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IN SEARCH OF SUSTAINABLE URBAN GREEN INFRASTRUCTURE THROUGH AN ECOLOGICAL APPROACH

- An Investigation of the Urban Green Landscape of Danderyd

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PREFACE

In the summer of 2017 I was offered the opportunity to perform an inventory of the green structures in the municipality of Danderyd, Sweden. The aim was to gather information as a starting point for the development of a new park program. During a period of eight weeks, the green areas of the municipality were studied with regard to both natural and social values. The green structures were located with the help of maps from Google maps and a bicycle map of the municipality. Notes were taken, describing general landscape character, main vegetation types and use. Documentation was also conducted with the help of photographs. As the inventory progressed I started to reflect on how all of these green structures were connected, which became the base for this master thesis. In the thesis, the initial inventory of 2017 is used as a pilot study and referred to as “the inventory” in the text.

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Furthermore, I would like to thank my former colleagues at the municipality of Danderyd for the opportunity to learn and work with them during the initial inventory.

I would also like to extend a special thanks to Professor Maria Ignatieva for helping me to get started with the project, encouraging me to write in a different language and offering advice on literature as well as general support.

SUMMARY

One of the greatest challenges of today's urban development is the formation of sustainable environments. Over the past several decades, there has been a shift in the global population from a more rural allocation to an urban one, resulting in the densification of cities and subsequent fragmentation of green areas. As green areas are being claimed for different types of development, they are becoming increasingly dispersed and receive a reduced ability to serve functions of value for both humans and the environment. Amplifying the amount of impervious surfaces, stormwater runoff and barrier effects in the urban environment as a consequence.

Moreover, urban environments have become a platform for the creation of globally homogenous landscapes, displaying similar methods of design and construction. This use of similar plant material and planning principles for urban spaces is leading to a loss of biodiversity and increasing costs with regard to management and maintenance. Thus, over the past several decades new design aesthetics for urban areas have begun to emerge which are more strongly founded in ecological approaches to design. These practices can be addressed on different scales and are more focused on the context of site, seeking to regenerate and strengthen its natural processes.

This master thesis seeks to investigate such ecological approaches to design by studying the green infrastructure of an urban environment anticipating new development and growth. One region, currently facing such changes is the municipality of Danderyd, Sweden. In consequence, there is a need to evaluate existing green areas and plan for future development of the green infrastructure. This master thesis aims to study the green infrastructure of the municipality in order find ecological approaches to support a more sustainable development.

A literature study was performed concerning the concepts of green infrastructure and ecological design. Further, a case study was conducted investigating the municipality on three different scales; large, intermediate and small. Finally, guiding principles regarding future development of the green infrastructure were presented for each scale. Approaches concerning the protection of existing natural areas, increasing biodiversity, stormwater management, green connections and creating stewardship opportunities were shown to be of particular significance.

Further research questions concerns the development of more detailed, site specific solutions and requires additional knowledge stretching between professional competencies. Thus, this master thesis can be seen as an initial step in order to support a sustainable green infrastructure in the municipality of Danderyd and environments with similar conditions. Additionally, it constitutes a means of sharing experiences gained with regard to ecological design solutions in this particular region.

SAMMANFATTNING

En av dagens stora utmaningar när det kommer till urban utveckling är hur hållbara miljöer kan skapas. Under de senaste årtiondena har det skett ett skifte från att människor bor ute på landsbygden till att de flyttar in mot städerna (Rottle & Yocom 2010, pp. 18-19). Detta har bidragit till en förtätning av befintliga stadsmiljöer, vilket även blivit ett slags ideal för den urbana strukturen. Jakten på den täta staden har däremot medfört en fragmentering av grönområden då de tas i anspråk för olika typer av exploatering. Detta har i sin tur resulterat i att befintlig grönstruktur fått en försämrad förmåga att uppfylla värdefulla funktioner och tjänster för både människor och djur (Boverket 1994, pp. 10-11).

Vidare har den urbana miljön även blivit en plattform för utformning av globala, homogeniserade landskap, med likartad design och planeringsprinciper. Denna användning av liknande växtmaterial och gestaltningsstilar har resulterat i en förslut av biologisk mångfald och ökade kostnader vid skötsel och förvaltning (Ignatieva 2018, p. 216).

Således har det under de senaste årtiondena utvecklats alternativa lösningar som har en starkare förankring i ekologiska principer för design. Dessa tillämpningar har ofta större fokus på den specifika platsens kontext och syftar till att regenerera och stärka dess naturliga processer. På detta vis eftersträvas etablering av produktiva landskap med hög biologisk mångfald, där målet är att besvara och återanvända befintliga resurser (Rottle & Yocom 2010, p. 162).

I Stockholmsregionen, Sverige, sker en ständig ökning av antalet invånare, vilket har resulterat i en förtätning av stadskärnan och de omgivande förorterna. Danderyds kommun, beläget norr om Stockholm, är en sådan förort som i dagsläget står inför en stor omdaning av sina centrala delar (Danderyds kommun 2013a, p. 119). I och med dessa förändringar har det uppkommit ett starkare behov av att utvärdera befintliga grönområden och planera för framtida utveckling av den gröna infrastukturen.

Syfte och mål

Syftet med detta examensarbete är att studera den gröna infrastrukturen i Danderyds kommun och ge exempel på hur den kan stärkas med hjälp av principer för ekologisk design. Studien kan utgöra ett hjälpmedel för att stödja utvecklingen av en hållbar grön infrastruktur i Danderyds kommun men även i andra miljöer med liknande förhållanden. Därtill syftar arbetet till att utgöra ett medel för att dela upptäckter och erfarenheter gällande ekologiska designlösningar i denna region.

Frågeställning

Den frågeställning som arbetet centrerats kring är följande: Hur kan principer för ekologisk design användas för att stödja en hållbar grön infrastruktur i Danderyds kommun på olika skalor?

Metod

Detta arbete har utgjorts av tre större delmoment; en *litteraturstudie* rörande begreppen grön infrastruktur och ekologisk design, en *fallstudie* av kommunen samt *framställning av planer och visualiseringar.* Resultatet presenteras i form av riktlinjer för tre olika skalor; kommunen i sin helhet (large scale), en stadsdel (intermediate scale) samt en enskild park (small scale).

Urban grön infrastruktur

Grön infrastruktur kan beskrivas som ett sammankopplat nätverk av naturområden och andra utrymmen som hjälper till att bevara värden och funktioner hos naturliga ekosystem och som bidrar med ett flertal fördelar för både människor och miljö (Benedict & McMahon 2006, p. 1). Detta nätverk kan bestå av en kombination av parker, trädgårdar, vägplanteringar, kyrkogårdar, övergivna marker (Ignatieva & Ahrné 2013, p. 7), urbana skogar och strandkorridorer (Rottle & Yocom 2010, p. 48).

Fördelar med grön infrastruktur
Grön infrastruktur bidrar till att bevara och återställa ekosystem och utgör habitat för inhemska växter och djur. Därtill absorberar den dagvatten och reducerar avrinning samt stärker kopplingar mellan olika grönstrukturer. Ytterligare bidrar den gröna infrastrukturen till ökad tillgänglighet till grönområden och möjlighet till rekreation (Rouse & Bunster-Ossa 2013, pp. 12-13).

Byggstenar i den gröna infrastrukturen

Nav (hubs)
Nav kan ses som ankare i det gröna infrastrukturnätverket och bidrar bland annat med habitat för inhemska växter och djur. De kan variera i storlek och form, men fungerar ofta som en källa och destination för människor, djur och växter (Benedict & McMahon 2006, p. 13).

Länkar (links)
Länkar binder ihop nätverket och bildar kopplingar mellan grönområden. Dessa är av vikt för att upprätthålla grundläggande ekologiska processer, bevara biologisk mångfald samt funktionaliteten inom systemet (Benedict & McMahon 2006, p. 13).

Lokaler (sites)
Lokaler kan bidra med både sociala och ekologiska värden genom att erbjuda områden för

rekreation och skydd av naturliga livsmiljöer. De kan var sammanlänkade med det större gröna nätverket, men behöver inte vara det (Benedict & McMahon 2006, p. 14).

Ekologisk design

Ekologisk design kan beskrivas som lösningar som tar hänsyn till mänskliga behov samtidigt som hälsan hos naturliga system stöds. Det utgör ett sätt att hantera olika utmaningar så som klimatförändringar, förlust av känsliga arter och värdefulla resurser. Vidare, är ekologisk design ett sätt att arbeta med lokala omständigheter och faktorer som är specifika för den givna miljön. Målet är att stärka ekologiska värden och återupprätta integriteten hos olika landskapssystem (Rottle & Yocom 2010, p. 6).

Fördelar med ekologisk design
Ekologisk design kan förbättra prestationen hos ekologiska system samt bidrar med självunderhållande miljöer som är anpassningsbara och samtidigt motståndskraftiga mot störningar. Principer för ekologisk design kan även bidra till att minska både tid och kostnader associerade med skötsel (Rottle & Yocom 2010, pp. 13, 74, 164).

Principer för ekologiska design
Det finns olika principer för att arbeta med ekologisk design. För detta examensarbete gjordes ett urval av lösningar som ansågs vara av speciell vikt för utvecklingen av Danderyds gröna infrastuktur. Dessa principer utgjordes av åtgärder för att ta tillvara på befintliga naturresurser, använda inhemska växter och stärka biologisk mångfald, hantera dagvatten, stärka gröna kopplingar samt synliggöra naturmiljöer och dess värden.

Large scale

Denna skala är betydelsefull för att skapa ett övergripande ramverk för en hållbar infrastruktur (Müller, Kelcey & Werner 2010, p. 130) och involverar bland annat etablering av ekologiska nätverk och korridorer (Yu 2006, p. 31). I detta examensarbete utgjordes den stora skalan av kommunen i sin helhet. För att lättare kunna analysera dess grönområden, delades de in i sju olika kategorier baserade på kommunens grönplan från 2012.

För den stora skalan ansågs det vara av vikt att bevara befintliga naturområden samt stärka gröna förbindelser. Att utveckla kopplingen mellan kommunens västra och östra sida samt relationen till utomstående grönområden bedömdes vara väsentlig. Gröna väggar, gröna tak, strukturer för dagvattenhantering samt skötselåtgärder betraktades som potentiella medel för att främja en hållbar grön infrastruktur på denna skala.

Intermediate scale

Denna skala involverar etableringen av ett grönt infrastruktursystem med funktioner av vikt för både ekologiska och sociala värden (Yu 2006, p. 31). Stadsdelen Stocksund valdes som utgångspunkt för studier på mellanskalan. Belägen i den södra delen av kommunen är stadsdelen relativt isolerad från de större naturområdena och har många små grönytor med bristande förbindelser sinsemellan. I likhet med den stora skalan, delades grönområdena för mellanskalan in i olika kategorier för att underlätta vidare analyser.

För denna skala blev det av vikt att stärka kopplingarna mellan stadsdelens olika grönområden. Potentiella gröna länkar bedömdes finnas längs kuststräckan, i stadsdelens centrala delar samt i dess norra utkant. Strukturer för dagvattenhantering så som regnträdgårdar och swales ansågs kunna stärka både hantering av vatten samt fungera som sammanbindande korridorer. Åtgärder för att gynna biologisk mångfald och introduktion av alternativ till den traditionella gräsmattan föreslogs som komplement i stadsdelens parker. Ytterligare, ansågs utökade möjligheter att nå stadsdelens naturområden vara av vikt.

Small scale

På den lilla skalan integreras ekologiska tillvägagångssätt med gestaltningen av en specifik plats (Yu 2006, p. 31), där målet är att stärka och återställa dess förutsättningar (Müller, Kelcey & Werner 2010, p. 133). Ovala parken belägen i västra delen av Stocksund valdes som representant för den lilla skalan. Parken har en formell karaktär med en stor andel gräsyta och närhet till hårdgjorda trafikmiljöer.

För denna skala blev det av vikt att undersöka hur dagvattenhantering kunde stärkas samt hur alternativ till den traditionella gräsmattan kunde minska graden av skötsel. Utveckling av en befintlig damm samt gräsfria-gräsmattor undersöktes. Även kopplingar till närliggande grönstråk ansågs kunna stärkas. Ytterligare bedömdes parken kunna utgöra en plattform för att introducera nya ekologiska lösningar i en central miljö.

Diskussion

Syftet med detta examensarbete var att studera den gröna infrastrukturen i Danderyds kommun för att undersöka hur ekologiska designprinciper kan stärka en hållbar utveck-

ling. Studien antydde att en implementering av ekologiska principer har potential att medföra sociala, ekologiska och ekonomiska fördelar. Genom att använda alternativ till den traditionella gräsmattan ansågs den biologiska mångfalden kunna stärkas och skötselåtgärder minska. Bevarande av befintlig vegetation samt introduktion av nya dagvattenlösningar bedömdes vara av vikt för att stärka både gröna kopplingar och vattenhantering. Sådana åtgärder ansågs även kunna bidra till ett ökat intresse för utvecklingen av en hållbar grön infrastruktur i kommunen.

DEFINITIONS

Green infrastructure

Green infrastructure consists of a variety of natural areas of different character, which may vary in size, function and ownership (Benedict & McMahon 2006, pp. 12, 14). It forms a network which can consist of a combination of parks, gardens, parkways, cemeteries and abandoned wastelands (Ignatieva & Ahrné 2013, p. 7), urban forests and stream corridors (Rottle & Yocom 2010, p. 48).

Ecological design

Ecological design can be described as design solutions which integrate human needs at the same time as the health of natural systems is supported. It is a means of generating resilience, enrich biodiversity and stimulate natural systems to become self-sustaining. Further, it promotes working with local conditions and factors inherent to a specific environment in order to enhance ecological values and re-establish the integrity of landscape systems (Rottle & Yocom 2010, p. 6).

Sustainable design

Sustainable design concerns the conservation of resources and includes environmental as well as social and economic values. Efficient use of materials, recycling and reuse are important aspect of the sustainability concept. The primary aim is to conserve and manage resources with as small a net loss as possible over time (Rottle & Yocom 2010, p. 78).

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INTRODUCTION

This chapter gives an introduction to the subject of this master thesis. It presents purpose and scope, research question, limitations and target group.

INTRODUCTION

One of the most predominating challenges in today's urban development is the formation of sustainable environments. Over the past several decades, there has been a shift in the global population from a more rural allocation to an urban one, a trend which has been anticipated to increase during the pending century (Rottle & Yocom 2010, pp. 18-19). As a consequence, densification of cities has become an ideal for the urban structure where green areas in many cases have been regarded as a reserve for future exploitation (Boverket 1994, p. 10).

There are several benefits with a more densely built city. With regard to the environment, it can result in less travel between distant locations which in turn reduces the amount of air-polluting emissions from vehicles. Further, it limits the formation of new suburbs far from the city core, reducing urban sprawl. However, the pursuit of a denser city environment also leads to fragmentation of green areas as they are being claimed for different types of development. As a result these increasingly dispersed areas receive a lessened ability to serve functions of value for both humans and the environment (Boverket 1994, pp. 10-11).

According to the Swedish Environmental Protection Agency, common ramifications of the exploitation of today's societies are an increase in the amount of impervious surfaces and amplified barrier effects. In turn, this causes a rise in the amount of stormwater runoff and leads to lowered functions of remaining green structures (Naturvårdsverket 2009, p. 58). In addition, the urban environment has become a platform for the creation of homogenous landscapes inspired by the principles of the picturesque, gardenesque and modernist styles. As a result, numerous international urban green spaces consist of large areas of highly maintained lawns in combination with small groups of scattered trees, shrubs and flowerbeds (Ignatieva 2018, p. 216).

Traces of such designs can be found in urban green areas worldwide and are based on a compilation of specifically selected plants. These plants are grown in global nurseries although originating from different parts of the world. According to Ignatieva, this use of similar plant material and planning principles for urban spaces is leading to a loss of biodiversity and increasing costs with regard to management and maintenance (Ignatieva 2018, p. 216).

