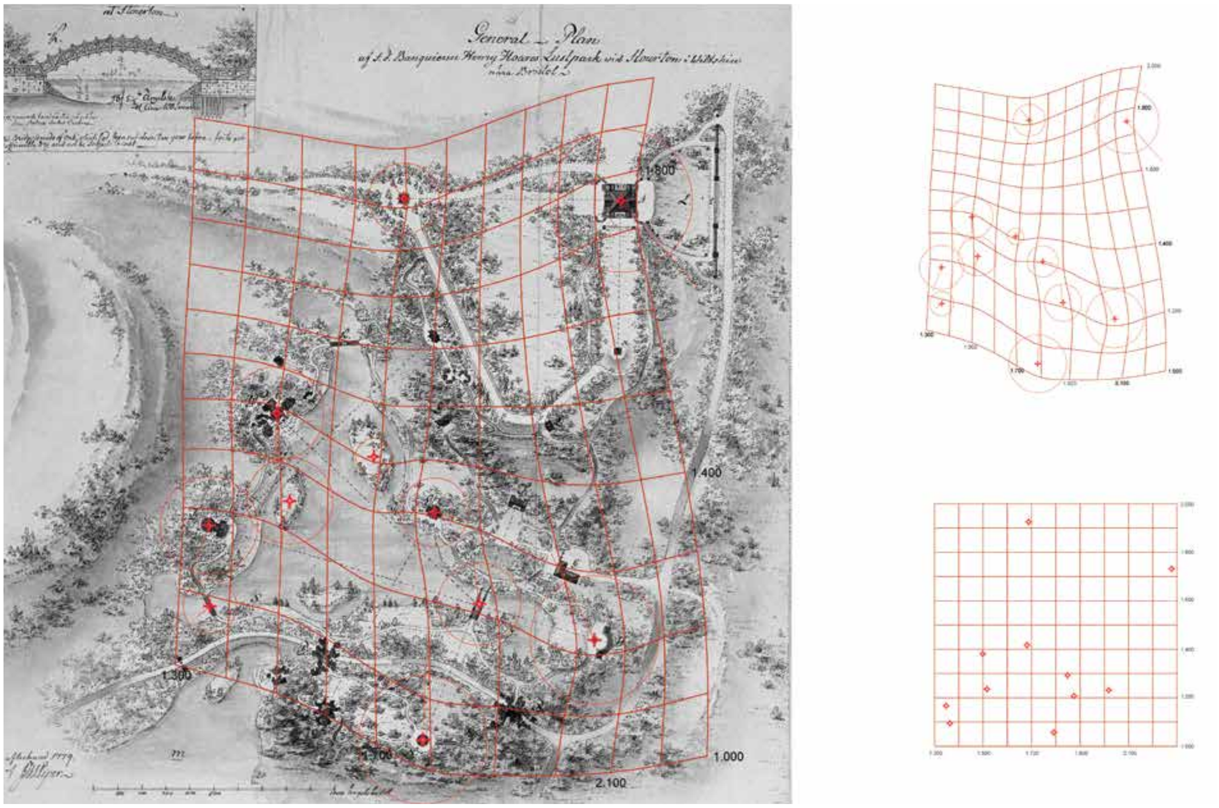

FIGURE 4.120 In historical times the view towards the Pantheon also seems to be important as exemplified by the Piper-plan (1779), which highlights the viewpoint at Bristol High Cross (bottom-right corner) by its proportional distortion in positional accuracy.
→ GIS-based analysis of the distortion of the Piper-plan in relation to the actual geographic situation (analysis: Steffen Nijhuis; map source: Royal Academy of Fine Arts, Stockholm)

Though it does not give a definitive answer to the responsive aspects of the symbolic form, this analysis points out that modern and past depictions by visitors (photos, drawings, maps, etc.) show a similar pattern, highlighting the same views to be important in their reception, namely the view towards the Pantheon (viewpoint at Bristol High Cross) and the view towards Bristol High Cross (viewpoint at the Pantheon). Despite the richness of the site it seems that these views in the experience of most visitors capture the very essence of Stourhead landscape garden.

§ 4.7 Organisation of the programmatic domains

Another important aspect of the landscape architectonic composition is the programmatic form. The programmatic form relates to programmes aimed at functions (e.g. production, recreation and culture) and activities (e.g. living, business, and leisure). It is focused on the organisation of the programmatic domains and land use in relation to apects of *otium*, recreational and cultural interests, and *negotium*, business activities. Functional patterns of movement in terms of logistics and accessibility are also important in connecting up the programme within the composition. Basic cartographic models on land-use and network-accessibility models are employed in order to analyse functional patterns, cohesion and interaction from the vertical perspective.

FIGURE 4.121 The 1,049 hectares of the estate as owned by the National Trust in 2010 (map: Steffen Nijhuis, based upon National Trust Ownership and GB 12.5 cm AerialPhoto2005 which is reproduced by permission of British Ordnance Survey. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey license number AL100018591)

§ 4.7.1 Functional aspects: *Otium* and *negotium*

In the early eighteenth century land buying was one of the few ways in which the bank's profits could be invested. Land ownership was also a precondition for power.[643] The concepts of *otium* and *negotium* play an important role in the development of estates such as Stourhead. Here landowners strived for a balance between economic benefit, cultural reflection and a meaningful encounter with nature.[644] For the rich city men of the Hoare family the lure of a country estate was also an important driving force to bank their assets in land and building grand houses like Stourhead House and the related gardens indulged their taste for refinement.[645] As visible on the historical private estate maps[646] the family acquired large patches of land (including Stourton village) where production, recreation and culture were important driving forces to shape Stourhead's landscape. Nowadays the National Trust owns 1,049 hectares of the estate, which includes Stourhead landscape garden.[647]

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[643] For example: Von Buttlar, 1982; Tabarasi, 2007

[644] Steenbergen et al., 2008.

[645] Hutchings, 2005, p.45ff.

[646] See paragraph 3.2.2.

[647] Though in brochures often 1,072 hectares is mentioned, recent property maps of the National Trust indicate 1,049 hectares. See paragraph 3.3.

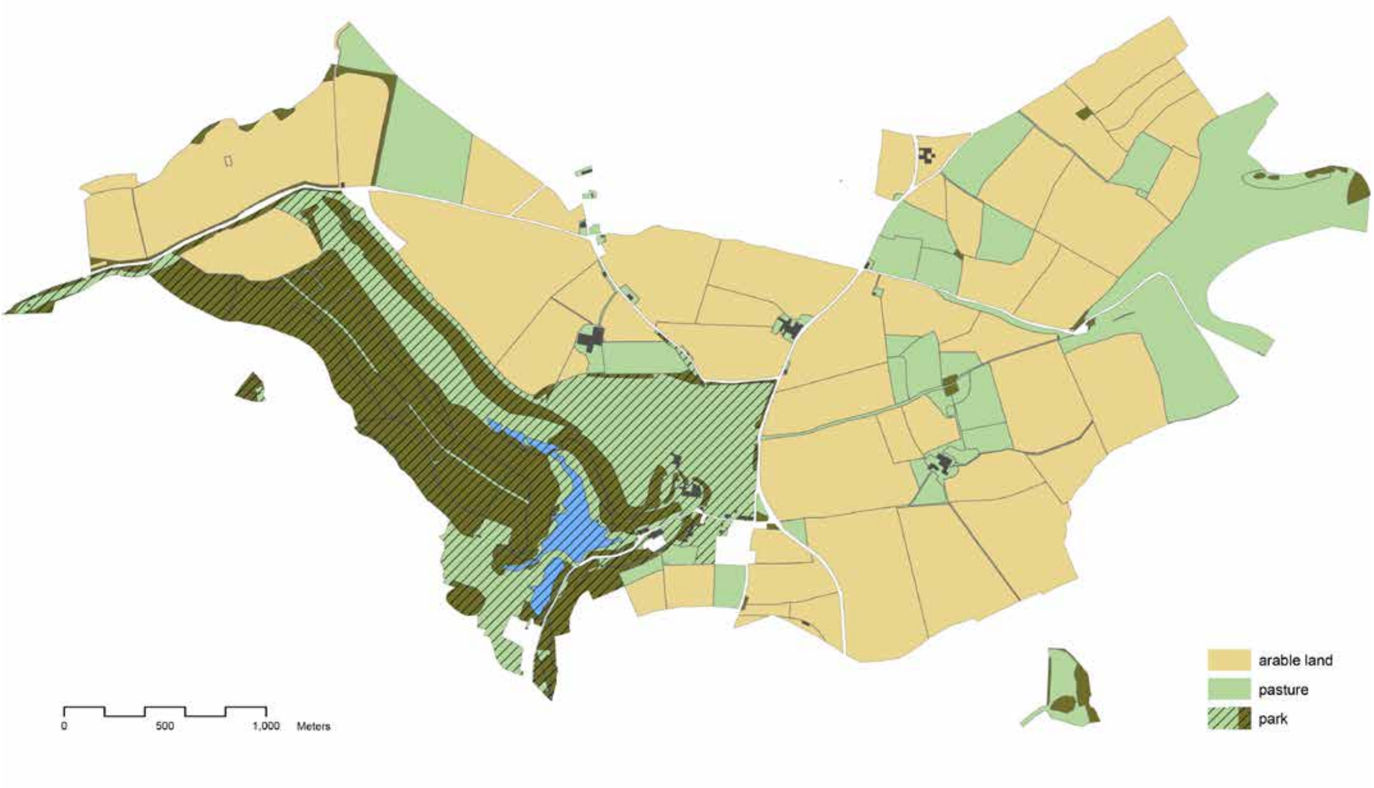

FIGURE 4.122 Land use at Stourhead in 2010. Arable land is the most dominant form of land use on the estate as owned by The National Trust.
→ GIS-based tracing based on the vertical aerial photograph as in Figure 4.121 (map: Steffen Nijhuis)

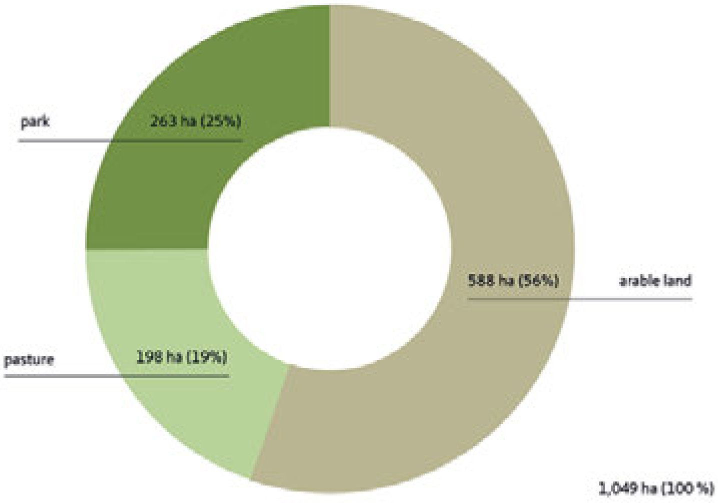

FIGURE 4.123 Comparison of types of land use. Growing crops (arable land) is the most dominant agricultural activity followed by grassland for grazing (pasture). The pleasure program in the form of the landscape garden covers a large part of the estate.
→ Numerical data derived from GIS-based calculation of the land-use map (graphic: Steffen Nijhuis)

For the programmatic form land use is an important indicator. The modern aerial photograph is retraced and vectorised in order to enable further analysis of the functional zoning [Figure 4.121 & Figure 4.122]. Calculations based on this land use map indicate that 786 ha (75%) of the estate is used for agriculture, 588 ha thereof is in use as arable land for growing crops (56 %) and 198 ha pasture for grazing (19 %). The pleasure programme represented by park land (the landscape garden) constitutes 263 hectares (25%) [Figure 4.123].

The analysis points out that large areas of the estate are in use as agricultural land. The higher parts of the grounds in particular, corresponding with the well-drained plateau, constitute an agricultural landscape, a patchwork of pastureland and arable land with clumps of trees and hedges. The direct environs of Stourhead House and the valley are in use as park land: the landscape garden. Here activities such as living and leisure prevail. Near the house the more functional aspects of daily life can be found such as the stables and the ice-house.[648] The walled garden, which is located on the warm south facing slope of valley's northern branch, once supplied fruit and vegetables to the house.[649] Also located here is the Pelargonium House, which contained Colt Hoare's 19th century Pelargonium collection.[650] The Great Lake remained functional as a fishpond, at least until the 1770s, suggested by the fishermen depicted on the Green Frog Service [see Figure 3.12]. Due to the development over time and the fact that the house is now mainly in use as a museum most of these features lost their original function and became artefacts in a heritage landscape. The estate also consists of several houses, which were for the workers related to Stourhead House (e.g. servants and gardeners) in former times, located mainly in Stourton Village. Here functions like a church, post office, and a pub can also be found. Nowadays the village is mainly used to house auxiliary services, management and visitors facilities. There are also several farm houses on the grounds for tenant farming. In comparing the current land use maps with the historical private estate maps it is obvious that this zoning changed little over time. However, the intentions regarding *otium* and *negotium* did change dramatically.

The landscape garden was and is the centre of the pleasure programme. It was here in particular that Henry Hoare and his successors realised their (changing) Arcadian ideals by landscape architectonic means, as discussed previously. The guide books issued by Colt Hoare (1800, 1810) and travel books and reports by visitors[651] illustrate that Stourhead landscape garden was already a popular destination in the eighteenth and nineteenth century for travellers seeking expressions of good taste and picturesque views ornamented with architectural features. Though the landscape garden was in first place a site for cultural reflection and relaxation for the Hoare's themselves, the garden also became a visitor-attraction. This was a nice 'by-product' that added to the status of the family and enlivened the views with people (as visible on many contemporary etchings and drawings), but was not regarded as an important source of income. For the inhabitants of Stourton village, however, the visitors were a source of income as they often stayed at Stourton's Inn (called: Spread Eagle Inn). Under the guidance of the National Trust Stourhead landscape garden became a tourist landscape and is now one of the best visited attractions of England.[652]

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[648] Here ice cut from the frozen lake was stored between layers of straw for use in summer-time.

[649] As addressed in the analysis of solar radiation (Figure 4.11) the south and west facing slopes of the valley garden are more open to sunlight. In combination with the south-western winds (in summer) these areas are generally warmer and dryer than others. In this respect the eastern branch of the valley stands out. While most of the slopes are afforested, here a greenhouse and vegetable garden are located on the south facing slope, taking advantage of the warmer and dryer conditions.

[650] According to the map of Piper (1779) there was also an Orangery slightly to the west, utilising the strong solar radiation of the site.

[651] See for example the visitors description by Sir John Parnell in 1768 (Edited and introduced by Woodbridge, 1982). See for example the travel book by Daniel Defoe (1778). A selection of eighteenth and nineteenth century texts that describe Stourhead can be found in Charlesworth (1993), chapters 70, 101 and 107.

[652] According to the Association of Leading Visitor Attractions: 395,406 visits in 2014. Retrieved from: http://alva.org.uk [accessed July 2015].