Thus, over the past several decades new design aesthetics for urban areas have begun to emerge which are more strongly founded in ecological approaches to design. Often these practices are more focused on the context of

site and seek to regenerate and strengthen its natural processes. In doing so, these approaches aim to create productive, biodiverse landscapes which promotes the protection and reuse of resources. According to Rottle and Yocom, choosing an ecologically grounded approach to the design of existing and newly developing urban areas decreases the environmental impact at the same time as social values are enhanced (Rottle & Yocom 2010, pp. 18, 162). Moreover, it offers manners in which to address concerns regarding biodiversity and sustainability of urban environments on different scales (Müller, Kelcey & Werner 2010, p. 129).

In Sweden, the region of Stockholm is exposed to a continuous loss of biodiversity. This is partly due to the high degree of exploitation, resulting in fragmentation and loss of green structures (Danderyds kommun 2016, p. 9). The inhabitants are steadily increasing, resulting in the construction of new developments and densification of the city core and surrounding municipalities. The municipality of Danderyd, located north of Stockholm, constitute one of these areas which is currently undergoing a substantial increase in the amount of developments (Danderyds kommun 2013a, p. 119). In the face of such changes, there is a growing need to evaluate existing green areas and plan for the future development of the green infrastructure.

Purpose and scope

This master thesis concerns the green infrastructure in the municipality of Danderyd. The aim is to investigate how ecological design approaches can be applied to make it more sustainable in the face of challenges. The results could constitute an aid in the development of a sustainable green infrastructure in the municipality itself and in other environments with similar conditions. Furthermore, the thesis aims to provide a means of sharing experiences with regard to ecological design solutions in this particular region.

Research question

How can ecological design approaches be used to support a sustainable green infrastructure in the municipality of Danderyd on different scales?

Limitation

The study was geographically limited to the municipality of Danderyd and thematically to the green infrastructure of the municipality and principles for ecological design. The project was further limited to three different scales; large, intermediate and small. The large scale was limited to the municipality borders, the intermediate scale to the district of

Stocksund and the small scale to the confines of Ovala parken (the Oval Park) located within the same district.

Target group

The target group primarily consists of municipalities, landscape architects, landscape architecture students, city planners, politicians and other occupational groups involved in the development of our environments. Moreover, the thesis addresses an international audience and aims to present possible ways of working with ecological design under the conditions specific to the region of investigation. Thus seeking to share experiences and potentially strengthening the general knowledge base regarding ecological design solutions.

METHODS

This chapter presents a description of the methods used during this master thesis. The study is comprised of three main phases; a literature study, a case study and the production of plans and visualizations.

METHODS

This section presents the methods used during the course of this master thesis. A literature study concerning the concepts of green infrastructure and ecological design is introduced. Further, a case study including the review of municipal documents, division into scales, SWOT-analysis and the development of guiding principles is presented. Lastly, the production of plans and visualizations is described.

Literature study

A literature study was conducted in order to gather information on green infrastructure and ecological design. Emphasis was placed on finding definitions, aims and strategies for working with these two concepts.

Search engines and literature recommendations
Books and scientific articles were found through the search engines Primo and Google Scholar. Keywords used in the search were; green infrastructure, ecological design, urban biodiversity, sustainable cities, sustainable city planning, low impact design, connectivity, greenways and globalization. Further literature was obtained through references in the scientific articles found through the search engines presented above. The chapter *Biodiversity-friendly designs in cities and towns: towards a global biodiversinesque style* (2018) by Ignatieva, was recommended by and acquired with the help of Professor Maria Ignatieva.

Urban green infrastructure
The main literature with regard to green infrastructure consisted of the books; *Green Infrastructure: Linking Landscapes and Communities* (2006) by Benedict and McMahon and *Green infrastructure: A Landscape Approach* (2013) by Rouse and Bunster-Ossa.

The authors of the first publication, Mark Benedict and Edward McMahon, possess knowledge within the fields of ecology, sustainability and design. Benedict has a PhD in botany/plant ecology (Island press n.d. b), while McMahon is an authority on sustainable development, land conservation and urban design who has coordinated several prosperous efforts to protect both urban and wilderness areas (Island press n.d. a). The book contributed with definitions of green infrastructure, information concerning planning of green infrastructure and the benefits thereof. Furthermore, it provided a description of the components of green infrastructure, as being composed of hubs, links and sites.

The second book of interest, with regard to green infrastructure, provided information concerning the benefits of a developed green infrastructure network. These benefits were di-

vided according to different categories, among which benefits for ecology and community were found. David Rouse is a landscape architect, whose projects include comprehensive plans for different scales, system plans for parks and open spaces as well as urban design plans. The second author, Ignacio Bunster-Ossa, is also a landscape architect. Moreover, he is a leading practitioner of an urban design approach which amongst other things combines ecology, community, infrastructure and recreation into its framework (Rouse & Bunster-Ossa 2013).

Ecological design

Literature regarding ecological design primarily consisted of the book *Ecological Design* (2010) by Rottle and Yocom and a compilation of scientific articles written by Ignatieva and various co-authors.

Nancy Rottle is an Associate Professor at the University of Washington who has dedicated large parts of her career on the theory and practice of ecological design and planning. In addition, she directs research regarding urban green infrastructure. Ken Yocom, PhD is an ecologist and landscape architect whose research focuses on the incorporation of ecological approaches in design practices (Rottle & Yocom 2010). Their publication, *Ecological Design*, provided a base for developing a general knowledge of what ecological design is. Further, it contributed with definitions, benefits and information regarding different approaches of working with ecological design.

Maria Ignatieva is a Professor at the Department of Urban and Rural Development at the Swedish University of Agricultural Sciences. She has a Master in Landscape Architecture and a PhD in botany and urban ecology. Her research projects concerns urban ecosystems, biodiversity and the development of principles for ecological design. Focus of later research has been the investigation of lawns as a social and ecological phenomenon (Ignatieva & Ahrné 2013, p. 9). Her publication, *Biodiversity-friendly designs in cities and towns: towards a global biodiversinesque style* (2018) provided a base for understanding different ways of working with ecological design and presented an introduction to the use of alternative biodiverse lawns.

Additional articles such as *Low Impact Urban Design and Development (LIUDD): matching urban design and urban ecology* (2008) by Colin, Ignatieva and Stewart presented different manners in which to work with native plants and stormwater management. *Biodiverse green infrastructure for the 21st century: from "green desert" of lawns to biophilic cities* (2013) by Ignatieva and Ahrné provided information

regarding homogenization of urban environments, benefits of introducing green roofs and green walls as well as alternative lawns. Lastly, *Planning and design of ecological networks in urban areas (2011)* by Colin, Ignatieva and Stewart introduced methods on how to increase the health and connections within ecological networks.

Case study - municipality of Danderyd

In order to further investigate the theories amassed through the literature study, a case study of the municipality of Danderyd was performed. According to Press Academia, a case study can be described as a strategy of research which investigates a particular phenomenon within its actual context (Press Academia n.d.). Thus, offering a means to apply the principles of the literature study in a real-life environment.

Study of municipal documents
A background study was conducted with regard to the history, present and future conditions of the municipality. Such publications, concerning the green infrastructure of Danderyd, were obtained through the municipality's website.

Information regarding categorization of green structures was found through the municipality's Green Infrastructure Plan (*Grönplan Danderyd 2011-2015*), published in 2012 by Almén, Hasselblom, Lind and Novakovic. This document also offered information concerning the current planning framework and future aims of the municipality. Furthermore, the publications *Naturbeskrivning (2012)* and *Naturmiljöer och biologisk mångfald* (2013) gave a more detailed description of the region's natural areas and vegetation. Information regarding grasslands was obtained through the municipality's website, enabling a greater insight of how these environments are managed within the municipality. Moreover, information concerning future development was acquired through the document *Miljökonsekvensbeskrivning (2013)*, while the publication *Miljöprogram (2016)* provided information regarding present and future challenges.

Compilation of collected material and division into scales
The material assembled through the initial inventory performed in 2017, literature study and review of municipal documents was compiled and related to three different scales. It became a manner in which to divide the study into a more manageable format for analysis and formation of guiding principles for future development.

The scales consisted of large, intermediate and small scale. The large scale focused on the municipality as a whole, dealing with issues such as general decline in biodiversity, landscape protection, ecological networks and corridors. The intermediate scale was constituted by a smaller district and concerned the formation of an integrated green framework within its urban structure, dealing with issues related to stormwater management, biodiversity protection and restoration. Lastly, the small scale concerned an individual park, focusing on site specific design and strengthening of its present conditions.

SWOT - analysis
A SWOT-analysis was performed for each scale; large, intermediate and small. Such an analysis takes into consideration the strengths, weaknesses, opportunities and threats of a specific landscape, which enables one to more clearly discern the possibilities and challenges of the environment. Strengths and weaknesses represent internal factors, whereas opportunities and threats are used to analyze external factors (Boverket 2006, p. 44).

The main aim of the analysis was to organize the collected material into a more manageable form with focus on possibilities and challenges of the different scales. It became a manner in which the information gathered from the initial inventory could be transformed to better comply with the different scales, instead of the individual sites, and at the same time be combined with knowledge obtained through literature studies.

Guiding principles
Guiding principles for future sustainable development were produced for each scale. The principles were based on the results of the individual SWOT-analyses and organized into five different categories of ecological approaches to design. The categories consisted of; *Protection, restoration and rehabilitation; Native plants and biodiversity; Stormwater collection and cleansing; Connecting fragmented patches* and *Reveal, immerse, teach* and were chosen based on the current and future needs of the municipality shown through the analyses.

Production of plans and visualizations

The information gathered from literature studies, inventories and analyses was processed and presented in the form of visualizations and plans. All illustrations in this project are made by the author in Adobe Illustrator. Working with digital programs presented an efficient way of managing information and different

layers, as compared to working with hand-made sketches. Further, it enabled an interactive way of color coding different areas and turning on and off different features, which made it easier to study different connections and scenarios.

The plan showing categorization of green structures is based on a topographic map from Lantmäteriet and a plan showing divisions of natural areas illustrated on page 7 in the municipality's Green Infrastructure Plan, produced in 2012. The latter guided the classification and location of different green structures, whereas the former contributed to the general structure, borders and infrastructure of the municipality.

Additional plans presented in this project, showing the comprehensive structure of the municipality and districts, were produced by studying topographic maps from Lantmäteriet on different scales. Further, the illustration showing the small scale park, was developed based on an orthophoto from Lantmäteriet. The visualization showing hubs, links and sites has been redesigned with inspiration from an illustration by Maryland Department of Natural Resources presented on page 13 in *Green Infrastructure: Linking Landscapes and Communities* (2006) by Benedict and McMahon.

URBAN GREEN INFRASTRUCTURE

This chapter presents an introduction to the concept of green infrastructure. What is it? Why is it important? How is it organized in the urban framework?

WHY GREEN INFRASTRUCTURE?

In this section the concept of green infrastructure is investigated in order to discern its definition, aims, benefits, planning framework and structure.

Introducing green infrastructure

According to Benedict and McMahon green infrastructure can be defined as

> "*an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife"* (Benedict & McMahon 2006, p. 1).

This network can consist of a combination of parks, gardens, parkways, cemeteries and abandoned wastelands (Ignatieva & Ahrné 2013, p. 7), urban forests and stream corridors (Rottle & Yocom 2010, p. 48).

According to Benedict and McMahon green infrastructure originates from two fundamental initiatives. The first addresses the protection and linkage of green spaces for the benefit of people in terms of recreation, health and aesthetics. In contrast, the second initiative considers the preservation and linkage of natural areas in order to promote biodiversity and counteract habitat fragmentation, thus aiming to protect native species, natural processes and ecosystems (Benedict & McMahon 2006, p. 16).

Czechowski, Hauck & Hausladen support this theory and states that green infrastructure aims to preserve, construct and connect habitats and green spaces by identifying areas that provide relevant ecosystem services and connecting them into a network. Such a network forms a spatial organization that accumulates and distributes these services over larger areas, increasing the benefits for both the human community and the environment (Czechowski, Hauck & Hausladen 2015, pp. 20-21).

Consequently the green infrastructure of a city or municipality forms an umbrella for both ecological and social values of the urban environment.

Benefits of green infrastructure

Green infrastructure provides significant ecosystem services, contributes to biodiversity and social values and has the ability to affect environmental and economic conditions in a positive manner (Ignatieva & Ahrné 2013, p. 1). Rouse and Bunster-Ossa states that green infrastructure has several benefits with regard to ecology. Among these are preserving and restoring ecosystems and providing habitats for native animal and plant species. Moreover, it has the capacity to absorb storm water and reduce runoff, lessening the risk of flooding and erosion. The green structure of the urban environment also has the ability to moderate local climate and decrease the heat island ef-

fect. It can improve environmental conditions by cleaning air and water as well as mitigating climate change by storing carbon and contributing to a decrease in energy consumption (Rouse & Bunster-Ossa 2013, p. 12).

There are also several benefits with regard to the community. According to Rouse and Bunster-Ossa, a well developed green infrastructure has numerous benefits for people as it provides increased access to green areas and opportunities for recreation. In addition, green infrastructure can promote public health by improving environmental quality and by enabling people to incorporate walking and biking as a part of their daily routine (Rouse and Bunster-Ossa 2013, p. 13). Rottle and Yocom state that improved physical health, mental restoration, education and inspiration are some of the benefits that stem from increased human contact with nature (Rottle & Yocom 2010, p. 6).

Moreover, the implementation of green infrastructure can create a stronger connection between people and nature (Rouse and Bunster-Ossa 2013, p. 13). According to Lafortezza et al, green infrastructure can contribute to an increased engagement in the landscape, thus providing cultural, ecological and psychological linkages between people and their environs (Lafortezza et al. 2013, p. 104). Such personal connections to the natural world is something which Rottle and Yocom argue may foster a sense of stewardship of nature, leading to a self-reinforcing process with beneficial effects for both humans and the environment (Rottle & Yocom 2010, p. 6).

Planning for green infrastructure

Green infrastructure planning provides a different approach to the conservation of land and protection of innate resources. By implementing methods for preservation in concord with land and infrastructure planning, allowing for contact with nature in combination with urban functions, green infrastructure provides an imperative framework for conservation development. It aids in the identification of opportunities for preservation as well as for development. Moreover, green infrastructure planning offers assistance in prioritizing areas for future expansion, thus optimizing land-use to better accommodate the needs of both the human community and the natural environment (Benedict & McMahon 2006, p. 2).

A green infrastructure plan can help identify key lands of importance with regard to future conservation and restoration efforts. In areas anticipating growth, such a plan can act as a guide that helps steer the location and shape of future development (Benedict & McMahon 2006, pp. 3-4).

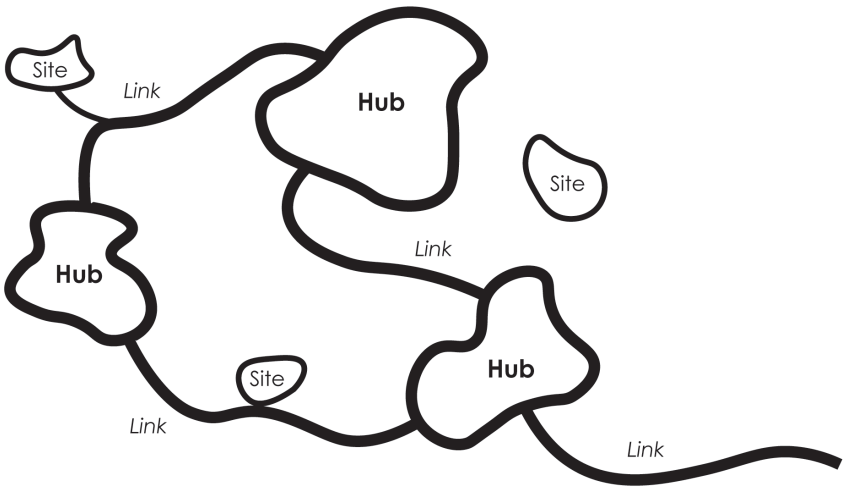


FIGURE 1 Illustrating a green infrastructure network consisting of hubs, links and sites.

Structure of green infrastructure

Green infrastructure embodies a variety of nature areas of different character. These areas may vary in size, function and ownership and constitute both green and blue values. Estuaries and waterways are equally important components in any green infrastructure network as areas that are perceived as green (Benedict & McMahon 2006, pp. 12, 14).

Thus, green infrastructure can encompass conserved nature areas such as woodland habitats, wetlands and riparian zones. It can include both public and private conservation areas, constituted by nature reserves, wildlife corridors, national and state parks. Moreover, working lands such as forests and farms are also included in the green infrastructure concept as well as additional open space such as parks and greenways (Benedict & McMahon 2006, p. 12).

A green infrastructure network can be described as consisting of a system of hubs, links and sites (*Figure 1*) which connects these natural areas and affiliated ecosystems together (Benedict & McMahon 2006, p. 13).

Hubs
Hubs can be considered as anchors in the green infrastructure network. They provide habitats for native plant and animal species and constitute the provenance for the ecological processes operating within the system. Hubs can vary in size and shape, however they often function as a source or destination for people and wildlife. They include large reserves such as state parks and forests, farmlands, regional parks and reserves as well as community parks and green areas subjected to measures of protection or restoration (Benedict & McMahon 2006, p. 13).

Links
Links constitute the ties that bind the network together. They form connections which are essential in order to uphold fundamental ecological processes and maintain the health and biodiversity within the system. Such links may serve as corridors and connect existing parks, preserves and natural areas and at the same time provide adequate room for plant and animal species to thrive. Thus reinforcing ecosystems and enhancing opportunities for recreation (Benedict & McMahon 2006, p. 13).

Sites
Sites are also included in the green infrastructure network. They can serve as contributors of social and ecological values by providing areas for recreation and natural habitat protection. Sites are smaller than hubs and may or may not be connected to a larger community or regional conservation system (Benedict & McMahon 2006, p. 14).

ECOLOGICAL DESIGN

This chapter presents an introduction to the concept of ecological design. What is it? Which benefits and approaches are there to working with ecological design?

WHAT IS ECOLOGICAL DESIGN?

In this section the concept of ecological design is investigated in order to decipher its meaning and potential use in a green infrastructure framework.

Introducing ecological design

According to Rottle and Yocom, ecological design can be described as solutions which integrate human needs at the same time as the health of natural systems is supported. It is a means of generating resilience in the face of impending natural disturbances and aims to enrich biodiversity and stimulate natural systems to become self-sustaining in order to form stability for both human and non-human populations (Rottle & Yocom 2010, p. 6).

In the urban environment, ecological design can be seen as a fashion in which to cope with challenges such as climate change, loss of sensitive species and valuable resources. It is a way of working with local conditions and factors inherent to a specific environment in order to enhance ecological values and re-establish the integrity of landscape systems (Rottle & Yocom 2010, p. 6).

Rottle and Yocom state that ecological design can be defined as both a verb and a noun (Rottle & Yocom 2010, p. 13). As a verb they explain that

> "*it embodies a series of actions that include the initiation of design concepts aimed at improving environmental health, developing those concepts into plans based upon the particular qualities and processes of places, and the implementation of detailed plans while responding to the dynamics of change over time* (Rottle & Yocom 2010, p. 13).

On the other hand, as a noun Rottle and Yocom describe that ecological design

> "*exists in the form of healthy, regenerative systems and components of our built environments. From parks and preserves, to buildings and streets, an ecological approach to design can be integrated into the fabric of our communities, serving as a new kind of infrastructure*" (Rottle & Yocom 2010, p. 13).

Thus implying that the concept could be integrated in the very system of green networks that build up our cities and municipalities.

In a broader perspective, Van der Ryn and Cowan (1996) define ecological design as

> "*any form of design that minimizes environmentally destructive impacts by integrating itself with living processes*" (Van der Ryn & Cowan 1996, p. 33).

Benefits of ecological design

Ecological design is beneficial for improving the performance of ecological systems and offers a more resilient alternative to the planning of the built environment. Moreover, it supports the development of self-maintaining environments which are adaptive yet resilient to disturbances. Further, ecological design can contribute to actively shaping the structures and processes of complex environments in such a way that ecological integrity can be maintained or even strengthened (Rottle & Yocom 2010, pp. 13, 14, 74).

Van der Ryn and Cowan states that design should be seen as a response to precise knowledge of place. They mean that this specific knowledge is the starting point of ecological design (Van der Ryn & Cowan 1996, pp. 72, 77), aiming to enhance rather than lessen local ecological integrity (Rottle & Yocom 2010, p. 16). Thus, advocating the ecological aspect in design provides methods for reducing the use of resources as well as preserving a diversity of habitats and increasing community health (Van der Ryn & Cowan 1996).

By promoting the role of ecology in design, specific methods for reducing pollution and the use of energy and materials are provided (Van der Ryn & Cowan 1996). As maintenance often constitutes a time consuming and costly factor with regard to energy consumption, principles of ecological design can aid in the reduction of both time and costs associated with maintenance in designed landscapes (Rottle & Yocom 2010, p. 164).

Moreover, ecological design helps support the preservation and restoration of biological systems so that healthy and diverse communities of native plants and animal species can be secured. Biodiversity is of importance since it enhances the resilience of an ecosystem to respond and acclimate to change. Research conducted on the planets ecosystems reveals that global biodiversity is declining, thus making issues related to biodiversity of principal significance (Rottle & Yocom 2010, pp. 54, 56).

DESIGN WITH ECOLOGICAL APPROACHES

This section presents different ecological design approaches which, based on performed inventories and analyses of the municipality, were deemed to be of importance for this particular project. Below, measures to protect existing nature areas, work with native plants and biodiversity, manage stormwater, connect fragmented patches of nature and encourage information and stewardship are presented.

Protection, restoration and rehabilitation

In this category principles for protecting and developing existing nature values are presented. The significance of water habitats and existing parks is investigated as well as the role of maintenance in ecological design.

Particularities and values of place
Van der Ryn and Cowan emphasize that solutions should develop from the unique qualities of place and that this aspect is often omitted in standardized design. They state that a deep and rich understanding of ecology must seep into the design of our built and natural environments as many design possibilities are lost due to homogenization and ignorance of the particularities of site (Van der Ryn & Cowan 1996, pp. ix, 3, 72).

According to Rottle and Yocom, it is important to protect existing biological values and native ecological functions as the measures required to restore ecosystems are much more complex than maintaining existing ones. It takes time for a landscape to reach a point of ecological integrity, thus it is significant to safeguard the components of such healthy systems (Rottle & Yocom 2010, pp. 86, 89, 106). In concurrence, Claes Florgård states that one of the most prominent concerns regarding the preservation of natural vegetation is that once lost it cannot simply be replaced by planting new species. He argues that biological and aesthetical values take decades or even centuries to establish (Müller, Kelcey & Werner 2010, p. 493).

Furthermore, Rottle and Yocom emphasize that water habitats and their edges are of significant importance when it comes to the protection and restoration of landscapes. They argue that such environments constitute one of the most diverse habitats with regard to the composition of plant and animal species. In addition, they state that existing parks can be used to increase the function of ecological processes as well as provide a framework for the creation of new habitats and production of new resources (Rottle & Yocom 2010, pp. 89, 156).

Maintenance as a design tool
Biological and physical conditions are ever changing, as vegetation grows and circumstances of the surrounding environment change. Thus, maintenance is a critical component of ecological approaches aiming to protect and rehabilitate landscape values (Rottle & Yocom 2010, p. 94).

Establishing a maintenance plan facilitates the continued survival of desired ecological processes. By enforcing maintenance actions such as regular controls, securing the flow of water systems and clearing of invasive species, ecological conditions of a site can be improved. A common measure of rehabilitation is to introduce plant material which is adapted to the current conditions of the site and will support coveted ecological processes (Rottle & Yocom 2010, pp. 86, 94).

Moreover, by developing an adaptive approach to management, where a project can be systematically evaluated, future adjustments are facilitated. Thus, the likelihood of enhancing ecological conditions of a site increases (Rottle & Yocom 2010, p. 95).

Summary: Protection, restoration, rehabilitation

- Safeguard existing biological values and native ecological functions
- Protect and restore water habitats and their edges
- Use existing parks to improve ecological functions and create new habitats and resources
- Use maintenance as an important tool to protect, restore and rehabilitate green areas

Native plants and biodiversity

In this category the significance of biodiversity and principles for working with native plant material are investigated. Furthermore, alternatives to the traditional lawn are introduced.

Urban biodiversity and native vegetation
At the present there are several approaches to increase native biodiversity (Ignatieva, Stewart & Meurk 2008, p. 62). Kongjian Yu, one of the pioneers within ecological design, states that landscape architecture should be regarded as an art of survival and argues that very simple skills and common native plants can be used to solve complicated issues. He signifies that landscape design should be in harmony with the processes of nature as well as the sustainable wellbeing of the human community (Yu 2006, p. 25, 35). In concurrence, Ignatieva means that designing with biodiversity is one of the essential parts in supporting urban sustainability (Müller, Kelcey & Werner 2010, p. 140).

Furthermore, Lennartsson and Simonsson argue that biodiversity is of great significance with regard to climate change and the effects thereof, further elaborating that the buffering and producing capacity of the ecosystems will be needed when the climate changes (Lennartsson & Simonsson 2007, p. 1). Designing with native plants can be a means of enhancing indigenous biodiversity (Müller, Kelcey & Werner 2010, p. 137). As plants that are native to a specific environment have acclimatized to the local conditions, fewer resources are required to support them. Thus, once established, they constitute a low maintenance alternative which at the same time offers habitat possibilities for different wildlife species (Rottle & Yocom 2010, p. 163).

Moreover, developing multi-layered planting designs further increases biodiversity and enhances the ability to sustain a more comprehensive variety of plant and animal species. Habitats that offer an assortment of large canopy trees, smaller trees, different types of shrubs as well as native grasses and ground vegetation can help establish such favorable conditions. By appropriate selection and placement of native plants, endemic ecological environments can be re-established (Rottle & Yocom 2010, pp. 156, 163).

Street trees, planting strips and green roofs
Native species can be used in the streetscape, along roads as street trees or in different types of plantings (Ignatieva, Stewart & Meurk 2008, pp. 70-71). Street trees have the ability to improve local conditions for wildlife and at the same time enhance the human environ-

ment by reducing the urban heat island effect. Effectively providing shade for roads and sidewalks. Furthermore, the use of planting strips can introduce diversity into the street environment as well as provide a varied assortment of habitats. Selecting a diverse set of species, including flowering and fruiting ones, can generate planting strips that constitute significant food sources for wildlife in the urban environment (Rottle & Yocom 2010, p. 140).

According to Ignatieva and Ahrné, green roofs also constitute an important component for increasing biodiversity in the urban landscape (Ignatieva & Ahrné 2013, p. 5). Green roofs can be covered by vegetation in varying degrees and have the potential to function as a platform for the use of native species (Ignatieva, Stewart & Meurk 2008, p. 71). Furthermore, they provide favorable conditions for different types of insects and pollinators (Veg tech n.d. d).

Alternative lawns

Indigenous plants can also be used in alternative, biodiverse lawns (Ignatieva, Stewart & Meurk 2008, p. 71). According to Ignatieva and Ahrné, lawns constitutes one of the most prevalent components in the green infrastructure of urban environments (Ignatieva & Ahrné, 2013, p. 2) and covers up to 70 percent of urban open space. It exists in both public and private gardens as well as make up the groundcover in cemeteries, golf courses and sport fields. Lawn can also be found in smaller areas such as those along the sides of roads (Ignatieva 2018, p. 220).

Ignatieva and Ahrné state that the environmental effects of lawns are closely related to the intensity of management. Measures such as frequent mowing, use of herbicides and fertilizers have negative impacts on the environment, biodiversity and human health. However, they also indicate that low intensity managed lawns may have positive environmental impacts, providing potential ecosystem services to urban environments. Examples of such services include recreation, pollination as well as management of water, nutrients and carbon (Ignatieva & Ahrné 2013, pp. 2-4).

Research performed in urban environments has shown that lawns are very similar when it comes to the composition of plant species. In Sweden, the majority of lawns are comprised of grass hybrids which originate from a confined number of nurseries and seed mixtures, thus forming habitats which have no counterpart in the native local landscape (Ignatieva & Ahrné 2013, p. 3).

Lately, Swedish lawns have been a subject of research through the project "*Lawns as an eco-*

logical and cultural phenomenon. Searching for sustainable lawns in Sweden", aiming to create alternative lawns based on local plants adapted to the northern climate. This approach seeks to develop biodiverse, cost-effective plant communities which also hold aesthetic qualities (Ignatieva 2018, pp. 224, 226).

Examples of such alternative lawns are those adapted for bumblebees and butterflies, lawns established on tough soils with high gravel content as well as different types of meadows and grass-free lawns. The grass-free alternative has the ability to provide a low-growing flowering carpet, consisting of native species, suitable for recreational use. Additionally, the grass-free lawn is relatively low in maintenance, needing to be cut only two to three times during the summer season (Ignatieva 2018, pp. 226, 227).

Promoting the design with native plants is a manner in which to introduce and bring forth the distinctiveness of the local flora, contributing to both visual and ecological values in the parks, gardens and streetscapes of the urban environment (Müller, Kelcey & Werner 2010, p. 137). Although the use of native plants has many benefits, some functions may require plant species which are not native to the local environment. In such circumstances, the aim should be to use non-invasive species suitable for the conditions specific to the site of concern (Rottle & Yocom 2010, p. 163).

Summary: Native plants and biodiversity

- Develop planting designs that establishes and supports a multi-layered habitat
- Use native species in the street environment, as street trees and in planting strips
- Use native plants on green roofs and in alternative lawns
- Develop alternative lawns adapted for wildlife and biodiversity
- Use of non-invasive species

Stormwater collection and cleansing

In this category principles for managing stormwater are presented. The concepts of rain gardens, swales, pervious surfaces, green roofs and green walls are introduced.

Stormwater management
Stormwater is increasingly treated through the aid of landscape structures, providing alternative solutions for its collection and cleansing (Rottle & Yocom 2010, p. 138). Generally, stormwater contains suspended material, oxygen consuming substances, nutrients and heavy metals which can cause problems with regard to water quality in lakes and watercourses (Veg tech n.d. c) and degrade the ecological conditions of these receiving water bodies (Rottle & Yocom 2010, p. 150).

Some environmentally sensitive approaches to managing stormwater in urban environments consist of introducing rain gardens, open swales and using ecologically liable pervious surfaces (Ignatieva, Stewart & Meurk 2008, p. 61). According to Ignatieva and Ahrné, the continued densification of urban areas also calls for the consideration of alternative placement of green structures. In addition to green areas located on the ground level, there is a need to investigate the potential for introducing green roofs and walls into the composition of developing urban environments (Ignatieva & Ahrné 2013, p. 4).

Rain gardens
A rain garden is a permeable planting bed that is used to delay, infiltrate and clean stormwater (Veg tech n.d. c). Precipitation and run-off is collected in the planting bed during rainfalls and dries out when the wet period has ended (Rottle & Yocom 2010, p. 164). Starting as a fine scale solution for managing stormwater in subdivisions and private gardens, rain gardens have been further developed and are now used with success even in the street environments of cities (Veg tech n.d. c).