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The landscape garden as a pleasure programme became a 'product', a business activity where finances are generated to maintain the house and garden. The presence of visitors also provides an important market for services that most people want to purchase like: meals and drinks, accommodation, souvenirs such as books, plants, NT-merchandise, etc. They represent an important economy not only for Stourhead landscape garden itself but also for the region. In order to facilitate the huge number of visitors, visitor-infrastructures have been constructed in recent decades, such as: a visitor reception, a restaurant, a shop, a garden centre and a large parking area. To direct the visually driven tourist's gaze the most important routes, sights and viewing points are indicated in visitors guide books and leaflets, helping visitors to 'consume' the landscape garden, particularly the Valley Garden, efficiently [Figure 4.124].

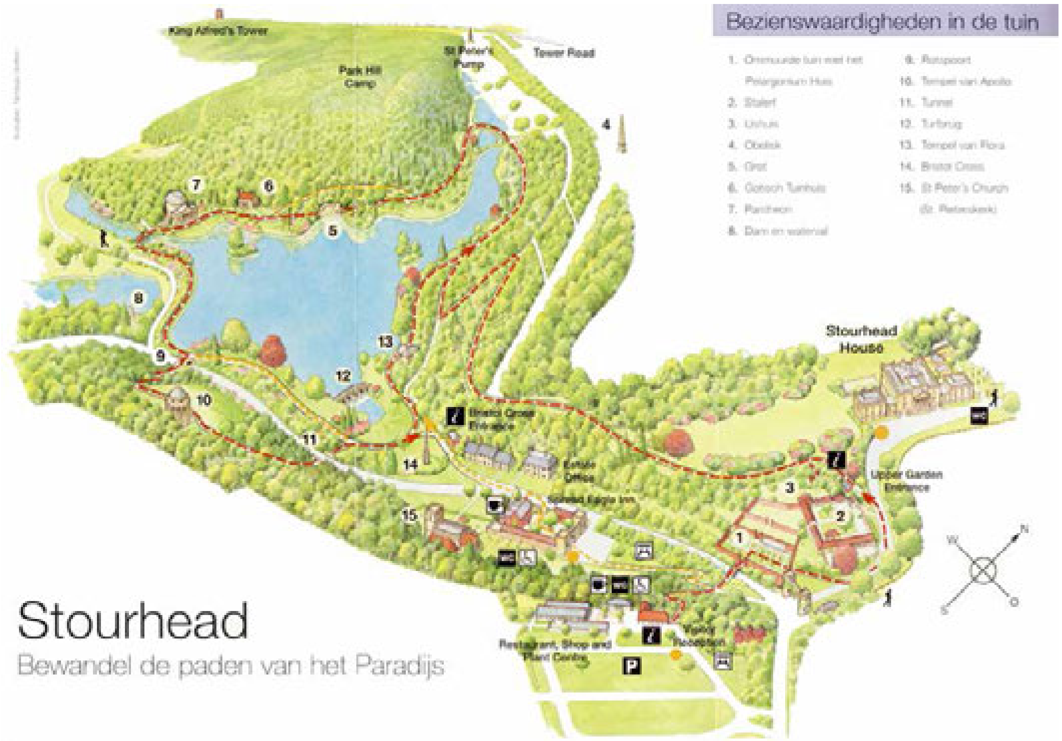

FIGURE 4.124 The pleasure program of Stourhead as expressed by a modern visitors map for Dutch tourists (image source: The National Trust, 2011)

The ridges and hills on the grounds are afforested due to relatively dry and poor soil conditions, and other conditions making it difficult to farm. Most of the forests are originally typical dry-land woodlands with broadleaves such as oak (*Quercus robur*), ash (*Fraxinus excelsior*) and beech (*Fagus sylvatica*). Some stands are dominated by planted conifers, grown for timber.[653]The Valley Garden in particular is full of exotic tree species and under-planting, which thrive on the sandy soils derived from the Greensands. The woodlands at Stourhead are the result of a huge tree planting programme initiated by Henry Hoare II from the 1720s onwards. A closer look at the development of

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[653] Conifer species include: douglas fir (*Pseudotsuga menziesii*), spruce (*Picea abies*), larch (*Larix europaea*), Western red cedar (*Thuja plicata*) and Western hemlock (*Tsuga heterophylla*).

the woodlands reveals that there is huge increase of wooded area between Stourhead 1785 (t_1) and 1887 (t_2). In Stourhead 2010 (t_3) one can observe a further densification of the woodland around the Great Lake [Figure 4.125]. This is the result of Richard Colt Hoare's continuing afforestation programme, entailing mainly planting on enclosed common land. He showed an early appreciation of the value of growing conifers for timber. Henry Hugh Arthur Hoare (1865-1947) was responsible for setting the direction of the forestry for the 20th century by starting widespread planting of Douglas fir in 1903. Nowadays growing conifers for timber is still an important source of income, with an afforestation programme still continued by Nick Hoare. The western part of the estate in particular is still owned and managed by the Hoare family and includes 496 hectares of woodland [Figure 4.126].

FIGURE 4.125 Development of woodland in Stourhead 1785 (t_1), 1887 (t_2) and 2010 (t_3) (maps: Steffen Nijhuis)

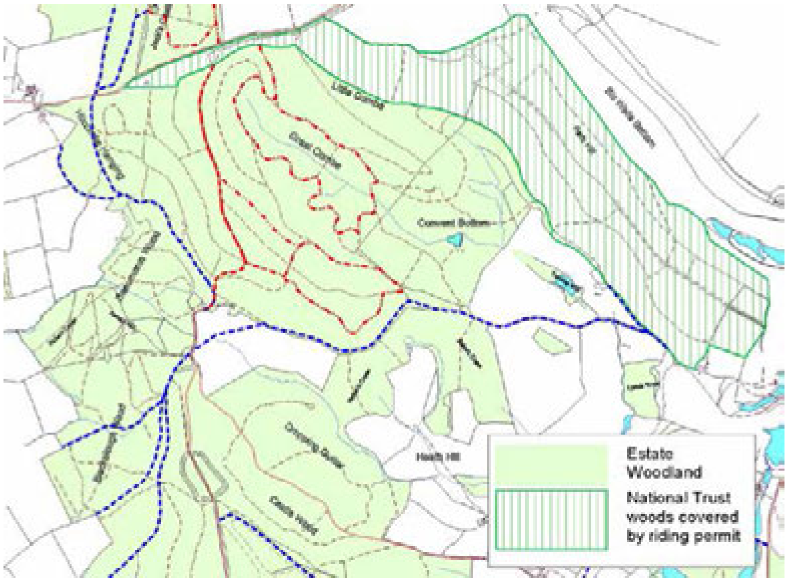

FIGURE 4.126 Forestry is still an important source of income for the Family Hoare. The Western Estate is still owned by them and in used for timber exploitation (image source: Hoare, 2013)

On a structural level the programmatic form of Stourhead landscape garden is determined by the possibilities of the natural landscape. Conditions such as the microclimate, soil and hydrology provide the basis for the functional zoning. At Stourhead the plateau is characterised by farmland. The valley consists of the Valley Garden with the Great Lake, which is the main part of the landscape garden. The hills and ridges are used for forestry. The programmatic form displays a changing relationship between *otium* and *negotium* over time. In the early stages of the estate's development there was a delicate balance between business, cultural and leisure activities.

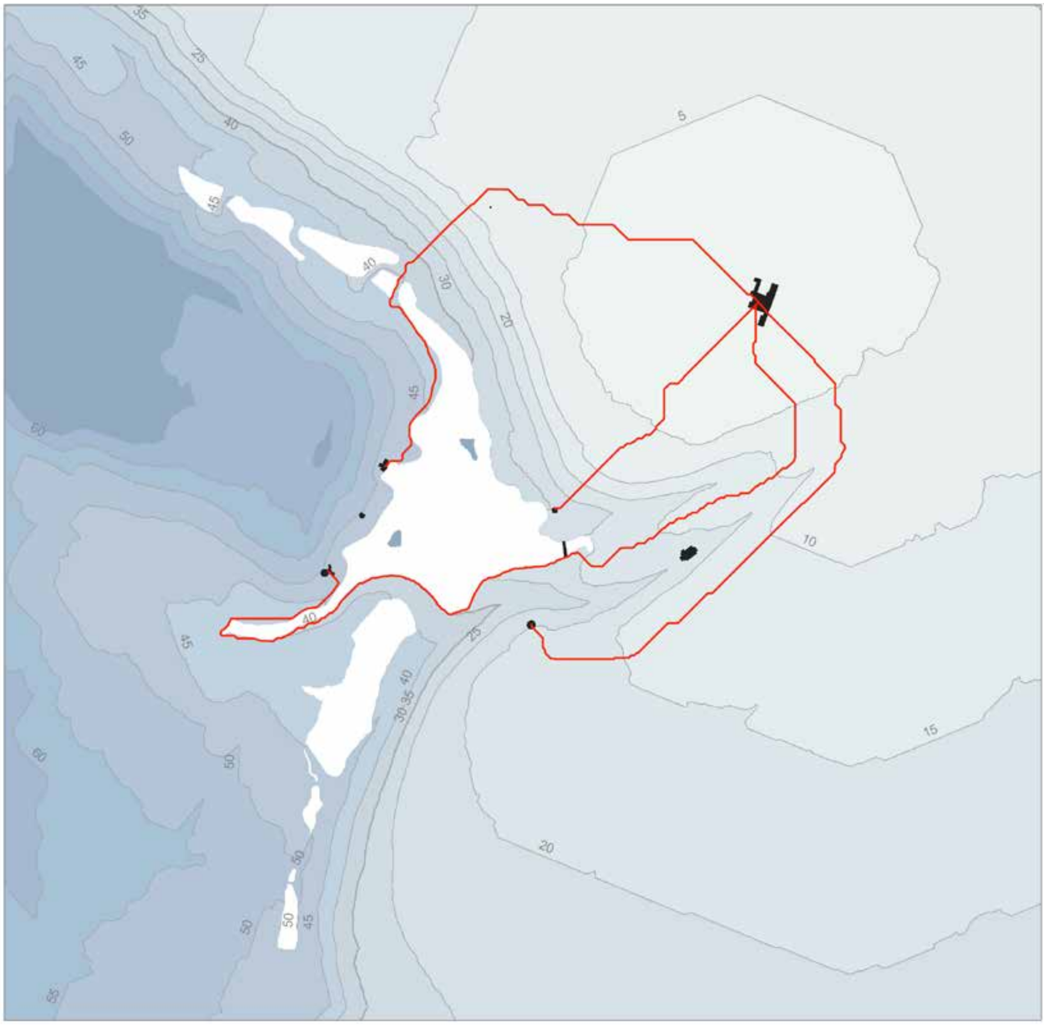

FIGURE 4.127 Points reached in walking time from the house and shortest routes based on terrain conditions. The numbers indicate walking time in minutes. → Composite GIS-map with cost distance-analysis, shortest-path analysis and the Temple of Flora, Pantheon, and the Temple of Apollo as destinations and Stourhead House as starting point (map: Steffen Nijhuis)

FIGURE 4.128 Route efficiency related to slope. → Composite GIS map with shortest-path analysis and slope analysis (map: Steffen Nijhuis)

The landscape garden was an integrated landscape where Arcadia also was used for forestry and fishing, and the agricultural landscape visually integrated. Nowadays the landscape garden is an autonomous business activity, next to forestry and agriculture, which also operate more or less autonomously (organisationally as well as visually). Leisure and culture became exclusive generators of income as important visitor attractions (*otium* = *negotium*). In that respect the landscape architectonic composition acted as a spatial framework that adapted to changing demands. The programmatic form changed from a product of culture to a product of business.

§ 4.7.2 Functional relationships of space

Functional relationships are established via the route network connecting the different programmatic domains and making them accessible. Here the functional logic of the route network in particular in relation to the Valley Garden is further explored, as this was and is an important part of the pleasure programme. A GIS-based simulation was performed to study the efficiency of the routes as an indicator of the functional logic. Therefore a cost raster was created that reflects relevant terrain conditions to map efficient wayfinding-behaviour, here mainly determined by the steepness of the slopes and water as a barrier. This cost raster is a raster dataset that identifies the cost of traveling through each cell in the raster and is used to calculate the cumulative cost of traveling from every cell in the raster to a source or a set of sources.[654] Based on this cost raster is possible to perform a cost distance-analysis, here expressed in walking time with Stourhead House as the starting point or source.[655] Technically speaking a cost distance-analysis is the calculation of the least cumulative cost from each cell to specified source locations over a cost raster.[656] As visible in the outcome the terrain conditions differentiate the estate in zones that can be reached from the house in a particular amount of time: the Temple of Flora in about 20-25 minutes and the Pantheon in about 40-45 minutes [Figure 4.127]. The classic walk from the House to the Inn at Stourton is about 3.1 kilometres and will take about 1 hour and 30 minutes, following the route via the Temple of Apollo.

Based on the cost raster a least cost path or shortest path-analysis was also performed, with the Temple of Flora, Grotto, Pantheon and Temple of Apollo as destinations. This analysis calculates the path between source and destination that costs the least to traverse.[657] Here cost is a function of time, distance and steepness (degree of sloping). The simulation points out that in most cases the actual route deviates from the calculated optimal route [compare Figure 4.127 with Figure 4.54]. This obviously indicates that the tracing of the routes not only depended on efficiency but also on the possibilities and limitations of the local environment. However, comparing the simulated paths with the actual paths one can identify some principles related to the possibilities of the landform and its affordances that have been used in the actual route tracing [Figure 4.128]. The route follows terrain elevations along the top contour of the ridges or along the bottom of the slopes of the valley and the curvature of the banks of the Great Lake. Manageable steep slopes are traversed directly on the contour gradient and longer slopes with an even ascent diagonally on the contour lines, which is the preferred way to manage elevations with a longer gradient going up- or downhill evenly. To avoid discomfort while

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[654] Wade & Sommer (2006), p. 43.

[655] Based on an average strolling speed of 2.5 kilometres per hour.

[656] Wade & Sommer (2006), p. 43.

[657] Ibid., p. 192.

walking, caused when the surface is not at right angles to the axis of the body, terrain shoulders are incorporated in the tracing of the paths. Furthermore, the shoreline of the lake determines a level stretch along the contour lines and expresses the preferred tracing of the route.

While comparing the routes of the time-slice snapshots and the simulation results one can learn that the tendency of the morphogenetic development of the route structure in Valley Garden is to become more 'efficient' in terms of duration and accessibility. For instance, nowadays the descent from the house and the steep ascent to the Temple of Apollo can be bypassed. So too can the levelled circuit walk around the lake with its entrance at the village. As the model points out people tend to make a detour around elevated areas, going around the side on a level stretch along a contour. As this 'logic' has been adopted in the current route structure, the original routes have changed considerably and the kinaesthetic effect of the walk related to the three-dimensionality (going up and down) of the route has decreased.

§ 4.8 Conclusions

Conclusion # 1: Terrain conditions as prerequisite

The basic form of the landscape architectonic composition is largely determined by two geomorphological complexes: the plateau and valley. Next to the possibilities for practical land-use offered by the basic form of the plateau and valley, geomorphology and water form are the basis for a landscape architectonic composition and activate and articulate the natural forms and processes of the site and its use. The differences in natural terrain conditions like elevation, slope, and aspect, as well as the variation in soil and presence of welling groundwater were the prerequisites for the allocation of the built elements, the tracing of the routes, and the creation of the Great Lake. The built elements, with their distinct architectonic forms, are generally built on a rise, shoulders, or particular contour lines, such as slope edges, ridge lines etc. The routes link the features to the house and respond to the landform and its opportunities for walking in order to dramatise the relationship between different parts of the basic form: on the plateau, the Pleasure Garden, and in the Valley Garden to frame the lake. The form of the lake demonstrates a designerly sensitivity to the delicate interplay between water level and curvature of the slopes.