Stormwater from roofs, roads and other impervious surfaces is lead to adjacent rain gardens where the plants clean and evaporate large parts of the water before the excess is infiltrated through the planting bed (Veg tech n.d. c). Plants are mainly chosen based on their capacity to tolerate conditions of surplus stormwater runoff from adjacent areas. However, rain gardens also have the potential to contribute to high aesthetic values depending on the design and plant material chosen (Ignatieva, Stewart & Meurk 2008, pp. 70-71).

Swales
Swales are constituted by gently sloping vegetative depressions which offer a cost-efficient manner in which to manage stormwater. They can aid in the treatment of stormwater runoff originating from roofs, streets and impermeable surfaces and can be planted with an assortment of trees, shrubs, grasses and additional types of ground covers (Environmental Services City of Portland 2006, p. 1).

As the water is lead along the course of the swale, the plants help slow and filter the run-off, allowing it to be cleansed of sediments and contaminants. Plants are chosen based on their ability to tolerate both wet and dry soil conditions (Environmental Services City of Portland 2006, p. 1), as well as for their capacity to absorb and manage water and pollutants (Ignatieva, Stewart & Meurk 2008, p. 70). Moreover, swales can provide habitats for wildlife and at the same time contribute to aesthetical enhancement of the urban landscape (Environmental Services City of Portland 2006, p. 1).

Pervious surfaces
Hard surfaces such as roads and impermeable walkways generates stormwater run-off during rainfalls. Creating opportunities to manage the polluted water caused by these surfaces can reduce the impacts on downstream recipients.

One manner in which to improve ecological conditions, with regard to stormwater, is by reducing the impervious areas of the streetscape (Rottle & Yocom 2010, p. 150).

Permeable substrates function as filters by enabling water to flow through the soil while detaining contaminants. Planting strips can be a useful approach in order to ameliorate the effects of stormwater by lowering the amount of hard surfaces. At the same time such plantings form visible boundaries which help distinguish between different forms of transportation in the street environment (Rottle & Yocom 2010, pp. 116, 149).

Green roofs
In ecologically oriented approaches, green roofs are regarded as an important component in water management practices. The most common function of modern green roofs is related to stormwater management (Ignatieva & Ahrné 2013, p. 4), as it both delays water and reduces run-off (Veg tech n.d. d). As formerly described, green roofs may also have functions which serve other ecosystem services, such as mitigating the effect of urban heat islands and creating habitats for animals and plants (Ignatieva, Meurk, van Roon, Simcock & Stewart 2008, pp. 16).

Green roofs can either be partly or entirely covered by vegetation (Ignatieva, Stewart & Meurk 2008, p. 71) and may vary in soil depth and ability to support different types of vegetation. One variant, which is mainly adapted to retain, infiltrate and reduce stormwater is the extensive green roof. Such structures feature plants adapted to dry conditions and which grow on a thin layer of soil. In the northern hemisphere, stone crop (Sedum spp.) constitutes the most commonly used species for such green roofs (Ignatieva et al. 2008, pp. 16-17).

Green walls

Green walls are vertical, or nearly vertical, structures covered with vegetation (Urban Greening 2013, p. 1). They have a long life-span and require a relatively low degree of maintenance (Veg tech n.d. b). While many green walls are used for their aesthetic value or to help even out variations in temperature (Environmental Services City of Portland 2014), modern technologies have enabled the development of green walls which support an assortment of different plants, enabling a broad diversity of both plant species and degree of coverage (Urban Greening 2013, p. 1).

By increasing the amount of plant coverage, the measures required for stormwater management by other means can be reduced (Urban greening 2013, p. 3). Moreover, there are green wall solutions that have the ability to harvest rainwater, thus forming a self-maintaining system in which additional irrigation of the vegetated wall is rendered unnecessary (Urban Greening 2013, p. 3). At the Portland Expo Center in Oregon, a green wall has been constructed which especially treats rainwater originating from the roof. By utilizing the force of gravity, water passes through the green wall system, where native plants aid in filtering and managing the runoff (Environmental Services City of Portland 2014).

Summary: Stormwater collection and cleansing

- Increase the amount of stormwater which is controlled and cleansed through landscape treatment
- Develop rain gardens, open swales and ecologically friendly pervious surfaces
- Develop green roofs and walls

Connecting fragmented patches

In this category principles for connecting green areas into a larger network are investigated. The concepts of flows, patches and corridors are introduced.

Flows
Flows can be described as processes of movement which act within and across the landscape. It can be constituted by more perceptible movements such as that of water and different species, both human and wildlife. However, flows are also represented in the form of energies which are developed, stored and dispersed throughout the landscape (Rottle & Yocom 2010, p. 130).

Acknowledging flows, their role and effects in a landscape system, facilitates the identification of limitations and possibilities with regard to future development. Thus, the value of existing and potential connections can be assessed as new plans and site designs are being developed (Rottle & Yocom 2010, p. 130).

Patches
The main land use or habitat form in a landscape constitutes the matrix of that environment (Rottle & Yocom 2010, p. 65). Through the process of fragmentation, the matrix becomes disrupted either by human or natural changes, actively isolating landscape areas into patches. Such patches form fragments which are distinctly separated from the prevailing landscape conditions of the matrix (Rottle & Yocom 2010, p. 68).

When considering patches, their size and proximity to other areas of similar character is of significance. Larger patches offer greater possibilities for developing a high degree of biodiversity. In addition, areas which are located in close proximity to one another increases the ability of species movement between patches (Rottle & Yocom 2010, p. 69). Thus, the smaller and more scattered the green areas are, their function for human use as well as for the continued survival of plant and animal species decreases. It also affects the capacity of managing stormwater as well as the ability to improve local climate and air quality (Boverket 1994, p. 11).

The connection between the urban green areas and the hinterland is also of importance in order to maintain functioning ecosystems (Boverket 1994, p. 13). According to Ignatieva et al. (2011), urban and rural ecological networks are of particular significance since these structures may provide the only means of connectivity and movement of species in today's fragmented landscapes (Ignatieva, Stewart, Meurk 2011, pp. 17-18). In order to develop a rich diversity of green structures within the urban framework, green corridors which links these areas to the surrounding landscape are needed (Boverket 1994, p. 13).

Corridors
Corridors are linear landscape structures which have the ability to act as links between patches. By providing green corridors in the urban environment the restoration and development of a larger, connected system of open spaces can be supported (Rottle & Yocom 2010, p. 66). Further, it has been shown that corridors which are broader and curvilinear in shape are favorable to narrow, more linear ones (Müller, Kelcey & Werner 2010, pp. 162-163). While places of intersection such as crossroads may form barriers (Rottle & Yocom 2010, p. 66), it is important to acknowledge that many species, such as birds, are able to use discontinuous stepping stones for their dispersal. Thus, the need for physical continuity depends on the desired function of the corridor (Ignatieva, Stewart & Meurk 2008, p. 66).

Furthermore, when designing for biodiversity and ecosystem health it is significant to consider the different spatial scales of ecosystems and their relations. As corridors may also provide passage for less desired species depending on habitat requirements, it is valuable to assess the desired flows and potential effects between scales (Rottle & Yocom 2010, pp. 66, 89).

According to Werner and Zahner, the main benefit of corridors is their ability to support functions of value for both human and wildlife communities. In addition to aiding in the conservation of species, green corridors can provide services such as climate mitigation and constitute places of recreational value (Müller, Kelcey & Werner 2010, p. 163). Trails for walking and cycling can correlate with these green structures and connect people with nature (Ignatieva, Stewart & Meurk 2008, p. 66).

Summary: Connecting fragmented patches

- Evaluate flows, their role and effects in the landscape system
- Endeavor to develop large, coherent green areas preferable to small ones
- Increase connections between existing green areas
- Develop connections between the urban greenery and hinterland
- Seek to develop broad, meandering corridors preferably to narrow and linear ones
- Reduce points of intersections in corridors
- Combine functions within corridors which supports both people and wildlife

Reveal, immerse, teach

In this category, Rottle and Yocom's theory *Reveal, immerse, teach* is further built upon. Different principles for highlighting existing natural values and nature areas are presented and the concept of "cues to care" is introduced.

Translating landscapes
Landscapes of high ecological value often require interpretation, as they have a tendency to appear complex or unfamiliar. Symbolic markings or framings to help focus attention can lead to a greater understanding of these environs. As such site-specific understanding is often needed to foster appreciation and stewardship of the landscape, ecological design covers a much broader range of practices than simply assembling ecological functions. Consequently, it also includes evoking human appreciation for landscapes, their components and processes (Rottle & Yocom 2010, p. 124).

According to Ignatieva (2018), it is essential to establish manners in which to translate ecological processes and functions into a cultural and aesthetic language that can be more easily understood and endorsed by the public at large (Ignatieva 2018, p. 217). Furthermore, Dunnett and Hitchmough states that designs imprinted with strong nature-like characteristics must be infused with aesthetic principles which aid in their interpretation. This is especially true when it comes to the urban environment, if the design is to be understood and appreciated by the general public (Dunnett & Hitchmough 2004, p. 5).

Urban areas constitute valuable platforms for introducing information about the natural values they contain, as it is in the urban environment that most people get in contact with nature on a daily basis (Almén, Hasselbom, Lind & Novakovic 2012a, p. 9). The concept of designing with nature is an effective method for reinforcing urban biodiversity and at the same time making it more perceptible and recognizable to people (Ignatieva & Ahrné 2013, p. 6). One manner in which to introduce local plants is by using them in the streetscape (Ignatieva, Stewart & Meurk 2008, p. 70) or by having them appear next to highly frequented and important buildings (Müller, Kelcey & Werner 2010, p. 137).

Cues to care
According to Nassauer, using methods which show signs of human intent can help people to better understand and accept complex ecological environments (Nassauer 2002, p. 200). Nassauer further states that signs such as tidiness and care for the landscape constitute symbols that can be used in order to adapt

cultural expectations to recognizing new landscape forms (Nassauer 2002, pp. 200, 203). Such methods of "cues to care" make the new more recognizable. Valuable ecosystems that are at risk of giving a messy and untidy impression can thus be associated with signs which indicate that the landscape is part of a larger intended pattern. These signals may vary in appearance, but the founding principle is that they express care for the landscape (Nassauer 2002, p. 203).

There are several examples of "cues to care" created through maintenance actions. By framing areas of greater biodiversity, signs of human intention can be communicated. This can be accomplished by mowing a strip of lawn along paths, thus giving a tidy impression without having to cover large areas with continuous lawn. When considering a smaller scale, trimming and pruning of vegetation can give an impression of care for the landscape. Furthermore, linear designs such as placing plants in rows can indicate human presence and intention (Nassauer 2002, pp. 203-204).

Moreover, it is often possible to add design features which draw attention to nature areas and restoration actions. Viewpoints, frames, integrating gateways, markers and art pieces can be used in the design of a site. Further, immersive structures such as boardwalks and paths can enhance human interaction with nature and at the same time communicate signs of human care. This can in turn foster awareness and appreciation of place which result in increased stewardship of the site (Rottle & Yocom 2010, pp. 86, 124).

Summary: Reveal, immerse, teach

- Reinforce urban biodiversity and make it more visible and recognizable to the general public
- Utilize existing nature in urban areas to increase people's contact with and knowledge of nature
- Introduce local plants through their use in the streetscape and placement next to important buildings
- Use "cues to care" to indicate human intention and care; mowing a strip of lawn along paths, trimming of vegetation and use of linear planting design
- Direct attention to particular aspects of landscape through viewpoints, frames, integrating gateways, markers and art pieces
- Increase human contact with nature through immersive structures such as boardwalks and paths

Green wall located in central Uppsala, Sweden

Preserved border of vegetation in Park am Gleis-dreieck in Berlin, Germany

Stormwater management in the streetscape of Uppsala, Sweden

Alternative lawn: grass-free lawn in Uppsala, Sweden

Cues to care: trimmed hedge of alder trees frames a nature-like stormwater pond, Danderyd

Cues to care: a mowed strip of lawn along a path frames a meadow area, Danderyd

CASE STUDY DANDERYD

This chapter gives an introduction to the case study of Danderyd, providing a description of the municipality and its green infrastructure. In following subchapters an analysis of the region divided into three different scales; large, intermediate and small scale is presented.

SITE DESCRIPTION

FIGURE 2 Map showing the location of the municipality in relation to Stockholm and adjacent communities. *Based on a topographic map by © Lantmäteriet.*

This section gives an introduction to the municipality of Danderyd, its history, challenges, framework for planning and description of present work toward a sustainable green infrastructure. Lastly, future aims are presented.

Introduction to the municipality

The municipality of Danderyd is located north of Stockholm, the capital of Sweden, in close proximity to the coast which surrounds the region on three sides. It can be divided into four main district; Djursholm in the east, Stocksund in the south, Danderyd in the west and Enebyberg in the north (Meyer & Winberg 2013, p. 2). The road E18 stretches through the municipality, in a north-south direction, forming a modern-day passageway with long historic continuity (Sweco 2015, p. 4).

Until the end of the 19th century, Danderyd was characterized as an agricultural district. Nevertheless, as the population of Stockholm was expanding and the Industrialization began to change the urban environment, there was a wish for a simpler and healthier life outside

FIGURE 3 Map showing the infrastructure and districts of the municipality. *Based on a topographic map by © Lantmäteriet.*

the city. With the arrival of the railway came the opportunity to transport goods from Danderyd to the capital and a transition into a garden city began (Sweco 2015, p. 14).

The alteration from agricultural to residential district was initiated by Henrik Palme, who bought the Djursholm estate in 1889. Inspired by travels to garden cities in America, he planned Djursholm after his experiences overseas. Djursholm was fashioned as a suburb to Stockholm, with large yards and a street network which emanated from the shapes of the land. Some decade later, the construction of Stocksund was initiated with the same urban ideals as Djursholm. Later, the continued transformation from agricultural land to residential town enabled the development of Enebyberg during the beginning of the 20th century (Sweco 2015, pp. 14-15).

In 1967 Stocksunds köping was incorporated into Djursholms stad, which marked the beginning of the formation of the municipality. Subsequently, the municipality of Danderyd was formed in 1971 due to the merging of Djursholms stad and Danderyds köping (Sweco 2015, p. 4).

Challenges

The municipality is facing several challenges, some of the most prominent with regard to green infrastructure are introduced in this section.

Growth of urban areas
The municipality is anticipating a substantial rise in the amount of inhabitants. In order to be able to meet the new demands, it is predicted that the number of developments need to increase by approximately 60-110 new dwellings a year until the year of 2030 (Danderyds kommun 2013a, p. 119). In the municipality's Comprehensive Plan of 2030, the central part of Danderyd is acknowledged as an area of development for both residential areas and workplaces. This constitutes the greatest change that the municipality has initiated in modern time (Sweco 2015, p. 3).

Climatic changes and water management
Climatic changes that will most likely affect the municipality are higher temperatures, an increase in precipitation and a rise in sea level. An increase in the amount of rainfall can result in higher flows in water courses and flooding. Hence, the long coastline and low lying areas may be facing future problems with averting stormwater, a phenomenon which is perceptible even at the present during extreme weather (Meyer & Winberg 2013). Furthermore, temporary high flows in stormwater systems may result in the municipality's pumping stations reaching their limit, thus causing contaminated water to reach the recipients (Meyer & Winberg 2013, p. 14).

According to the municipality's Environmental Program (2016-2020), the coastal waters are not able to meet the Water Framework Directive's requirements with regard to a good ecological and chemical status. The largest problems are eutrophication and environmental toxins (Danderyds kommun 2016, p. 7). At the present, excess nutrients and pollutants that reach the coastal areas mainly comes from water that runs from roofs of buildings and hard surfaces (Danderyds kommun 2013a, p. 118).

Connections and access to nature
An analysis of the municipality, performed in 2015, states that there is a need to map ecological connections and recreational values in the municipality (Sweco 2015, p. 21). The road E18 constitutes a big barrier, in a north-south direction, that divides the municipality in two. This calls for the development of green links and passageways (Almén, Hasselbom, Lind & Novakovic 2012b, p. 2). Furthermore, a large part of the coastline is occupied by private residential yards, which stresses the

importance of valuing and allowing public access to remaining shore areas (Sweco 2015, p. 20). It has also been discovered that, even though the municipality has many recreational environments, its green structures are not fully used by the inhabitants due to lack of information (Almén et al. 2012b, p. 2).

Today's planning framework

The growth of urban areas within the region means a greater degree of exploitation at the same time as the need for green environments increases. In order to secure the quality of future living areas, strategies for urban nature is of great importance (Almén, Hasselbom, Lind & Novakovic 2012a, p. 10). This aspect is further heightened as the municipality has many natural values even outside of areas that are under special protection (Danderyds kommun 2013a, p. 118).

The municipality's Green Infrastructure Plan aims to work as a collected document of the regions green structures and is foremost an aid for officials and politicians during planning and development. This plan is subordinate to the Comprehensive Plan and the Environmental Program of the municipality (Almén et al. 2012a, pp. 3-4).

At the present the municipality has a Green Infrastructure Plan for the period 2011-2015 and a decision has been made to develop a Blue-green Infrastructure Plan that also incorporates biodiversity values and ecological relationships of importance (Danderyds kommun 2017, p. 8).

Present work toward a sustainable green infrastructure

In this section some of the actions taken to support a sustainable green infrastructure in the municipality are presented.

Meadows
By varying the maintenance of green areas, a high degree of biodiversity can be attained. Meadows are one important biotope which has been enabled through different types of maintenance in the municipality (Danderyds kommun 2013b, p. 84). All meadow areas are divided into two parts, which are mowed during different times of the year, thus allowing for newly cut meadows during the whole season. This has been shown to be beneficial for both flora and fauna (Danderyds kommun 2018).

Furthermore, there are some meadow areas where the grass is allowed to grow higher permanently. Examples of such environments are the forest edge and in places where it does not hinder accessibility. In contrast the traditional lawns of the municipality are cut within an interval of 14 days, apart from a few parks where maintenance is performed within even shorter intervals (Danderyds kommun 2018).

As discoveries of several red listed species have been made in the meadows of the municipality, the desire to develop more meadow areas within the region have been strengthened (Almén et al. 2012b, p. 18). One example of such actions is a constructed meadow area in the district of Stocksund, which has been planted with a meadow mixture of native plants.

Water management
Projects to clean water have been carried out with the use of floating islands in Edsviken, located in the western part of the municipality. The constructed wetland has an area of 200m^2 and was built in the year of 2014. The aim was to reduce levels of phosphorus, nitrogen and heavy metals as well as acting as compensation for the naturally occurring riparian zone which was lost during a road construction in the area (Veg Tech n.d. a).

Further, the municipality has initiated work toward climate adaptation through the construction of flood protection at Nora strand in the year of 2010. This area, also located in the western part of the municipality, had previously been affected by recurrent flooding (Meyer & Winberg 2013, p. 3). Additionally, a stormwater pond has been constructed in the area.

As a means to delay stormwater flow and reduce the risk of flooding, a system of open ditches exists within the municipality. This forms a network of wetlands as stormwater is led through the system. Thus contributing to manners in which to manage excess water as well as providing habitats for animals and plants (Danderyds kommun 2013b, p. 85).

Future aims

The municipality aspires to prevent contaminants and excess nutrients from reaching the recipients through new stormwater solutions. In addition, there is an objective to construct new open stormwater systems which may also function as corridors (Almén et al. 2012a, p. 24).

With regard to connectivity, there is an expressed interest in investigating measures which can be applied in order to increase green connections and decrease barrier effects (Almén et al. 2012a, p. 24).

There is also a wish to continue the development of parks and street environments as well as enhancing means of orientation (Almén et al. 2012a, p. 24).

Furthermore, there is a desire to increase biodiversity and the experience value of the municipality's grass areas through variation in maintenance (Almén et al. 2012a, p. 24).

LARGE SCALE

This chapter concerns the large scale approach of this master thesis. It further develops the results gained from the previous stages of the study, presenting manners in which to strengthen the green infrastructure with the help of ecological approaches on this scale.

LARGE SCALE - MUNICIPALITY

In this section the green infrastructure is described as seen from a large scale perspective, the municipality as a whole. An introduction of the large scale concept is presented, followed by a general description of the municipality's green infrastructure. The latter is based on the findings of the inventory performed in 2017. Subsequently, the green structures are divided into seven different categories and described with reference to the initial inventory. Lastly a *SWOT-analysis* and *Guiding principles* for future development are presented.

Large scale

At the large scale, ecological design approaches can be used to plan for the protection of landscapes and define the growth pattern of urban development (Yu 2006, p. 31). It addresses issues concerning the general decline in biodiversity as a result of habitat loss and fragmentation and constitutes an important scale for creating a holistic framework for a sustainable infrastructure (Müller, Kelcey & Werner 2010, p. 130).

Actions at this scale concern regional landscapes, and involve issues such as flood prevention, ecological networks and corridors (Yu 2006, p. 31). Project at this level entails the formation of greenways, green corridors along highways, paths and riparian zones as well as the development of a system of parks (Müller, Kelcey & Werner 2010, p. 130).

Inventory

The findings of the inventory performed in 2017 provided information regarding the general layout of the municipality's green infrastructure, which is accounted for in this part.

The inventory showed that the municipality has many natural areas preserved. The largest are located in the northern part of the municipality and are constituted by an assortment of grasslands, pastures, agricultural lands and mixed forests. They form important hubs in the municipality, providing anchors in the green infrastructure network. There are also slightly smaller areas such as state parks, additional golf courses, wetlands and cemeteries which constitute further hubs.

Besides these structures, a number of smaller park and nature areas were found during the inventory, which are more or less linked to the larger green structures of the municipality. Many of these areas constitute sites which lack connections to each other besides the relations through residential areas with yards. However, they provide places for recreation and conservation of natural habitats.

Through the inventory, it was discovered that many of the existing links in the municipality are constituted by discontinuous patches of green areas. These are dispersed along the coastline as well as stretching diagonally

through the municipality. Old railway embankments and alleys form more continuous green links which connects some of the green structures together.

Moreover, the municipality has several important connections to surrounding green structures. One is represented by the region's oak population, which is related to the dispersed oak forest protected within the Royal National City Park (Danderyds kommun 2013a, p. 118). Further, the municipality contains one of the green wedges stretching through the region of Stockholm. These wedges form a network which infiltrates the settlements from different direction, enabling plants and animals to spread from the surrounding hinterlands to the urban areas (Almén et al. 2012a, p. 10, 18). In the municipality of Danderyd, this wedge is called Rösjökilen and is located in the north-west, forming an important link further north.

Categorization of green structures

For this master thesis the green structures of the municipality were divided into seven different categories formulated in the Green Infrastructure Plan of 2012. The categories consist of landscaped parks, urban nature parks, nature areas, golf courses, cemeteries, greenways and green traffic areas.

The following paragraphs, presents the municipality's definition of each category followed by a description of the green structures based on the inventory performed in 2017.

Landscaped parks
Definition: the landscaped parks are often centrally located and function as green aesthetic elements in the urban environment. They offer places for recreation and constitute areas with a high maintenance level (Almén et al. 2012a, p. 5).

Inventory: the inventory showed that the majority of the landscaped parks contain a high percentage of lawn and grasslands. They exist within every district but are most densely located in the southern part of the municipality, in the district of Stocksund.

Urban nature parks
Definition: the urban nature parks consist of green areas of different sizes, located in or adjacent to residential areas. These parks are valuable due to their accessibility. They are landscaped in varying degrees and the maintenance level is generally low (Almén et al. 2012a, p. 5).

Inventory: the inventory showed that the urban nature parks are dispersed over the municipality with a high density in the districts of Djursholm and Stocksund. They are constituted by a variation of woodlands and grasslands, several of which are meadows.

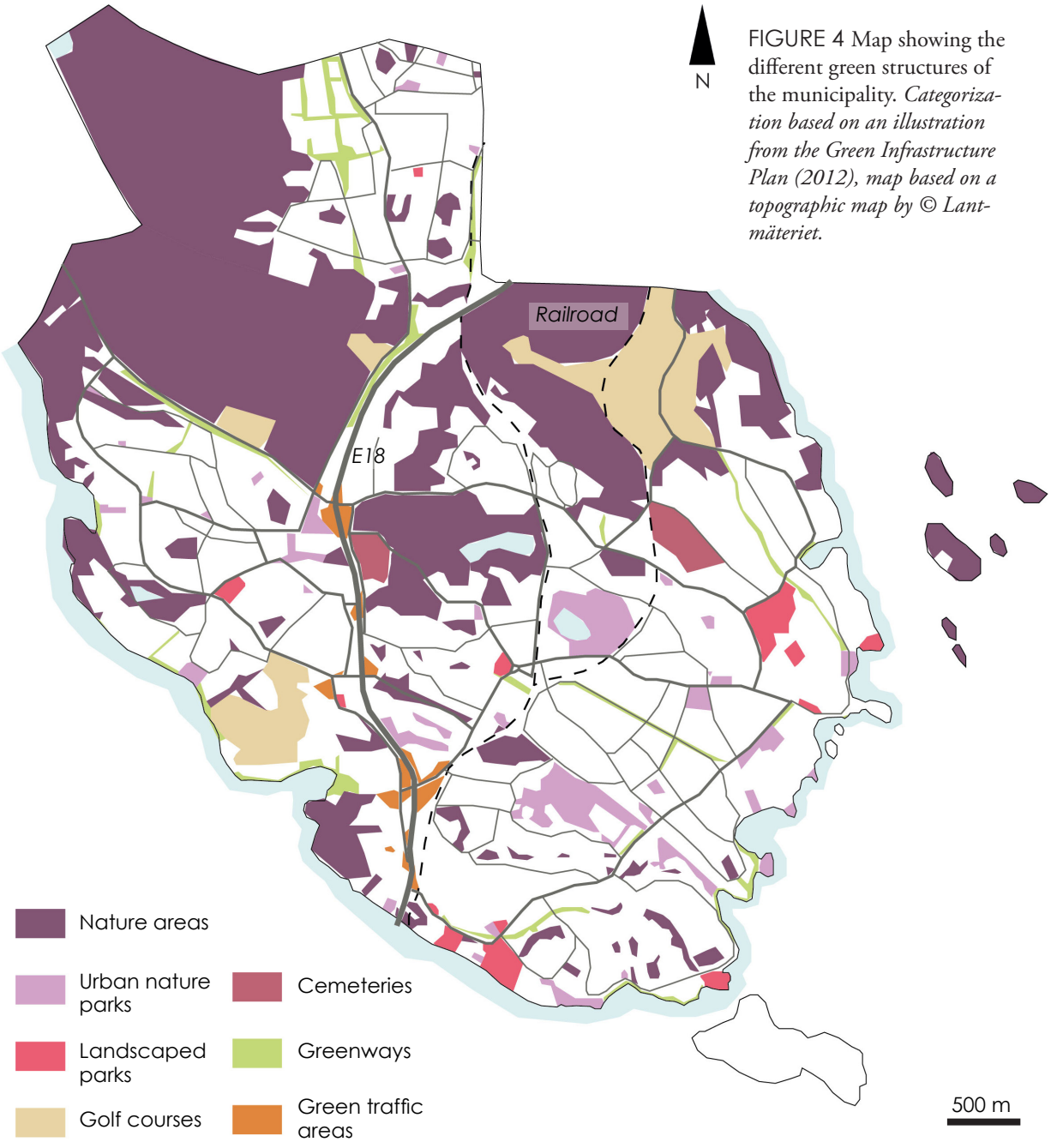


FIGURE 4 Map showing the different green structures of the municipality. *Categorization based on an illustration from the Green Infrastructure Plan (2012), map based on a topographic map by © Lantmäteriet.*

Nature areas

Definition: nature areas are more separated from settlements and are often bigger and more coherent than other green areas. The maintenance level is low, however a variation in landscape characters and biotopes is sought (Almén et al. 2012a, p. 5).

Inventory: the nature areas are most prominent in the northern part of the municipality. The major ones are constituted by woodlands, grasslands, pastures and wetlands. In addition, smaller nature areas are dispersed over the municipality in the form of patches of nature surrounded by settlements.

Golf courses
Definition: golf courses within the municipality offer recreational opportunities and contribute to biodiversity values to some extent (Almén et al. 2012a, p. 5).

Inventory: There are three major golf courses within the municipality; Stockholms golf course located in the south-west, Djursholms golf course in the north-east and Danderyds golf course with accompanying driving range in the north-west. Even though a major part of these green areas consists of lawn, there are biological values provided by groves of old trees such as birch, pine and oaks as well as by water bodies which form habitats for amphibian species.

Cemeteries
Definition: cemeteries are important environments for biodiversity and are valuable with regard to the cultural identity (Almén et al. 2012a, p. 6).

Inventory: There are two cemeteries in the municipality, constituted by Djursholms kyrkogård, located in the east and Danderyds kyrkogård located in the central part of the municipality in close proximity to the road E18. Both of the cemeteries contain valuable communities of older trees. In addition, large oak trees can be found in the cemetery located in Djursholm.

Greenways
Definition: greenways constitute connecting links between different green structures. They form valuable green corridors for the dispersal of animals and plants as well as for the recreational use of people. The maintenance is higher in relation to the nature areas as this category also includes alleys and grass areas (Almén et al. 2012a, p. 6).

Inventory: there are several greenways of varying size and lengths dispersed within the municipality. Many of the greenways are located along or in close proximity to the major roads of the region. The coastline is also the location of several greenways, some more developed than others. Additionally, greenways can be found along old railway embankments in Djursholm and Stocksund, forming potential green connections within the urban structure.

Green traffic areas
Definition: the main function of the green traffic areas is to constitute a green element in the street environment. As these areas are landscaped, the maintenance level is high (Almén et al. 2012a, p. 6).

Inventory: the inventory showed that the green traffic areas are mostly located in proximity to the road E18. They consist of grass areas adjacent to roads and boards of vegetation with trees and shrubs as well as roundabouts with different types of planting beds.

Landscaped park

Urban nature park

Nature area

Golf course

Cemetery

Greenway along an old railway embankment

Green traffic area

Greenway along the coastline

ANALYSIS - LARGE SCALE

SWOT large scale

Strengths
Many natural areas preserved
Meadow areas, floating islands and a system of open ditches
Natural areas with the ability to collect and clean stormwater
Existing green infrastructure of value for recreation and health
Oak community with connection to the Royal National City Park
Connection to the green wedge Rösjökilen
Water bodies and wetlands
Agricultural lands

Weaknesses
Partly low connectivity between green areas, especially in the southern part of the municipality
E18 forms a barrier separating the eastern and western sides of the municipality
Decreased water quality along the coastline
Natural areas not fully used due to lack of information

Opportunities
Natural areas with a large amount of native vegetation, beneficial for indigenous biodiversity and can be further developed
Opportunities to evaluate and build upon previous experiences of ecological design approaches
A long coastline, ecotone of high value, increases opportunities to achieve a high degree of biodiversity
Possibility to build on existing green structures in order to strengthened connections
New development of the central parts of Danderyd may provide opportunities to bridge the gap caused by the road E18

Threats
New development may pose a risk for natural areas lacking specific protection. Thus increasing the risk of further fragmentation and subsequent loss of connections and biodiversity

Climatic changes with increased risk of temperature rises, increased precipitation and flooding

GUIDING PRINCIPLES - LARGE SCALE

In this section guiding principles are presented with regard to the development of a sustainable green infrastructure seen from a large scale perspective.

Guiding principles for the municipality

The principles are divided into the categories; *Protection, restoration and rehabilitation; Native plants and biodiversity; Stormwater collection and cleansing; Connecting fragmented patches* and *Reveal, immerse, teach* which were formerly presented in the chapter concerning ecological design.