Conclusion # 2: Establishing relationships between the plateau and valley

Stourhead House has a dominant position on the plateau and is oriented towards the agricultural landscape. By its position, the house functions as an initial link between the plateau and the valley. The Pleasure Garden directly surrounding the house has a triangular form based on the natural morphology, like local terrain heights and the valley edge. Architectural features at strategic points integrate the house with the Pleasure Garden and articulate the relationship with the valley. Features like Alfred's Tower and St Peter's Pump integrate the western part of the grounds into the basic form of the plateau. The Great Lake is the heart of the Valley Garden. The basic form of the water plane, its dimension, and its surrounding, curving shorelines, emphasised and put forward by small islands, constitutes an ideal basic condition for staging an intricate open-air landscape theatre. Via the placement of architectural features around the Great Lake, the basic form of the valley became

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a formal system that can be seen as an extension of the Pleasure Garden from around the house into the valley. Through the strategic topographic allocation, on edges, on rises and in axes related to the house, the features not only articulate the basic form of the valley, but also establish direct relationships between the lower and higher landscapes. Integrating the basic form of the plateau and the valley, Stourhead landscape garden becomes an overall composition.

Conclusion # 3: Successive development of the composition

The landscape architectonic composition is the result of a successive development characterised by three main landscape architectonic transformations. It started with the construction of the house and the surrounding Pleasure Garden on the plateau, followed by the development of the garden in the valley, and finally the incorporation of the rest of the grounds with their patterns of natural vegetation (e.g. afforested ridges) and agricultural land-use. The gradual integration of the different landforms into a cohesive basic form was mainly constituted by landscape architectonic interventions, including the placement of the house, the design of the lake, several built architectural features, and a system of routes accentuating the different landforms and at the same time connecting them. Over time, the basic form of the plateau and the valley became more autonomous parts of the composition, as the articulation of their transition decreased through the removal of features. At the same time, the Valley Garden became the more dominant part of the landscape gardens' composition, especially as the architectural features that had made up the 'former' Pleasure Garden were demolished. This is also visible in the development of the route system. The initial route dramatised the differences between the basic form of the plateau and the valley while at the same time tying them together. The later routes focus more on the valley itself and articulate its differentiated, intricate, and rich natural form with a circular walk around the lake.

Conclusion # 4: From articulation of spaces to autonomous spaces

The successive development of the corporeal form started with the articulation of the spatial relationship between the plateau and the valley by planting masses and creating transitional spaces with architectural features on the edges of the plateau and the slopes of the valley. The architectural features were positioned at strategic locations as attraction points opening up views towards the valley. The Fir Walk was an important feature acting as a transparent spatial interface integrating the upper and lower parts into an overall composition. In the valley, the planting mass emphasised it's asymmetrical nature and articulated the open space by the contrasting treatment of the slopes, creating a particular space-mass dynamic between the foliage on the western slope and the mostly open southern slope with the planted top edge. Over time, the Valley Garden became the dominant part of the composition through densification via the planting of trees with under-planting on the slopes and the removal of architectural features in the transition zone from the plateau to the valley. As a result of the extensive planting programme, the slopes became continuous spatial boundaries emphasising the introverted character of the valley, with the central position of the lake creating an autonomous space. Selected views became framed by the plantings and later more pronounced or overgrown as these grew. The addition of incidental strong colours by individual trees and shrubs in the scenery as well as the variety of individual exotic species also toned down the variety in space. In the early stages of the development of the corporeal form, the accent was on the articulation of the relationship between the plateau and the valley and the spatial variation of the spaces themselves. Later, the autonomous character of spaces became more dominant, toning down the spatial variation in structural terms.

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Conclusion # 5: Designed from the observer's point of view

Visual connections are important to the visible form of the landscape architectonic composition. Sightlines virtually organise and connect the features on opposite sides of the lake. Here, portrayal blends with the landscape at hand. The relationship between the house and the broader landscape context is established by sight-relationships between the Temple of Apollo, Alfred's Tower, and the Obelisk. Stourhead House is located on a moderate rise on the plain and responds to the orientation of the regional landscape, and is also aligned with the church tower of Stourton. Alfred's Tower marks the highest point of the estate and virtually connects the house, Great Oar Pasture, and Valley Garden with the scale of the estate and beyond, overlooking the region. The visual form of the Valley Garden consists of a progression of views linked to the steps of the walking individual. The designed views and resting points, as well as the related routes that circulate and lead, demonstrate sensitivity towards the mechanics of visual perception and kinaesthetics. The views are carefully designed, employing depth cues, optical illusions, and critical horizontal and vertical viewing angles. Movement is not suggested but truly experienced by following the routes and their scenography with formal, transitional, and progressive elements. The visible form of the Valley Garden is a four-dimensional composition with a gradual experience of garden scenes (transitory views) via progressive movement guided by the circular route and its destinations.

Conclusion # 6: The quality is in the richness of meaning

Transformations in presentational and referential elements of the symbolic form demonstrate that it is not possible to impose a fixed meaning on the landscape garden. In presentational terms the development of the spatial composition suggests a changing meaning of nature and landscape. The Arcadian landscape changed from a varied pastoral landscape into a more closed forest landscape that emphasised the Great Lake, and where the effects of nature were more important. Finally Arcadia became a 'product', a place to experience 'authentic' history, study arboriculture and daydream – focused on a tourist's gaze intent on certain determined views and a structured experience. In parallel, space definition and light-shade experience show a gradual change from a half-open park landscape with great variety of undirected, open spaces with light and shade effects alike, into a closed and shady landscape with a central position for the light and open space of the lake. In referential terms the architectural features play an important role as iconographic elements in the views. The appearance and sequence of paired classical and medieval features, strolling around the lake, suggests a double dialoguing allegorical structure that evokes historical or moralistic narratives with references to mythical heroes and England's past. However, here too it is not possible to impose a fixed meaning since several (mainly oriental) features have been removed over the centuries and some views are changed by the planting and growth of trees. Whether the landscape garden contains a story with a deeper meaning, or is a kind of memory system facilitating pleasure and relaxation, it has above all over time accumulated into a richly layered site that promotes and provokes a wide range of narratives, ideas and emotions. The quality of the landscape garden is thus in the richness and not in the clarity of meaning. Despite the richness of the site it seems that the view towards the Pantheon (viewpoint Bristol High Cross) and the view towards Bristol High Cross (viewpoint Pantheon) in the experience of past and present-day visitors capture the very essence of Stourhead landscape garden.

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Conclusion # 7: The landscape garden as an adaptive framework

Stourhead is a multifunctional landscape, focused on production, recreation and cultural functions. The programmatic form displays a mix of agricultural land use, forestry and park land (pleasure programme). The functional zoning is directly related to the possibilities allowed by the underlying natural landscape (e.g. soil, hydrology, and microclimate). The well-drained plateau is mainly in use as arable land next to pastureland and the woodlands are located on the hills and ridges with the relatively dry and poor soil conditions. The pleasure programme is mainly centred in the valley, with the Valley Garden full of exotic tree species and under-planting, which thrive on the sandy soils derived from the Greensands. Though in general the programmatic form changed little over time, the intended balance between *otium* and *negotium* did change dramatically. In the early stages of its development there was a delicate balance between leisure, cultural and business activities, which all co-existed in the landscape garden (agriculture, forestry, fishing were part of the landscape garden). Nowadays the landscape garden is in the service of thousands of visitors, and focusses mainly on business-activity. It became a product itself, a popular tourist attraction with hardly any space for agriculture and forestry. These functions are still an important part of the estate but function organisationally as well as visually autonomously. The trend of simplifying the route structure of the Valley Garden, increasing the efficiency in terms of accessibility (ease to move) and duration, is in line with this development, but decreased the kinaesthetic effect related to the three-dimensionality of the route. Though the landscape architectonic composition developed over time, it acted as an adaptive framework, organising the varying programmes and adapting to functional changes.

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5 Synthesis and outlook

§ 5.1 GIS: New insights into old masterpieces?

Technology enables researchers to gain new insights from old masterpieces. For example, through application of a new x-ray technology, researchers revealed an unfinished self-portrait by Rembrandt van Rijn under the surface of a seventeenth-century painting called 'Portrait of an Old Man' [Figure 5.1].[658] In analogy, this study employed GIS as a tool to delve into the deeper layers of Stourhead landscape garden. Using inventive modelling, analysis, and visualisation techniques in an interactive process, combined with the calculating power of computers, opened up possibilities to reveal new information and knowledge about the basic, spatial, symbolic and programmatic form. It enabled the discovery of particularities of the designed landscape of Stourhead, such as the delicate relationship between the morphology of the valley, the water level of the Great Lake, and its curving shorelines. It helped elucidate the tracing of the routes, their spatial relationships, and the visual properties of the views (e.g. horizontal and vertical view angles). Also gained was an understanding of the composition as a product of time, that is to explore the landscape garden as a *longue durée* and also as a temporal experience generated by the movement of its spectators. Finally, tacit knowledge of on-site design, designing based on the possibilities of the given terrain from an individual's perspective, hidden in the old masterpiece Stourhead was able to be revealed with geo-information technology. All of which is hardly possible by traditional means.

FIGURE 5.1 An old master painting called 'Old man with a beard' (18 x 17.5 cm) by Rembrandt van Rijn around 1630 (photograph R. Gerritsen). Right: Discovery of an unfinished self portrait of Rembrandt under the surface of that painting though application of X-ray fluorescence analysis (XRF) in 2011 (image courtesy of Joris Dik, TU Delft)

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[658] Alfeld et al., 2013.

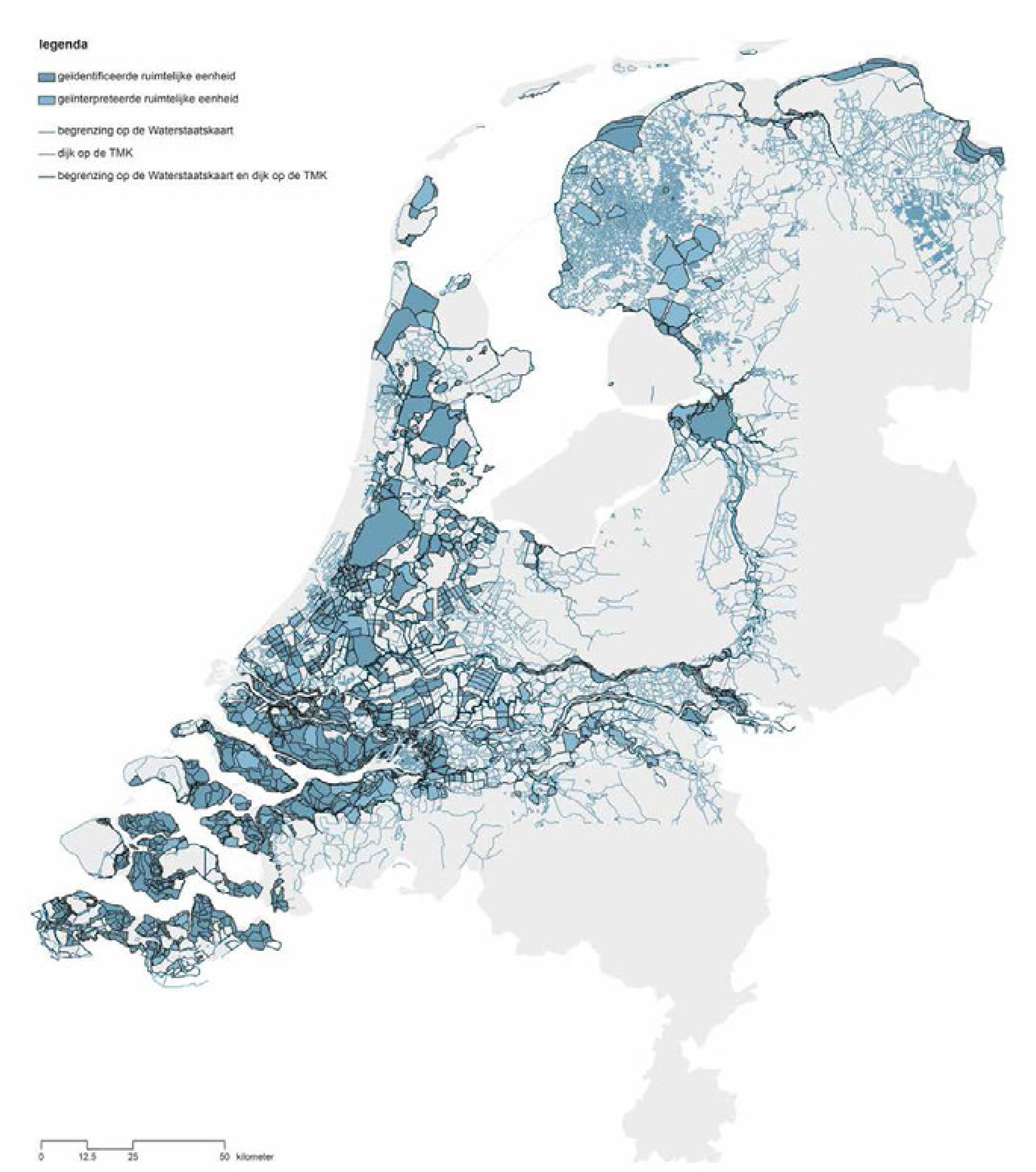

FIGURE 5.2 GIS-based polder map of the Netherlands. For the construction of the design-oriented polder map topographic and water board maps (183) of the period 1850-1891 of the whole country had to be digitised, geo-referenced, geo-rectified, evaluated as well as vectorised, which was a time-consuming effort (Nijhuis & Pouderoijen, 2013; Steenbergen et al., 2009)

Stourhead, as a kind of 'old portrait' of Henry Hoare and his circle, acted as a critical information-oriented case study for identifying and illustrating the potential role of GIS as a tool for landscape design research. As such, the study was an exploratory exercise, a quasi-experiment, for testing the hypothesis. It generated a learning process that constituted a prerequisite for advanced understanding, while developing and utilising an analytical framework for landscape design analysis. This chapter reflects on the process of discovery and its results, illustrated with other applications in a wider context. It presents the conclusions and synthesises the findings of the study. Finally, recommendations are made on how best to implement GIS as an indispensable tool in landscape architecture.

§ 5.2 GIS and landscape design research

§ 5.2.1 GIS-based modelling: From data to information

In this study, GIS was employed for the (1) collection, evaluation and interpretation of contemporary and modern data, (2) digitising geo-rectification and vectorisation of data and (3) integration and processing of the topographic data into a digital landscape model (DLM) of Stourhead landscape garden. The (pre-)processing, storage and organisation of topographic data by means of GIS provided the digital basis for analysis of the landscape architectonic composition. In particular, topographic data about landform, hydrography, vegetation, and built and constructed elements were selected and integrated into the DEMs and DLMs as representations of the physical reality. An important limitation is that not all relevant large-scale topographic data was available in digital form (e.g. hand drawn plans, historic maps). GIS was used in the process of transforming analogue cartographic data into digital formats (vector, raster and surface-definitions).