Protection, restoration and rehabilitation
Existing vegetation is of significant value and should be protected and closely evaluated when it comes to new development. It is possible to take measures which enable the inclusion of these structures in the growth of new urban areas.

The main hubs offer possibilities to support a healthy green infrastructure in the municipality and should thus be safeguarded. This can be accomplished by increased regulations and restoration of links to surrounding natural areas as well as between the hubs themselves. Moreover, the nature areas of the north-west constitute a doorway to the green wedge Rösjökilen and should receive increased protection.

The health of the oak community within the municipality is of importance in order to strengthen the ecological network of the Royal National City Park. This can be accomplished through adaptive management and maintenance actions.

Native plants and biodiversity
Existing green areas can be further strengthened by using native species in different types of plantings and as ground cover. Native species can be used in the form of alternative lawns, meadows and on green roofs. Ecological values in existing parks and green areas could thus be enhanced. Moreover, as there are several reference areas within the municipality where the use of meadows have been shown to strengthen ecological values (Almén et al. 2012b, p. 18), the possibility of further developing such methods increase.

The new development of the central parts of Danderyd opens up new opportunities for the use of native species and increasing biodiversity. Buildings and residential areas could be developed with an ecologically sustainable approach in mind, aiming to increase biodiversity and strengthen the local flora. The use of alternative lawns and meadows could constitute functional and decorative elements in

the new residential communities at the same time as the new house developments allows for an extended use of green roofs.

Stormwater collection and cleansing
Enhancing the water quality in lakes and areas along the coastline is one of the main impediments within the municipality. This can be remedied through two main approaches; (1) decreasing the amount of pollutants and excess nutrients reaching the coast and internal water bodies, (2) enhancing the present conditions in existing waters and water bodies.

As previously stated, the preservation of existing green areas can aid in the management and cleansing of stormwater. However, by incorporating further structures which deals with issues regarding stormwater treatment, the negative impacts on the recipients can be alleviated. The development of a system of rain gardens, open swales and pervious surfaces can aid in the capture and cleansing of stromwater. At the same time such structures may also provide aesthetic qualities, enhancing the experience of the municipality's streetscape.

Existing planting strips and roadside areas can be evaluated in order to find possibilities for further development of stormwater structures. Greenways and green traffic areas constitute environments which could offer suitable conditions for such development. Thus providing enhanced stormwater treatment and introducing the possibility of combining these functions with recreational use. By introducing open stormwater systems, corridors for both humans and wildlife species may be created and further developed.

The pending urban development offers opportunities with regard to stormwater treatment as well. The new areas can incorporate cohesive systems which are built to collect and clean excess water. Perchance, the new development may even offer opportunities to alter existing closed stormwater systems into open ones during the construction period. Furthermore, the introduction of green walls and roofs, especially constructed to treat stormwater, may also be implemented in combination with the new development as well as on existing buildings.

Moreover, in order to enhance the conditions in existing water bodies, green structures with the ability to clean water from contaminants can be utilized. By building on prior experiences with floating islands, such means of bioremediation can be used to an extended degree. These structures can be further adapted to the specific needs and conditions of the different water bodies.

Connecting fragmented patches
One of the most prominent challenges, when it comes to increasing flows and connectivity within the municipality, is the barrier that E18 constitutes. With only a few underpasses available, it effectively reduces physical connections between green areas of the western and eastern side of the municipality. An initial step to lessen the barrier effect can be to strengthen the green values of these underpasses, creating connections leading from green areas on both sides.

With the new development in central Danderyd comes an opportunity to bridge the gap that has been created by E18. Incentives calling for the development of green buildings could result in the development of green walls, roofs as well as green links in the newly built environment. Thus the future development could act as a framework for increasing the green connections between the eastern and western sides.

In order to increase connectivity between hubs and sites, green links can be further developed within the municipality. Green corridors can be developed along the main roads, through the preservation of existing trees and the planting of new street trees. Moreover, connections between existing green areas can be strengthened by creating links with new plantings and by filling in gaps in existing connections. Such actions could support the formation of larger, more coherent areas.

Strengthening the greenways of the coastline and along the old railway embankments allows for possibilities to create broad, meandering corridors. As previously stated, such corridors are preferable to narrow linear ones (Müller, Kelcey & Werner 2010, pp. 162-163). It also allows for the creation of corridors which combine functions such as wildlife movement and recreational opportunities for people. Furthermore, strengthening the greenways along the coast creates potential for the urban greenery to be more connected to the hinterland, as the shoreline encircle the municipality on three sides.

Reveal, immerse, teach
The municipality is rich in natural environments, however shortage of information (Almén et al. 2012b, p. 2) and indications of human intent may cause people not use them to their full extent. Increased access to natural areas in the form of paths and boardwalks can aid people in the discovery of the varied landscapes within the municipality. As many of the nature areas exhibit a great variety in topography, consequently making them more difficult to access, immersive features and development of existing paths can create opportunities for

more people to experience the values in these areas as well.

Both nature areas and urban nature parks have a more wild and nature-like character, which can make them less legible. Legibility and orientation can be improved by adding visual aids such as signs, markers and art pieces. In addition, viewpoint and frames can also be used to direct attention to particular aspects of these landscapes. Such elements may also evoke interest and invite people to discover these environments.

Existing nature areas can be used as a platform for combining human recreation and contact with natural systems. As many of the natural areas are without particular protection (Danderyds kommun 2013a, p. 118) and at risk of being further fragmented due to new developments and densification, increased stewardship formed by such measures can help in their protection.

Moreover, using "cues to care" through different measures of maintenance can be a means of framing ecological values and indicate human intent. The municipality already displays such signs in the form of mowed strips of lawn along paths. Such actions can be further developed throughout the municipality, for example in combination with meadow areas.

Summary: Guiding principles - large scale

Protection, restoration and rehabilitation
Safeguard existing vegetation --> protect hubs, green wedges and oak communities, inclusion of existing vegetation in the growth of new urban areas
Native plants and biodiversity
Introduce native species and alternatives to the traditional lawn --> introduce meadow areas, alternative biodiverse lawns and green roofs
Stormwater collection and cleansing
Introduce structures for landscape treatment of stormwater --> establish a system of rain gardens, open swales and pervious surfaces. Introduce green walls, green roofs and floating islands
Connecting fragmented patches
Strengthen greenways and increase connectivity between the eastern and western side --> development of green walls, green roofs and green links
Reveal, immerse, teach
Increase legibility and access to existing natural areas --> develop paths and boardwalks, introduce “cues to care” through different types of markers and measures of maintenance

INTERMEDIATE SCALE

This chapter concerns the intermediate scale approach of this master thesis. It further develops the results gained from the previous stages of the study, presenting manners in which to strengthen the green infrastructure with the help of ecological approaches on this scale.

INTERMEDIATE SCALE - DISTRICT

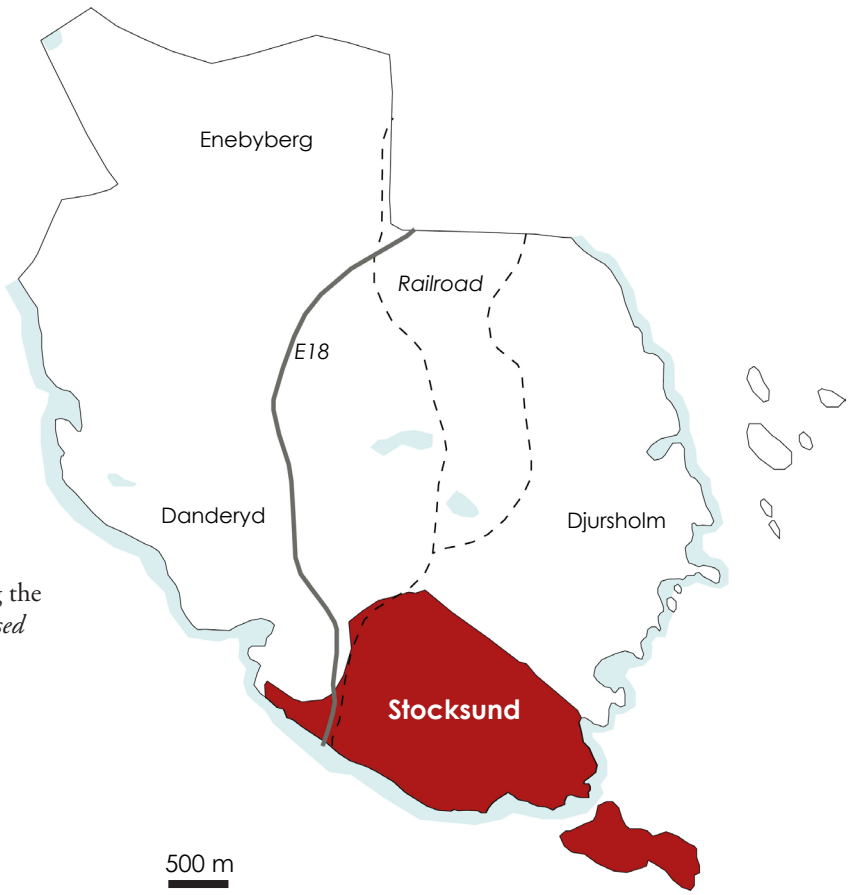


FIGURE 5 Map showing the district of Stocksund. *Based on a topographic map by © Lantmäteriet.*

In this section the green infrastructure is described as seen through an intermediate scale perspective, in the form of a district. A description of the intermediate scale concept is presented, followed by an introduction to the district. The green structures of the district are divided in accordance to the categories presented in the Green Infrastructure Plan of 2012. Each category is briefly described with reference to the initial inventory. Lastly a *SWOT-analysis* and *Guiding principles* for future development are presented.

Out of the four districts in the municipality, Stocksund was chosen to represent this scale. This decision was based on three main factors; the district constitute the most isolated one in relation to the main hubs of the north, it contains a large amount of fragmented green areas and a high percentage of the more intensely maintained landscaped parks.

Intermediate scale

At the intermediate scale, the structure of the regional landscape is to be integrated within the urban framework. Approaches at this scale involve the formation of an urban green infrastructure which forms a system of integrated functions of both ecological and social value (Yu 2006, p. 31).

Approaches at this scale are of significance for the community level, involving smaller districts and subdivisions. It deals with concerns such as urban biodiversity protection and the introduction of methods for water management such as green roofs, rain gardens, swales and pervious surfaces (Müller, Kelcey & Werner 2010, pp. 131-132).

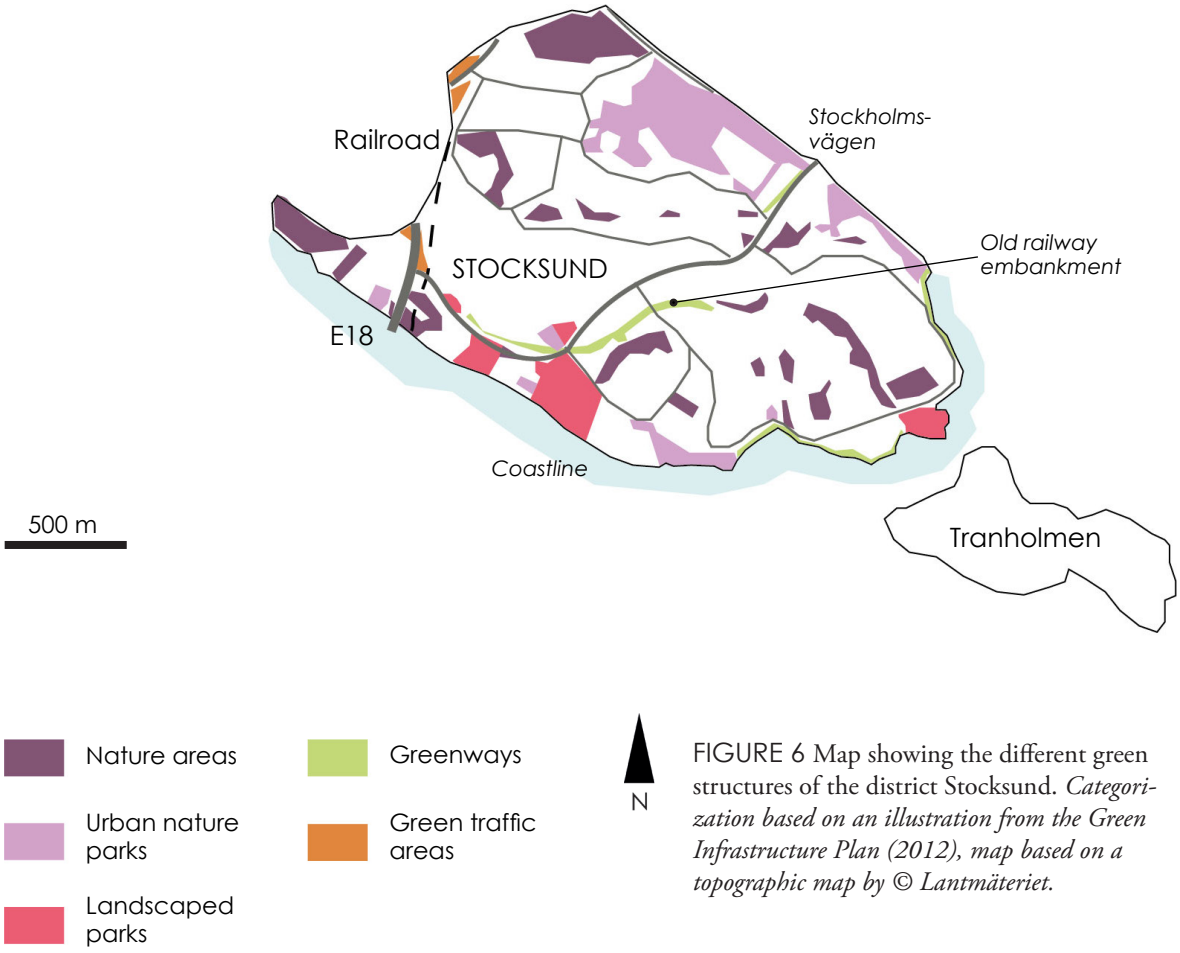


FIGURE 6 Map showing the different green structures of the district Stocksund. *Categorization based on an illustration from the Green Infrastructure Plan (2012), map based on a topographic map by © Lantmäteriet.*

Inventory

Through repeated visits to the district of Stocksund during the inventory of 2017, its character and general structure could be mapped. The district is located in the most southern part of the municipality and its main structure is that of a garden city. The topography is varied and the community is bordered by the district of Djursholm in the north-east, E18 and the railroad in the west and the coast in the south. The road Stockholmsvägen stretches through the central parts of the community. The district also contains Tranholmen, an island located in the south-east, which will not be included in this investigation.

Categorization of district green structures

The district of Stocksund contains landscaped parks, urban nature parks, nature areas, greenways and green traffic areas. In the following paragraphs, the findings of the inventory performed in 2017 are presented for each category.

Landscaped parks

The landscaped parks are located in the southern part of the district, with the highest density along the coastline. Many of these parks are constituted by open undulating grasslands

with clusters of trees and a high percentage of lawn.

Several of the landscaped parks in the district contain fruiting and flowering trees as well as fully grown native trees. Different types of planting beds exist within these parks, ranging from formal borders of roses and perennial plants to more wild and nature-like plantings.

Many of the landscaped parks are located in close proximity to one another. However, green links between them are partly broken due to discontinuity in vegetation, bigger roads and residential facilities along the coast.

Urban nature parks
The urban nature parks are mainly located in the outskirts of the district. The largest and most cohesive area can be found in the north where it forms a green link in a north-west-southeast direction.

The urban nature parks of the district are constituted by a combination of woodlands and grasslands. The woodland areas contain large populations of oak trees of substantial size. The grasslands of the north include a high amount of meadow areas, while the grasslands of the south are constituted by continuous lawn in a higher degree.