To understand the development of a landscape architectonic composition over time in the context of landscape design research, it was important to have topographic data of different significant time-slice snapshots. There was no digital data available for the historical situations; their construction was a time-consuming activity. In that respect, archival research was an important resource. In the case of Stourhead, the construction of the DLMs was thus dependent on the availability of historical cartographic data and complementary topographic sources. A complicating factor was that the historical maps were mostly not available in digitised (e.g. scanned historical maps) or digital form (e.g. georeferenced vector or raster maps) and was an extra task in the research process. A lack of historical data is a common experience in landscape design research [Figure 5.2]. However, the tendency of archives to make their collection cartographic data available in digital form is a beneficial development as it makes the research process more efficient and allows more focus on the research itself and not on the pre-processing.

Regarding Stourhead, GIS was a vehicle for source criticism that offered the possibility to evaluate cartographic data via cartometric analysis, thus enabling the review of the accuracy and reliability of (historic) maps. This shows how GIS promotes accurate work and thus more precise analysis, since the data determines the accuracy of the analysis [Figure 5.3]. It was also possible to compare different data sources so they could mutually reinforce each other. Interpretation of the measurement results

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remains an important factor, since precision does not guarantee usability for design research. Here, the difference between data and information becomes apparent. Data can be accurate but useless for design research, while inaccurate data can be highly informative. However, some data, like that contained in Piper's map, is in general not accurate in planimetric terms, though highly significant since it is the only available historical map showing architectural features in detail as well as landscape architectural aspects such as spatial-visual relationships (views).

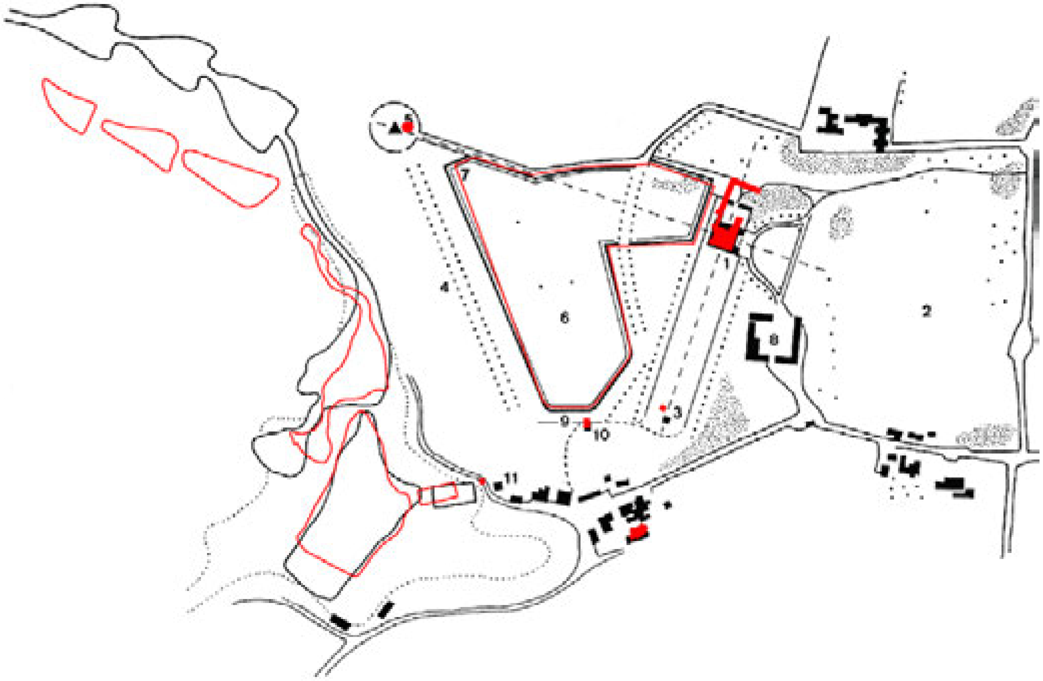

FIGURE 5.3 GIS-based landscape design research promotes accurate analysis. Overlay of manual reconstruction by Reh (1995) (black lines) and GIS-based reconstruction (red lines) of Stourhead House with the Pleasure Garden 1733-1754 (map: Steffen Nijhuis)

Modern geo-referenced vector and raster maps as well as geodata on relief, soil and geology provided an essential foundation to construct the DEMs and DLMs, but had to be augmented with information from other sources. In particular, building heights and vegetation were missing, and data on the architectural features and the routes were not available in digital form. Thus the available data was, in most cases, not directly useable for the construction of the DLMs, given that these should constitute all the elements that make up the fabric of the landscape architectonic composition (e.g. landform, hydrography, vegetation, and built and constructed elements). In order to construct the DLMs, selective use and integration of available digital data sources was necessary. A complicating factor in this type of research is that it is sometimes hard to judge beforehand which elements are important for the composition. Here, the interpretative nature of design research comes into play, since the design researcher determines what elements to include and is therefore situated between objectivist and subjectivist judgements.

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Two-dimensional and three-dimensional referenced objects also had to be added to the datasets in order to make them complete. The lack of available 3D referenced objects provided for a particularly laborious endeavour. For each time-slice snapshot, the detailed objects had to be constructed based on measurements, growth curves of vegetation, etc. The attributes of important features were also described or calculated and added to the digitised features via a related attribute-table (e.g. legend, year of creation, type of surface). The collection and creation of data made it possible to apply data analysis based on attributes and to create a spatially-oriented database.

Conclusion # 1: The difficulty is in the data-availability

The lack of large-scale digital data on Stourhead for different time-slice snapshots was a serious limitation for the GIS-based design research. Since there were no integral datasets of the modern and historical situations that include 2D and 3D referenced landform, hydrography, vegetation and built elements, the DLMs were based on a multitude of available analogue and digital topographic data that had to be selected, digitised, geo-referenced, integrated and constructed. This was a laborious, time-intensive and important part of the research. Once missing data could be acquired or (re-) constructed and the DLMs constructed, there was a solid basis to perform a wide range of analytical operations and to quickly create different visual representation. GIS proved to be an useful tool for the selection, evaluation (i.e. cartometric analysis), construction, and integration of design data and for the construction of DLMs of the landscape architectonic composition.

§ 5.2.2 GIS-based analysis: From information to knowledge

In this study, GIS was employed to explore the DLMs in order to (1) reveal patterns and relationships, employing analytical principles from the horizontal and vertical perspective, and (2) carry out measurement, simulation and experimentation of aspects of the basic, spatial, symbolic, and programmatic forms of the landscape architectonic composition and its development over time.

GIS and the basic form

GIS-based overlay operations, combining different data sources through the location, were deployed to get a grip on the topological and chorological relationships of natural (e.g. climate, landform, soil) and artificial features. Although overlay analysis is a common operation that can be performed manually, some layers that are interrelated could hardly be constructed by hand, since these are very time-consuming or too complex to handle. Examples include database querying and the time-slice snapshots, which made it possible to study the development of the layout over time. Morphometric analysis of the DEM made it possible to investigate relevant aspects of landform such as elevation, slope, and aspect in order to understand the allocation of architectural features and tracing of routes via overlay operations. Hydrological and climatic (insolation) analysis generated results (by means of algorithms), which were in turn the basis for further analytical operations used to reconstruct water patterns and reveal spatial relationships. Other applications of GIS-based landscape design research focusing on the basic form have shown similar procedures in which automated analysis is combined with overlay operations [Figure 5.4]. By precise ex-post experiments with the water level of the Great Lake, the delicate relationship between the water level of the lake and variations of the slopes could be studied to discover the optimal curvature of the shoreline.

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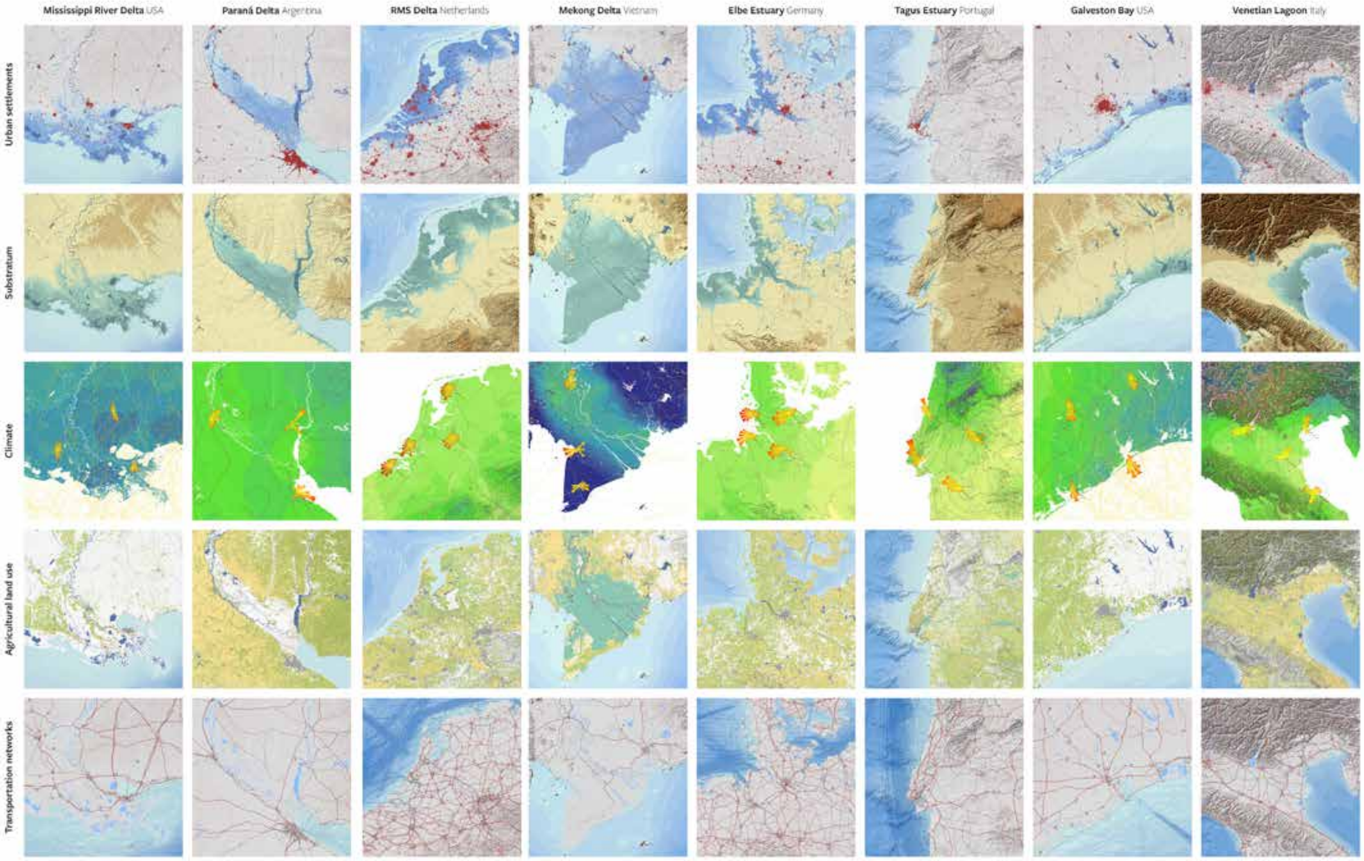


FIGURE 5.4 GIS-based mapping and comparison of urbanized deltas. Systematic exploration of the basic form by overlay and automated map analysis on environmental conditions (substratum and climate), networks, land use and urban settlements by means of GIS. Results served as input for advisory documents for the development of new policies on water management for the Dutch government (Nijhuis & Pouderoijen, 2014, Meyer & Nijhuis, 2014; Meyer et al., 2014)

GIS and the spatial form

Virtual 3D-landscapes and visibility analysis with single, cumulative and sequential viewsheds, as well as hemispherical visibility-analysis were important operations for understanding the spatial form of Stourhead landscape garden, all of which are not possible manually. In particular, the application of the different types of viewshed analysis in the context of landscape design research is new, exploring the visible form of landscape architectonic composition. They revealed, for instance, visual properties of views (viewing angles, angular size and scale) and their sequence. Next to the use of the more common virtual 3D-landscapes, augmented with data on vegetation growth, the cumulative and sequential viewsheds made it possible to analyse the composition three-dimensionally from the inside out, as an individual strolling through the composition, relative to route tracing in a horizontal and vertical way. The sequence of space-visibility and mass could be analysed, as could the visual dominance of the fabric and development of the spatial composition over time. It provided transparent and systematically acquired measurements that expressed a levelling of the space-mass ratio over time. This kind of GIS-based landscape design research is also employed in analysis of cultural landscapes focusing on the visible form [Figure 5.5].

The framed views of Stourhead, the analysis of the angular extent, the visual coverage of the views – especially their angular extent in relation to visual physiology – provide interesting results. This analysis enabled the measurement of the views' sequential relationships in time based on slow-motion vision by walking, taking into account tactile properties such as differences in heights along the course of the path.

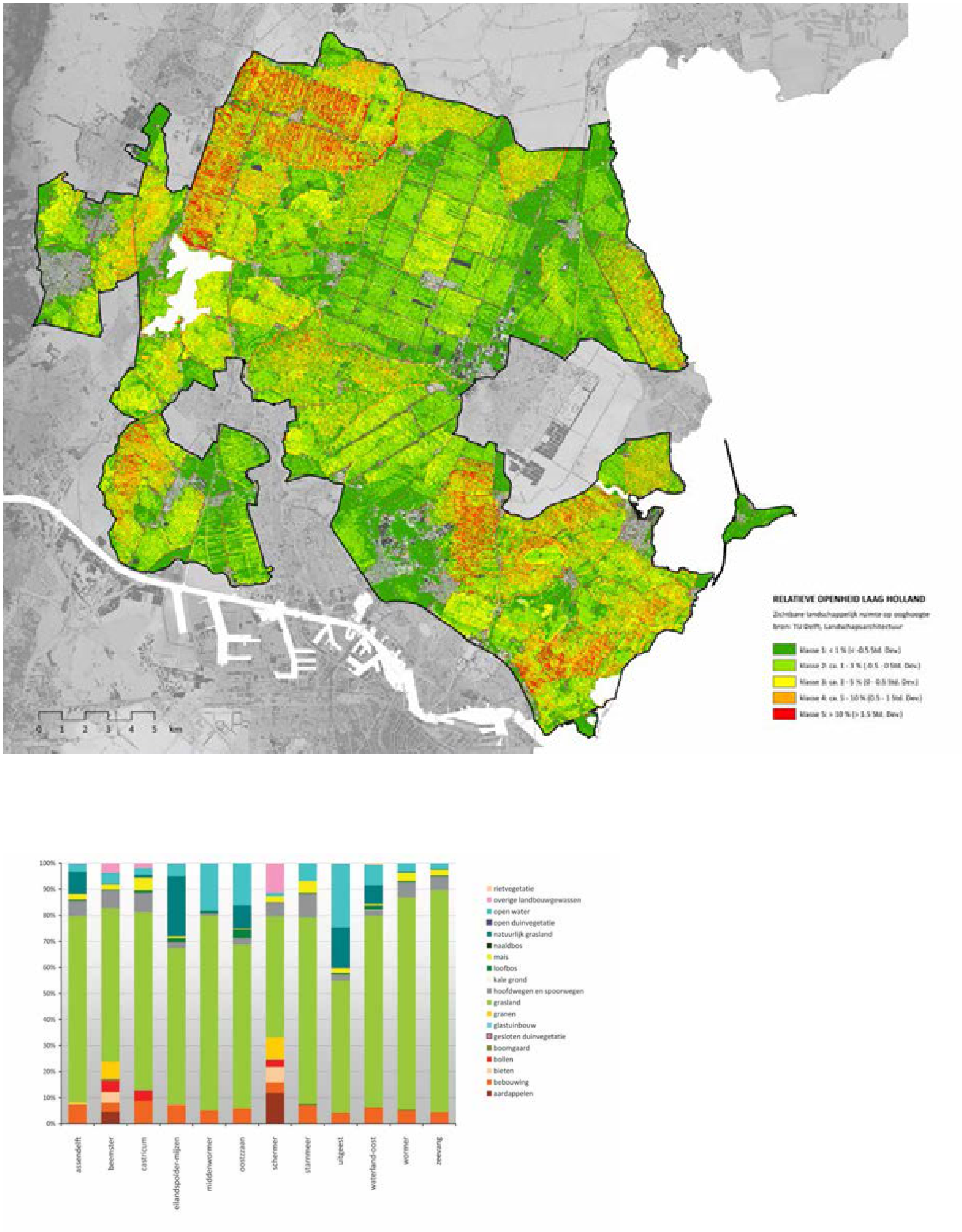
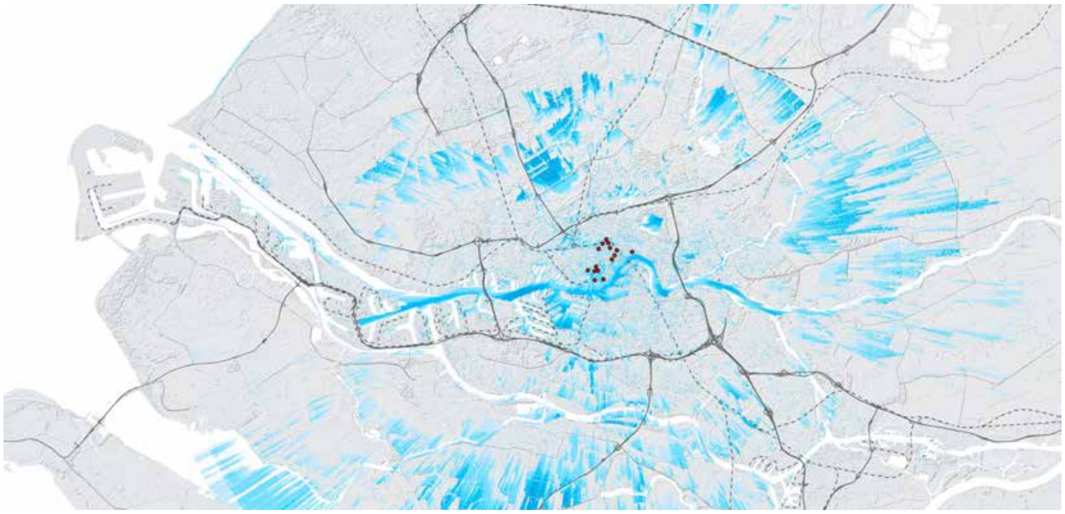
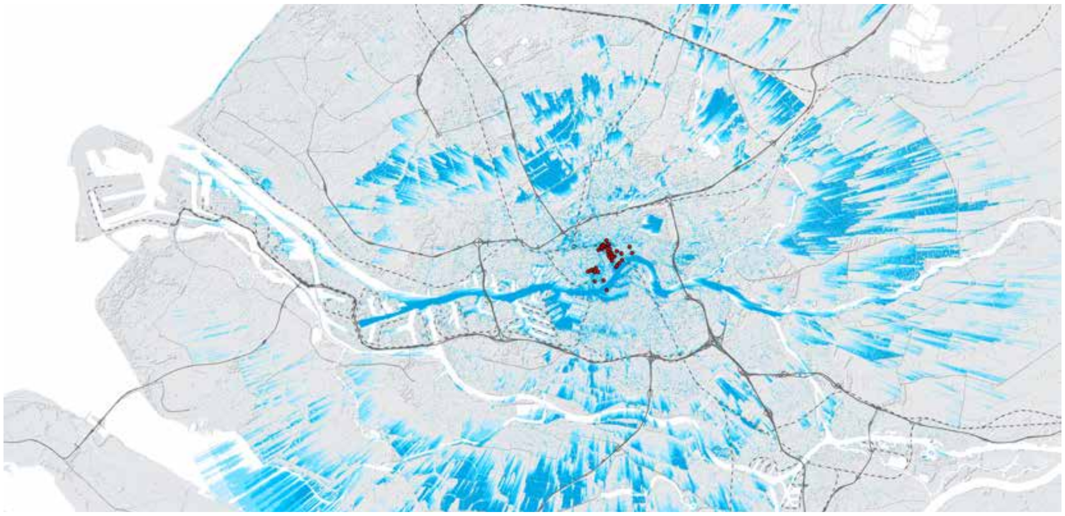


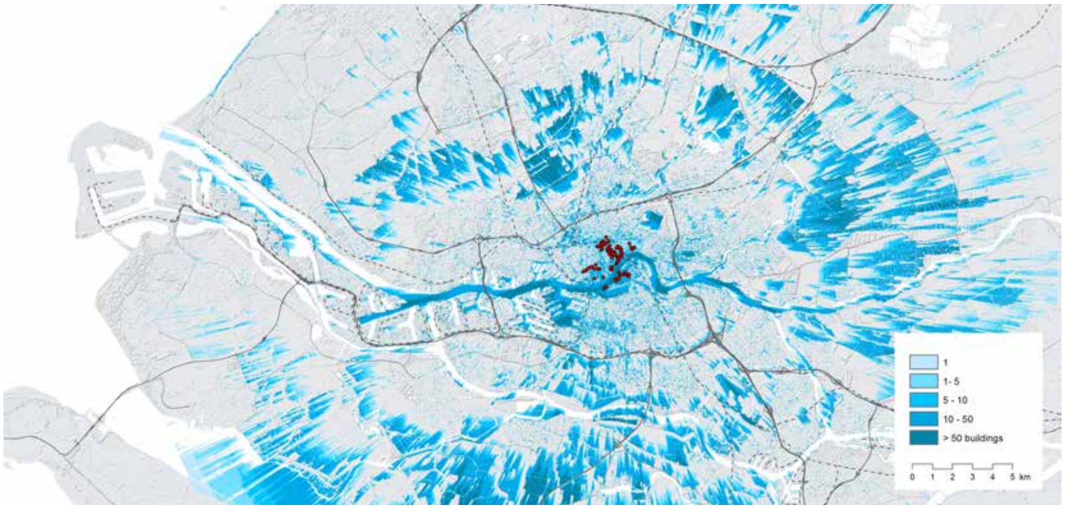
FIGURE 5.5 Description and monitoring of the relative spaciousness of the cultural landscape *Laag Holland* (the Netherlands). This landscape design research was focused on the spatio-visual characteristics of this territory and was executed for the provincial government of Noord-Holland and Noord-Hollands Landschap (NGO) and served as input for policy documents like the Structural Concept of Noord-Holland 2014 (*Structuurvisie Noord-Holland 2040*) and the Policy Framework for Landscape and Cultural History (*Leidraad Landschap en Cultuurhistorie*). Top: cumulative visible area. Bottom: Visual dominance of land-use (Nijhuis, 2010a, 2010b; Nijhuis & Reitsma, 2011; Nijhuis, 2012; Bos et al., 2012)



1970



1992



2015

FIGURE 5.6 The visibility of Rotterdam's skyline explored for the purposes of planning and design (the Netherlands). Analysis of the visibility of high buildings (> 50 metres) in the period from 1970 to 2015 at full daylight with a meteorological optical range of 20 km (25% of the time) in relation to the vertical size and area of the buildings (Van der Hoeven & Nijhuis, 2011, 2012)

This knowledge can serve as input to academic discourses on Stourhead landscape garden as total work of art, providing measurements and facts to refine theories in historical-interpretative research as well as practical clues for heritage management.

GIS also enabled simulating the visibility of important architectural features like Alfred's Tower and the Obelisk in a systematic and transparent way to provide insight into their visual relationships with other parts of the garden. For example, the initial visibility of Alfred's Tower from the Temple of Apollo could be evaluated in relation to the development of the landscape garden as a whole. The visibility range from Alfred's Tower could also be analysed taking atmospheric conditions, the earth's curvature, etc. into account. Analogously, this type of analysis has been practically applied to assess the visibility and development of skylines and in studies on the placement of wind turbines [Figure 5.6].

GIS and the symbolic form

The symbolic form of Stourhead could only partly be addressed in this study. The meaning attached to composition, i.e. the semantic information, is subjective and dependent on the receiver. As previously elaborated, this subjective part contains symbolic, cultural, and personal elements that determine the experience of landscape architectonic space. GIS only enabled the study to lay bare some of the morphological conditions for reception. The sequence of images with iconographic elements organised by the composition and the imposed routes, connecting tactile experience and visual appearance, has particularly provided new insights. The number of iconographic elements in the views acquired by counting emblematic focal points and their development over time has provided clues for understanding Stourhead as an allegorical structure. The experience of shadow is also an important aspect of the composition that could be analysed by applying shadow analyses connected to the tracing of routes. The application of hemispherical viewsheds allowed the study to assess the notion of scale and the role that spatial boundaries can play in spatial experience. Contemporary and modern sources, like the Piper map and crowdsourcing, were employed to understand the composition's appraisal of visitors via map-distortion-analysis and density analysis. They provide clues for understanding the composition's appraisal, indicating which parts of the composition are regarded as the most important. Since the study of meaning is in the field of semiotics and cognitive sciences, it is hardly possible to generate definitive answers to questions of symbolic form via GIS-based landscape design research on its own. However, it can provide some clues: on the one hand, by exploring morphological potentials to evoke a certain meaning (e.g. amount of elements in the view, tracing of the route, dark-light intensities) and, on the other, by measuring cognitive acts and actions of the subjects (e.g. number of photos taken as an indicator of appraisal). Application of other sensors, such as GPS-devices, proved to be useful in other research contexts, especially for the latter task [Figure 5.7].

GIS and the programmatic form

Traditional mapping was the basis for understanding the programmatic form, employing vertical aerial photographs and topographical maps. Due to a lack of detailed and vectorised land-use data of the whole estate in its present state, a modern aerial photograph had to be retraced in order to create this data. This enabled to calculate different types of land use. There was also the possibility to retrace the historical maps in order to acquire more insight into the development of land use over time. However, since delineating and calculating land-use zoning is a well-known application of GIS, the focus was on the functional interactions between different zones of the estate in terms of logistics and accessibility. Here, GIS enabled a study of the functionality of routes and a comparison of aesthetic motivations of route tracing and measures of route efficiency. Similarly, analytical operations have been applied in the evaluation of proposed design interventions in urban contexts [Figure 5.8].

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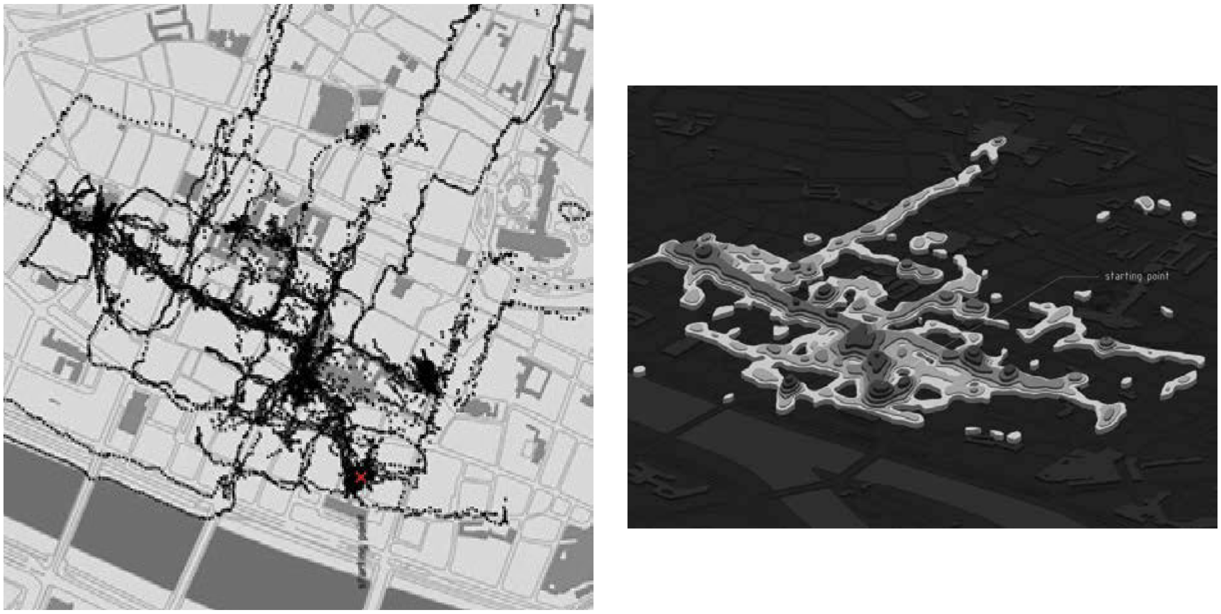

FIGURE 5.7 GPS-monitoring of pedestrian movement by tourists in Rouen (France). In order to reveal their movement behaviour several dozens of tourists were asked to carry GPS-devices while visiting the town centre. The tracking data revealed their activity patterns and provided input for potential design interventions by the Municipality to improve accessibility of the historic town centre (Nijhuis, 2008; the survey was conducted by a team of students led by Stefan van der Spek)

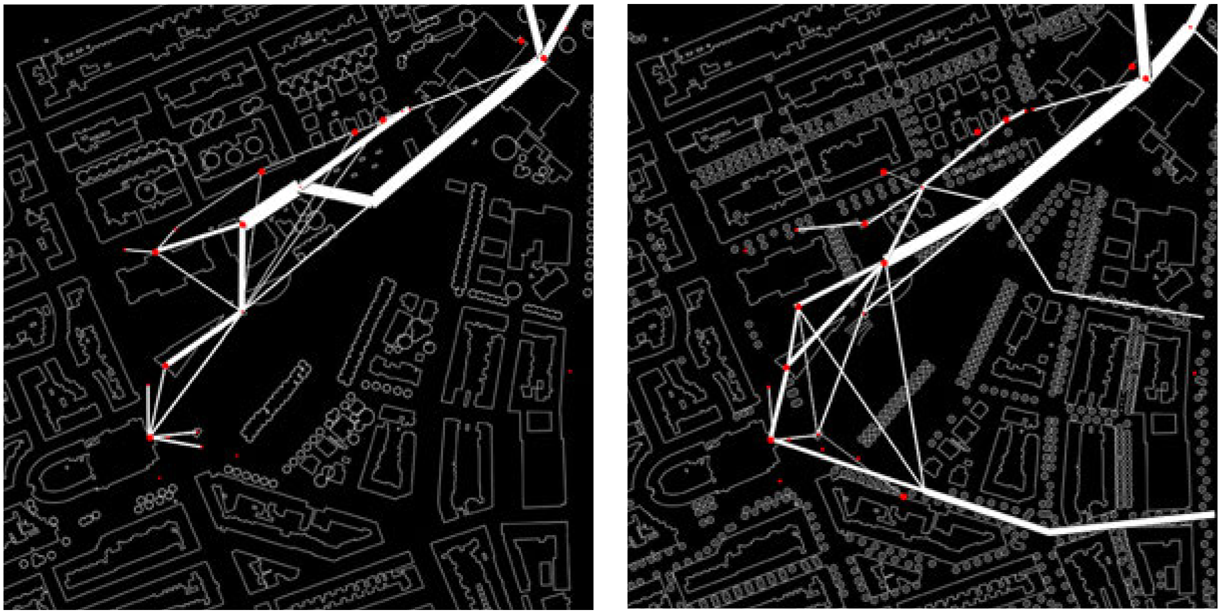

FIGURE 5.8 GIS-based analysis and simulation of movement patterns at the *Museumplein* in Amsterdam (the Netherlands). Simulations of visitor flows now (left) and in the future (right), as a basis for the Municipality of Amsterdam to make decisions on future developments (Den Ruijter & Nijhuis, 2008)