Nature areas
The nature areas vary in size and are scattered over the district, forming small islands of woodlands and to some degree grasslands. The largest areas are located in the northern and western parts of the district.

Many of the nature areas can be found on heights with surrounding residential houses, making them difficult to reach. Populations of hazel and oak are common features as well as pine trees which forms small forests on the heights.

Greenways
The major greenways within the district are located alongside Stockholmsvägen, the old railway embankment and the coastline. These green links partly connects to other parks and natural areas within the district. The density of vegetation varies from broad plantings with trees and shrubs to narrow planting strips with grass and trees.

Green traffic areas
The green traffic areas of the district are located in the west, in close proximity to the current railroad and the road E18. These green areas are mostly composed of grasslands with trees and shrubs and plantings in roundabouts containing grass and shrubs.

Landscaped park

Urban nature park

Nature area

Greenway along the coastline

Green traffic area

Greenway along an old railway embankment

ANALYSIS - INTERMEDIATE SCALE

SWOT intermediate scale

Strengths
Natural areas of varying character
Woodland areas and open grasslands
Use of meadows
Population of oak trees
Green link in the north of the district

Weaknesses
Many isolated green structures
The district is located far from the main hubs
Challenging topography hindering recreational use to some degree
Lawn is a big feature in many of the parks, especially in the south
High percentage of landscaped parks - high maintenance
Broken green links due to roads, residential areas and discontinuity in vegetation

Opportunities
Possibility to develop green connections within the district and along roads
Opportunities to develop greenery along the coastline
Possibility to increase biodiversity, means of stormwater management and ecological processes in existing parks
Opportunities to increase access to natural areas

Threats
Densification and subsequent loss of green areas and natural values

Fragmentation, leading to loss of connections and weakened capacity of remaining green structures

GUIDING PRINCIPLES - INTERMEDIATE SCALE

In this section guiding principles are presented with regard to the development of a sustainable green infrastructure seen from an intermediate scale perspective.

Guiding principles for the district of Stocksund

The principles are divided into the categories; *Protection, restoration and rehabilitation; Native plants and biodiversity; Storm water collection and cleansing; Connecting fragmented patches* and *Reveal, immerse, teach* which were formerly presented in the chapter concerning ecological design.

Protection, restoration and rehabilitation
The district contains a varied set of natural areas. Such variations should be protected as it offers different wildlife habitats and recreational values for people. Additionally, the conditions in existing green areas can be further developed in order to create new habitats and resources.

The oak community should be safeguarded and favorable conditions supporting this population should be sought. Strategies for succession should be developed, including future planting of new oak trees.

The water habitats and their edges constitute valuable environments and should be prioritized when it comes to protection and rehabilitation. As the district has a long coastline, it is important to protect and further developed these areas in order to strengthen ecological processes.

Native plants and biodiversity
Many of the landscaped parks of the district contain a high percentage of lawn. The use of lawn is also spread through some of the greenways and urban nature parks. In order to increase biodiversity and lower the degree of maintenance, the use of alternatives to the traditional lawn can be incorporated into these environments in a higher degree.

Areas of lawn are especially common in the southern part of the district, creating places for recreation in close proximity to the coast. In order to increase biodiversity values in these areas, the use of grass-free lawns can be implemented in selected places and in combination with traditional lawn. As these structures provide a short cut carpet, recreational use is still possible.

In addition, meadow areas can be used in a higher degree in the different parks. Placement of such features could be directed to the outer boarders of the parks, still enabling opportunities for recreation and play in its central parts.

Furthermore, by establishing planting designs which supports a more multi-layered structure, a higher diversity of habitats can be created in the district parks. Moreover, the use of native species can be used to increase indigenous biodiversity.

During the summer, pots and urns are placed along parts of the old railway embankment. The plant composition in such structures could also be inspired by the local landscape and might even display examples of urban agriculture.

Stormwater collection and cleansing
Natural areas of the district constitute valuable resources for stormwater management, as they contribute to slow down and cleanse runoff before it reaches the coastal waters.

Additional stormwater solutions can be developed along district roads, along greenways and in green traffic areas. Vegetated swales, rain gardens and different kinds of pervious surfaces such as planting strips can be introduced in these areas. Such structures can enhance stormwater management and at the same time contribute to new aesthetic values in the streetscape.

One of the central roads in the district, Stockholmsvägen, could be a potential site for further development of stormwater solutions. In addition, green roofs and walls can be incorporated in new development and on existing buildings.

Connecting fragmented patches
The district has three major flows of movement within its borders; one along the coastline, one in its central parts and one in the north forming a diagonal link reaching further into the municipality.

Many of the green areas along the coast are located in close proximity to one another, however discontinuity is caused by gaps in vegetation. Such gaps can be bridged by incorporating additional plantings and trees where room is available. Biodiverse lawns and solutions for stormwater management may also form elements which can increase connectivity.

Greenways along Stockholmsvägen and the old railway embankment allows for further development of green links within the district. By enforcing the connectivity and green values within these areas, a centrally located corridor can be developed which combines the fragmented areas in a higher degree. Moreover, this would decrease the barrier effect which is presently caused by Stockholmsvägen. Further corridors may also be developed along the main roads of the district.

The green link in the north is constituted by meadows, woodlands and grass areas. This corridor can be further strengthened through the continued development of meadow areas. These meadows may even be allowed to continue further down the coastline as an alternative to lawn, creating additional connections.

In case of new development, the implementation of green roofs, walls and stormwater solutions can be used to increase connectivity and partly compensate for green areas lost.

Reveal, immerse, teach
The district comprises several natural areas, many of which are covered by woodlands and display large variations in topography. Such prerequisites make it difficult to reach and experience some of these areas. By introducing new trails and developing existing ones, access to these environments can be facilitated.

Such elements enable immersion in nature and may promote increased stewardship and awareness of natural values. In addition, other forms of "cues to care" such as signs, markers and maintenance measures may increase the use of the natural areas of the district.

Moreover, the high degree of easily accessible landscaped parks offers opportunities to introduce different sustainable solutions to the general public. Such environments may constitute places of education and invite visitors to discover new ways of using ecological approaches to solve bigger landscape issues.

Summary: Guiding principles - intermediate scale

Protection, restoration and rehabilitation
Safeguard the varied character of the nature areas within the district --> protect the oak community, restore ecological functions within existing green areas, protect and restore the water habitats along the southern coastline

Native plants and biodiversity
Enhance biodiversity in existing parks --> introduce native species, alternative lawns, meadows and a higher degree of multi-layered habitats

Stormwater collection and cleansing
Develop additional structures for stormwater management --> establish rain gardens, open swales, pervious surfaces, green walls and roofs

Connecting fragmented patches
Increase connectivity between landscape patches --> enhance the green connections along the coastline, the central greenway and the northern green link

Reveal, immerse, teach
Increase opportunities to reach and experience natural areas and ecological solutions --> introduce new trails and develop existing ones, introduce “cues to care” and display different sustainable solutions in the easily accessible landscaped parks

SMALL SCALE

This chapter concerns the small scale approach of this master thesis. It further develops the results gained from the previous stages of the study, presenting manners in which to strengthen the green infrastructure with the help of ecological approaches on this scale.

SMALL SCALE - PARK

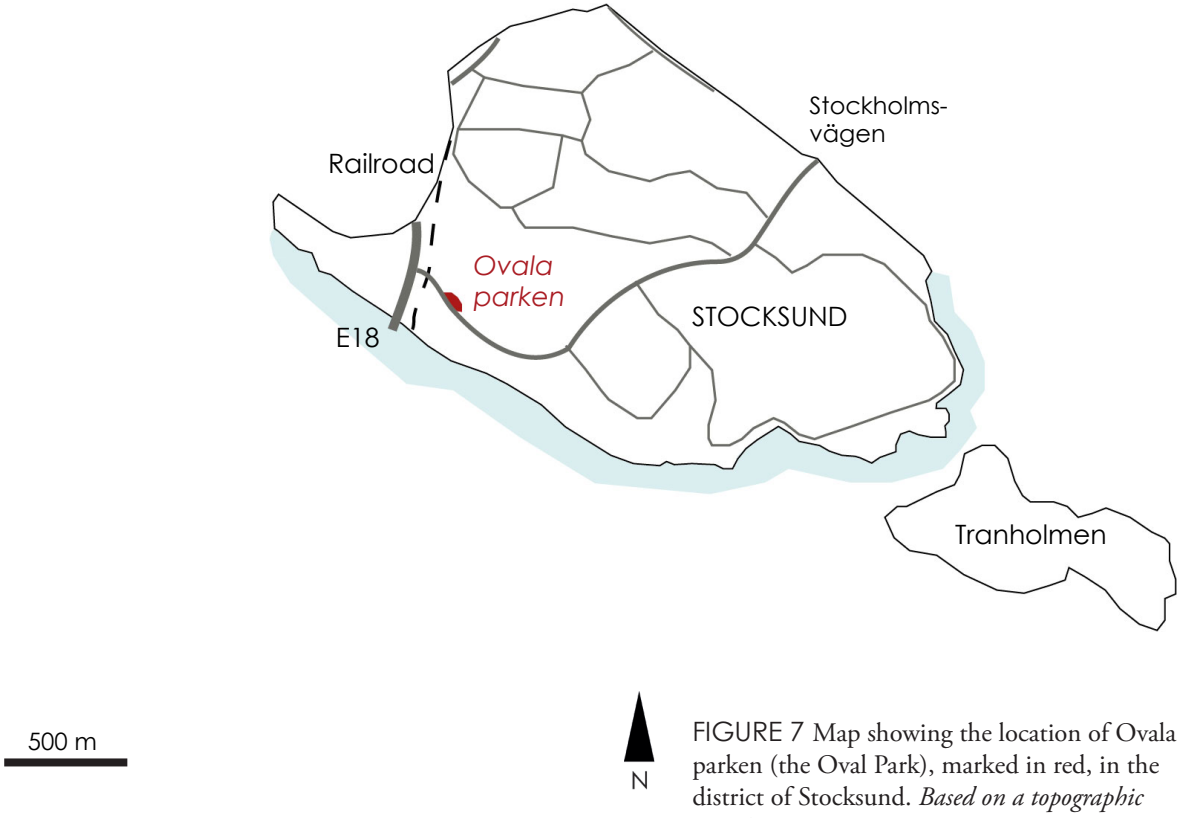


FIGURE 7 Map showing the location of Ovala parken (the Oval Park), marked in red, in the district of Stocksund. *Based on a topographic map by © Lantmäteriet.*

In this section the green infrastructure is described as seen through a small scale perspective, in the form of an individual park. An introduction to the small scale concept is presented, followed by a description of the park. The latter is based on the findings of the inventory performed in 2017. Furthermore, a *SWOT- analysis* and *Guiding principles* for future development are presented.

For the small scale perspective, the park *Ovala parken* in Stocksund was chosen. This decision was based partly on maintenance demands and partly on new circumstances with regard to stormwater. The park consists of large areas of lawn, thus requiring a relatively high degree of maintenance. Such actions could possibly be lowered through means of ecological design. Furthermore, a former woodland area located in close proximity to the park has recently been converted into residential houses, thus affecting the amount of stormwater managed through landscape treatment. It is possible that management of water could be facilitated through stormwater solutions in the park.

Small scale

At the small scale, ecological approaches are concerned with the design specific to site, thus piloting the development of land areas within the urban framework (Yu 2006, p. 31). Approaches at this scale generally concern areas such as parks, road sides, streets and meadows and aims to strengthen and restore the conditions of such sites (Müller, Kelcey & Werner 2010, p. 133).

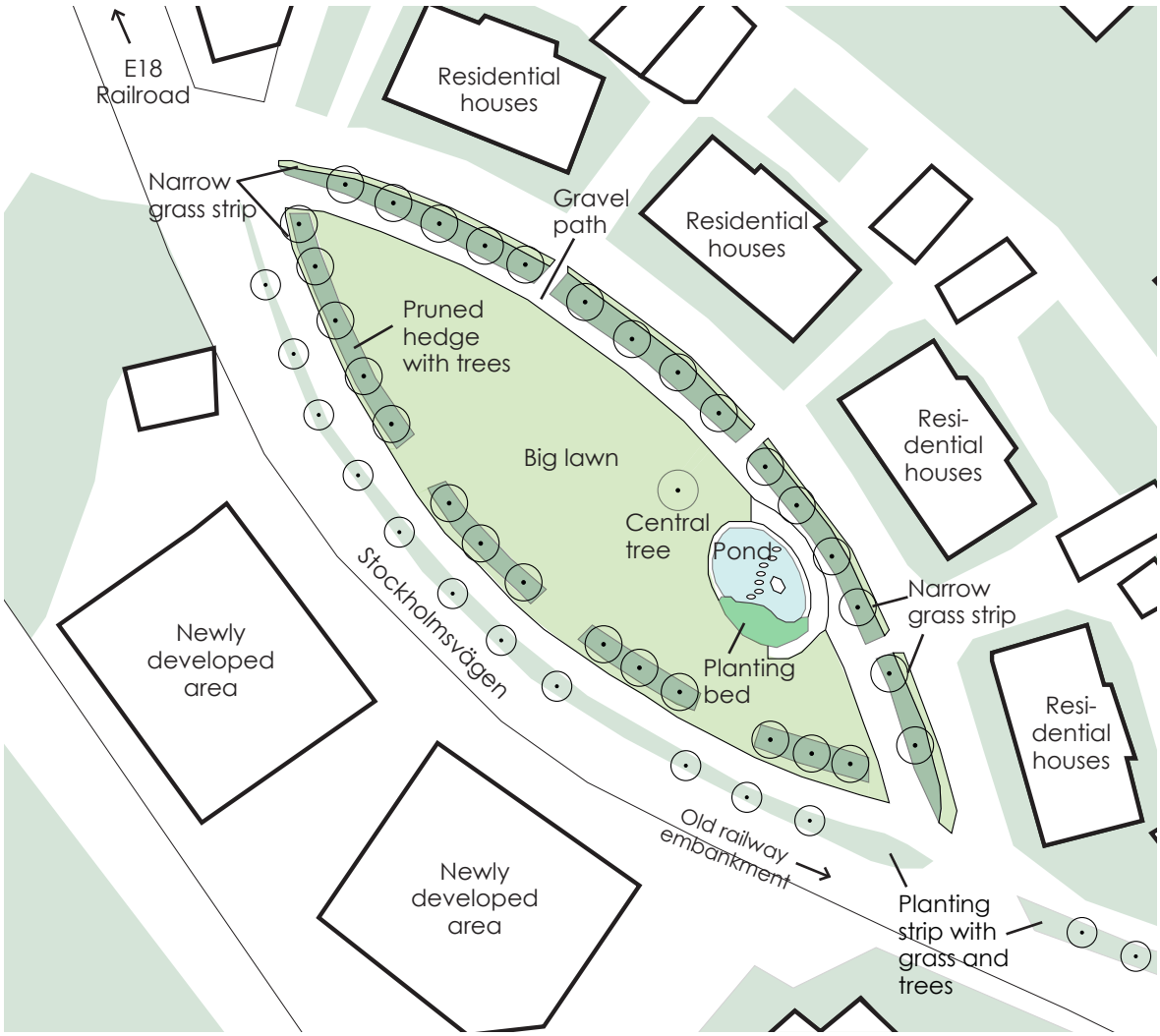


FIGURE 8 Plan illustrating Ovala parken (the Oval Park) and its surroundings. *Based on an orthophoto by © Lantmäteriet.*

Inventory

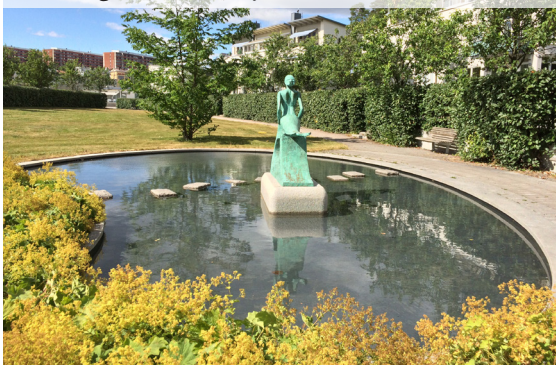
Ovala parken is a landscaped park located in the western part of Stocksund. During the inventory of 2017, the park was visited on several occasions, enabling the study of its general characteristics and structure. It is situated in between Stockholmsvägen and a neighborhood area, forming a small green environment for the residents as well as for the public. The park has a formal character, with an oval shaped lawn and a central pond. The statue "Sjöjungfrun" by Mats Åberg is situated in the water and a planting bed with lady's mantle surrounds parts of the water feature.

The park has a slightly concave shape and is surrounded by pruned hedges of swedish whitebeam, in which fruiting trees are situated in rows. Constructed gaps in the hedge provide framed viewpoints into the park. A pathway made of gravel stretches along the east side of the area, along which several benches are placed. The benches are partly enclosed by the hedge, forming smaller rooms. One lone tree placed centrally in the lawn forms a landmark in the park.

The park is located in close proximity to Stockholmsvägen and adjacent traffic environments with large expanses of impervious surfaces. A combined walk- and bicycle way and a narrow planting strip along Stockholmsvägen separate the park from the road.

Impervious surfaces surround the park

Planting bed with lady's mantle



The south entrance, view over the pond

The north entrance, large areas of lawn

Narrow grass strip facing Stockholmsvägen

Narrow grass strip toward the residential houses

The pond requires regular maintenance

Stepping stones submerged by rise in water level

ANALYSIS - SMALL SCALE

SWOT small scale

Strengths
Public park
Easy to find and centrally located
Layers of shrubs, trees and ground cover
Fruiting trees in hedges, hides fallen fruit and provides food for animals
Hedge of swedish whitebeam relates to species found in the natural areas of the municipality
Pervious pathway of gravel is beneficial for stormwater treatment
The gently sloping, concave form of the park and large grass areas can help direct and manage stormwater

Weaknesses
High percentage of lawn - less biodiversity
High maintenance - mowed lawn, pruned hedges and pond which needs to be kept clean
Narrow grass strips on the outside of the hedge
Relatively low diversity among plant species

Opportunities
Possibility to more strongly connect the park to greenways along Stockholmsvägen and the old railway embankment
Opportunities to enhance biodiversity in the form of alternative lawns and meadow areas
Possibility to increased measures for stormwater management, the pond can be further developed to more efficiently handle stormwater, creation of rain gardens
Opportunities to display ecological approaches to design in a central environment

Threats
Further exploitation, with loss of biodiversity and green connections
Increase of impervious surfaces in the surrounding environment and risk of a rise in stormwater flows

GUIDING PRINCIPLES - SMALL SCALE

In this section guiding principles are presented with regard to the development of a sustainable green infrastructure seen from a small scale perspective.

Guiding principles for Ovala parken (the Oval Park)

The principles are divided into the categories; *Protection, restoration and rehabilitation; Native plants and biodiversity; Storm water collection and cleansing; Connecting fragmented patches* and *Reveal, immerse, teach* which were formerly presented in the chapter concerning ecological design.

Protection, restoration and rehabilitation
Existing qualities of the park can be used to improve ecological functions and create new habitats and resources. The park contains several natural values, in the form of trees and shrubs, which should be preserved in order to safeguard existing biological values. The fruiting trees located in the park may offer food for wildlife and are thus a valuable feature.

Furthermore, by reducing the amount of traditional lawn the maintenance degree can be lowered. The narrow grass strips at the borders of the park can be planted with alternatives to lawn, perennials or smaller shrubs which require less maintenance. Thus presenting ways of lowering the costs and time spent on managing these areas.

Native plants and biodiversity
The layering of the park's vegetation can be further developed in order to create a more varied set of habitats. By supporting a multi-layered structure and introducing more species into the park, biodiversity can be increased.

Moreover, by implementing alternatives to traditional lawn, biodiversity and ecological processes of the area can be enhanced. Meadow areas, placed at the park's borders, or patches of grass-free lawn constitute potential manners in which to accomplish such actions. This also allows for the possibility to introduce more native species into the park.

Stormwater collection and cleansing
The close proximity to traffic environments, with large amounts of impervious surfaces, makes the park a good candidate for stormwater collection and cleansing. By introducing further means of handling stormwater, such as rain gardens and appropriate vegetation, the water from adjacent roads and hard surfaces can be managed within the area.

By developing the existing pond to more specifically be able to manage stormwater, existing resources can be utilized. Moreover, the

introduction of other water harvesting elements such as barrels may create opportunities to collect water for irrigation, thus lowering the amount required by other means.

Connecting fragmented patches
By increasing the connection to surrounding green areas, recreational and ecological values can be improved. Connecting the park more strongly to the former railway embankment and Stockholmsvägen can improve the greenway which moves through the central parts of the district. This can be achieved by filling in gaps in vegetation and introducing elements such as alternative lawns and vegetative structures for stormwater management.

Reveal, immerse, teach
Being a public park makes it easily accessible, where the central location offers opportunities to display new sustainable alternatives to park design. Introduction of vegetation and stormwater solutions can create interest and lead to a sense of stewardship, which may result in the implementation of new ecological solutions in other parts of the municipality.

Summary: Guiding principles - small scale

Protection, restoration and rehabilitation
Safeguard existing natural values and reduce costs and time spent on maintenance --> protect trees and shrubs, introduce alternatives to lawn for example as a substitute to the narrow grass strips

Native plants and biodiversity
Introduce a higher degree of native species and biodiversity --> use of alternative lawns such as grass-free lawn and meadow patches, develop multi-layered habitats

Stormwater collection and cleansing
Adapt the park to handle stormwater to a larger extent --> rain gardens, introduce means of water harvesting, development of existing pond

Connecting fragmented patches
Reinforce connections to surrounding green areas --> connect to the greenway of Stockholmsvägen and the old railway embankment

Reveal, immerse, teach
Increase means of displaying new sustainable alternatives to park design --> stormwater solutions, alternatives to traditional lawn, native plants

DISCUSSION

This chapter presents a discussion regarding the methods and results of this master thesis. Moreover, further research questions are reflected upon.

DISCUSSION

This section contains discussions with regard to the different parts of the project. The purpose and research question of the project are presented in order to more easily compare the aim with the results. The chapter is divided into a method discussion, a result discussion and concluding remarks. Lastly, further research questions are presented.

Purpose & research question

This master thesis concerned the green infrastructure in the municipality of Danderyd and aimed to investigate how ecological design approaches could be applied to make it more sustainable in the face of challenges. The research question of the project consisted of the following:

How can ecological design approaches be used to support a sustainable green infrastructure in the municipality of Danderyd on different scales?

The results could constitute an aid in the development of a sustainable green infrastructure in the municipality itself and in other environments with similar conditions. Further, the thesis aimed to provide a means of sharing discoveries and experiences with regard to ecological design solutions in this particular region.

Method discussion

Several methods were used during the course of the master thesis. They included a *literature study* concerning the concepts of green infrastructure and ecological design; a *case study* including the review of municipal documents, division into scales, SWOT-analysis and the production of Guiding principles. Additional methods consisted of the *production of plans and visualizations*.

Literature study
The literature study was beneficial in order to gain a greater understanding of the two concepts green infrastructure and ecological design. It constituted an aid in finding their definition, aim and benefits. Further, it provided information on how a green infrastructure network might be structured, as well as different approaches to working with ecological design. Moreover, having performed the inventory prior to the literature study made it easier to form an idea of what kind of ecological approaches could be of interest for the project.

Case study
In order to further investigate the theories assembled through the literature study, a case study of the municipality was performed.

Through reviewing municipal documents, the classification of green structures was found. This categorization, described and illustrated in the Green Infrastructure Plan published in 2012, constituted an important part in this master thesis as it guided the division of green structures for further analysis. Further background studies with regard to the municipality were of additional importance. It became a way of compiling some of the existing investigations and analyses, finding gaps and advice on how to move forward with my own investigation.

SWOT-analysis and division into scales provided a means of analyzing the green infrastructure of the municipality in a more manageable form. The different scales advised on which aspects to address on each level, thus affecting which strengths, weaknesses, opportunities and threats that were emphasized for the different areas of investigation. However, as many of the ecological approaches are connected and can be applied in different manners on different scales, it was difficult to completely separate them from one scale to another.

For example, problems regarding stormwater management in a district can be alleviated by introducing rain gardens or swales along a specific road. However, such approaches to stormwater management can also be applied in a large scale perspective, where several such constructions along municipality roads forms a larger interconnected system of wetlands.

Furthermore, guiding principles for future sustainable development were produced for each scale. The principles were based on the results of the individual SWOT-analyses and organized into five different categories of ecological approaches to design. The categories consisted of; *Protection, restoration and rehabilitation; Native plants and biodiversity; Stormwater collection and cleansing; Connecting fragmented patches* and *Reveal, immerse, teach* and were chosen based on the current and future needs of the municipality shown through the analyses.

As there are many different manners in which to work with ecological design, the categories chosen could have been more extensive, of a different character as well as more organized according to priority. With regard to the latter alternative, a greater knowledge concerning economic circumstances, ecological values and planning framework is required.

Production of plans and visualizations
The information gathered from literature studies, inventories and analyses was processed and presented in visualizations and plans. All illustrations were made in Adobe Illustrator.

Working with digital programs presented an efficient manner in which to manage large amounts of information. Opportunities such as handling different layers, color coding particular areas as well as adding and removing various features made it easier to study different connections and scenarios. Furthermore, the use of other programs such s GIS could have been a useful alternative for managing and analyzing information in this project.

Result discussion

This section presents discussions regarding the results of the study. The use of ecological design in a green infrastructure framework is reflected upon and a deeper deliberation on working with different scales is presented. Furthermore, the potential benefits and disadvantages of writing in a different language are addressed.

Ecological design in a green infrastructure framework

According to Benedict and McMahon, green infrastructure addresses benefits for both people and the environment (Benedict & McMahon 2006, p. 16). Thereby it offers a platform for working with both natural and social values, serving several different needs in a community.

Furthermore, ecological design constitutes a means of working with local conditions and can be incorporated into the fabric of our communities (Rottle & Yocom 2010, pp. 6, 13). Thus, by implementing ecological solutions into the green infrastructure network, existing recourses can be utilized to a greater extent.

In the case of Danderyd, it is possible that solutions such as the protection of natural values, stormwater treatment, enhanced connections and measures to increase stewardship might support both social and ecological values. In addition it may also lower the degree of maintenance.

Rottle and Yocom states that principles of ecological design can aid in the reduction of both time and costs associated with maintenance in designed landscapes (Rottle & Yocom 2010, p. 164). Implementing alternatives to the traditional lawn offers one example of how maintenance measures could be lowered in the municipality while still allowing for recreational opportunities.

According to Ignatieva (2018), the grass-free alternative to lawn has the ability to provide a low-growing flowering carpet, suitable for recreational use. In addition, it is relatively low in maintenance needing to be cut only

two to three times during the summer season (Ignatieva 2018, p. 227). In comparison traditional lawns of the municipality are cut within a maximum of 14 days, and in some cases within even shorter intervals (Danderyds kommun 2018). Lowering the degree of maintenance in one area may open up possibilities for increasing maintenance in another area, thus enabling investment of time and economic founding in an environment of greater need.

Further, many of the approaches presented in this master thesis may serve several functions at the same time. For example, the use of rain gardens or swales along a road can help with the management of stormwater as well as provide green and blue corridors for wildlife and humans. Moreover, by selecting native plant species in these structures, indigenous biodiversity can be strengthened. Thus providing multiple benefits and together supporting a more sustainable green infrastructure.

Scales

Investigating the municipality on three different scales made it possible to more closely analyze the need for ecological approaches on each level. In addition, it made it easier to comprehend the overall connections between the scales, enabling the discovery of gaps and important relationships.

However, studying the municipality on multiple levels also limited the amount of time that could be spent analyzing each scale. In order to attain a deeper understanding and present specific design proposals for each individual scale a longer time-span for the project would have been required.

At the large scale, strengthening connections between different green areas became of importance. Green roofs and walls, stormwater solutions and alternatives to lawn were shown to be potential tools in order to increase connectivity and at the same time support biodiversity and water management in the urban environment. The development of the central parts of Danderyd increases the possibility to incorporate such elements into the new environment. Additionally, this could strengthen the connection between the east and west side of the municipality and lower the barrier effects caused by E18.

At the intermediate scale, connecting fragmented areas, increasing stormwater management and enhancing biodiversity in existing parks became of focus. Examples of stormwater management, such as rain gardens and open swales could be a means of increasing both connectivity and manage stormwater within the area. Additional links were suggested along the coastline, as well as in the central

and northern part of the district. However, connecting different areas requires additional knowledge about the ecological networks and values that already exists in these areas. Thus, this project may act as a first step with the potential to inspire and present ideas regarding possible solutions for future development.

At the small scale it became of importance to consider stormwater management, alternatives to traditional lawn and investigate ways in which to lower the degree of maintenance. The existing pond could be further developed in order to more specifically handle stormwater, thus utilizing already existing features of the park. Further, alternative lawns could help lower the degree of maintenance required in the park. As research has been performed on alternative lawns in Sweden, the possibility to find solutions that can be adapted to the site conditions of Danderyd increases. Examples of alternative lawns can be found in both Stockholm and Uppsala, thus increasing the possibility to find suitable plant material and solutions adapted to the local climate.

Language

Writing in a different language may have affected the result in both positive and negative ways. Since English is not my native language it is possible that the time disposed for writing became longer than if I would have chosen to write in my native language, Swedish. The time potentially earned by writing in Swedish could have been designated to perform deeper analyses of the green infrastructure of the municipality. Moreover, writing in a different langue makes it easier for misunderstandings to arise due to choice of words or ways of phrasing.

Nevertheless, as implied in the ecological approach "*Reveal, immerse, teac*h", an important aspect of projects concerning ecological design is to share knowledge and experiences. As a global language, English may enable an international audience to take part in manners in which to work with ecological design in the region specific to this study. Thus, this master thesis may provide an example that inspires or guides others when it comes to answering similar questions in their own municipality.

Concluding remarks

This master thesis investigated how ecological design approaches can be used to support a sustainable green infrastructure in the municipality of Danderyd on different scales.

The study indicates that there are several approaches to ecological design which could be implemented within the municipality. Actions regarding the protection of existing natural resources, increasing biodiversity, introducing new stormwater solutions, enhancing connections between green areas as well as opportunities to access and learn more about them could strengthen the protection, use and functions of the municipality's green infrastructure.

However, further knowledge regarding ecological networks, biological values and regulations are required in order to implement such ecological solutions. This requires a transdisciplinary approach to planning and management.

As the central parts of Danderyd are under development, it is important to recognize the potential of existing natural resources as well as the value of introducing ecologically liable solutions to its new infrastructure. This could increase ecological processes, reduce present and future barrier effects as well as inspire further projects regarding sustainable green infrastructure in the municipality.

Further research questions

Further research questions concern site-specific design solutions and choice of appropriate plant material. It could be of significance to investigate which native plants could be incorporated into the green infrastructure, as well as finding appropriate plant material for rain gardens and alternative lawns.

The municipality contains several small scale environments. For the investigation in this thesis a park was chosen to represent the small scale. However, road sides, roundabouts, patches of greenways or nature areas could also be subjects of study. How could they help support a more sustainable green infrastructure through the means of ecological design?

Another important question is how ecological design solutions can be implemented and accepted within the municipality. Strategies for design of streetscapes and parks could be investigated.

Additionally, prioritizing the need for the chosen ecological approaches within the three scales could be a means to help guide future actions toward a more sustainable development.

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