Since GIS could be used as a powerful analytical tool in every category of architectural analysis, the danger is that the computational outcomes come to be regarded as knowledge on their own. This is not possible, since knowledge entails a knower who interprets and synthesises the results into knowledge. This implies that the result is dependent on and biased by its user, since the tool is used in a particular way to address particular questions, but is limited by the available time and data, the capacities to handle the tool, and the limitations of the system itself. Particularly regarding the latter, there are some substantial limits to the tool's ability to represent objects and relationships, people, and places due to the ambiguous relationship between the creators of GIS, GIS as a system, and its output.[659] In fact, GIS itself reflects a conceptualization of reality based on a particular type of reasoning and language used by its creators and is biased by social, economic, legal, political, and ethical issues. [660]

Conclusion # 2: Extending possibilities and refined analysis

GIS turned out to be an apt tool for systematic analysis of aspects of the basic, spatial, symbolic, and programmatic forms and for understanding the composition as a product of time (the time of its conception, development, and mutation). For understanding the basic and programmatic form analytical operations from the vertical perspective, such as map overlaying, hydrological, climatic and morphometric analysis (i.e. slope, convexity), ex-post experiments (development of the lake) and simulations (i.e. route efficiency) helped to derive knowledge that would have been difficult, if not impossible, to gain using manual methods. In this way, GIS enabled analysis of specific design aspects in a more precise, systematic, transparent, and quantified manner. It was also possible to analyse kinaesthetic aspects of the composition, such as the shape of a walk, and to acknowledge the route as important operative structure in the designed landscape. For understanding the spatial and symbolic form analytical operations from the horizontal perspective, in particular the different visibility analyses from the inside out, also demonstrated an important added value. They made it possible to measure visual phenomena (e.g. visible relationships, views and their optical characteristics, dark and light, morphological semiotics) that are often subjects of intuitive and experimental endeavours, taking into account physiological, psychological, and anthropometric aspects of spatial morphology, which was hardly possible before. Here, time also played a crucial role in that it addressed the temporal experience by movement of individuals through the landscape garden. In that respect, GIS-based analytical principles provide access to new types of design-knowledge through combining general scientific knowledge of visual perception and way finding with an examination of site-specific design applications. The outcome of the computational analysis is not knowledge on its own, but must still be interpreted by the design researcher in order to acquire knowledge. The outcome should also be regarded as a result within a particular research domain and biased by the design researcher.

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[659] For a full elaboration on social, economic, legal, political and ethical issues related to GIS see: Curry, 1998.

[660] For an elaboration on data as an artefact in which people, policy and agendas are reflected see: Schuurman, 2004, p. 53ff.

FIGURE 5.9 Augmented landscape model at a permanent exhibition on garden and landscape at the Beeckestijn Podium for Garden and Landscape Culture (Velzen-Zuid, The Netherlands). The GIS-based model (GIS-CAM) of 2.20 by 2.60 metres, which represents an abstract version of the 'bare' natural landscape (contour lines of the relief), is augmented by a six-minute film and voice-over, showing the transitional and gradual development of the landscape of *Kennemerland* in maps– from the early Middle Ages (800 A.D.) to the future (2030) (model and maps by Steffen Nijhuis, Michiel Pouderoijen, photos by Tinker Imagineers)

§ 5.2.3 GIS-based visual representation: Revealing and communicating knowledge

In this study GIS-based visual representation concentrated on revealing and communicating knowledge from landscape architectonic compositions through a wide variety of visual means offered by the technology. Maps, virtual 3D-landscapes, charts and tables are used in the cyclical cognitive process in which the design researcher acquires knowledge of the object via interaction with the visual representations. In this study, contouring, vertical profiling, hypsometric tinting, and hill-shading of the DEMs were effective means for the recognition of landform. The virtual 3D-landscapes were means to show the development of the landscape architectonic composition over time. GIS also offered means to represent visible aspects of the landscape architectonic compositions in alternative ways via the different visualisations of the viewsheds as well as the delineation of kinaesthetic experiences via diagrams. However, by nature the application of GIS in design research tends to represent DLMs in either a realistic or symbolic way that is at odds with usual schematic-iconic landscape architectural analytical representations. Here, the landscape design is ideally represented in such a way that the composition is recognisable by reducing characteristics and details to their very essence. Thus an important aspect of GIS-based visual representation is to find the right balance between using available data and creating customised data. The former doesn't always fit the required level of detail and the latter is time-consuming. Again the devil is in the data; with the right data, one can construct the DLMs easily and represent them in a multitude of ways.

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In the case study of Stourhead, GIS was applied in the process of using graphical analytical techniques, such as dissection and spatial association analysis (graphical overlaying), by selecting and combining features while exploiting the power of composite maps, sections and 3D-models. Through comparing different time-slice snapshots, similarities and dissimilarities that appeared enabled to understand the development of the landscape architectonic composition.

In this study 3D-printing (and other forms of rapid prototyping) or augmented models were not used for analysis, evaluation, and presentation. However such tools show serious options for design research and presentation to a wider audience [Figure 5.9].[661]

Conclusion # 3: Multiple modes for visual thinking and communication

GIS was applied in visual thinking and communication by exploring and visualising the landscape architectonic composition in several phases of its study. GIS offered alternative ways to represent the role of temporality, the development of the composition as a long-term structure, but also as a 4D-experience. While handling and processing huge amounts of data, control of the visualisation process is transferred from the GIS-specialist to the design researcher using visual representations as raw material or as final product. Throughout the research, GIS made it possible to switch between the different modes of visual representation: maps, sections, 3D-models, tables, and graphs in order to explore relationships dynamically through the scales and time-stages. Later, the most suitable representations were chosen to be published in this thesis. The choice of the most effective mode of representation, including a specific level of detail, remains an important human factor and depends on the objectives at stake.

The application of GIS enriched and deepened the framework for landscape design research as developed in Delft through its possibilities for digital modelling, analysis and visual representation of the landscape architectonic categories. The examples showcased that GIS enables researchers to address aspects of visible form and the role of movement (walkscapes) within the framework through measurements and simulations, which were hardly possible by other means. Temporal aspects such as the development of the composition over time and sequential experience have been analysed in a systematic manner by time-slice snap shots. The potential to evaluate, process, link and integrate different data sources also opens possibilities to apply knowledge from history, cognition, natural processes, etc. In these respects, GIS has been a vehicle for developing and changing the Delft approach in landscape design research to include other important aspects in formal analysis.

§ 5.3 Lessons learned

In the process of GIS-aided knowledge acquisition from Stourhead landscape garden, the application of GIS showed possibilities and limitations for landscape design research on two levels: (1) On the level of expression, related to the creation of visual representations of designed landscapes; (2) On the content level, related to knowledge acquisition from designed landscapes.

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[661] Nijhuis & Stellingwerff, 2011.

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§ 5.3.1 Employing the graphic capacities of GIS

In the case of Stourhead, drawings and historical maps of the landscape architectonic composition were used in (or converted into) a digital format for selective retrieval and display. The digital format offered the possibility to change and alter the content and expression when required, while not having to redo the full drawing. In some cases graphical entities were traced from digitised and geo-referenced analogue drawings and maps, only to be selectively redrawn with additional annotation. While using a common accurate base map, several drawings were prepared independently, though could be aggregated and displayed in a variety of combinations. Access to large symbol and colour libraries allowed for quick creation and comparison of drawings. If required, graphical features in a layout could be altered several times, comparing alternatives before selecting the best arrangement.

In this perspective, GIS *facilitated* the process of knowledge acquisition via the possibility to create and explore visual representations interactively, offering alternative readings through switching visualisation modes and simulation of landscape of the past and of the future. Via the DVM, drawings became multi-dimensional data structures that can be linked with other data and presented in various ways [Figure 5.10]. The visual representations produced via DVM have the ability to convey data and information on the landscape architectonic composition as measurements, relationships, processes, comparisons, causality, function, and operation in ways almost impossible to achieve manually.[662]

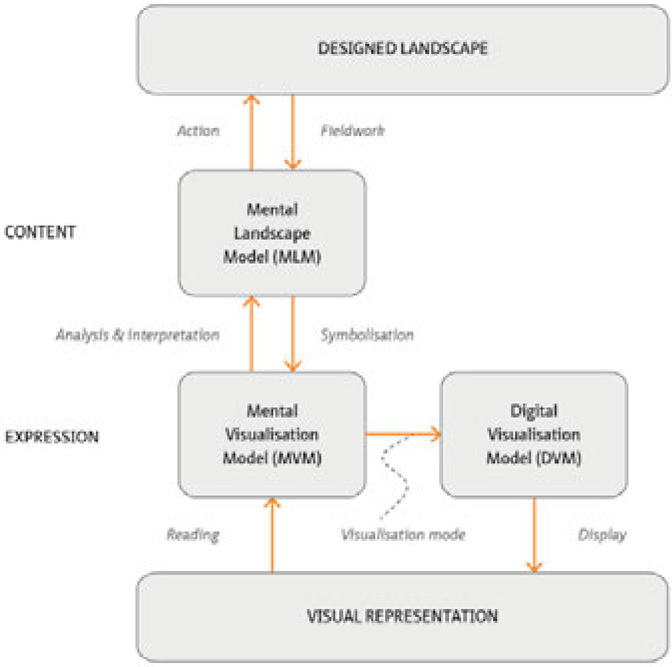

FIGURE 5.10 The translation of the designed landscape via mental content (MLM) and mode of expression (MVM) into a visual representation and vice versa, augmented by the application of a digital visualisation model (DVM) (graphic: Steffen Nijhuis, adapted from Van der Schans, 1995)

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[662] Cf. Gänshirt, 2007; Cantrell & Yates, 2012.

At the level of expression, GIS offers design researchers the functionality of a DVM, providing a platform for the production, processing, and interactive display of maps, sections and virtual 3D-landscapes employing digital technology for CAD, computer graphics, and 3D-modelling. Since all of these technologies are integrated, it is possible to switch interactively between different modes of expression for effective symbolisation and display (e.g. 2, 2.5, 3 or 4 dimensions), as well as offering powerful functionality for precise drawing, editing, and updating. GIS offers the possibility to increase the speed, productivity, and precision of visual representation of designed landscapes in the process of knowledge acquisition.

An essential element of GIS is to bring together data from different sources, which can contribute to a better understanding or alternative reading of a designed landscape. The geographic location is the common denominator that links the data and this ability is an important distinction from other digital media. When compared to manual drawing, the translation from MVM to DVM is rather technical, demanding a conscious, precise, and systematic way of working. Sometimes this can be considered counterproductive for visual thinking insofar as the process of intuitive drawing is filtered by the possibilities of the software and ease of operation. Manual drawing requires time, attention, and focus, which stimulate thinking via linking the hand and the eye via the brain. As research points out, these factors stimulate 'digestion' of the information and support knowledge acquisition and the development of understanding. GIS as a DVM, and digital technology alike, have the tendency to reflect rather than think, efficiently processing only what has been entered in digital form.[663] To what extent the pencil and pen can be replaced by a mouse and stylus is subject to ongoing study by cognitive sciences. The assumption is that digitation enables design researchers to internalise and externalise ideas in other ways.

An important limitation of GIS as DVM is that it tends to produce visual representation on both sides of the spectrum: realistic *or* symbolic visual representations (e.g. detailed maps derived from remote sensing vs. abstract symbolic thematic-maps). GIS-based visual representations tend to rely either on existing accurate data or on abstract symbolic data on a particular scale. However, design researchers usually employ schematic-iconic visual representations (which sit in between realistic and symbolic representations) in order to convey the landscape architectonic composition in such a way that the morphological structure is exposed while leaving out particulars. Automated procedures for abstraction are not sufficient because they are based on objectivist approaches and purposefully leaving out details is a matter of subjectivist interpretation. Thereby switching between the scales is often a necessity, but multi-scalar data is often lacking in existing datasets.

Conclusion # 4: GIS as facilitator

GIS has the potential to *facilitate* the process of knowledge acquisition via the possibility to create and explore visual representations interactively, offering alternative readings through the possibility to switch visualisation modes and simulate situations that do not exist anymore or yet. Via the DVM researchers can gain multi-dimensional data structures that can be linked with other data and presented in various ways. The visual representations produced via a DVM have the ability to convey data and information on the landscape architectonic composition via measurements, relationships, time, processes, comparisons, causality, function, and operation in ways almost impossible to achieve manually. An important limitation of GIS as a DVM is that abstraction for means of analysis is dependent on selection, reduction and the researcher's interpretation, which is subjective in nature.

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[663] Treib, 2008b.

§ 5.3.2 Employing the integrative and analytical capacities of GIS

In the case of Stourhead, vertical aerial photographs, elevation and bathymetric data, and GPS-coordinates were an important basis for the construction of the DLMs representing different time-slice snapshots of the grounds. This data from the landscape architectonic composition served as direct input for the DLM [Figure 5.11]. For the DLM 2010, (Stourhead 2010, t_3) modern, general geo-data such as the ordnance survey maps, property maps, geological and soil maps, as well as data from other sources (e.g. lists of plant species) were important sources. For the construction of DLM 1785 (Stourhead 1785, t_1), and DLM 1887 (Stourhead 1887, t_2), analogue historical topographic data was digitised, geo-rectified and vectorised employing the DVM. Here, information from the analogue visual representation (e.g. historical map) was selectively translated electronically as input for the DLMs (Figure 5.11: trajectory from visual representation to DVM, to DLM). Additional data on vegetation heights was generated via statistical regression analysis. The DLMs of Stourhead were constructed by selecting and integrating specific topographic features (e.g. landform, water, vegetation, built and constructed elements) from this multitude of sources. The DLMs remain 'neutral' in such way that they resemble the landscape architectonic composition and its constituent spaces, paths, edges, foci, and thresholds in an abstract way. The DLMs act as a substitute for reality, which makes them easier to work with.

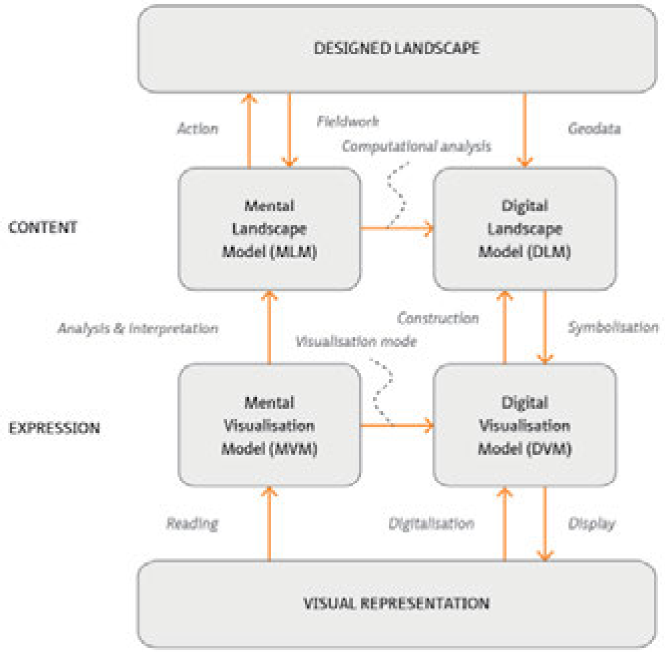

FIGURE 5.11 The translation of the designed landscape via mental content (MLM) and mode of expression (MVM) into a visual representation and vice versa, augmented by the application of a digital landscape model (DLM) and digital visualisation model (DVM) (graphic: Steffen Nijhuis, adapted from Van der Schans, 1995)

In the case of Stourhead, GIS was used to collect data and information from the DLMs exploring and delineating quantitative and qualitative aspects of the landscape architectonic composition. GIS was particularly employed to measure morphometric aspects of elevation, geometry and insolation, but also simulations of vegetation heights, movement, and visibility, as well as for experiments with water levels and visibility. In that way, it helped to grasp the tacit knowledge of on-site design concealed in the composition. However, despite the intelligence of the tool, computers have no cognitive capabilities (i.e. thinking, remembering, or understanding), thus GIS only can function at the direction and discretion of the design researcher. The choice of analytical operations still depends on the MLM and the questions raised (Figure 5.11: trajectory from MLM to DLM, to DVM, to visual representation). The outcome of the computational analysis must still be interpreted by the design researcher in order to gain knowledge (Figure 5.11: trajectory from landscape architectonic composition to MLM, to DLM, to DVM, to visual representation, to MVM and MLM).

Conclusion # 5: GIS as mediator

GIS facilitated the process of knowledge acquisition via the DVM and graphical analytical operations and *mediated* via the DLM and computational analysis offering intelligent integrating and analytical capabilities for exploring huge amounts of data and information. The application of GIS can be understood as an extension of the fundamental cycle of observation, visual representation, analysis, and interpretation in the process of knowledge acquisition with alternative visual representations and digital landscape models as mediating external cognitive tools. This offered possibilities to explore new aspects of the basic, spatial, symbolic, and programmatic forms of the landscape architectonic composition via measurement, simulation, and experimentation, while at the same time offering alternative ways to understand the landscape architectonic composition by the possibility to explore new elements in the framework of landscape design research such as the visible form, kinaesthetic aspects and development over time. However the impact of GIS is unavoidably depending on the knowledge, direction and discretion of the design researcher; in that respect, GIS is by definition a tool. To gain knowledge from landscape architectonic compositions, interpretation of the computational outcome by the design researcher is inevitable.

§ 5.3.3 The relationship between landscape design and GIS-based landscape design research

The basis of landscape design is the understanding and development of landscape architectonic compositions. In this study, the emphasis rests on gaining understanding via landscape design research. However, analysis and invention are closely related; understanding is the basis for design intervention. Thus, landscape design builds on landscape design research. Landscape design involves exploring possibilities and synthesising knowledge and information at various levels of scale employing drawings, 3D-models, and mapping as analytical and generative tools. In fact, the knowledge formation cycle is extended and serves as the basis for design generation where the thinking process transforms from knowledge acquisition into invention of new landscape architectonic compositions. This design generation cycle is characterised by an iterative thinking process incorporating creation, development, and testing alternatives in order to arrive at a new landscape architectonic composition. In the creation cycle, the designer's initial ideas are given tangible form. This rudimentary design is elaborated in a development cycle to achieve greater coherence, completeness, and specificity. The test cycle is the moment of truth, when the design is tested against the criteria and standards set by the designer. In each of these iterations, GIS can play a facilitating and mediating role for data processing in terms of pre-processing and model construction, for knowledge generation in terms of ex-post analysis, description, and visualisation, and for design generation in terms of ex-ante analysis, experiments, and simulation of design proposals [Figure 5.12].

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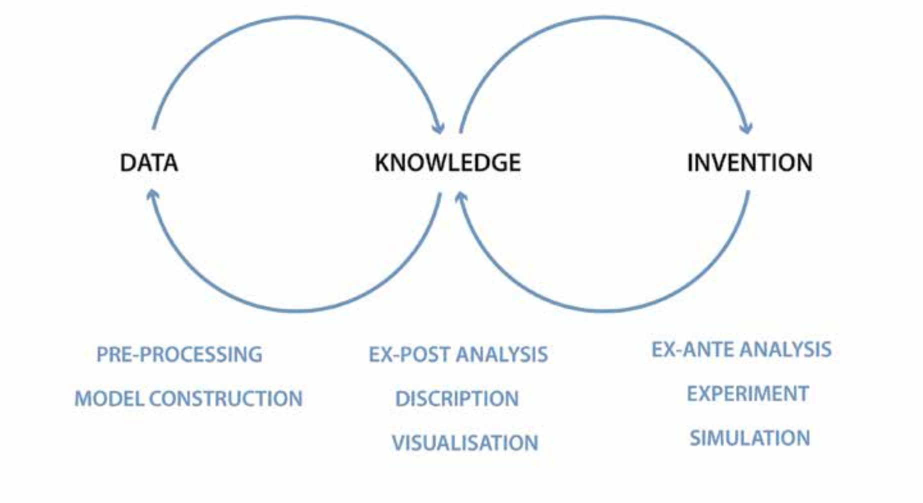

FIGURE 5.12 GIS as a facilitator and mediator in the knowledge formation-cycle and design generation-cycle: an iterative process from data to knowledge, from knowledge to invention (graphic: Steffen Nijhuis)

In the case of Stourhead, the emphasis was on data processing and knowledge generation (ex-post analysis). Both data and knowledge can serve as the basis for conservation strategies (i.e. replacement of trees) and design interventions (i.e. opening up views, adding new features), which can be simulated and evaluated by means of GIS without literal execution (ex-ante analysis). GIS-based landscape design research then becomes a tool for creation, reflection and evaluation in landscape design. To use GIS in the design generation cycle, the creation of new data or the adjustment of existing data is an important basis for applicability. Therefore, the development of user interfaces for drawing and modelling should be improved in order to fit the designers' needs in the different design iterations.

Conclusion # 6: GIS as reflective and evaluative design tool

In this study GIS demonstrated to be an useful tool for modelling, analysis and visual representation of past and present landscapes. This implies that GIS can also be applied in landscape design for reflection and evaluation of proposed design interventions in terms of ex-ante analysis, experimentation, and simulation exploring their effects in a cyclical and repetitive way. In order to become fully operational in the design cycle, drawing and modelling interfaces should fit the needs of landscape designers.

§ 5.4 Extending the toolbox of landscape architecture

Though there are some limitations, this study illustrates that GIS is useful for knowledge acquisition from landscape architectonic compositions. GIS can be seen as a powerful external cognitive tool that supports design researchers in mediating and facilitating knowledge acquisition in a cyclical process. This underlines the interdependency of GIS and the design researcher. The tool makes no sense without the user. Using the calculating power of computers, combined with inventive analysis, modelling, and visualisation techniques in an interactive process opens up the possibilities to reveal new information and knowledge about layout, spatial construction, processes, and use. GIS-based design research has the possibility to cultivate spatial intelligence in landscape architecture through three mains fields of operation:

- GIS-based modelling: description of existing and future landscape architectonic compositions in digital form;
- GIS-based analysis: exploration, analysis, and synthesis of landscape architectonic compositions in order to reveal new or latent architectonic relationships, while utilising the processing capacities and possibilities of computers for ex-ante and ex-post simulation and evaluation;
- GIS-based visual representation: representation of (virtual) landscape architectonic compositions in space and time in order to retrieve and communicate information and knowledge of landscape design.

In all three fields of operation GIS functions as an interpretative tool that by its application deepens and broadens the body of knowledge in landscape architecture in two ways:

Firstly, by following the discipline and developing specific aspects of it via application of GIS in addressing the ‘same types of design-knowledge’, but in a more precise, systematic, transparent, and quantified manner. It makes for precise delineation and alternative ways of representation of landscape architectonic compositions over time. GIS helps to reproduce and transfer research methodology and offers an integrative, transparent, and systematic approach for advanced spatial analysis. It also comprises measurement (quantities), testing, and verification of expert knowledge or known architectonic phenomena in landscape architecture.

Secondly, by expanding the field by setting in motion fundamental new developments via GIS in generating ‘new types of design-knowledge’ by advanced spatial analysis and the possibility of linking up and/or integrating other information layers, fields of science, and data sources. In that respect, the field of landscape design research can be extended by offering alternative ways of understanding landscape architectonic compositions, especially regarding visual form and the incorporation of time, movement, and development processes (vegetation growth, human alterations). GIS offers the possibility of integrating and exploring other fields of science (e.g. visual perception, way-finding studies) and dealing with complexity (more variables). GIS-based landscape research offers the possibility to enrich formal reading by revealing tactile and sensorial potentialities of a design, which was hardly possible before, and also expands the analysis with data derived from psychological and phenomenological approaches addressing matters of reception of a design.

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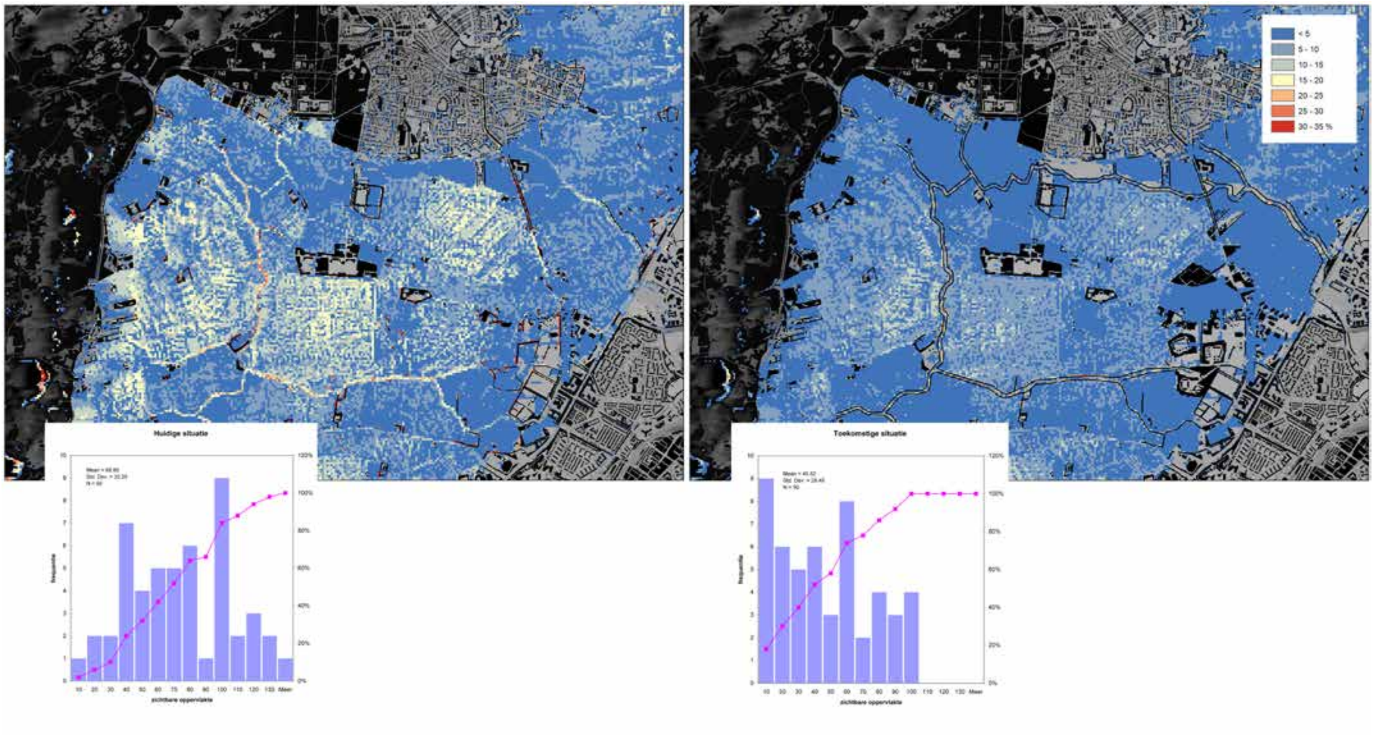

FIGURE 5.13 *Ex-ante* GIS-based visual impact analysis of a landscape development plan in a cultural heritage landscape for the Provincial Advisor of Spatial Quality of Noord-Holland. Left: situation 2010. Right: projected future situation (source: Nijhuis, 2010b)

§ 5.5 Prospects and recommendations

The technical possibilities increase every day and GIS-software is becoming more user-friendly by offering intuitive, interactive, and dynamic digital environments. There is also an increasing interest in the role that digital data and GIS can play in landscape architecture, in both practice and education.[664] Additionally, public digital infrastructure is under development to provide up-to-date and reliable geographic information online, accessible to everyone.[665] Furthermore, GIS as an integrative platform can contribute to the growing need for multidisciplinary and flexible ways of working – to cope with complex issues and to develop solutions, while involving other disciplines and stakeholders.

Regarding the development of the discipline – related to digital tools such as GIS – education and research institutions have an important task. They must take the lead to inspire students and professionals, develop and transfer knowledge, and add to the traditional toolbox of landscape architecture. This means that GIS and its use in research, design, and presentation must be an integral part of the teaching and research curricula in order to develop a digital culture[666] where

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[664] For example: ECLAS et al., 2011.

[665] For example: VROM, 2008; NCG, 2010.

[666] See for digital culture in architecture: McCullough, 2004; Picon, 2010.

digital and analogue tools are complementary means for thinking and communication in landscape architecture. Next to implementation and integration into existing landscape architecture curricula, the development of specific MOOCs (Massive Open Online Courses) is an interesting field to explore in this respect.[667]

GIS as a tool in landscape architecture can be developed in at least three ways. First, through the development of academic knowledge on the application of GIS in landscape architecture design, and to cultivate it by development of theory, methods, and techniques from the perspective of the discipline. Secondly, by its implementation in education to make future landscape architects more familiar with the application of the tool. And finally, by transferring knowledge and applications to society (valorisation). To encourage these developments, not only is intense dialogue in academic circles needed, but also among those with landscape architecture professionals and societal partners. High-quality publications must play a role her, though use must also be made of various platforms for knowledge dissemination and discussion.

In order to fully exploit GIS as a tool in landscape design research, there are recommendations for future development that offer a way to draw GIS back to the field of landscape architecture, where it began.

Enforcing link between landscape designers and GIS

The link between landscape designers and GIS should be enforced since the potential of GIS is still often underutilized due to a lack of awareness and prejudice. Since there is a gap between the rapid advances in technology and the human factor, it is not functional to start from the technology point of view, since from this view 'everything' is possible. Then one could assume that landscape designers know about the GIS-functionality in principle, but do not understand how it could be helpful in a certain task, or it seems too complicated to use and therefore the designers never find out about the possibilities.[668] A countervailing force could be to start from the landscape designer's perspective, taking disciplinary concepts and principles as a starting point to showcase and develop practical applications. Concepts of GIS that link to the very heart of landscape design in a natural and intuitive way can help to break down barriers to using GIS in the practice and education of landscape architecture. The four characteristic principles of study and practice in landscape design have the potential to establish that link, i.e. (1) landscape as a three-dimensional construction, (2) landscape as history, (3) landscape as a scale-continuum, and (4) landscape as a process.[669] In this respect, a survey amongst landscape architects (academics and professionals) is needed to identify and statistically underpin the fields of interest and the actual bottlenecks of GIS-implementation in academia and the professional field.

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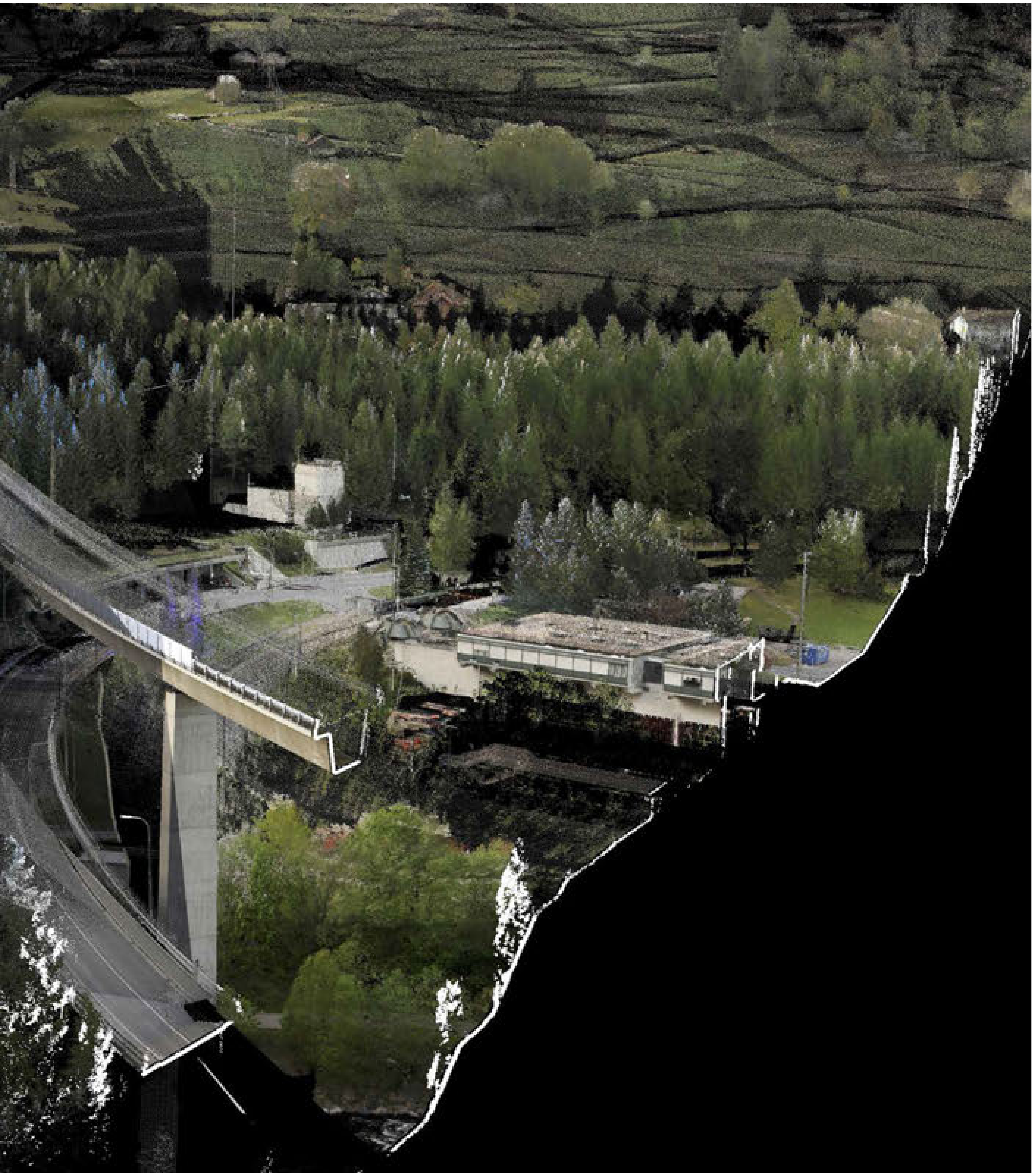
[667] See for instance the successful MOOC 'Geodesign: Change your world' developed by Kelleann Foster of the Stuckeman School of Architecture and Landscape Architecture, Penn State University (Foster, forthcoming).

[668] Cf. Frank, 1993, pp. 11-12. For similar reasons, individuals use only 5% of the functions available in text editors (Whiteside et al., 1982).

[669] See for an elaboration: Nijhuis, 2014b.

FIGURE 5.14 True-colour 3D laser scan of a landscape section through infrastructures near Airolo (Switzerland) combining terrestrial laser scanning and point cloud technology (image courtesy of Pascal Werner, Chair of Professor Girot, ETH Zurich, 2015)



Societal relevant applications

Societally relevant applications of GIS-based landscape design research can be developed through the involvement and cooperation of governmental organisations (i.e. ministries, cultural heritage agencies), NGOs (i.e. Gelders Genootschap, National Trust) and private parties (i.e. project developers, estate owners). There is an increasing demand for knowledge-based planning, design, and management of cultural and urban landscapes. GIS-based design research can offer means for measurement, simulation, and experimentation via transparent and replicable methods that serve as the foundation for the formulation of new landscape designs, as well as inform conservation strategies for the development and protection of cultural heritage such as gardens and designed landscapes [Figure 5.13]. In addition, GIS can help with the increasing demand for multidisciplinary and flexible working methods, in order to find solutions to complex problems together with people from other fields and with stakeholders.

Understanding the landscape as product of time (Δ_t)

Since GIS offers a broad range for visualisation of temporal aspects (e.g. structural change, growth of vegetation), capturing data of particular objects (e.g. high-definition 3D laser scanning), reconstruction of time-slice snapshots and evaluation of topographical sources, it enables landscape architecture researchers to conceive and understand cultural and designed landscapes as products of time: the time of conception, development, and mutation. By involving time, movement, and process (e.g. erosion and sedimentation, vegetation growth), GIS provides a tool to engage in the development of landscape by offering means for fresh thinking about the preservation and development of (heritage) sites and landscapes through its modelling, analytical and visualisation capabilities. In retrospective approaches, heritage can be brought back to life through realistic reconstructions displayed on novel digital interfaces (mobile technologies, multi-touch interfaces) and in prospective approaches it offers means to study design proposals for their implications and impacts. The role of time in geodata of cultural and designed landscapes and the challenges of its construction, management, and preservation is an important issue that needs to elaborated upon.

Development data collection methods and use of field instruments

The widespread availability of data, such as free digital topographic maps, terrestrial LiDAR, location based services (LBS), and crowdsourcing for implementation in GIS (via e.g. data exchange concepts like Web 2.0) opens up great possibilities to overcome data issues in the field of landscape architecture, as well as to integrate and explore knowledge from other disciplines. The development and availability of three-dimensional data is also promising and will help to address fundamental issues related to spatial design known from the previous chapters. Though the developments in data and data infrastructure are important, there will be always a gap between the commonly available data and the data needed for GIS-based landscape design research. The data needed depends on the research objectives and disciplinary perspective, so it is hardly possible to develop standardized data sets that are directly usable and often remain too general or specific. Therefore landscape designers should advance in the use and development of field instruments for data acquisition in order to fill that gap by themselves. Field instruments are ground-based and airborne tools, such as drones, 3D laser scanning, and electronic distance measurement instruments for acquiring the data needed to advance some specific purpose in GIS-based landscape design research. These instruments can be utilized for landscape architects by landscape architects [Figure 5.14]. Besides the application of field instruments, development of practical methods and means for collecting, processing, and storage of data is an important issue has have to be addressed (e.g. point cloud technology).

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FIGURE 5.15 Illuminating Clay (left) and Sandscape are examples of tangible user interfaces, with which there is a rapid interaction between actions and their effects. The designer shapes the landscape by moulding 'three-dimensional clay or sand'. The landscape formed is calculated and displayed on screens (image courtesy of Carlo Ratti, MIT Media Lab, Tangible Media Group, 2002)

Advancement of Geo-IT

Geo-information technology (Geo-IT) is developing at high speed. It seems that every day there are new technical possibilities and the software becomes more and more user-friendly. GIS is becoming more intuitive and interactive, and working environments more dynamic. However, from the landscape design point of view, it is important to develop 3D functionality in terms of 3D-modelling, 3D-analysis and 3D visual representation. Another potential field for development is tangible user interfaces. Tangible user interfaces are focused on human-computer interaction. Such intuitive interfaces provide a rapid interaction between actions and their effects [Figure 5.15]. The implementation and development of rapid-prototyping techniques is also working for landscape design researchers. The combination of GIS and computer-aided manufacturing (CAM) makes it possible to translate digital drawing and models into physical models and prototypes of objects via 3D-printers, CNC-milling, and laser cutting.

Bridging disciplines

GIS as facilitating and mediating platform may support the exchange and synthesis of knowledge from the sciences, technology, and design while taking the location as the basis for their combination or integration. This spatial turn prepares ground upon which landscape architecture researchers can collaborate with related design disciplines such as urban design and architecture, and also scholars from the humanities and life sciences. By critically engaging the technology and directing it to the subject matter of landscape architecture, it has the ability to combine general scientific knowledge derived from landscape ecology, environmental psychology, cultural history, etc., with the examination of site-specific design applications. In this way, GIS can stimulate a multi- and interdisciplinary discourse in landscape architecture as a basis for exchange amongst related disciplines and synergy of scientific knowledge, the possibilities offered by the technology and design as an integrating activity. Similarly, there are promising endeavours in the social sciences to create a language that bridges disciplines, reconceptualises humanities as a discipline including a spatial perspective, and the integration of geography using GIS as a vehicle.[670] This demonstrates that GIS as a tool has the ability to develop and bridge disciplines.

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[670] For example: Bodenhamer et al., 2010; Nyerges et al., 2011.

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Appendix A Overview of obtained cartographic data of Stourhead landscape garden

HISTORICAL CARTOGRAPHIC DATA
Map of the Parish of Stourton 1722 (Wiltshire Record Office 383.316)
Map of the manor of Stourton belonging to Richard Colt Hoare, John Charlton, 1785 (Wiltshire Record Office 135/4)
Plan of the Valley Garden at Stourhead. F.M. Piper, 1779 (Royal Academy of Fine Arts, Stockholm)
Ordnance Survey Map of Stourton, 1900-1923, 6-inch map (British Ordnance Survey)
Ordnance Survey Map of Stourton, National Grid Series, 1889, 1:2,500 (British Ordnance Survey)
MODERN CARTOGRAPHIC DATA
Modern geodata topography and property
Digital geo-referenced raster maps (raster):
Ordnance Survey Map of Stourton, 2009, 1:10,000, TIFF (British Ordnance Survey)
OS VectorMap District, 2011, 1:25,000, TIFF (British Ordnance Survey)
GB 12.5cm AerialPhoto, 2005 (JPG), TIFF (British Ordnance Survey)
GB 25cm AerialPhoto, 1997 (ECW), TIFF (British Ordnance Survey)
Digital geo-referenced vector maps (shape):
Ordnance Survey Map of Stourton, 2009, 1:10,000 (British Ordnance Survey)
Ordnance Survey Map of Stourton, 2009, 1:2,500 (British Ordnance Survey)
GB National Trust Ownership, Acquisitions and Disposals, 2011, 1:2,500* (National Trust)
OS VectorMap District, 2011, 1:25,000 (British Ordnance Survey)
Thematic modern geodata on relief, soil, geology, hydrology
Digital geo-referenced raster maps:
Global digital elevation data (SRTM-90m), 2010, 16 meters vertical accuracy (cgiar-csi)
Digital geo-referenced vector maps (shape):
OS Landform Profile DTM-point vector (ASCII XYZ), 1:1,250-1:10,000 (British Ordnance Survey)
BGS DigMapGB-50, 1:50,000 (British Geological Survey), idem to: British Geological Survey Geological Map, E297-Wincanton, 1:50,000 (British Geological Survey)
BGS DiGMapGB-625, 1:625,000: Great Britain and Northern Ireland (British Geological Survey)
Digital hydrogeological data, 1:625,000: Great Britain and Northern Ireland (British Geological Survey)
ESDB v2.0: The European Soil Database distribution version 2.0, (European Commission and the European Soil Bureau Network), EUR 19945 EN, 2004

TABLE APP.A.1 Overview of obtained cartographic data of Stourhead landscape garden

* *Estimated map scale*

Appendix B

Planimetric accuracy standards for various map scales

LIMITING RMSE (METRES)	MAP SCALE
0.0125	1:50
0.025	1:100
0.05	1:200
0.125	1:500
0.25	1:1,000
0.5	1:2,000
1	1:4,000
1.25	1:5,000
2.5	1:10,000
5	1:20,000

TABLE APP.B.1 Planimetric accuracy standards for various map scales (Source: Federal Geographic Data Committee, 1998)

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Curriculum vitae

Steffen Nijhuis was born on 25 March 1976 in Doetinchem, the Netherlands. Following his training as a gardener, he completed his studies in Landscape Architecture at Larenstein University of Applied Sciences in conjunction with Wageningen University in 2002. From his graduation onwards he worked as a landscape architect and GIS-specialist at Vista Landscape Architecture and Urban Planning. There he was advisor to the Dutch government, regional and municipal authorities and private parties, and gained experience in regional design and geodesign. In 2006 he entered academia and was appointed full-time Assistant Professor of Landscape Architecture at the Chair of Landscape Architecture, in the Department of Urbanism at the Faculty of Architecture and the Built Environment, Delft University of Technology. There his work focuses on theories, methods and techniques, as well as their practical applications in the fields of landscape architecture, urban design and GIS, with a focus on the following: GIS-based design research, regional design, history of cultural and designed landscapes, geodesign, delta urbanism, and visual landscape assessment. He is initiator, editor and (co)author of several academic books such as: Composing Landscapes (2008), The Polder Atlas of the Netherlands (2009), Delta Urbanism: The Netherlands (2010), Exploring the Visual Landscape (2011), Urbanizing Deltas in Transition (2014) and Flowscapes: Designing Infrastructure as Landscape (2015), all published by renowned publishers. He also published various peer-reviewed and indexed journal articles and book chapters. He is a project leader and heads up the landscape architecture research program, as well as being series editor of RiUS (the Research in Urbanism Series) and is advisor to (inter)national NGO's, and governmental and regional authorities. He is member of several scientific committees and review boards, and guest lecturer at Wageningen University, Larenstein University of Applied Sciences, the University of Groningen and the Academy of Architecture in both Groningen and Rotterdam. Furthermore he is coordinator of the international Landscape Architecture MSc-Graduation studio and (post-)MSc methodology-courses, and supervisor of MSc and PhD graduation projects.

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